

ELECTRONICS TECHNICIAN 3 & 2 VOL. 1
(COMMUNICATIONS)

NAVAL TRAINING COMMAND

RATE TRAINING MANUAL

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PREFACE

The primary purpose of all Navy training is to produce a victorious, combat Navy which can guarantee victory at sea. This victory is dependent upon the readiness of the personnel aboard. Each man is assigned tasks to perform according to the needs of the ship. This rate training manual, consisting of two volumes, is based upon the technical tasks required of Electronics Technicians Third and Second Class. Special efforts have been made to make the manual useful for the Fleet, the Naval Schools, and the Naval Reserve. Conscientious use of this manual and its associated enlisted correspondence course/functional individual training system (ECC/FITS) will contribute greatly to the Navy's "training for victory at sea."

As one of the Navy's rate training manuals for a specific rating, this Manual was prepared by the Naval Training Publications Detachment, Washington, D.C., for the Naval Training Command. Special credit is given to the following Commands for their reviews during the preparation of the manual: The Naval Schools Command, Treasure Island, San Francisco, Calif.; The Naval Examining Center, Great Lakes, Ill.; The Training Command, U.S. Atlantic Fleet, Norfolk, Va.; The Training Command, U.S. Pacific Fleet, San Diego, Calif.; The Naval Ship Systems Command, Washington, D.C.; and The Naval Electronic Systems Command, Washington, D.C.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

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CHAPTER 1

PREPARING FOR ADVANCEMENT

This rate training manual (consisting of two volumes) has been prepared for men of the U.S. Navy, and Naval Reserve. Consistent study of this manual will contribute greatly to the Electronics Technician's ability to maintain the electronic equipment aboard ship at maximum efficiency so that victory at sea will be guaranteed. The ET qualifications used as a guide in the preparation of the manual are those listed in the Manual of Qualifications for Advancement, NAVPERS 18068-C for Electronics Technicians Third and Second Class.

Chapters 2, 3, and 4 of this volume cover general maintenance procedures, microelectronics, and general purpose test equipment. The remaining eight chapters deal with communication systems. An electronic system is defined according to MIL-STD-280, and the system concept is then used in discussing the various communication systems.

Simplified block diagrams are used to show the relationship between the various sets, groups, and units that make up the systems. Block diagrams are also used, for the most part, in describing the functional operation of the units, assemblies, and subassemblies. The joint electronics type designation system, and the metric system, are shown in appendixes I and II.

Volume 2 of this manual discusses radar systems and electronic navigation systems.

The remainder of this chapter gives information on the enlisted rating structure, the ET rating, requirements and procedures for advancement, and references that will help you, both in working for advancement and in performing your duties as an ET. This includes information on how to make the best use of rate training manuals. It is strongly recommended that you study this chapter carefully before beginning study of the remainder of this manual.

THE ENLISTED RATING STRUCTURE

The two main types of ratings in the present enlisted rating structure are general ratings and service ratings.

GENERAL RATINGS identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

SERVICE RATINGS identify subdivisions or specialties within a general rating. Although service ratings can exist at any petty officer level, they are most common at the P03 and P02 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

THE ELECTRONICS TECHNICIAN RATING

When you decided to become an ET, you selected one of the most interesting and challenging fields available to men in the Navy. Electronics Technicians maintain electronic equipment used for communications, detection, tracking, recognition and identification, and navigation. Advances in electronics continue to bring about improvements in these equipments, and new equipment is continually being developed. Thus, the ET is a keyman in our modern Navy.

Electronics Technician rates are included in the personnel allowance for practically all Navy ships including repair ships and tenders. Billets for ET3s and ET2s are also included at Naval communication stations, Naval air stations, Naval training stations, Fleet weather centers, and shore-based repair facilities.

The ET rating was established in 1948, and includes service ratings ETR (radar) and ETN (communications) at the E-4 and E-5 levels. For advancement to ET1, you must be qualified in both service ratings. Navy Enlisted Classification (NEC) codes for the rating are listed in the

Manual of Navy Enlisted Classifications NAVTRA 15105 (revised). The classification codes identify those men with special training and/or qualifications on equipments such as special radar and communications sets, secure communications equipment, inertial and satellite navigation equipment, ground controlled approach equipment, tactical data systems equipment, electronic standards equipment, and equipment related to special projects.

The ET should have a good background in mathematics. If you are lacking in this area, the mathematics training manuals Mathematics, Vol. 1, NAVPERS 10069-C, Mathematics Vol. 2, NAVPERS 10071-B, and Mathematics, Vol. 3, NAVPERS 10073-A are recommended. Skill in the use of tools and test equipment will be acquired through performance of your daily duties. Gaining the necessary technical knowledge and keeping abreast of the changes in your field will require reading and studying in your spare time.

Upon advancement to ET3, you will be evaluated on your leadership and supervisory ability as well as your ability to perform your technical duties. Study the leadership principles and techniques discussed in Military Requirements for Petty Officer 3 and 2, NAVPERS 10056 (revised).

As you study material concerning leadership traits, keep in mind that probably none of our most successful leaders possess all of these traits to a maximum degree, but a weakness in some traits are more than compensated for by strength in others. Critical self-evaluation will enable you to realize the traits in which you are strong, and the traits which you must strive to improve. Leadership principles can be taught, but a good leader acquires that quality only through hard work and practice.

SAFETY

Before starting his first job, the ET must be aware of the hazards involved, and the precautions to be observed when working with electrical and electronic circuits and equipment. These precautions include the following:

1. Precautions for the prevention of electric shock, such as securing power and tagging switches; use of shorting stick, rubber mats and gloves; proper grounding of equipment; and special precautions when working on energized circuits, and with high voltages.

2. Precautions to be observed when working aloft. These include the use of proper safety

equipment, and guarding against electric shock, stack gases, and electromagnetic radiation.

3. Precautions to be observed when using solvents and handling radioactive and cathode-ray tubes.

In addition to the material in this training manual, safety procedures of importance to the ET are contained in the following publications:

1. Basic Electronics, Vol. 1, NAVPERS 10087-C chapter 2

2. Basic Electricity, NAVPERS 10086-B, chapter 1

3. Electronics Installation and Maintenance Book (EIMB), NAVSHIPS 0967-000-0100, section 3

4. NAVSHIPS Technical Manual, NAVSHIPS 0901-000-0000, chapter 9600 section 2, and chapter 9670 section 5.

SECURITY

The security of the United States in general, and of Naval operations in particular, depends to a large extent upon the success attained in safeguarding classified materials. Electronics Technicians maintain and repair various types of classified electronics equipment, and therefore, have access to restricted areas and classified information. Each ET must be diligent in complying with all regulations pertaining to the security of electronics equipment, spaces, and printed matter.

Security Classifications

Official information that requires protection in the interest of national defense is limited to three categories of classification. In descending order of importance, these categories carry the designation of Top Secret, Secret, or Confidential.

TOP SECRET.—Top Secret material or information is that of which the defense aspect is paramount, and the unauthorized disclosure of which would result in **EXCEPTIONALLY GRAVE DAMAGE** to the Nation. Such grave damage might consist of, but is not limited to—

1. Leading to a definite break in diplomatic relations affecting the defense of the United States, an armed attack against the United States or her allies, or a war

2. The compromise of military or defense plans, or intelligence operations, or scientific or technological developments vital to the national defense

SECRET.—The classification Secret is limited to defense information or material, the unauthorized disclosure of which could result in **SERIOUS DAMAGE** to the Nation, such as jeopardizing the international relations of the U.S., endangering the effectiveness of a program or policy of vital importance to national defense, compromising important military or defense plans or technological developments, or revealing important intelligence operations.

CONFIDENTIAL.—The use of the classification Confidential is limited to defense information or material, the unauthorized disclosure of which could be **PREJUDICIAL TO THE DEFENSE INTERESTS** of the Nation, such as:

1. Operational and battle reports that contain information of value to the enemy
2. Intelligence reports
3. Military radiofrequency and call sign allocations that are especially important, or are changed frequently for security reasons
4. Devices and material relating to communications security
5. Information that reveals strength of land, air, or naval forces in the United States and overseas areas, identity and composition of units, or detailed information relating to their equipment
6. Documents and manuals containing technical information used for training, maintenance, and inspection of classified munitions of war
7. Operational and tactical doctrine
8. Research, development, production, and procurement of munitions of war
9. Mobilization plans
10. Personnel security investigations and other investigations, such as courts of inquiry, which require protection against unauthorized disclosure
11. Matters and documents of a personal or disciplinary nature, which, if disclosed, could be prejudicial to the discipline and morale of the armed forces
12. Documents used in connection with procurement, selection, or promotion of military personnel, the disclosure of which could violate the integrity of the competitive system

NOTE: Official information of the type described in items 10, 11, and 12 is classified Con-

findential only if its unauthorized disclosure could in fact be prejudicial to the defense interests of the Nation.

Security Areas

The shipboard and shore station spaces that contain classified matter are known as security areas. These security areas (sometimes called sensitive areas) have varying degrees of security interest, depending upon their purpose and the nature of the work and information or materials concerned. Consequently, the restrictions controls, and protective measures required vary according to the degree of security importance. To meet different levels of security sensitivity, three types of security areas have been established: **EXCLUSION**, **LIMITED**, and **CONTROLLED** areas.

EXCLUSION AREA.—The cryptocenter, registered publications issuing office (RPIO) vault, classified conference room, and other spaces requiring the highest degree of control of access are designated exclusion areas. They contain classified matter of such nature that admittance to the area permits, for all practical purposes, access to such matter.

Exclusion areas are fully enclosed by walls or bulkheads of solid construction. All entrances and exits are guarded, and only persons whose duties require access and who possess appropriate security clearances are authorized to enter, after being positively identified. Normally, a list of personnel authorized entry, signed by the CO, is posted in the area.

LIMITED AREA.—Radio central, message center, relay station, transmitter rooms, and other communication spaces usually are designated limited areas.

Operating and maintenance personnel whose duties require freedom of movement within limited areas must have proper security clearances. The commanding officer may, however, authorize entrance of persons who do not have clearances. In such instances, escorts or attendants and other security precautions must be used to prevent access to classified information located within the area.

Entrances and exits of limited areas are either guarded or controlled by attendants to check personnel identification, or they may be protected by automatic alarm systems.

CONTROLLED AREA.—Passageways or spaces surrounding or adjacent to limited or

exclusion areas are often designated controlled areas. Although a controlled area does not contain classified information, it serves as a buffer zone of security restriction. Moreover, it provides greater control, safety, and protection for limited and exclusion areas.

Controlled areas require personnel identification and control systems adequate to limit admittance to those having bona fide need for access to the area.

Security Investigations And Clearances

Before a person can have access to classified material, his character and his past must be checked to the extent appropriate to the sensitivity of the material he will be handling. Following are the two basic qualifications.

1. He must be of unquestionable integrity, trustworthiness, and loyalty to the United States.
2. He must be of excellent character and of such habits and associations as to cast no doubt upon his discretion and good judgment in handling classified information.

TYPES OF INVESTIGATIONS.—To determine whether an individual meets the criteria for a security clearance, two types of personnel security investigations are made. They are the national agency check (NAC) and the background investigation (BI).

A national agency check consists of the review of the records and files of several Government agencies to determine if any derogatory information exists on the individual or on an organization to which he may have belonged.

The background investigation is much more extensive than a national agency check. It is designed to develop information on whether the access to classified information by the person being investigated is clearly consistent with the interests of national security. It inquires into the loyalty, integrity, and reputation of the individual.

TYPES OF CLEARANCES.—A personnel security clearance is an administrative determination that an individual is eligible, from a security standpoint, for access to classified information of the same or lower category as the clearance being granted.

Of the two types of clearances (INTERIM and FINAL), an interim clearance is granted as the

result of a lesser investigative process, and is a method for establishing temporary eligibility for access to certain levels of classified information.

An interim clearance is granted only when the delay in waiting for completion of the necessary steps for final clearance would be harmful to the national interest. Procedures to effect a final clearance are initiated simultaneously with initiation of the procedures for an interim clearance. The only type of clearance not granted to military personnel is the interim **CONFIDENTIAL**.

A final clearance is granted when it is determined that an individual is eligible, from a security standpoint, for access to classified information of specific levels.

Each clearance, final and interim, is evidenced by a certificate of clearance. Certificates of clearance are made a matter of record and become a permanent part of an individual's service record.

Security Violations And Compromises

No one in the Navy is authorized to handle any classified material except that required in the performance of duty. All other persons are unauthorized, regardless of grade, duties, or clearance.

If it is known—or even suspected—that classified material is lost, or is passed into the hands of some unauthorized person, the material is said to be compromised. The seriousness of the compromise depends on the nature of the material and the extent to which the unauthorized person may divulge or make use of what he learns.

Individuals found responsible for the loss, unauthorized disclosure, or possible subjection to compromise of classified information, and individuals who violate security regulations, are promptly disciplined regardless of rank or position. Disciplinary action for military personnel may include trial by court-martial.

Accounting for and Control of Dissemination of Classified Material

The control of classified material is necessary for several purposes. It must be controlled to limit dissemination and to prevent excessive production or reproduction; it must be controlled so that, when regraded or declassified, the holders or recipients can be ascertained

and notified; it must be controlled so that the office or person normally responsible for its security can be ascertained; and Top Secret material must be controlled so that its location can be determined promptly and so that those who have access to its contents can be ascertained. These requirements can generally be fulfilled by effective supervision, conscientious and informed execution of personal responsibilities, and efficient administration. In addition, the importance of Top Secret material requires a formal record for hand to hand transfer of custody from one accountable office or command to another. Secret material also requires a record of transfer of custody from one accountable command to another; and for Top Secret material, there is a special system for recording those who have access to Top Secret material.

The Accounting system for an activity must provide readily available information on: what classified material it has received, what classified material it has produced, who has custody of a particular Top Secret document, and what disposition has been made of Top Secret and Secret material.

When military or civilian personnel resign or are to be separated from the Naval Establishment or released from active duty, all classified material held by them shall be turned in to the source from which received, to their commanding officer, or to the nearest naval command, as appropriate, prior to delivery of final orders or separation papers. In addition, any person in the Naval Establishment about to be relieved must deliver to his successor all classified material in his custody. Appropriate receipts must be completed covering as a minimum all Top Secret material.

Persons in command are responsible for controlling the dissemination of classified information emanating from or distributed within their commands. They are also responsible for the promulgation of additional directives that may be required to prevent unauthorized dissemination of information under their control. Classified material must not be removed from a command without the specific permission of the commanding officer or his authorized representative.

The dissemination of classified material is limited to those persons whose official duties require them to have knowledge or possession of such material. Responsibility for determining whether a person's official military or other

governmental duties require that he possess or have access to any classified information and whether he is authorized to receive it rests upon each individual who has possession, knowledge, or command control of the information involved, and not upon the prospective recipient. These principles are equally applicable whether the prospective recipient is an individual, a U.S. military command, a defense contractor or another federal agency. In the case of a foreign government there is the additional requirement for written authorization from the Chief of Naval Operations.

Classified information must not be disclosed over telephones because of the insecurity due to executive cut-in, phantom voice interception, microwave transmission intercept, and wire-tapping. Telephones located in sensitive areas must be provided with a means of complete disconnection such as a plug or jack arrangement if they are to be considered safe. Intercom systems located in sensitive areas must be confined to the sensitive area.

From a security viewpoint, the printing, duplicating or reproduction of classified material poses many problems; it contributes to the increasing volume of classified material; it permits quick and easy production of uncontrolled material containing classified information; the equipment or processes require care or special procedures to prevent or eliminate latent impressions or offset versions of the classified information; and a quantity of excess and waste material is produced which can also contribute to compromise of the classified information.

Classified material may be produced or reproduced, however, when authorized by appropriate authority. Classified material produced or reproduced by any means must be recorded, and samples, waste or overruns resulting from the reproduction process must be safeguarded as specified in the Department of the Navy Security Manual for Classified Information, OPNAV Instruction 5510.1 series.

Transmission of Classified Material

Classified material must be safeguarded during transmission from one place to another as well as when held within a command. Due to the very nature of the problem, compromise or loss is more probable during transmission than at any other time. For this reason, specific rules ensure maximum security consistent with the need for rapid communication of the information.

Top Secret material may not be sent through any postal system, United States or foreign. It may be transmitted only by one of the following means:

1. Direct personal contact of military personnel (E-7 or above) and U.S. civilian employees (GS-7 or above) who have been cleared for access to Top Secret information. Military personnel (E-5 and E-6) and U.S. civilian employees (GS-5 and GS-6) who have been cleared for access to Top Secret information may transmit between Department of Defense elements located in relative close proximity to one another, provided the transmission is accomplished (begun and completed) during normal daytime duty hours on the same day.
2. Armed Forces Courier Service
3. Electric means in encrypted form

Secret and Confidential material may be sent by any of the methods authorized for transmitting Top Secret material, or by U.S. registered mail.

The foregoing rules apply only within the continental United States. When the national borders must be crossed, the rules are modified slightly. Secret and Confidential matter can be transmitted by U.S. registered mail provided it stays within U.S. military postal channels. Within the continental U.S., Canada, and Alaska, Secret and Confidential may be sent by registered mail with registered mail receipt.

Commanding officers are authorized to establish systems for transmitting classified material within the confines of their commands. Such systems must ensure that:

1. Top Secret material always is controlled by Top Secret control officers.
2. Personnel transmitting the classified material have security clearances for the highest category they are allowed to handle.
3. Personnel whose primary duties entail transmission of classified material are authorized in writing for such duties.
4. All personnel entrusted with transmitting classified material are instructed properly concerning their duties.

Transmission of classified material to Department of Defense contractors must meet the following conditions:

1. The contractor must have an appropriate clearance.

2. The releasing activity having cognizance over the contract or program under which the classified material is being released must determine that the contractor has a "need to know".

3. The recipient of the classified material must have the ability to physically safeguard the material.

Stowage of Classified Material

All classified matter not in actual use must be stowed in a manner that will guarantee its protection. The degree of protection necessary depends on the classification, quantity, and scope of the material.

A numerical evaluation system has been developed for determining the relationship between the security interest and the level of protection required. The more secure the stowage facilities, the higher the numerical values assigned. Table 1-1 shows the numerical values required for quantity and type of documents of each classification. Table 1-2 is a guide for evaluating stowage facilities. Both of the tables must be used together.

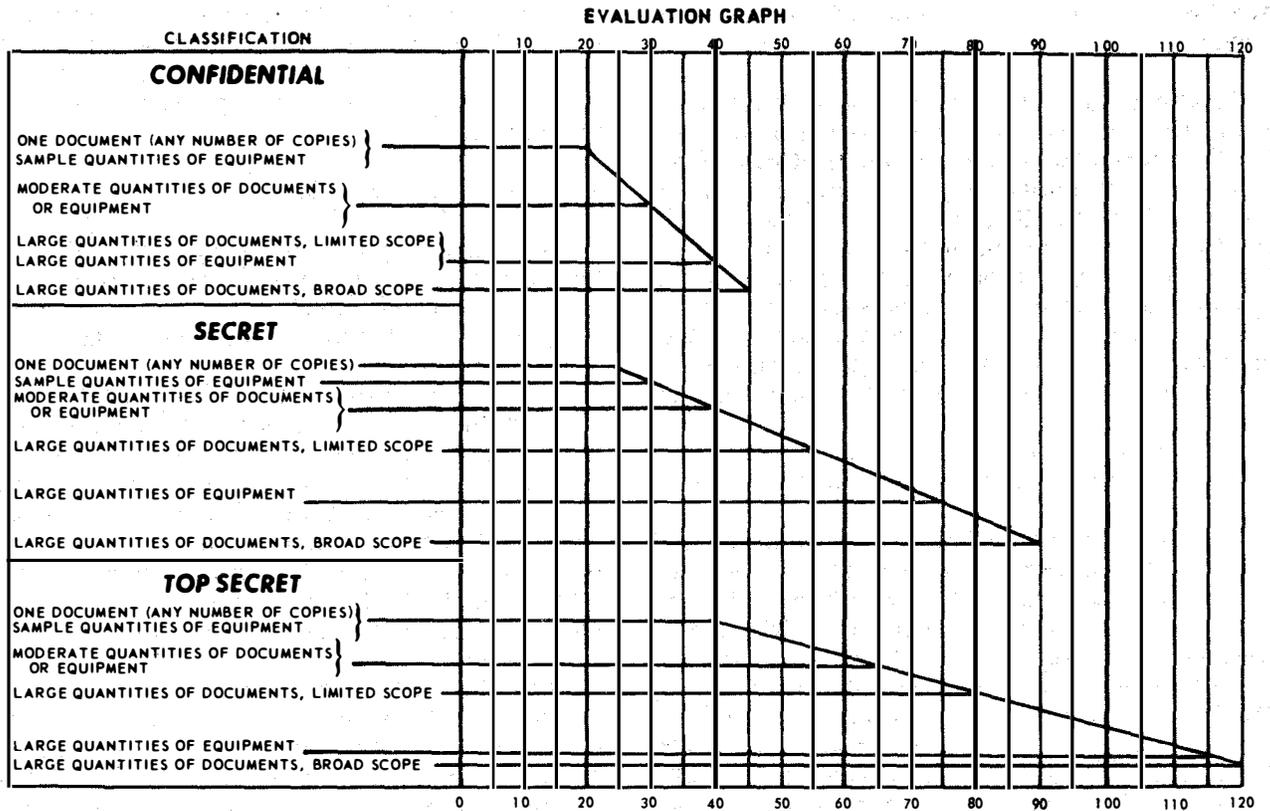
Assume that a ship stows plain language translations to encrypted messages in a metal container with attached keylock in the cryptocenter. Visitors are not allowed in any of the communication spaces. Only cryptographers may enter the cryptocenter itself or remove anything from its safe. The cryptographer on watch acts as a guard in attendance at the container. From table 1-2 a numerical value may be assigned to these facilities as follows:

| | <u>Value</u> |
|--|--------------|
| Sheltered aboard a commissioned ship.. | 25 |
| Stowed in metal container with attached high security key padlock..... | 5 |
| Military guard in attendance at container | 60 |
| Total | <u>90</u> |

From the graph in table 1-1 it can be seen that stowage facilities with a numerical value of 90 are secure enough for everything but large quantities of Top Secret equipment and large quantities of Top Secret documents covering a broad scope.

Keys or combinations to safes and lockers containing classified material are made available only to persons whose duties require access to them. At least every 12 months keys or combinations must be changed. They also must be

Table 1-1.—Numerical values required for classified material
SECURITY OF MATERIAL IN STORAGE



31.2

changed whenever any person having knowledge of them is transferred from the organization, and at any time the keys or combinations are suspected of being compromised. A key padlock should also be changed whenever a key is lost.

Any time discovery is made of an unlocked and unattended safe or cabinet that contains classified material, report the condition immediately to the senior duty officer. Do not touch the container or contents, but guard them until the duty officer arrives. The duty officer then assumes responsibility for such further actions as locking the safe, recalling the responsible persons, and reporting the security violation to the commanding officer. The custodian must hold an immediate inventory of the contents of the safe and report any loss to the commanding officer.

Destruction of Classified Material

Classified material that is not required must not be allowed to accumulate. It must either

be sent to stowage at a naval records management center, or it must be destroyed. Classified documents are destroyed by burning, pulping, pulverizing, or shredding. Burning is the method used most commonly in the fleet. When destruction is accomplished by means other than burning, the residue must be inspected to ensure complete mutilation.

When classified papers are burned, the destruction must be witnessed by two commissioned officers. If sufficient officers are unavailable, warrant officers, enlisted men (E-7 or above), or U.S. civilian employees in grade GS-7 or above may witness the burning, provided they are cleared for at least the highest classification of material being destroyed. If none of these personnel categories are available, a mature and reliable enlisted man in pay grade E-5 or E-6, or a U.S. civilian employee in grade GS-5 or GS-6, may be designated as a witnessing official.

Destruction of classified matter falls into two categories, routine and emergency. Destruction, when authorized or ordered, must be complete.

Destruction of superseded and obsolete classified materials that have served their purpose is termed routine destruction. Emergency destruction of classified material is authorized when there is danger of the material falling into enemy hands.

The most efficient method of destroying combustible material is by burning. It is likely that as an ET 3 or 2 you may be called upon to assist in burning classified material. Every member of the burn detail should know exactly what is to be burned and should doublecheck each item before it is burned. To facilitate complete destruction of bound publications, tear them apart, crumple the pages, and feed the pages to the fire a few at a time. If burn material is carried in a bag that is not to be burned, turn the bag inside out to make certain every piece of paper is removed and burned. All material must be watched until it is completely consumed. The ashes must be broken up and scattered so that no scraps escape destruction.

When no incinerator is available, which often is true aboard ship, classified material may be burned in a perforated metal drum or container with a cover of wire netting. Care must be taken to prevent the classified material from being carried away by the wind. As destruction is accomplished, a list is made of the material that has been destroyed. Informing higher authority of exactly what material has been destroyed is second in importance only to the actual destruction.

Emergency destruction of classified material is authorized any time it is necessary to prevent its capture by an enemy. On board ship, classified material is not subjected to the same risks as on land. If a ship is in danger of sinking or is severely disabled, however, action is taken in accordance with the ship's emergency destruction bill, the execution of which is an all-hands evolution.

This bill details the method and the order of destruction of classified matter.

Cryptographic (crypto) material has the highest priority for emergency destruction. Insofar as humanly possible, it must not be permitted to fall into enemy hands. After cryptomaterial is destroyed, noncrypto communications material by order of classification beginning with the highest classification is destroyed, then other classified material in the following order:

1. Classified material pertaining to future plans and operations.

2. Classified material pertaining to standing, operating, or tactical procedures.

3. Equipment of a classified nature, together with pertinent technical, descriptive, and operating instructions

4. Remaining classified material. The order of destruction to follow classification; the highest classified material being destroyed first.

When it is necessary to dispose of equipment that must remain classified, destruction shall be accomplished by any means that will prevent recognition and reconstruction or by jettisoning in random water areas of at least 1000 fathoms depth. This does not apply to crypto equipment. Special instructions are issued for this equipment.

Command Security Programs

Security is a means—not an end. Regulations that govern the security of classified material are comparable to electronic safety regulations. They do not guarantee protection, and they do not attempt to meet every conceivable situation. If strictly adhered to, however, they will provide a satisfactory degree of security.

To ensure that the required security measures are implemented, each command formulates written security procedures to reflect the command's particular requirements. These security procedures specify what is to be done, how it is to be done, who is to do it, and who is to supervise it.

In order that classified information may be controlled with maximum efficiency, the commanding officer or officer in charge of each command designates an officer to act as the CLASSIFIED MATERIAL CONTROL OFFICER. In commands that initiate, receive, or process top Secret documents, he appoints a TOP SECRET CONTROL OFFICER. When an activity possesses crypto material, the CO names a CRYPTOSECURITY OFFICER. In addition, certain commands may designate a SPECIAL SECURITY OFFICER.

In performing his duties, the classified material control officer—

1. Serves as the commanding officer's adviser and direct representative in cases pertaining to security of classified material

2. Assures that all persons who are to handle classified information are properly cleared and instructed. The clearance status should be recorded and be accessible for verification

Chapter 1—PREPARING FOR ADVANCEMENT

Table 1-2.—Table of numerical equivalents

| Element of Security | Value | Element of Security | Value |
|--|-----------|---|-----------|
| 1. Stowage Areas: | | 2. Stowage Containers—Continued | |
| a. Security Fences: | | q. Class 6 map and plan, approved GSA security container..... | 55 |
| (1) Classified area surrounded by a security fence with all gates secured or controlled..... | 5 | 3. Guarding: | |
| b. Protective Lighting: | | a. Supporting Guard Force: | |
| (1) Security areas lighted by protective lighting..... | 5 | (1) Civilian Supporting Guard Force..... | 10 |
| c. Building or Ship:* | | (2) Military Supporting Guard Force..... | 15 |
| (1) Conventional frame or good quality temporary structure..... | 5 | b. Guards: | |
| (a) Controlled areas within..... | 15 | (1) Civilian Guards: | |
| (b) Limited areas within..... | 25 | (a) Civilian guard in general area..... | 10 |
| (c) Exclusion areas within..... | 35 | (b) Civilian guard check of container each hour..... | 15 |
| (2) Masonry or steel structure with substantial partitions, floors and ceilings (including magazines)..... | 10 | (c) Civilian guard check of container each ½ hour..... | 20 |
| (a) Controlled areas within..... | 20 | (d) Civilian guard in attendance at container..... | 30 |
| (b) Limited areas within..... | 30 | (2) Military Guards: | |
| (c) Exclusion areas within..... | 40 | (a) Military guard in general area..... | 15 |
| (3) Aboard a Commissioned Ship..... | 25 | (b) Military guard check of container each hour..... | 20 |
| (a) Controlled area..... | 35 | (c) Military guard check of container each ½ hour..... | 25 |
| (b) Limited area..... | 40 | (d) Military guard in attendance at container..... | 60 |
| (c) Exclusion area..... | 50 | c. Sentry dog accompanying military or civilian guard..... | 10 |
| (4) "In Service" or MSC chartered vessel..... | 10 | 4. Protective Alarm Systems: | |
| (a) Controlled areas within..... | 20 | a. Area Alarm System: | |
| (b) Limited areas within..... | 30 | (1) Make or break (electro-mechanical) alarm to detect entry into immediate area..... | 5 |
| (c) Exclusion areas within..... | 40 | (2) Other alarm system to detect entry into immediate area..... | 10 |
| 2. Stowage Containers:** | | (3) Alarm system to detect entry or attempted entry into immediate area..... | 15 |
| a. Metal, keylock (built-in)..... | 0 | (4) Alarm system to detect entry or attempted entry and approach to immediate area..... | 25 |
| b. Metal, key padlock (attached)..... | 0 | b. Container Alarm Systems: | |
| c. Metal, high security key padlock (attached)..... | 5 | (1) Make or break (electro-mechanical) alarm to detect opening of container.. | 10 |
| d. Metal, combination padlock (attached).... | 5 | (2) Other alarm system to detect opening of container..... | 15 |
| e. Metal, high security combination padlock (attached)..... | 10 | (3) Alarm system to detect opening or tampering with container..... | 20 |
| f. Metal, combination lock (built-in)..... | 15 | (4) Alarm system to detect opening or tampering with and approach to container..... | 25 |
| g. Strongroom or weapons magazine..... | 15 | | |
| h. Class C Vault..... | 50 | | |
| i. Class B Vault..... | 60 | | |
| j. Class A Vault..... | 70 | | |
| k. Class 2, approved GSA security container.. | 60 | | |
| l. Class 3, approved GSA security container.. | 50 | | |
| m. Class 4, approved GSA security container.. | 60 | | |
| n. Class 5, approved GSA security container.. | 70 | | |
| o. Class 6, approved GSA security container.. | 55 | | |
| p. Class 5 map and plan, approved GSA security container..... | 70 | | |

* Buildings must be under U.S. Government control or if not under U.S. Government control the space occupied within the building must be at least a controlled area.

** Evaluate as indicated provided other elements in the security program are available to minimize the possibility of unauthorized access to the container.

3. Formulates and coordinates security control measures within the command

4. Maintains a program of declassification and downgrading of information

5. Prepares classification guides to aid in the proper classification of material originated within the command. Preparation of such guides usually is limited to shore activities

6. Exercises security control over visits to and from the command

7. Reviews proposed press releases, and indicates classified information that must be deleted therefrom

8. Performs the duties of Top Secret control officer if another officer is not so designated

The Top Secret control officer, subordinate to the classified material control officer, is responsible within the command for the receipt, custody, accountability, and distribution of Top Secret information and for its transmission outside the command. In performing his duties, the TOPSEC control officer is governed by certain basic rules. He must, for instance—

1. Avoid unnecessary dissemination of Top Secret information

2. Release to a subordinate echelon only the absolute minimum of Top Secret information necessary for proper planning or action

3. Transmit Top Secret information within the command by direct personal contact

4. Maintain a continuous chain of receipts for Top Secret material

5. Maintain a current roster of persons within the command who are cleared for access to Top Secret information

Certain commands within the Naval Establishment are designated to maintain a Special Security Officer (SSO). The Special Security Officer and all persons detailed to assist him are granted a special clearance by the designator.

Material intended for the Special Security Officer is wrapped in a double sealed opaque envelope. The outer container bears, the command address. The inner container bears the command address, the classification of the material, and the notation "To be Opened Only by the Special Security Officer." Packages so marked are immediately delivered, with the inner container unopened, to the Special Security Officer. If the receiving command does not have a Special Security Officer, the inner container is not opened and will be marked "No Special

Security Officer at this Command." The inner envelope is placed in an outer opaque envelope and returned to the sender via Armed Forces Courier Service.

Additional information concerning security is included in the Department of the Navy Security Manual For Classified Information, OP-NAV Instruction 5510.1 series.

ADVANCEMENT

Some of the rewards of advancement are easy to see. You get more pay. Your job assignments become more interesting and more challenging. You are regarded with greater respect by officers and enlisted personnel. You enjoy the satisfaction of getting ahead in your chosen Navy career.

But the advantages of advancement are not yours alone. The Navy also profits. Highly trained personnel are essential to the functioning of the Navy. By each advancement, you increase your value to the Navy in two ways. First, you become more valuable as a specialist in your own rating, and second, you become more valuable as a person who can train others and thus make far-reaching contributions to the entire Navy.

HOW TO QUALIFY FOR ADVANCEMENT

What must you do to qualify for advancement? The requirements may change from time to time, but usually you must:

1. Have a certain amount of time in your present grade.

2. Complete the required military and rating manuals, and correspondence courses.

3. Demonstrate your ability to perform all the PRACTICAL requirements for advancement by completing the Record of Practical Factors, NAVPERS 1414/1.

4. Be recommended by your commanding officer, after the petty officers and officers supervising your work have indicated that they consider you capable of performing the duties of the next higher rate.

5. Demonstrate your KNOWLEDGE by passing written examinations on the occupational and military qualification standards for advancement.

Chapter 1—PREPARING FOR ADVANCEMENT

Some of these general requirements may be modified in certain ways. Figure 1-1 gives a more detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this information for inactive duty personnel.

Remember that the qualifications for advancement can change. Check with your division officer or training officer to be sure that you know the most recent qualifications.

Advancement is not automatic. Even though you have met all the requirements, including passing the written examinations, you may not be able to "sew on the crow" or "add a stripe." The number of men in each rate and rating is controlled on a Navywide basis. Therefore, the number of men who may be advanced is limited by the number of vacancies that exist. When the number of men passing the examination exceeds the number of vacancies, some system must be used to determine which men may be advanced and which may not. The system used is the "final multiple" and is a combination of three types of advancement systems.

- Merit rating system
- Personnel testing system
- Longevity, or seniority, system

The Navy's system provides credit for performance, knowledge, and seniority, and, while it cannot guarantee that any one person will be advanced, it does guarantee that all men within a particular rating will have equal advancement opportunity.

The following factors are considered in computing the final multiple:

| <u>POINTS</u> | <u>FACTOR</u> | <u>WEIGHT</u> |
|--------------------|---|---------------|
| 80 (MAX) | Examination Score | 40% |
| 50 (MAX) | Performance (Average of marks received) | 25% |
| 20 (MAX) | Total Active Service (1 per yr) | 10% |
| 20 (MAX) | Time in Present Grade (2 per yr) | 10% |
| 15 (MAX) | Awards (pts per award) | 7.5% |
| 15 (MAX) | PNA (Maximum 3 per exam cycle) | 7.5% |
| 200 (MAX POSSIBLE) | | 100% |

PNA (passed, not advanced) points are awarded as follows: A maximum of three points can be accrued each examination. Over five examination cycles, a maximum of 15 points can be obtained. The Naval Examining Center maintains historical tapes on candidate PNA point awards. These are awarded to passing candidates not advanced as follows:

| <u>EXAMINATION FACTOR</u> | | <u>PERFORMANCE</u> | |
|---|---------------|----------------------------------|---------------|
| <u>STANDING</u> | <u>SCORE</u> | <u>EVALUATION</u> | <u>FACTOR</u> |
| <u>RELATIVE</u> | <u>POINTS</u> | <u>RELATIVE</u> | <u>POINTS</u> |
| <u>STANDING</u> | | <u>STANDING</u> | |
| Exceeding above average (Score in 70s) | 1.5 | Upper 25% by peer group standing | 1.5 |
| Above average (Score in 60s) | 1.0 | Peer group standing of 26% - 50% | 1.0 |
| Average (remainder of passing candidates) | 0.5 | Peer group standing of 51% - 75% | 0.5 |
| | | Lower 25% by peer group standing | 0.0 |

NOTE: Maximum of 3 multiple points per cycle.

All of the preceding information (except the examination score and PNA points) is submitted to the Naval Examining Center with your examination answer sheet. After grading, the examination scores and PNA points for those passing are added to the other factors to arrive at the final multiple. A precedence list, which is based on final multiples, is then prepared for each pay grade within each rating. Advancement authorizations are then issued, beginning at the top of the list, for the number of men needed to fill the existing vacancies.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the qualifications for advancement, work on the practical factors, study the required rate training manuals, and study other material that is required for advancement in your rating. To prepare for advancement, you

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| REQUIREMENTS * | E1 to E2 | E2 to E3 | #† E3 to E4 | #E4 to E5 | † E5 to E6 | † E6 to E7 | † E7 to E8 | † E8 to E9 |
|---|---|--|--|----------------|-----------------|--|---|--|
| SERVICE | 4 mos. service— or comple- tion of | 8 mos. as E-2. | 6 mos. as E-3 | 12 mos. as E-4 | 24 mos. as E-5. | 36 mos. as E-6. 8 years total enlisted service. | 36 mos. as E-7. 8 of 11 years total service must be enlisted. | 24 mos. as E-8. 10 of 13 years total service must be enlisted. |
| SCHOOL | Recruit Training. (C.O. may ad- vance up to 10% of gradu- ating class.) | | Class A for PR3, DT3, PT3, AME 3, HM 3, PH 3, FTB 3, MT 3, | | | Class B for AGC MUC, MNC. †† | | |
| PRACTICAL FACTORS | Locally prepared check- offs. | Record of Practical Factors, NavPers 1414/1, must be completed for E-3 and all PO advancements. | | | | | | |
| PERFORMANCE TEST | | | Specified ratings must complete applicable performance tests be- fore taking examinations. | | | | | |
| ENLISTED PERFORMANCE EVALUATION | As used by CO when approving advancement. | Counts toward performance factor credit in ad- vancement multiple. | | | | | | |
| EXAMINATIONS ** | Locally prepared tests. | See below. | Navy-wide examinations required for all PO advancements. | | | Navy-wide, selection board. | | |
| RATE TRAINING MANUAL (INCLUD- ING MILITARY REQUIREMENTS) | | Required for E-3 and all PO advancements unless waived because of school comple- tion, but need not be repeated if identical course has already been completed. See NavPers 10052 (current edition). | | | | Correspondence courses and recommended reading. See NavPers 10052 (current edition). | | |
| AUTHORIZATION | Commanding Officer | Naval Examining Center | | | | | | |

* All advancements require commanding officer's recommendation.
 † 1 year obligated service required for E-5, and E-6; 2 years for E-7, E-8, and E-9.
 # Military leadership exam required for E-4 and E-5.
 ** For E-2 to E-3, NAVEXAMCEN exams or locally prepared tests may be used.
 †† Waived for qualified EOD personnel.

Figure 1-1.—Active duty advancement requirements.

Chapter 1—PREPARING FOR ADVANCEMENT

| REQUIREMENTS * | E1 to E2 | E2 to E3 | E3 to E4 | E4 to E5 | E5 to E6 | E6 to E7 | E8 | E9 |
|--|--|---|----------|----------|----------|----------------------------------|-----------------------------------|-----------------------------------|
| TOTAL TIME IN GRADE | 4 mos. | 8 mos. | 6 mos. | 12 mos. | 24 mos. | 36 mos. with total 8 yrs service | 36 mos. with total 11 yrs service | 24 mos. with total 13 yrs service |
| TOTAL TRAINING DUTY IN GRADE † | 14 days | 14 days | 14 days | 14 days | 28 days | 42 days | 42 days | 28 days |
| PERFORMANCE TESTS | Specified ratings must complete applicable performance tests before taking examination. | | | | | | | |
| DRILL PARTICIPATION | Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series. | | | | | | | |
| PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS) | Record of Practical Factors, NavPers 1414/1, must be completed for all advancements. | | | | | | | |
| RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS) | Completion of applicable course or courses must be entered in service record. | | | | | | | |
| EXAMINATION | Standard Exam | Standard Exam required for all PO advancements. Also pass Military Leadership Exam for E-4 and E-5. | | | | | Standard Exam, Selection Board. | |
| AUTHORIZATION | Commanding Officer | Naval Examining Center | | | | | | |

*Recommendation by commanding officer required for all advancements.

† Active duty periods may be substituted for training duty.

Figure 1-2.—Inactive duty advancement requirements.

will need to be familiar with (1) the Quals Manual, (2) the Record of Practical Factors, (3) BIBLIOGRAPHY FOR ADVANCEMENT STUDY, NAVTRA 10052, and (4) applicable rate training manuals. The following sections describe them and give you some practical suggestions on how to use them in preparing for advancement.

Quals Manual

THE MANUAL OF QUALIFICATIONS FOR ADVANCEMENT, NAVPERS 18068C, gives the minimum occupational and military qualification standards for advancement to each pay grade within each rating. This manual is usually called the "Quals Manual," and the qualifications themselves are often called "quals." The qualification standards are of two general types: (1) military qualification standards and (2) occupational qualification standards.

MILITARY STANDARDS are requirements that apply to all ratings rather than to any one particular rating. Military requirements for advancement to third class and second class petty officer rates deal with military conduct, naval organization, military justice, security, watch standing, and other subjects which are required of petty officers in all ratings.

OCCUPATIONAL STANDARDS are requirements that are directly related to the work of each rating.

Both the military requirements and the occupational qualification standards are divided into subject matter groups. Within each subject matter group, they are further divided into PRACTICAL FACTORS and KNOWLEDGE FACTORS. Practical factors are things you must be able to DO. Knowledge factors are things you must KNOW in order to perform the duties of your rating.

In most subject matter areas, you will find both practical factor and knowledge factor qualifications. In some subject matter areas, you may find only one or the other. It is important to remember that there are some knowledge aspects to all practical factors, and some practical aspects to most knowledge factors. Therefore, even if the Quals Manual indicates that there are no knowledge factors for a given subject matter area, you may still expect to find examination questions dealing with the knowledge aspects of the practical factors listed in that subject matter area.

You are required to pass a Navywide military/leadership examination for E-4 or E-5, as

appropriate, before you take the occupational examinations. The military/leadership examinations are administered on a schedule determined by your commanding officer. Candidates are required to pass the applicable military/leadership examination only once. Each of these examinations consists of 100 questions based on information contained in MILITARY REQUIREMENTS FOR PETTY OFFICERS 3 & 2, NAVPERS 10056 and other publications listed in BIBLIOGRAPHY for advancement study, NAVTRA 10052.

The Navywide occupational examinations for pay grades E-4 and E-5 will contain 150 questions related to occupational areas of your rating.

If you are working for advancement to second class, remember that you may be examined on third class qualifications as well as on second class qualifications.

The QUALS MANUAL is kept current by means of changes. The occupational qualifications for your rating which are covered in this training manual were current at the time the manual was printed. By the time you are studying this manual, however, the quals for your rating may have been changed. Before using any set of quals always check them against an UP-TO-DATE copy of the QUALS MANUAL.

Record of Practical Factors

Before you can take the servicewide examinations for advancement, there must be an entry in your service record to show that you have qualified in the practical factors of both the military qualifications and the occupational qualifications. The RECORD OF PRACTICAL FACTORS, mentioned earlier, is used to keep a record of your practical factor qualifications. This form is available for each rating. The form lists all practical factors, both military and occupational. As you demonstrate your ability to perform each practical factor, appropriate entries are made in the DATE and INITIALS columns.

Changes are made periodically to the MANUAL OF QUALIFICATIONS FOR ADVANCEMENT, and revised forms of NAVPERS 1414/1 are provided when necessary. Extra space is allowed on the Record of Practical Factors for entering additional practical factors as they are published in changes to the QUALS MANUAL. The Record of Practical Factors also provides

space for recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as minimum qualifications for advancement.

Until completed, the NAVPERS 1414/1 is usually held by your division officer; after completion, it is forwarded to the personnel office for insertion in your service record. If you are transferred before qualifying in all practical factors, the incomplete form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form actually is inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start all over again and requalify in the practical factors which have already been checked off.

NAVTRA 10052

The BIBLIOGRAPHY FOR ADVANCEMENT STUDY, NAVTRA 10052 (revised), is a very important publication for any enlisted person preparing for advancement. This bibliography lists required and recommended rate training manuals and other reference material to be used by personnel working for advancement.

NAVTRA 10052 is revised and issued once each year by the Naval Training Command. Each revised edition is identified by a letter following the NAVTRA number. When using this publication, be SURE that you have the most recent edition.

If extensive changes in qualifications occur in any rating between the annual revisions of NAVTRA 10052, a supplementary list of study material may be issued. When you are preparing for advancement, check to see whether changes have been made in the qualifications for your rating. If changes have been made, see if a Notice has been issued to supplement NAVTRA 10052 for your rating.

The required and recommended references are listed by pay grade in NAVTRA 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level.

In using NAVTRA 10052 you will notice that some rate training manuals are marked with an asterisk (*). Any manual marked in this way is MANDATORY—that is, it must be completed at

the indicated rate level before you can be eligible to take the servicewide examination for advancement. Each mandatory manual may be completed by (1) passing the appropriate enlisted correspondence course that is based on the mandatory training manual; (2) passing locally prepared tests based on the information given in the training manual; or (3) in some cases, successfully completing an appropriate Navy school.

Do not overlook the section of NAVTRA 10052 which lists the required and recommended references relating to the military qualification standards for advancement. Personnel of ALL ratings must complete the mandatory military requirements training manual for the appropriate rate level before they can be eligible to advance.

The references in NAVTRA 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NAVTRA 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Rate Training Manuals

As a result of the establishment of the Naval Training Support Command under the Chief of Naval Training, new editions of rate training manuals, correspondence courses, curricula, and other training publications formerly designated with the abbreviation NAVPERS are being designated with NAVTRA. This training manual, for example, is NAVTRA 10195-A, which means that it is a publication of the Naval Training Support Command which succeeds a manual designated NAVPERS 10195.

In this chapter, and elsewhere in this manual, training publications which already carry the new abbreviation are so listed; those not yet changed are listed as NAVPERS numbers.

There are two general types of rate training manuals. RATING manuals (such as this one) are prepared for most enlisted ratings. A rating manual gives information that is directly related to the occupational qualifications of ONE rating. SUBJECT MATTER manuals or BASIC manuals give information that applies to more than one rating.

Rate training manuals are revised from time to time to keep them up to date technically. The revision of a rate training manual is identified by a letter following the NAVTRA number. You can tell whether any particular copy of a training manual is the latest edition by checking the

NAVTRA number and the letter following this number in the most recent edition of LIST OF TRAINING MANUALS AND CORRESPONDENCE COURSES, NAVTRA 10061. (NAVTRA 10061 is actually a catalog that lists all current training manuals and correspondence courses; you will find this catalog useful in planning your study program.)

Each time a rate training manual is revised, it is brought into conformance with the official publications and directives on which it is based; but during the life of any edition, discrepancies between the manual and the official sources are almost certain to arise because of changes to the latter which are issued in the interim. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in NAVTRA 10052, the Naval Examining Center uses it as a source of questions in preparing the Fleet-wide examinations for advancement. In case of discrepancy between any publications listed in NAVTRA 10052 for a given rate, the Examining Center will use the most recent material.

Rate training manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you are preparing for advancement.

1. Study the military qualifications and the occupational qualifications for your rating before you study the training manual, and refer to the quals frequently as you study. Remember, you are studying the manual primarily in order to meet these quals.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the manual intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the book without any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear

picture of the scope and content of the book. As you look through the book in this way, ask yourself some questions:

- What do I need to learn about this?
- What do I already know about this?
- How is this information related to information given in other chapters?
- How is this information related to the qualifications for advancement?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training manual, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the material.

9. Use enlisted correspondence courses whenever you can. The correspondence courses are based on rate training manuals or on other appropriate texts. As mentioned before, completion of a mandatory rate training manual can be accomplished by passing an enlisted correspondence course based on the rate training manual. You will probably find it helpful to take other correspondence courses as well as those based on mandatory manuals. Taking a correspondence course helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study rate training manuals. You are working for advancement to third class or second class right now, but some day you will be working toward higher rates. Anything extra that you can learn will help you, both now and later.

SOURCES OF INFORMATION

Besides training manuals, NAVTRA 10052 lists other publications on which you may be examined. You should not only study the sections required, but should become as familiar as possible with all publications you use.

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the military requirements for advancement and the occupational qualifications of your rating.

PUBLICATIONS YOU SHOULD KNOW

Electronic technical publications include various handbooks, bulletins, and manuals published and distributed by the Ship Systems Command, and manufacturers' technical manuals. The Navy Stock List of Publications and Forms, NAVSUP 2002, furnishes a complete list of NavShips technical publications along with instruction for ordering copies.

One bulletin of great importance to the ET is Electronics Information Bulletin (EIB), NavShips 0967-001-0000 published biweekly for naval electronics activities. A complete file of these bulletins should be maintained.

This bulletin lists field changes and corrections that must be made in instruction books and other publications that are used in the maintenance of electronic equipment. It also lists electronics publications that become available, and gives valuable suggestions, from case histories, for servicing electronic equipment.

The Electronics Installation and Maintenance Book (EIMB) furnished data applying to all types of electronics equipment including the theory of operation of basic electronic circuits. The EIMB is organized and issued as 12 separate handbooks, each with its own NavShips number. A complete listing of all handbooks, stock numbers, and most recent changes can be found in current issues of the EIB.

Another NavShips publication of importance to the ET is the Naval Ships Technical Manual,

NAVSHIPS 0901-000-0000. This manual is the basic doctrine publication of the Naval Ship Systems Command. Chapter 9670 is of particular importance to the ET and should be a part of the ET library.

The Naval Ship Systems Command Technical News is a monthly publication which contains interesting and useful articles on all aspects of shipboard engineering. This magazine is particularly useful because it presents information which supplements and clarifies information contained in the Naval Ships Technical Manual and because it presents information on new developments.

The manufacturers' technical manuals that are furnished with most electronic equipment are valuable sources of information on operation, maintenance and repair. The manufacturers' technical manuals that deal with Naval Ship Systems Command equipment are usually given NAVSHIPS numbers. These manuals are described in chapter 2 of this training manual.

Some publications are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance in rating; it is likely to be a waste of time and may even be seriously misleading.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Training films are listed in the UNITED STATES NAVY FILM CATALOG, NAVAIR 10-1-777 (formerly NAVWEPS 10-1-777), published in 1971. Copies may be ordered in accordance with the NAVY STOCK LIST OF PUBLICATIONS AND FORMS, NAVSUP 2002. Monthly supplements to the Film Catalog are distributed to catalog holders.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly. Thus, some films become obsolete rapidly. If a film is obsolete only in part, it may sometimes be shown effectively if before or during its showing you carefully point out to trainees the procedures that have changed.

CHAPTER 2

MAINTENANCE

Maintenance may be defined as the function of retaining equipment in, or restoring it to, an operational condition. This includes many operations such as servicing, repair, modification, modernization, overhaul, rebuilding, testing, inspecting, and providing spare parts. Maintenance of electronics equipment is divided into two main categories—preventive maintenance and corrective maintenance.

Preventive maintenance consists of the accomplishment of those maintenance actions deemed necessary to maintain uninterrupted operation within design specifications, and to reduce or eliminate failures, thus prolonging the useful life of the equipment. If these actions are performed on a regular periodic basis, the maintenance is referred to as planned/preventive maintenance.

Corrective maintenance (or repair) is the correction of damage to equipment so as to restore it to an operational condition. This includes the isolation of trouble (troubleshooting), replacement of defective parts, and the readjustment and/or realignment of equipment to bring it up to a satisfactory operating level. Corrective maintenance may also be classified as class A, B, or C maintenance.

Class A maintenance (rebuilding or restoring) is the act of overhauling, repairing, modifying (field changing) and/or restoring a specific electronic set, group, unit, assembly, or subassembly so that it meets its most recent equipment design and technical specifications, and is essentially as good as new equipment.

Class B maintenance (overhaul) is the act of repairing and/or modifying a specific electronic set, group, unit, assembly or subassembly so as to restore its operating characteristics to the extent required to meet its most recent design and technical specifications.

Class C maintenance is the act of repairing on board ship a specific electronic set,

group, unit, assembly, or subassembly to correct those deficiencies specified by a particular job order or work request.

Maintenance may also be referred to as operational, technical, and tender/yard maintenance.

Operational maintenance consists of inspection, cleaning, lubrication, and servicing, and may also consist of adjustments and minor parts replacement not requiring high technical skill or internal alignment.

Technical maintenance consists of replacement of parts, subassemblies, or assemblies, and the alignment, testing, and adjustment of equipment. This type of maintenance requires skill and detailed knowledge of the equipment.

Tender/yard maintenance is maintenance which requires a major overhaul or complete rebuilding of assemblies, subassemblies, or parts.

In Department of Defense maintenance publications, the terms organizational, field, and depot maintenance are substituted for operational, technical, and tender/yard maintenance.

SAFETY PRECAUTIONS

Safety precautions relating to maintenance of electronics equipment are discussed in chapter 2 of Basic Electronics, Vol. 1, NAVPERS 10087-C, and chapter 9670, section 5 of the NAVSHIPS Technical Manual. The following paragraphs review and build upon the material contained in these publications by discussing precautions when handling fluorescent tubes and when working aloft. Also presented are some of the important "DOs" and "DON'Ts" concerning safety for Electronics Technicians.

PRECAUTIONS WHEN HANDLING FLUORESCENT TUBES

Precautions to be observed when handling radioactive and cathode-ray tubes are discussed

in Basic Electronics, Vol. 1, NAVPERS 10087-C. Fluorescent tubes manufactured before 1949 contained a poisonous chemical and therefore special precautions were necessary when handling and disposing of these tubes. These special precautions are no longer necessary for the fluorescent tubes in use today. However, the general precautions relating to any breakable glass objects should be observed.

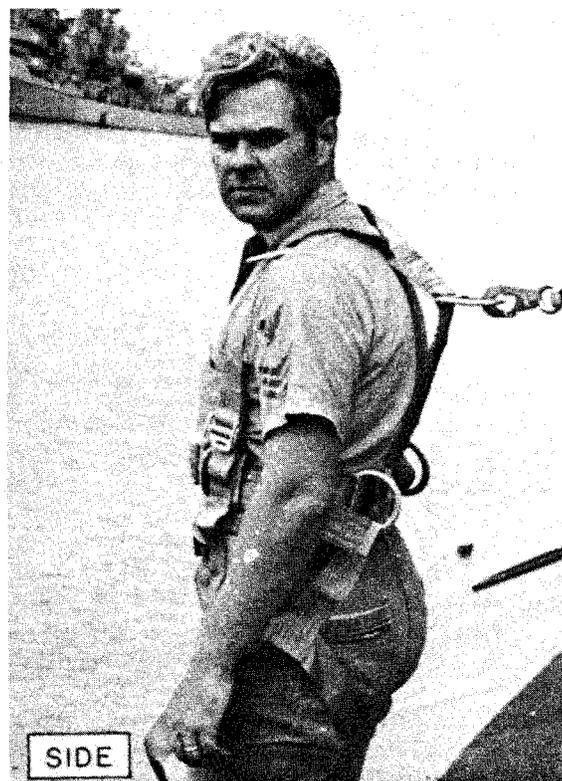
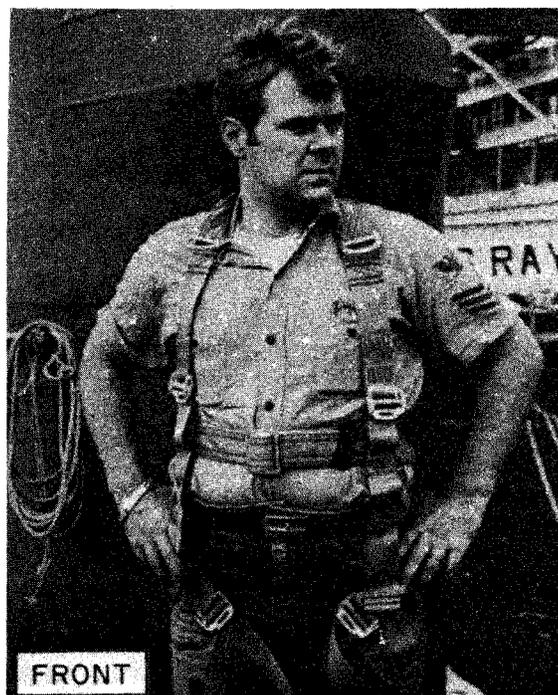
PRECAUTIONS WHEN WORKING ALOFT

Hazards while working aloft include death or injury from falling, asphyxiation from stack gasses, electric shock (either from the equipment being worked on or from induced voltages in guy wires and other ungrounded conductive materials due to radiation from radio and radar antennas). Also included are overexposure to radiation from high powered radar antennas, contact with rotating or oscillating antennas or other moving machinery, and overexposure to inclement weather conditions.

In addition to the danger from electric shock due to energized equipment and induced voltages, there may also be a shock hazard due to static charges. Static charges are caused by electrically charged particles that exist naturally in the air. Under certain conditions these charged particles will collect on metallic objects such as wire antennas and produce a shock hazard. Grounding the objects concerned will eliminate the hazard. Shocks from static charges will not cause direct harm to the individual, but any unexpected shock while aloft may cause a person to fall.

Before going aloft, permission must be obtained from the officer of the deck, and all transmitters and machinery in the vicinity of the work area must be secured and tagged. Permission must also be obtained from the engineer officer to ensure that boiler tubes will not be blown or boiler safeties set during the time the work is being done aloft. If in port or at anchor, permission must also be obtained from the OOD of any ships alongside. Notify these ships when work is completed.

An approved parachute-type safety harness (fig. 2-1) must be worn at all times when working aloft. (The lineman's type safety belt is no longer authorized for Navy use.) Safety harnesses must be checked periodically in accordance with the Planned Maintenance Subsystem. Tools to be used on the job should be placed in a canvas bag and hauled up with a line to the job



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Figure 2-1.—Parachute-type safety harness.

location. To guard against dropping tools and seriously injuring someone, it is recommended that the tool being used be tied to the safety harness with a piece of line.

POINTS TO REMEMBER

Some important points to remember relating to safety are listed in the following paragraphs.

Remember to secure power from ALL sources, tag supply switches, and discharge all capacitors and other devices that may contain a stored electrical charge before working on electrical or electronics equipment.

Do not work on energized equipment unless in an emergency, and then only after obtaining permission from appropriate authority and taking special precautions. Voltages as low as 30 volts can be dangerous under certain conditions. Approximately 100 milliamperes through the heart area for 1 second can be fatal.

Do not use your fingers to test a "hot" circuit; use an approved meter. Do not hold test probes when measuring voltages over 300 volts. Do not work alone when working on energized circuits and equipments.

Use an approved fuse puller to remove and replace cartridge fuses. Do not short out, block open, or otherwise disable any interlock switch.

Observe all "high voltage," "RF radiation," and other types of safety warning signs. Ensure that the metal cases of portable test equipment and power tools are properly grounded. Do not use a power tool that has a frayed cord or damaged plug.

Take time to be safe—hurrying invites accidents.

PREVENTIVE MAINTENANCE

Preventive maintenance actions enable the technician to prevent troubles from occurring in equipment, and to correct any other troubles before they result in actual breakdown of the equipment. These actions (which normally consist of cleaning, lubrication, periodic tests and inspections, and recording of performance data) are carried out as specified by the Planned Maintenance Subsystem (PMS) for the individual equipment or system concerned.

The PMS is a subsystem of the 3-M System, and is discussed in Military Requirements for PO3&2, NAVPERS 10056-C. As an ET3 or ET2 you will be concerned mainly with the Weekly PMS Schedule (OPNAV 4790/15), the Maintenance

Requirement Cards (OPNAV 4700-1), the Feedback Report (OPNAV 4790/7A), and that portion of the Work Center PMS Manual (OPNAV 43P1) that applies to your equipment.

THE WEEKLY PMS SCHEDULE

A Weekly PMS Schedule (fig. 2-2) is posted in each Work Center, and is used by the Work Center Supervisor to assign and monitor the accomplishment of the required PMS actions by the work center personnel.

The Weekly PMS Schedule contains the following:

a. A particular Work Center, date, and approval signature

b. A list of the systems, subsystems, and components assigned to the maintenance group, and related Maintenance Index Pages (MIP) in the Work Center PMS Manual (OPNAV 43P1)

c. Names of the maintenance personnel assigned to individual maintenance actions

d. The maintenance requirements to be performed during one week.

e. A column for scheduling outstanding repairs and PM checks due in next 4 weeks. This enables the Work Center Supervisor to list forthcoming PM checks and corrective maintenance actions as being beyond the capability of the ship's personnel, lack of spare parts, or lack of proper tools. These repairs may be phased into the workload and accomplished with currently scheduled maintenance.

The Weekly PMS Schedule is used as follows:

a. The weekly and daily maintenance requirements are entered on the Weekly PMS Schedule, using the Maintenance Index Page (MIP) as a guide. Weekly requirements may be entered on Monday to provide ease of rescheduling. Daily requirements must appear each day. These may be preprinted on the Weekly PMS Schedule.

b. The Work Center Supervisor transposes all PMS requirements for the current week from the Quarterly Maintenance Schedule to the Weekly PMS Schedule. He is responsible for updating the Quarterly Maintenance Schedule when the weekly PMS requirement has been completed. He must achieve a balanced work load and give appropriate consideration to the week's operating schedule. He must ensure that related maintenance actions are scheduled together.

Chapter 2—MAINTENANCE

| WORK CENTER | | | PMS SCHEDULE FOR WEEK OF | | | | APPROVAL SIGNATURE | | |
|-----------------------|--------------------|----------------------------|--------------------------|------------------------------------|-----------|-----------|--------------------|-----------|---|
| <i>COMMUNICATIONS</i> | | | <i>2-8 AUGUST 1971</i> | | | | | | |
| MIP | COMPONENT | MAINTENANCE RESPONSIBILITY | MONDAY | TUESDAY | WEDNESDAY | THURSDAY | FRIDAY | SAT.-SUN. | OUTSTANDING REPAIRS AND P.M. CHECKS DUE IN NEXT 4 WEEKS |
| <i>C1</i> | <i>AN/URR-35</i> | <i>ABLE</i> | | | <i>M2</i> | | | | |
| <i>C2</i> | <i>AN/URR-27</i> | <i>BAKER</i> | | <i>M1, M2, M3</i> | | | | | |
| <i>C3</i> | <i>AM-1365/URT</i> | <i>CHARLES</i> | | <i>(M1)</i> → <i>M1</i> | | | | | |
| <i>C5</i> | <i>AN/WRT-2</i> | <i>DOW</i> | <i>W1</i> | | | | | | |
| <i>C7</i> | <i>AN/URC-32A</i> | <i>GREEN</i> | <i>W1</i> | | | | <i>W1</i> | | |
| <i>C8</i> | <i>AN/SRR-39A</i> | <i>HAPP</i> | <i>W1</i> | → | | <i>W1</i> | | | |
| <i>C10</i> | <i>AN/WRT-1A</i> | <i>INGLE</i> | <i>W1</i> | → | | <i>W1</i> | | | |
| <i>C13</i> | <i>CV-691/U</i> | <i>JUSTICE</i> | | | | | | | |
| <i>C14</i> | <i>AN/URA-17</i> | <i>KIDD</i> | <i>W1</i> | | | | | | |
| <i>C16</i> | <i>AN/SRA-33</i> | <i>LOWE</i> | | | | | | | |
| <i>C17</i> | <i>AN/SRA-38</i> | <i>MAY</i> | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

UPDATE THIS SCHEDULE DAILY

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Figure 2-2.—Weekly PMS schedule.

MIPs/MRCs must be reviewed to determine related maintenance requirements.

c. Maintenance personnel obtain PMS assignments from the Weekly PMS Schedule, obtain MRC cards, tools, and material, and perform the maintenance action. The completed maintenance action is then reported to the Work Center Supervisor.

THE MAINTENANCE REQUIREMENT CARD

The Maintenance Requirement Card (MRC) provides maintenance personnel with detailed guidance for the performance of each planned/preventive maintenance action. MRCs are grouped as follows:

MRC Set—Consists of the complete index of MRCs describing the minimum maintenance requirement for a specific system, subsystem, or component. The MRCs in a set are listed under the same MIP number.

MRC Group—Consists of MRCs covering all planned maintenance requirements listed on the MIPs assigned to one specific work center.

MRC Deck—Consists of all MRC groups and Equipment Guide Lists (EGLs) for the centers within a department. An example is the master MRC deck for the Operations Department.

Maintenance requirement cards for specific electronics equipment are shown in chapter 11 of this manual.

CORRECTIVE MAINTENANCE

To perform effective corrective maintenance the ET must have a good working knowledge of the basic principles of electricity and electronics. The only way to acquire this knowledge is by diligent study. The ET must also be thoroughly familiar with the theory of operation of the equipments that he must service.

Skill in the use of test equipment (and hand-tools) is also necessary for effective corrective maintenance. Skill comes with practice and with careful study of the technical manual that comes with each piece of test equipment. The ET should take advantage of every opportunity to learn more about every type of electronic test equipment used aboard ship.

Maintenance personnel must try to find the source of the trouble causing the equipment failure, particularly when the trouble is a recurrent one. The recurrence of a fault usually indicates that the EFFECT, not the CAUSE, has been remedied.

There are numerous ways to isolate a fault to a component (part) of a system, depending on the type of equipment. The technician must, first of all, know what each component does before he can know that it is not functioning properly.

The best way (the most economical in time and effort) to isolate a fault is by using a logical troubleshooting method. This method (called the six-step troubleshooting method) is discussed in chapter 12 of this manual.

MAINTENANCE DATA COLLECTION SUBSYSTEM

The maintenance data collection subsystem (MDCS) is the subsystem of the 3-M System which provides a means for recording and reporting information (such as manhours and material expenditures) associated with the various categories of maintenance actions.

The subsystem uses coded data elements to record much of this information in order to standardize the data collected and to facilitate its processing and use. The failure and corrective action information recorded on maintenance action documents, and the material usage information recorded on associated supply documents are retrievable, through this system, for engineering analysis and maintenance history. In addition, the system makes it possible to report the need to delay the accomplishment of required maintenance or to indicate the principal reason for this delay. The MDCS forms that you will be mainly concerned with as an ET3 or ET2 are the Maintenance Data Form OPNAV Form 4790-2K and supply requisition form NAVSUP Form 1250.

Maintenance Data Form (OPNAV Form 4790-2K)

Routine maintenance action reporting is accomplished on a multipurpose Maintenance Data Form which, occasionally, is augmented by Supplemental Report Form. The Maintenance Data Form is used to report the completion or deferral of a maintenance action, or to request needed assistance. The standard data elements which must be completed to report any categories of maintenance information have been grouped together in separate, clearly labeled sections of the form to simplify data recording and to facilitate automatic data processing (ADP).

In addition to the standard data elements, the form provides special shaded sections to record data elements for maintenance actions associated with specially identified systems or equipments, or reports completed under certain unique circumstances. In this manner, provision has been made for reporting special or additional maintenance related information. The form is a single sheet, multipurpose form printed on NCR (no carbon required) paper.

To provide a complete record of a maintenance action, it may be necessary to use two or more reporting forms. Information on a maintenance action may be recorded on a deferral, subsequent changes to that deferral, a work request, associated supply documents, and any number of special supplemental reports. To ensure against the loss of essential data on these forms, they must be unmistakably linked to each other, and to the proper maintenance action, until all the data have been properly processed. This is accomplished by assigning to each maintenance action a unique identification number, and by ensuring that this number appears on each associated data collection form.

In the MDCS this identification is a 13 character number known as the Job Control Number (JCN). It is composed of a five character Unit Identification Code, a four character Work Center Code, and a four character sequential serial number called the Job Sequence Number (JSN). The JSNs are normally numerical and are assigned, in sequence from 0001 through 9999 by the Work Center Supervisor. The numbers are then recycled to 0001. The time lapse before recycle occurs is usually sufficient to preclude any confusion in identifying maintenance action documents. Provisions have been made for extending the range of JSNs by using a

letter in lieu of the first numeral (A001, B205, etc.)

COMPLETED MAINTENANCE ACTION (OPNAV Form 4790-2K).—The Completed Maintenance Action form (fig. 2-3) is prepared for the following:

- a. All reportable corrective maintenance
- b. Authorized alterations which are completed without having first been deferred
- c. PMS actions for which the MRC specifies the use of repair parts or material
- d. PMS actions which require that meter readings be reported as part of the MRC procedure
- e. PMS actions during which clearances, tolerances, or readings are obtained which must be reported in accordance with Type Commander (TYCOM) instructions
- f. Preventive maintenance actions other than PMS. Routine PMS actions are not reported

To fill out the Maintenance Data Form for a completed maintenance action (fig. 2-3), enter your ship's name and hull number in the upper left corner, check the maintenance action completed box in the upper right corner, and complete the rest of the form as described below. (Appendices referred to are those in the 3-M Manual, OPNAV 43P2.)

Block 1: The Unit Identification Code (UIC) is the code for your activity. If this code consists of only four digits, enter a zero as the first digit.

Block 2: Work Center codes are in Appendix 3. The first two characters identify the department and division; the last two digits identify the work center. (0E01 is the electronic maintenance group of the operations department.)

Block 3: The job sequence number (JSN) is a four digit work serial number assigned sequentially by the Work Center Supervisor. The UIC, Work Center Code, and JSN make up the job control number as stated previously.

Block 4: Enter the equipment identification code (EIC) for the equipment on which maintenance was performed. This code is found in the EIC Master Index Manual. To determine the proper EIC, refer to the system level EIC sequence section of the Master Index and find the name of the system that includes your equipment. Opposite the system name is a number or letter followed by six zeros. The

number or letter identifies the section of the manual in which the EIC codes for the equipment associated with the system are listed.

For example, (as in the case of fig. 2-3), you find in the system level EIC sequence section that the EIC code for radar and IFF systems is P000000. You then refer to the P section of the system, subsystem, equipment EIC sequence and find the EIC code for the SPS-10 radar set to be P113000.

In addition to the EIC sequence section, the Master Index also includes a nomenclature sequence section. This section lists the noun names of systems, subsystems, and equipments (along with their EIC codes) in alphabetical order.

Block 5: Enter the code that best describes the first indication of trouble. These codes are contained in Appendix 4. The 9 listed in block 5 is the code for "fails to radiate."

Block 6: Enter the code from Appendix 5 which describes the circumstances under which the need for corrective maintenance was discovered.

Block 7: Enter the Julian date. A Julian calendar is shown in Appendix 2. The last numeral of the year is entered first, followed by 3 digits for the consecutive day of the year. The 1140 listed in block 7 is 20 May 1971. (The 20th of May is the 140th day of the year.)

Block 8: Enter the code from Appendix 6 which best describes the status of the equipment at the time the need for maintenance was discovered. The 2 in block 8 of figure 2-3 means nonoperational.

Block 9: Enter the serial number of the equipment as identified by the first four characters of the EIC in block 4. This would be the serial number of the AN/SPS-10 radar set in the example shown in figure 2-3.

Block 10: Enter the allowance parts list number assigned to the part being repaired or replaced. This number is found in the Coordinated Shipboard Allowance List (COSAL), and the List of Effective Pages (LOEP) in the Departmental Master 3-M Manual, OPNAV 43P1. If the number is not listed in the COSAL or LOEP, enter "not listed."

Block 11: This block is completed when a field change or alteration is performed.

Block 12: Enter the code from Appendix 7 which best describes the action taken to complete the maintenance.

Block 13: Enter the total manhours to the nearest tenth expended on the maintenance. Enter

zeros in the spaces to the left which are not used. For example, if two men worked 1.5 hours, the entry would be 0030.

Block 14: Enter the rate of the senior man performing the maintenance.

Block 15: Enter the Julian date of the day the maintenance is completed.

Block 16: Enter the code from Appendix 6 which best describes the status of the equipment after the maintenance is completed. (1 indicates operational.)

Block 17: Enter the code from Appendix 8 which best describes the cause of the failure. (9 indicates normal stress or deterioration.)

Block 18-21: Completed when the equipment contains a time meter. Not filled in when field changes or alterations (block 11) are involved. Enter in block 18 the time to the nearest tenth of an hour that was actually spent on the maintenance. Include troubleshooting time, repairing time, and time spent checking equipment after the repair. This time is actual clock time, not manhours. For example, if one man (or any number of men) worked for 2.5 hours, the time entered would be 0025.

Block 19: Enter a single numeral (1-9) to indicate the percentage to the nearest 10% of active maintenance time (block 18) that was spent on troubleshooting. If no troubleshooting was involved, enter zero.

Block 20: Enter the equipment meter or counter reading to the nearest hour, at the time the first indication of trouble was recognized. If more than one meter is installed, use the one that monitors operating hours for the equipment being worked on.

Block 21: Record the meter designation that applies to block 20. When no designator has been assigned, leave blank.

Block 22-42: Discussed later under deferred maintenance.

Block 43: Enter the noun name of the equipment identified in block 4, using abbreviations as necessary. Use AN nomenclature when available. Briefly describe what was wrong with the equipment and what was done to correct the fault. Print one letter to a space.

Block 44-47: Leave blank.

Block A: Signature of the senior man performing the maintenance.

Block B: Signature of the Work Center Supervisor.

Blocks 48-54: To be filled in only if the equipment being worked on is included in the selected equipment list appearing in Appendix

18. Enter in block 48 the EIC code for the equipment being worked on, as in block number 4.

Block 49: Enter the manufacturer's part number or the Federal Stock Number (FSN). The FSN number should be used only if there is no manufacturer's part number. Check the appropriate box for the number used.

Block 50: If the manufacturer of the part is known, enter his code number here. Manufacturer's codes are obtained from the Supply Department.

Block 51: Enter the serial number of the part. If the number is large, use only the last ten characters.

Block 52: Enter the code from Appendix 12 which best describes the condition of the failed part. (Code 2 indicates an open coil winding.)

Block 53: Enter the reference designation for the part from the appropriate schematic diagram.

Block 54: Enter from Appendix 13 the code which best describes what was done with the faulty part. If there are several faulty parts, complete the rest of section 5 but document only the most significant parts. (Code D indicates discarded.)

Blocks S-Z are for use as directed by Type Commanders. Section 6 is for the use of repair activities in planning, scheduling, and controlling work.

DEFERRED MAINTENANCE ACTION (OP-NAV Form 4790-2K).—The Deferred Maintenance Action form (fig. 2-4) is prepared for maintenance actions which cannot be completed within the time normally required. The initial documentation is completed in duplicate. A copy of the form is submitted as soon as the need to defer maintenance is recognized. The original of the deferral is retained on board for documentation of additional data, and is submitted only after the deferred maintenance is completed, or the deferral is cancelled. Deferred action reports are submitted for reportable maintenance which falls in the following categories:

a. Cannot be accomplished because of the ship's operations. (In this respect, the ship's operations are considered to include both in port and at sea activities that preclude the accomplishment of required maintenance.)

b. Cannot be accomplished because of a lack of parts or material.

c. Cannot be accomplished because of a need for technical skills or equipment not available on board. (Outside assistance is required.)

d. All PMS actions (monthly and less frequent) that must be deferred for outside assistance will be reported as a deferred maintenance action.

To fill out the Maintenance Data Form for a deferred maintenance action, proceed as follows:

Section 1 is completed in the same manner as described for the completed action form.

Section 2 is filled in upon completion of the deferred action.

Block 22: Enter the code from Appendix 9 that best describes why the maintenance cannot be accomplished. (Code 7 indicates that the required part is not on board.)

Block 23: Enter the total manhours to the nearest tenth expended up to the time of the deferral.

Block 24: Enter the rate of the senior man engaged in the maintenance.

Block 25: Enter the Julian date of the day the maintenance is deferred.

Block 26: Enter the code from Appendix 6 that best describes the status of the equipment at the time of deferral.

Block 27: Enter the code from Appendix 10 that best describes the type of availability need to complete the deferral. (Code 5 indicates ship's force.)

Block 28: Enter the code from Appendix 11 that best describes the urgency for completing the deferral. (Code 3 indicates routine repair.)

Block 29: Enter an X when failed part information is required. The activity completing the maintenance will furnish the necessary data.

Blocks 30-33: Completed when equipment contains a time meter or counter. Refer to blocks 18-21 of the completed maintenance action form.

Blocks 34 and 35 are completed when an internal work request is submitted.

Block 36: Enter the estimated manhours to the nearest whole hour required to complete the action. This entry is for the Work Center shown in block 2 when the deferral is to be completed by the ship's force. For other types of availabilities, the entry is for the total ship's force manhours in connection with the deferral.

Block 37: When the type of availability is ship's force and assistance is required, enter the Work Center that will provide the assistance.

Block 38: The Work Center listed in block 37 will enter its estimate of total manhours required to complete its portion of the maintenance. When the type of availability is other than

ship's force, the type commander's representative will fill in block 38.

Blocks 39-42 are completed when an internal work request is submitted.

Block 43: Enter the name or AN designator of the equipment identified in block 4. All deferrals must include the following information:

1. The trouble, followed by three Xs
2. What needs to be done
3. Parts needed to complete the work

After a deferral has been submitted, the reason for the deferral could change. Any change in the deferred action taken, or to the type of availability requires submission of a new deferral form. Such changes will usually cause other data to be incorrect; therefore, the new form must be carefully checked.

When the deferred maintenance is completed, check the completed maintenance block, complete the blocks in section 2, and describe in block 43 what was done.

WORK REQUEST. (OPNAV Form 4790/2K)— Appropriate blocks on four sheets of the maintenance data form are filled in to record the need for outside assistance. Variations, however, from the standard number of copies may be required by certain repair activities. These procedures are intended to accommodate those activities desiring to use the internal work request concept for planning and controlling maintenance assistance between Work Centers within the activity. Basic information for initiating the Work Request normally will come from the ship's copy of an associated deferred action form.

The Work Request is also used to request assistance from another Work Center within the ship or activity. It is filled in from the information contained on the filed copy of the deferred action. The Work Request contains the same JCN as the associated deferred action.

For those activities that do not desire to control internal Work Requests, or where the situation precludes the planning and control of requested work, the initiation and accomplishment of the work may be documented by using the single sheet Work Request procedures outlined in OPNAV 43P2 and 42P5.

For the Work Request, blocks 1 through 11, 28 and 29 of the Maintenance Data Form are completed, using the information contained on the deferral form. In block 43 enter the name

or AN designator of the equipment and tell what needs to be done.

In blocks A and B print the names of two contact men. If the equipment is to remain on board, fill in the location blocks.

In block 69 list all applicable blueprints, technical manuals, schematics and other documents. When the work has been accomplished, complete the deferral copy retained on board and forward it to the department head.

SUPPLY REQUISITION FORMS.—Documenting material usage and cost data on maintenance transactions requires the joint effort of the ship's supply and maintenance personnel. NAVSUP Form 1250 and DD Form 1348 (discussed in Military Requirements for PO3&2, NAVPERS 10056-C) are the source documents used to record material usage and cost data in support of maintenance actions. Supply personnel are expected to assist maintenance personnel whenever difficult or unusual documentation problems arise. Issues of materials which do not directly involve a maintenance action or minor consumables will not be reported in the MDCS.

When a repair part is needed before a specific maintenance action can be completed, the maintenance man aboard a non-mechanized ship uses NAVSUP Form 1250 to request the issue of the part from the ship's supply department. Supply personnel issue the part, if it is in stock aboard ship. If it is not in stock, the information on the form is used by supply to order the part from off-ship sources.

When a repair part is required to complete a specific maintenance action aboard a mechanized ship, the maintenance man uses DD Form 1348.

After appropriate action has been taken by the supply personnel, the requesting maintenance man receives a copy of the supply request along with the material. In cases where the material is not available on board, the supply document is marked NIS (not in stock) or NC (not carried), as appropriate, and the supply personnel take appropriate action to obtain the requested material.

Field Changes

Field Changes are the means by which approved and authorized alterations and modifications are made to electronic equipments for the purpose of improving the equipment performance, operational characteristics, or maintenance features. Recommendations for Field

Changes may originate from various sources such as the Fleet, naval shipyards, contractors, project managers, and equipment engineers.

Field Changes are mandatory and are to be accomplished on the equipment affected in accordance with the instructions contained in the Field Change bulletin at the earliest opportunity. Field Changes are issued in kits and are classified as type 1, 2, 3 or 4 as follows:

A type 1 Field Change kit includes all parts, materials, special tools, and instructions required to accomplish the change to the affected equipment and to revise existing equipment nameplates, publications, and charts.

A type 2 Field Change kit contains the instructions to accomplish the Field Change and to correct the related publications. The required parts are not included.

A type 3 Field Change kit includes the instructions to accomplish the change, and some of the parts, materials, and special tools required to accomplish the change and to revise the existing nameplates, publications, and charts.

A type 4 Field Change includes the instructions for accomplishing the change and for correcting the related publications. No parts or special tools are required.

Field Changes are further classified as class A, B, or C as follows:

A class A Field Change is a change approved for accomplishment by forces afloat or station personnel. No installation funding is required.

A class B Field Change is a change approved for accomplishment by Naval Shipyards, tenders, and repair facilities, without reference to the cognizant Systems Command, upon allocation of funds by the Type Commander.

A class C Field Change is a change normally requiring shipyard or other industrial assistance for accomplishment, and the cognizant Systems Command is obligated for funding.

When a Field Change is accomplished, record its completion on the Field Change Accomplishment plate of the equipment affected, and on the appropriate MDCS Maintenance Data Form in accordance with OPNAV 43P2.

ENVIRONMENTAL EFFECTS ON ELECTRONIC EQUIPMENT

It is beyond the scope of the chapter to present all the problems encountered from environmental conditions, because individual methods of installation and stowage of electronic equipments

differ from ship to ship and from one naval shore station to another. However, some of the preventive and corrective measures that should be taken under adverse environmental conditions, and the effects on the equipment subjected to these conditions, are given in the following paragraphs.

TEMPERATURE

Extremely low temperature may cause brittleness in certain types of metals, and loss of flexibility to rubber, insulation, and similar material. Extremely high temperatures may cause deformation, and deterioration of terminal boards, seals, insulation and heat-sensitive devices. Rapid changes of temperature may be especially damaging to certain types of electronic components.

The cooling or heating of air spaces surrounding the components of electronic equipment is generally accomplished and controlled by blowers, fans, hot oil and water coolers, etc., either to dissipate the heat generated by the equipment components, or to heat or cool the surrounding ambient air. Regardless of the method employed for the cooling or heating of spaces, if personnel neglect to keep the screens, filters, fans, ducts, surface area of coolers, and equipment free from foreign matter, the heating or cooling will be greatly affected, which may result in equipment damage or malfunction caused by improper temperature control.

HUMIDITY

High humidity, (prevalent in tropical climates) is the "arch enemy" of electronic equipment. Its resultant damage to equipment parts is caused by condensation and fungus growth, under conditions of both high salt-laden moist air and high temperature. In this case, adequate ventilation of the equipment is of the utmost importance to protect the equipment components from entrapped moisture and extremely high operating temperatures. To overcome any adverse effects on electronic equipments, maximum and minimum temperature gradients should be controlled by one of the cooling or heating mediums provided.

In many cases, critical electronic components are encapsulated, potted, or sealed, to protect them from the detrimental effects of moisture and temperature variations. However,

sealing the component does not completely eliminate the problem of high-humidity conditions, because the seals sometimes must be broken for maintenance or repair work. There is also the possibility that the electronics technician will not always have on hand the suitable sealing compounds to repair or replace sealed components. Where this condition exists, except in cases of emergency, the repair or replacement of sealed components should not be performed in the field.

Equipment that is to remain idle and deenergized for a considerable length of time should have their space heaters (if provided) turned ON to keep the insulation and equipment dry. If space heaters are not provided for the equipment, electric lamp bulbs or a portable electric heater as a temporary measure can be placed within or near the equipment. This is especially important in humid or cold climates.

CORROSIVE ATMOSPHERE

The effect of a corrosive atmosphere on metal parts, and insulation can cause serious damage to unprotected electronic equipment. For this reason, the technician should be cognizant of the harmful effects of all corrosive elements. He must be especially aware of the effects produced by salt spray or salt-impregnated air. To prevent corrosive effects, a regular periodic cleaning schedule for most equipments has been established by PMS. This schedule normally includes dusting and cleaning, lubrication of the moving parts, and the application of approved solvents or wetting agents to remove any accumulation of foreign matter, such as soil, dust, dirt, oil film, and salt-impregnation. Failure to adhere to this regular periodic cleaning schedule can lead to degradation and early equipment failure. In addition, all access doors and panels should be securely fastened and in place when maintenance work is not being performed on the equipment.

In the event that a piece of electronic equipment becomes soaked with salt water, oil or acquires a thick coat of oily dirt, the following procedure may be used to clean the equipment:

1. Deenergize the equipment.
2. Disconnect and remove the drawers or units which are to be cleaned.
3. Remove all tubes, subassemblies, assemblies, cover plates, plug-in cables, and any parts which could be affected by water.

4. Move all of the items to a place near a source of fresh water, such as a shower stall.
5. Liberally wash down the items with fresh water; for oil and greasy dirt, use an approved dry cleaning solvent or a nonionic detergent.
6. Rinse thoroughly with fresh water and allow the excess water to drain off.
7. Use clean, low pressure air to blow out as much of the water as possible.
8. Completely dry the parts using heat lamps, electrical heaters, hot air blowers, or the galley ovens. Be careful not to overheat the parts.
9. Clean out all connectors with solvent and pipe cleaners.
10. After the parts are dry, make visual inspections and resistance tests to locate damaged parts. Replace parts as necessary.
11. Reassemble and reinstall all parts of the equipment, and make all required tests and alignments as indicated in the technical manual.

RECORDS AND REPORTS

In addition to the 3-M System forms discussed earlier, there are various other types of record and report forms that concern the ET. Some of the common ones are described briefly below.

REFERENCE STANDARDS BOOK

The Reference Standards Book includes: (1) Reference Standards Tests, (2) Reference Standards Summary Sheets, and (3) Performance Standards Sheets. When these three items are contained in a single publication, they constitute a Reference Standards Book for a particular equipment or system.

Reference Standards Tests consist of a series of measurements made initially when the equipment is operating at peak performance. These measurements, containing upper and lower limits, provide maintenance personnel with standards against which subsequent measurements may be compared in order to ascertain equipment readiness at any given time. The Reference Standards Tests are accompanied by blank spaces (fig. 2-5) which are used by maintenance personnel to record the results of subsequent measurements. This allows maintenance

personnel to develop a performance history of an equipment. The Reference Standards Tests are scheduled on a routine basis such as daily, weekly, and monthly. These tests are superseded and canceled when the PMS is implemented. Reference Standards Books are to be retained on board ships, however, even after PMS has been installed, in order that technical data on installed equipments will be available for ready reference.

Two identical Reference Standards Summary Sheets precede the front matter of a newly issued Reference Standards Book. The Reference Standards Summary Sheets provide blank spaces for maintenance personnel to record the results of all Reference Standards Tests. After the sheets are filled in, one is retained in the book and the second is submitted to NAVSHIPS for evaluation.

A Performance Standards Sheet (fig. 2-6) lists the capability of a particular equipment or system. The sheet also lists the measurements that can be performed to determine if the equipment is operating at its designed capability. A Performance Standards Sheet is used by maintenance personnel to determine the overall operation of an equipment by test results from the Reference Standards Book with the data given on the Performance Standards Sheet. This sheet is usually the first page in a newly issued Reference Standards Book.

ELECTRONIC PERFORMANCE & OPERATIONAL REPORT

The Naval Ships System Command must keep tab on new (and converted) equipments to evaluate their usefulness. This is accomplished with the Electronic Performance and Operational Report, NAVSHIPS 3878, shown in figure 2-7.

It is not desired that reports be submitted on all equipments. Detailed instructions for the preparation and submission, and a listing of equipment requiring a report are contained in NAVSHIPS Instruction 9670-20E. When applicable, NAVSHIPS 3878 is submitted quarterly to the Naval Ships Systems Command.

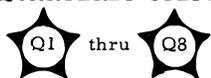
The NAVSHIPS 3878 reports are essential to keeping the Naval Ships System Command informed on equipment performance and operation. Because they provide firsthand information on equipment under actual operating conditions and report the maximum ranges obtained, they are extremely valuable in evaluating the electronics maintenance program, enforcing manufacturers'

Chapter 2—MAINTENANCE

QUARTERLY STEPS

NAVSHIPS 94715.42

AN/WRR-2, -2A
AN/FRR-59, -59A



OPERATING CONDITIONS AND CONTROL SETTINGS:

Equipment in full operation and conditioned for A1 reception.
O. L. THRES: OFF

| STEP NO. | ACTION REQUIRED | READ INDICATION ON | REFERENCE STANDARD |
|----------|--|-------------------------------|-----------------------------|
| ★ Q1 | Record over-all sensitivity of Mode A1 at low end of 2-4 mc band. | Signal Generator AN/URM-25 | μV (1.5 max.) |
| | *PROCEDURE: Connect signal generator to the ANT IN jack (J957). Adjust generator for a 2-mc unmodulated signal and set output at 5 μV . Set BAND selector to 2-4. Tune receiver to 2 mc and adjust the ANT COMP and HF ADJ controls for maximum indication on the RESONANCE meter. Reduce generator output to zero and adjust RF GAIN for a -2 db indication on the LINE A OUTPUT meter. Set generator output to 5 μV and adjust generator frequency for a maximum indication on the RESONANCE meter. Readjust generator output for a +18 db indication on the LINE A OUTPUT meter. Record the generator output in microvolts. | | |
| ★ Q2 | Repeat for high end of band. | Signal Generator AN/URM-25 | μV (1.5 max.) |
| | PROCEDURE: Tune receiver to 4 mc and repeat step Q1. | | |
| ★ Q3 | Record over-all sensitivity of Mode A1 at low end of 4-8 mc band. | Signal Generator AN/URM-25 | μV (1.5 max.) |
| | PROCEDURE: Set BAND selector to 4-8. Tune receiver to 4 mc and repeat step Q1. | | |
| ★ Q4 | Repeat for high end of band. | Signal Generator AN/URM-25 | μV (1.5 max.) |
| | PROCEDURE: Tune receiver to 8 mc and repeat step Q1. | | |
| ★ Q5 | Record over-all sensitivity of Mode A1 at low end of 8-16 mc band. | Signal Generator AN/URM-25 | μV (1.5 max.) |
| | PROCEDURE: Set BAND selector to 8-16. Tune receiver to 8 mc and repeat step Q1. | | |
| ★ Q6 | Repeat for high end of band. | Signal Generator AN/URM-25 | μV (1.5 max.) |
| | PROCEDURE: Tune receiver to 16 mc and repeat step Q1. | | |
| ★ Q7 | Record over-all sensitivity of Mode A1 at low end of 16-32 mc band. | Signal Generator AN/URM-25 | μV (1.5 max.) |
| | PROCEDURE: Set BAND selector to 16-32. Tune receiver to 16 mc and repeat step Q1. | | |
| ★ Q8 | Repeat for high end of band. | Signal Generator AN/URM-25 | μV (1.5 max.) |
| | PROCEDURE: Tune receiver to 32 mc and repeat step Q1. | | |

Figure 2-5.—Sample page from Reference Standards Book (reference Standards tests).

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6 April 1972

NAVSHIPS 94715.32

AN/WRR-2, -2A
AN/FRR-59, -59A

PERFORMANCE STANDARD SHEET
for
RADIO RECEIVING SETS AN/WRR-2, -2A, AN/FRR-59, -59A

TABLE I - OPERATIONAL PERFORMANCE

The many variables involved, such as radio propagation conditions at the time of the test, power output of the transmitter being received and the type of antenna installation, preclude definitive predictions of operation ranges. To achieve optimum reliable ranges, frequency selection should be made in accordance with DNC-14, as corrected by half-hourly radio propagation predictions given over WWV and WWVH.

NOTE: KC = KHZ

TABLE II - STANDARDS FOR EQUIPMENT MEASUREMENT

| MEASUREMENT | STEP | STANDARD |
|---------------------------|-------------|---|
| Bandwidth (IF, 1.0 KHz) | Q19 and Q20 | 0.8 KHz min. (at 6 db) 2.4 KHz min. (at 60 db) |
| Receiver Sensitivity (Sr) | Q1 thru Q8 | 1.5 μ v max. |
| Performance Figure (PF)* | Calculate | 1.5 max. |

* PF = Sr (μ v)

Total time required to perform Table II measurements - 1 hour.

All steps refer to tests in the Reference Standards Book, NAVSHIPS 94715.42

This Performance Standards Sheet supersedes NAVSHIPS 93550.32

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Figure 2-6.—Performance standards sheet.

guarantees, evaluating installation adequacy, improving equipment operation and safety, and improving equipment design.

The NAVSHIPS 3878 report contains a place for general remarks on the back of the form (not shown). Indicated here is any pertinent

information not included elsewhere on the form such as detailed information on any unusual difficulty encountered in operation; exceptional maintenance required; and suggestions for improvement in design, tests, and new applications.

Chapter 2—MAINTENANCE

| ELECTRONIC PERFORMANCE & OPERATIONAL REPORT | | | | | | | | | | REPORT: RUSHIPS-0076-1 | | | | | |
|--|--|--|--|---------------------------------|--|--|--|---|--|--|--|---------------------------------|--|----|--|
| NAVSHIPS 3876 (Rev. 4-66) <i>Submit original only to Bureau - No forwarding letter required</i> | | | | | | | | | | | | | | | |
| FROM: USS RANGER (CVA-61) | | <input type="checkbox"/> LMT | | REPORT CLASSIFICATION | | DATE | | | | | | | | | |
| (Ship name, type and hull no.) | | <input checked="" type="checkbox"/> FLEET <input checked="" type="checkbox"/> PAC | | UNCLASSIFIED | | 31 MARCH 1971 | | | | | | | | | |
| TO: | | | | REPORTING PERIOD | | FROM | | TO | | | | | | | |
| TYPE AND MODEL OF EQUIPMENT | | AM-1365/URT Amplifier | | SERIAL NUMBER | | 383 | | | | | | | | | |
| FIELD CHANGES TO DATE | | None | | NOT ACCOMPLISHED | | None | | HOURS DURING PERIOD OF THIS REPORT | | OPER-ATED 180 NOT IN OPER-ATING CONDITION 56 | | | | | |
| PERFORMANCE FIGURE (PF) & TECHNICAL EVALUATION | | | | | | OPERATIONAL EVALUATION | | | | | | | | | |
| <input checked="" type="checkbox"/> OUT-STANDING <input type="checkbox"/> GOOD <input type="checkbox"/> SATIS-FACTORY <input type="checkbox"/> UNSATIS-FACTORY | | | | | | <input checked="" type="checkbox"/> OUT-STANDING <input type="checkbox"/> GOOD <input type="checkbox"/> SATIS-FACTORY <input type="checkbox"/> UNSATIS-FACTORY | | | | | | | | | |
| PEAK POWER OUTPUT (PT) | | | | AVER. VSWR IN TRANSMISSION LINE | | | | AVER. ECHO BOX RING TIME | | | | MIN. DISCRIMINABLE SIGNAL (PWS) | | | |
| | | | | | | | | | | | | | | | |
| MAX. RANGE TARGETS DETECTED | | MI | | MI | | MI | | MAX. ALTITUDE AT RANGE DETECTED | | MI | | MI | | MI | |
| MAX. ALTITUDE TARGETS DETECTED | | FT | | FT | | FT | | RANGE AT MAX. ALTITUDE DETECTED | | FT | | FT | | FT | |
| TARGET CLASS. TYPE - DETAIL (SEE REVERSE) | | I | | | | | | TARGET CLASS. TYPE - DETAIL (SEE REVERSE) | | | | | | | |
| MAXIMUM RELIABLE RADAR RANGE | | | | | | MINIMUM RELIABLE RADAR RANGE | | | | | | YDS | | | |
| | | | | | | | | | | | | | | | |
| SOURCE LEVEL (LS) | | RECEIVING SENSITIVITY | | SEA STATE | | PROCEDURE USED | | | | | | | | | |
| db//uBAR | | db//VOLT/uBAR | | | | | | | | | | | | | |
| NOISE LEVEL db//VOLT | | 5 KNOTS | | 10 KNOTS | | 15 KNOTS | | 20 KNOTS | | 25 KNOTS | | 30 KNOTS | | | |
| MAXIMUM RANGE SONAR TARGETS DETECTED AND TRACKED | | RANGING | | LISTENING | | SOUNDING | | | | | | | | | |
| TARGET CLASSIFICATION TYPE AND DETAIL | | YDS | | YDS | | FATHOMS | | | | | | | | | |
| ST PATTERN | | | | | | | | | | | | | | | |
| OWN SHIP'S SPEED. | | KTS | | KTS | | KTS | | | | | | | | | |
| PERCENT OF TIME OUT OF CONTACT WHILE WITHIN RANGE (IF ANY) | | 0 % | | ANTENNA SYSTEM | | | | INTERFERENCE (Frequency, Intensity, and source) | | | | | | | |
| | | | | No problems | | | | No problems | | | | | | | |
| POWER OUTPUT | | Voice 100 | | AVERAGE VSWR | | 1.5:1 | | REL RANGE | | 40 miles | | RECEIVER SENSITIVITY | | NA | |
| WATTS | | | | VOLTS | | | | MILES | | | | VOLTS | | | |
| MAXIMUM RANGE AND ALTITUDE TARGETS WITH UNFILTERED TARGET CLASSIFICATION TYPE AND DETAIL (SEE REVERSE SIDE) | | MI | | FT | | MI | | FT | | MI | | FT | | | |
| MAXIMUM RELIABLE RANGE AND ALTITUDE | | MI | | FT | | MI | | FT | | MI | | FT | | | |
| TARGET CLASSIFICATION TYPE AND DETAIL (SEE REVERSE SIDE) | | | | | | | | | | | | | | | |
| MAX. RANGE SONAR TARGETS DETECTED | | ST PATTERN | | MAX. RELIABLE SONAR RANGE | | ST PATTERN | | | | | | | | | |
| YDS | | | | YDS | | | | | | | | | | | |

Figure 2-7.—Electronic Performance and Operational Report.

SHIP ELECTRONICS INSTALLATION RECORD

The ship Electronics Installation Record (NAVSHIPS 4110) furnishes an up-to-date inventory of the electronic equipment aboard each ship to interested Fleet and shore activities. To be effective, the NAVSHIPS 4110 must be extremely accurate and kept current. Detailed instructions for preparing, revising, and submitting NAVSHIPS 4110 are found in Reporting Electronic Equipment Installation, NAVSHIPS 0967-088-5010 (formerly NAVSHIPS 900, 135D).

Format

The ship's data portion of the NAVSHIPS 4110 (fig. 2-8) is filled in by NAVSHIPS. The

ship makes no entries in this part of the form except to fill in the date on which preparation or revision of the form is completed by the ship.

The SSC column on the form is filled in by NAVSHIPS with a numerical code equivalent to equipment nomenclature to facilitate automatic data processing.

The equipment data portion of the form is filled in by the ship under the column headings of **CATEGORY, LOCATION, EQUIPMENT MODEL, SERIAL NUMBER, and EQUIPMENT VOLTAGE.** The equipment is listed on the form (1) in category order, (2) within each category by location, and (3) within each location by numerical and alphabetical sequence. The equipment is divided into eight major categories as follows:

completed by ship

check to ensure latest revision

| SHIP ELECTRONICS INSTALLATION RECORD | | | | | | | | | | | | | | | | |
|--------------------------------------|--------|-----------|----------|-----------------|--------|------|----------|---------------|----------------|-----------|-----------|------|----|--|------|-----------|
| NAVSHIPS 4110 (REV 2 59) | | | | | | | | | | | | | | | | |
| DATE REVISED BY SHIP _____ | | | | | | | | | | | | | | | | |
| BUSHIPS REPORT-9670-2 | | | | | | | | | | | | | | | | |
| SHIP | | SHIP NAME | | | Status | AREA | FLT FROM | DIST COMM | BERTH AREA | PLAN YARD | SHIP VOLT | DATE | | | DIST | OVHL YARD |
| TYPE | NUMBER | | | | | | | | | | MO | DAY | YR | | | |
| S C C CODE FOR BUREAU USE ONLY | | CAT | LOCATION | EQUIPMENT MODEL | | | | SERIAL NUMBER | EQUIPT VOLTAGE | | REMARKS | | | | | |
| | | | | | | | | | 1 | 2 | | | | | | |
| | | | | | | | | | | | | | | | | |

Figure 2-8.—Ship Electronics Installation Record (NAVSHIPS 4110).

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| <u>EQUIPMENT</u> | <u>CATEGORY</u> |
|---|-----------------|
| Communications | 1 |
| Radar and Radar Identification | 2 |
| Sonar and Sonar Identification | 3 |
| General Purpose Test | 4 |
| Infrared, Radiac, Radio Navigation, and Countermeasures | 6 |
| Intercommunications | 7 |
| Power Supply | 8 |
| Misc. Commercial, Shore and Certain Test Equipment | 9 |

Category 5, formerly Fire Control Equipment, is now deleted. Category 7, IC equipment, is reported to the Electronics Supply Office (ESO) in accordance with NAVSHIPS Instruction 9670.85. Code numbers (listed in NAVSHIPS 0967-088-5010) are used in the LOCATION and EQUIPMENT VOLTAGE columns of the form to indicate the equipment location and input voltage(s).

The REMARKS column provides space for any remarks deemed necessary by the ship. The Naval Ship Engineering Center (NAVSEC) includes a 4-digit code in this column. The first digit is the category code, and the remaining three digits are the subcategory code. The complete 4-digit code, however, is normally referred to as the subcategory or SCAT code. This SCAT code can be cross referenced to the equipment in the NAVSHIPS 0900-001-2000 series publications. A general guide to SCAT codes for electronic equipments follows:

| <u>EQUIPMENT</u> | <u>SCAT CODE</u> |
|--------------------|-------------------|
| Communications | 0001 through 1999 |
| Radar | 2000 " 2999 |
| Sonar | 3000 " 3999 |
| Test | 4000 " 4999 |
| Infrared | 6000 " 6099 |
| Radiac | 6200 " 6399 |
| Navigation | 6500 " 6999 |
| ECM | 6700 " 6999 |
| Power | 8000 " 8999 |
| Commercial & Shore | 9000 " 9999 |

Revising and Submitting

Corrected NAVSHIPS 4110s are submitted as follows: (1) for ships being overhauled—one week prior to completion of the overhaul, and (2) for all ships not undergoing construction, conversion, or overhaul—when a major change is made in the ship's installation record. When changes to the installation record are extremely minor, the update may be reported by the use of the Electronics Equipment Interim Report (NAVSEC 9670/3 fig. 2-9). One post card is required for each minor change. When the post card is received by NAVSEC, the NAVSHIPS 4110 is updated, but no new outputs are generated for distribution. Therefore, the use of these cards should be limited to extremely minor changes.

When updating the NAVSHIPS 4110, two copies are prepared; one for submission to NAVSEC and one for the ship's file. Ensure that the latest copy of the form is used for updating. If a revision is submitted on any copy other than the latest, it will be returned to the ship for resubmission.

To correct the data for an equipment, cross out the incorrect data and write in the correct data. Ensure that the corrections are kept in the proper column or immediately adjacent to the deleted data as shown in figure 2-10.

When an equipment is deleted, a colored line (preferably red or green) should be drawn through the data for the affected equipment (fig. 2-11). Do not obliterate the old data as ADP personnel must be able to read the deleted information.

When a new equipment is added to the list, it may be inserted in any space available, but preferably on a separate sheet. It is not necessary to insert new items by category or location. This will be done automatically by machine processing. When an equipment on the list is replaced by a new equipment, delete the equipment being replaced, and add the new equipment to the list as shown in figure 2-12.

NOTE: The Ships Equipment Configuration Accounting System (SECAS), when implemented, will replace the NAVSHIPS 4110.

EQUIPMENT TECHNICAL MANUALS

Equipment technical manuals include information essential to the proper installation, operation, and maintenance of the equipments to which they apply. There are various types of technical manuals (all of which contain

| | |
|---|---------------------------------|
| DATE _____ | |
| FROM: Commanding Officer | |
| USS _____ | |
| TO: Commander, Naval Ship Engineering Center (SEC 6271C) | |
| N110 UPDATE | |
| <input type="checkbox"/> ADD | <input type="checkbox"/> DELETE |
| MODEL _____ | SERIAL NO. _____ |
| LOCATION _____ | VOLTAGE _____ |
| MANUFACTURER _____ | |
| REMARKS _____ | |
| ELECTRONICS EQUIPMENT INTERIM REPORT NAVSEC 9670/3 (REV. 3-70) S/N-0101-115-0026 | |

| | |
|--|---|
| USS _____ | POSTAGE AND FEES PAID DEPARTMENT OF THE NAVY |
| FPO _____ | |
| OFFICIAL BUSINESS | |
| COMMANDER, NAVAL SHIP ENGINEERING CENTER (SEC 6271C) | |
| CENTER BUILDING | |
| PRINCE GEORGE'S CENTER | |
| WYATTSVILLE, MARYLAND 20702 | |

Figure 2-9.—Interim report post cards.

35.82.2

essentially the same types of information) in different formats and arrangements. Electronics equipment technical manuals that you will be using (fig. 2-13) include the conventional manuals which are divided into sections or chapters, each containing specific related information, and the Symbolic Integrated Maintenance Manual (SIMM) which incorporates new concepts in presenting technical data. (See page 40)

Other types of technical manuals which you may encounter include interim and temporary manuals which precede the approved military manuals, and the manufacturer's technical manuals which may be issued in place of the standard military manuals.

CONVENTIONAL MANUALS

The most common conventional equipment technical manuals are the 6- and 8-part manuals. Their organization and a description of the material contained in these manuals are presented in the following paragraphs.

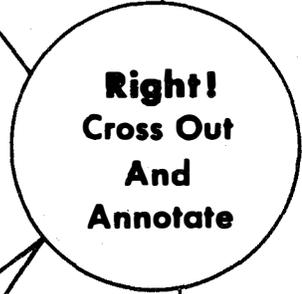
The 6-Part Technical Manual

Front Matter

1. General Information
2. Installation
3. Operation

Chapter 2—MAINTENANCE

| SHIP ELECTRONICS INSTALLATION RECORD | | | | | | | | | | | | | | |
|--------------------------------------|--------|------|----------|-----------------|-----------------|---------------|-----------|-----------|-------|------------------------|-----------|----|---|-----|
| DATE REVISED BY SHIP 7-10-70 | | | | | | | | | | BU SHIPS REPORT-1670-1 | | | | |
| SHIP NAME | Status | AREA | FLT FROM | DIST COMM | BERTH AREA | PLAN YARD | SHIP YARD | SHIP VOLT | DATE | DIST | OWHL YARD | | | |
| ANCHORAGE | A | P | 10 | | | | NF | | MO | DAY | YR | 19 | 1 | 1BE |
| NUMBER | CODE | CAT | LOCATION | EQUIPMENT MODEL | SERIAL NUMBER | EQUIP VOLTAGE | | REMARKS | | | | | | |
| | | | | | | 1 | 2 | | | | | | | |
| 0056 | | | | | | | | 14 | 1436 | | | | | |
| 805 | | | 162 | C-1004b/SG | K262 | | | 14 | 1364 | | | | | |
| 805 | | | 162 | C-1138b/VR | 3266 | | | 8 | 1991 | | | | | |
| 800 | | | 162 | C-7594/J | A217 | | | 14 | | | | | | |
| 193 | | | 162 | CU-1653/L | B181 | | | 14 | | | | | | |
| 193 | | | 162 | CU-1653/L | B183 | | | 14 | | | | | | |
| 193 | | | 162 | CU-1653/L | B188 | | | 14 | | | | | | |
| 193 | | | 162 | CU-1653/L | B189 | | | 14 | 1388A | | | | | |
| 193 | | | 162 | CU-1653/U | 235 | | | 0 | 1354 | | | | | |
| 7400 | | | 162 | LS-474/L | QTY 1 | | | 0 | 1433 | | | | | |
| 8808 | | | 162 | SB-988/SRT | 2801 | | | 0 | 1433 | | | | | |
| 0301 | | | 162 | SB-1203/UG | 2832 | | | 0 | 1433 | | | | | |
| 0301 | | | 162 | SB-1203/UG | 2859 | | | 0 | 1433 | | | | | |
| 0301 | | | 162 | SB-1203A/UG | 2871 | | | 0 | 1433 | | | | | |
| 0301 | | | 162 | SB-1203A/UG | 514-PNY | | | 0 | 1432 | | | | | |
| 0301 | | | 162 | SB-1203A/UG | 255-PNY | | | 0 | 1432 | | | | | |
| 1000 | | | 162 | SB-1210/UGQ | 265-PNY | | | 0 | 1431 | | | | | |
| 1000 | | | 162 | SB-1210/UGQ | 368 | | | 0 | 1431 | | | | | |
| 84400 | | | 162 | SB-2244/UGQ | 378 | | | 0 | 1431 | | | | | |
| 84400 | | | 162 | SB-2244/UGQ | A 62 | | | 8 | | | | | | |
| 84400 | | | 162 | TA-790/U | 1915 | | | 8 | | | | | | |
| 24400 | | | 162 | TSEC/HY-2 | 1924 | | | 8 | | | | | | |
| 30700 | | | 162 | TSEC/HY-2 | 2971 | | | 8 | | | | | | |
| 30700 | | | 162 | TSEC/HY-2 | 2971 | | | 8 | 1761 | | | | | |
| 30700 | | | 162 | TSEC/HY-2 | 2676 | | | 8 | 1761 | | | | | |
| 30700 | | | 162 | TSEC/KG-14 | 3401 | | | 8 | 1761 | | | | | |
| 608400 | | | 162 | TSEC/KG-14 | 3868 | | | 8 | 1761 | | | | | |
| 608400 | | | 162 | TSEC/KG-14 | 3952 | | | 8 | 1761 | | | | | |
| 608400 | | | 162 | TSEC/KG-14 | 4069 | | | 8 | 1728 | | | | | |
| 608400 | | | 162 | TSEC/KG-14 | 3822 | | | 8 | 1728 | | | | | |
| 669700 | | | 162 | TSEC/KW-7 | 5878 | | | 8 | 1728 | | | | | |
| 669700 | | | 162 | TSEC/KW-7 | 6456 | | | 8 | 1728 | | | | | |



35.82.1

Figure 2-10.—Proper corrections.

4. Troubleshooting combines functional description and troubleshooting chapters
5. Maintenance combines corrective maintenance, preventive maintenance, and alignment chapters
6. Parts List

The 8-Part Technical Manual

Front Matter

1. General Information
2. Operation
3. Functional Description
4. Scheduled Maintenance
5. Troubleshooting
6. Corrective Maintenance includes alignment
7. Parts List
8. Installation

Front Matter

This chapter will be found in each volume of a multivolume technical manual and contains the following information:

A COVER and a TITLE PAGE which lists the equipment or system nomenclature, the security classification, publication, number, volume number (if required), and the command in charge of the equipment. In addition, the TITLE PAGE includes an approval date and, if needed, a change number and date.

A FORWARD which explains the content, usage, and intent of the manual.

A LIST OF EFFECTIVE PAGES (table 2-1) which lists all pages of the manual and indicates the change status of each page. (See page 40)

A CHANGE RECORD which is to be filled in with information concerning the changes entered in the manual, such as the change number, the person making the change, and the date.

| SHIP ELECTRONICS INSTALLATION RECORD | | | | | | | | | | | | | | | BUS SHIPS REPORT 1670-1 | |
|--------------------------------------|-----------|----------|-----------------|---------------|---------------|------------|-----------|-----------|----|----------|----|------|-----------|---------|-------------------------|--|
| DATE REVISED BY SHIP <u>7-10-70</u> | | | | | | | | | | | | | | | | |
| NUMBER | SHIP NAME | Status | AREA | FLT FROM | DIST COMM | BERTH AREA | PLAN YARD | SHIP VOLT | NO | DATE DAY | YR | DIST | OVHL YARD | REMARKS | | |
| 036 | ANCHORAGE | A | P | 10 | | | | | | 27 | 70 | 19 | LBE | | | |
| CODE | CAT | LOCATION | EQUIPMENT MODEL | SERIAL NUMBER | EQUIP VOLTAGE | | | | | | | | | | | |
| USE ONLY | | | | | 1 | 2 | | | | | | | | | | |
| | | 010 | AN-3729/SR | A632 | 8 | | | | | | | | | | | |
| | | 010 | AN-3729/SR | A785 | 8 | | | | | | | | | | | |
| | | 010 | AN-3729/SR | B249 | 8 | | | | | | | | | | | |
| | | 010 | AN-3729/SR | LB51 | 8 | | | | | | | | | | | |
| | | 010 | AN/SGC-1A | LB79 | 8 | | | | | | | | | | | |
| | | 010 | AN/SGC-1A | B110 | 8 | | | | | | | | | | | |
| | | 010 | AN/SRA-12B | B13 | 8 | | | | | | | | | | | |
| | | 010 | AN/SRA-17C | B7 | 8 | | | | | | | | | | | |
| | | 010 | AN/SRA-17C | | 8 | | | | | | | | | | | |
| | | 010 | AN/SRA-43 | A341 | 8 | | | | | | | | | | | |
| | | 010 | AN/SRA-43 | A359 | 8 | | | | | | | | | | | |
| | | 010 | AN/SRA-43 | A361 | 8 | | | | | | | | | | | |
| | | 010 | AN/SRA-43 | A369 | 8 | | | | | | | | | | | |
| | | 010 | AN/SRA-43 | A3 | 8 | | | | | | | | | | | |
| | | 010 | AN/SRA-49 | A186 | 8 | | | | | | | | | | | |
| | | 010 | AN/SRR-19A | A1044 | 8 | | | | | | | | | | | |
| | | 010 | AN/UCC-1C(V)-R1 | A1051 | 8 | | | | | | | | | | | |
| | | 010 | AN/UCC-1C(V)-R1 | 1264 | 8 | | | | | | | | | | | |
| | | 010 | AN/UGC-20A | NONE | 8 | | | | | | | | | | | |
| | | 010 | AN/UGM-1 | A311 | 8 | | | | | | | | | | | |
| | | 010 | AN/URA-17B | A322 | 8 | | | | | | | | | | | |
| | | 010 | AN/URA-17D | A323 | 8 | | | | | | | | | | | |
| | | 010 | AN/URA-17E | A181 | 8 | | | | | | | | | | | |
| | | 010 | AN/WRR-3A | A528 | 8 | | | | | | | | | | | |
| | | 010 | AN/WRR-3B | K255 | 8 | | | | | | | | | | | |
| | | 010 | C-1004B/SG | G233 | 8 | | | | | | | | | | | |
| | | 010 | C-1138B/UR | G667 | 8 | | | | | | | | | | | |
| | | 010 | C-1138B/UR | B10 | 8 | | | | | | | | | | | |
| | | 010 | C-386B/SRC | B189 | 8 | | | | | | | | | | | |
| | | 010 | LS-474/u | B203 | 8 | | | | | | | | | | | |
| | | 010 | LS-474/u | | 8 | | | | | | | | | | | |

**Wrong!
Don't
Obliterate**

**Right!
Cross Out
Lightly**

35.82.1

Figure 2-11.—Proper method of deletion.

An INDEX containing: a Table of Contents, listing the number and title of the chapters, sections, and main paragraphs; a List of Illustrations, listing the number, title and page number of each figure; a List of Tables, listing the number, title, and page number of each table.

In multivolume manuals, Volume I contains a complete index covering all volumes. The other volumes contain only their own indexes.

A DESCRIPTION OF CODES AND SYMBOLS which are particular to that technical manual, including how to interpret the symbols used.

General Information

This chapter provides a functional description of the equipment or system to allow command personnel and other users to easily and rapidly determine the intended use, capabilities,

limitations, and relationships of the units and contains the following:

An INTRODUCTION which provides an explanation of the purpose, scope, supersedure data, and applicability of the manual, including the models, serial numbers, and configurations of the equipment covered.

A GENERAL or EQUIPMENT DESCRIPTION which briefly and nontechnically describes the intended use, capabilities, and limitations. The RELATIONSHIP OF UNITS is a pictorial illustration (figure 2-14) of all the units of a set or system showing the basic interconnections between the units and other equipment. (See page 41)

The REFERENCE DATA, which includes Nameplate Data, Functional Characteristics, Capabilities and Limitations, Rated Outputs, and Environmental Characteristics. EQUIPMENT, ACCESSORIES AND DOCUMENTS SUPPLIED which lists all equipment, test equipment, publications, and accessories required but not

Chapter 2—MAINTENANCE

| SHIP ELECTRONICS INSTALLATION RECORD | | | | | | | | | | | | | | | |
|---|-----------|----------|-------------------------------|---------------|----------------|------------|-----------|-----------|----|------|----|------|----------|-----|--|
| DATE REVISED BY SHIP 7-10-70 | | | | | | | | | | | | | | | |
| BUSHIPS REPORT-9470-1 | | | | | | | | | | | | | | | |
| SHIP NUMBER | SHIP NAME | STATUS | AREA | EL FROM | DIST COMM | BERTH AREA | PLAN YARD | SHIP VOLT | NO | DATE | YR | DIST | OWN YARD | LBE | |
| 3056 | ANCHORAGE | A | P | 10 | | | NF | | 1 | 27 | 70 | 19 | | | |
| CODE | CAT | LOCATION | EQUIPMENT MODEL | SERIAL NUMBER | EQUIPT VOLTAGE | | REMARKS | | | | | | | | |
| USE ONLY | | | | | 1 | 2 | | | | | | | | | |
| | | | AN/URA-38 | A59 | | | 8 | 1896 | | | | | | | |
| 700 | | 020 | AN/URC-9 AN/SRC-21 | 4326347 | | | 8 | 1130 | | | | | | | |
| 700 | | 020 | AN/URC-9 | G348 | | | 8 | 1130 | | | | | | | |
| 700 | | 020 | AN/URC-9 | G349 | | | 8 | 1130 | | | | | | | |
| 700 | | 020 | AN/URC-9 | G350 | | | 8 | 1220 | | | | | | | |
| 100 | | 020 | AN/URC-10 | B475 | | | 8 | 1220 | | | | | | | |
| 100 | | 020 | AN/URC-10 | B594 | | | 8 | 1220 | | | | | | | |
| 100 | | 020 | AN/URC-10 | A263 | | | 8 | 1338 | | | | | | | |
| 101 | | 020 | AN/URR-27A | J25 | | | 8 | 1115 | | | | | | | |
| 513 | | 020 | AN/URT-7D | A314 | | | 11 | 1010 | | | | | | | |
| 513 | | 020 | AN/URT-23(V) | A361 | | 8 | 11 | 1010 | | | | | | | |
| 8193 | | 020 | AN/URT-23(V) | A368 | | 8 | 11 | 1010 | | | | | | | |
| 8193 | | 020 | AN/URT-23(V) | A489 | | 8 | 11 | 1010 | | | | | | | |
| 8193 | | 020 | AN/URT-23(V) | A490 | | 8 | 11 | 1010 | | | | | | | |
| 8193 | | 020 | AN/URT-23(V) | C201 | | | 8 | 1020 | | | | | | | |
| 8200 | | 020 | AN/URT-24 | 49514 | | | 3 | 1078 | | | | | | | |
| 1200 | | 020 | AN/VRC-46 | 50511 | | | 3 | 1078 | | | | | | | |
| 1200 | | 020 | AN/VRC-46 | 50514 | | | 3 | 1078 | | | | | | | |
| 1200 | | 020 | AN/VRC-46 | 50569 | | | 3 | 1078 | | | | | | | |
| 1200 | | 020 | AN/VRC-46 | 52542 | | | 3 | 1078 | | | | | | | |
| 1200 | | 020 | AN/VRC-46 | 52959 | | | 3 | 1078 | | | | | | | |
| 1200 | | 020 | AN/VRC-46 | C39 | | | 11 | 1085 | | | | | | | |
| 10101 | | 020 | AN/WRT-1A | B112 | | | 8 | 1966 | | | | | | | |
| 55700 | | 020 | CU-691/U | F15 | | | 8 | 1025B | | | | | | | |
| 74305 | | 020 | MX-1743B/SRC | F31 | | | 8 | 1025B | | | | | | | |
| 74305 | | 020 | MX-1743B/SRC | F36 | | | 8 | 1025B | | | | | | | |
| 74305 | | 020 | MX-1743B/SRC | F9 | | | 8 | 1025B | | | | | | | |
| 74305 | | 020 | MX-1743B/SRC | A233 | | | 8 | 1025B | | | | | | | |
| 738001 | | 020 | MX-1986A/SRC | A259 | | | 8 | 1025B | | | | | | | |
| 738001 | | 020 | MX-1986A/SRC | A309 | | | 8 | 1025B | | | | | | | |
| 738001 | | 020 | MX-1986A/SRC | 433 | | | 8 | | | | | | | | |
| 738001 | | 020 | AN/SRC-21 | | | | | | | | | | | | |

Wrong!

Right!

Delete
Entire Item
And Pick-Up
New Item As
Shown

Figure 2-12.—Proper method of deletions and additions.

35.82.1

supplied. A table of **FIELD CHANGES AND FACTORY CHANGES**, which lists the changes that apply to that equipment, and whether they were accomplished.

Operation

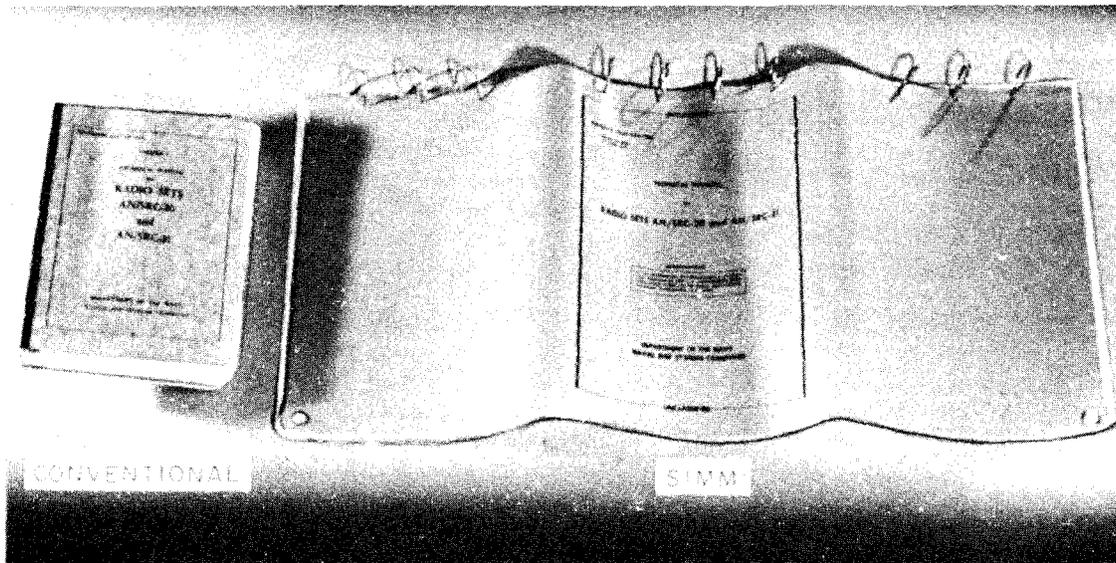
This chapter contains routine and emergency operating instructions, safety precautions, operating limits, complete starting and stopping instructions, and any instructions required by the operator to prepare the equipment for use. An **INTRODUCTION** describes the operator's relationship to the equipment and identifies the units having controls and indicators which he uses. A **DESCRIPTION OF CONTROLS AND INDICATORS** includes names, positions, and operating functions of each control (figure 2-15) and the normal operating condition of each indicator. (See page 42)

The **OPERATING PROCEDURES** include Operator Turn-on, Modes of Operation, Operation Under Interfering Conditions, Operator Turn-off, Emergency Operation, and Emergency Turn-off.

The **OPERATOR'S MAINTENANCE** contains Operating Checks and Adjustments, Preventive Maintenance, and Emergency Maintenance. In some technical manuals this chapter is in a separate volume to allow it to be kept near the equipment for easy reference.

Installation

This chapter contains all the information required for the installation of the equipment, such as site selection, unpacking and handling, clearances, and recommendations for reduction of electromagnetic interference. In addition, this chapter contains tests and test procedures



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Figure 2-13.—Equipment technical manuals.

required to demonstrate that the equipment is capable of satisfying operational requirements. It also contains an **INSTALLATION STANDARDS SUMMARY SHEET** (figure 2-16), which is used to record the results of the installation verification tests. (See page 43)

Functional Description

This chapter provides a detailed analysis of the principles of operation of the overall equipment and its major functions, including supporting functions such as power, cooling and control. **OVERALL FUNCTIONAL BLOCK DIAGRAMS**

(figure 2-17) show all the major functions of the equipment by means of blocks which represent individual units or assemblies. Each block is identified by name, nomenclature, and number. Connecting lines and arrowheads show the direction of signal flow. Inputs and outputs are titled and waveforms may be included. Each of the major functions of the equipment is described on a separate **FUNCTIONAL BLOCK DIAGRAM** (figure 2-18), which depicts the development of each function from input to output in detail. The electrical connections and functions of a specific circuit arrangement are shown by the **SIMPLIFIED SCHEMATIC DIAGRAM** (figure 2-19).

Table 2-1.—List of effective pages showing changes

| PAGE NUMBERS | CHANGE IN EFFECT | PAGE NUMBERS | CHANGE IN EFFECT |
|---------------|------------------|---------------|------------------|
| Title Page | 2 | 3-6B | 1 |
| A | 2 | 3-7 & 3-8 | Orig |
| B & C | Orig | 4-1 thru 4-4 | Orig |
| i | 2 | 4-4A | 2 |
| ii thru vii | Orig | 5-1 thru 5-18 | Orig |
| 1-0 thru 1-5 | Orig | 5-18A | 1 |
| 2-0 thru 2-17 | Orig | 6-0 thru 6-20 | Orig |
| 3-0 thru 3-6 | Orig | 7-1 thru 7-4 | 1 |
| 3-6A | 2 | i-1 thru i-3 | 2 |

74.258(162A)

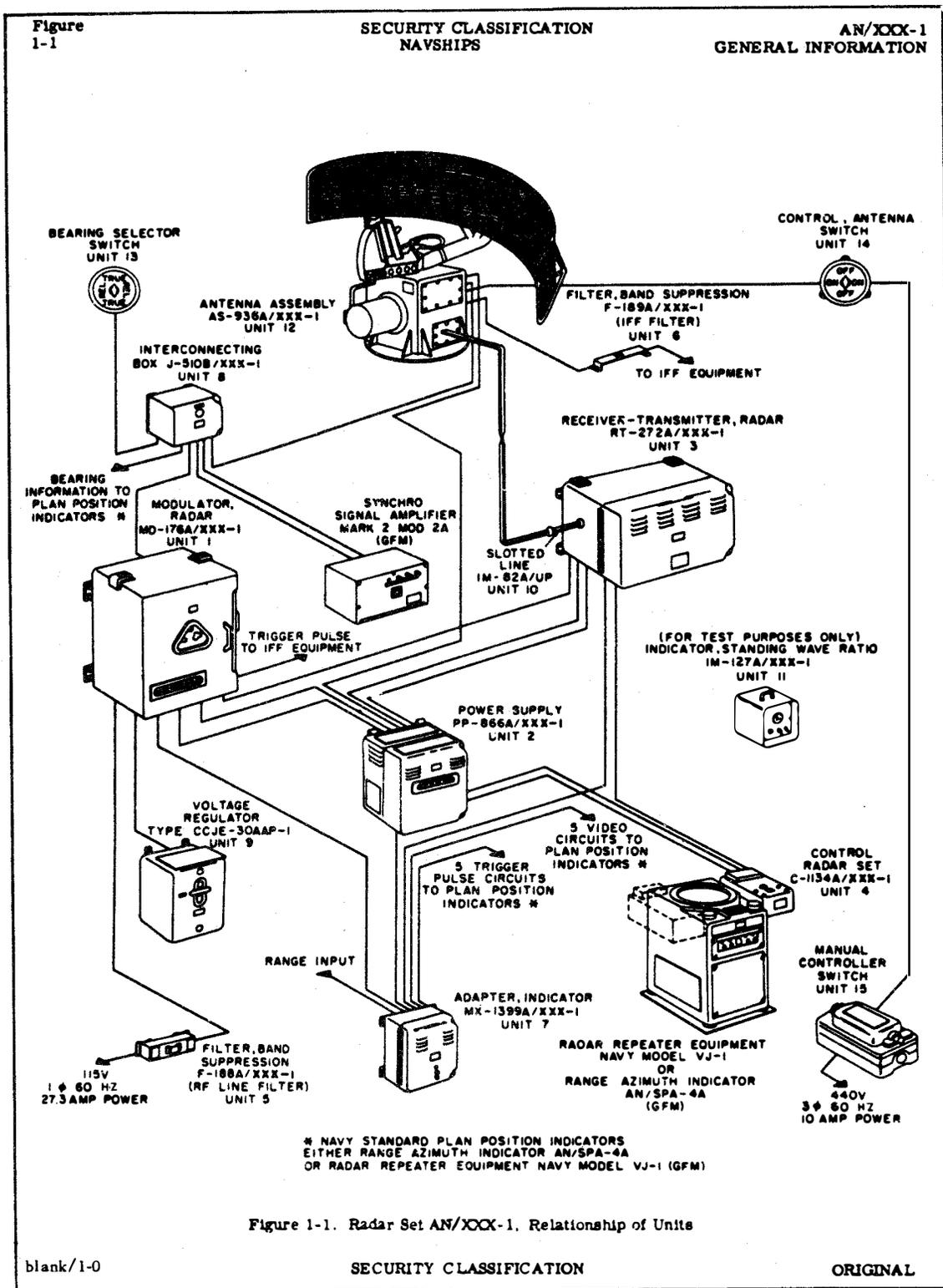
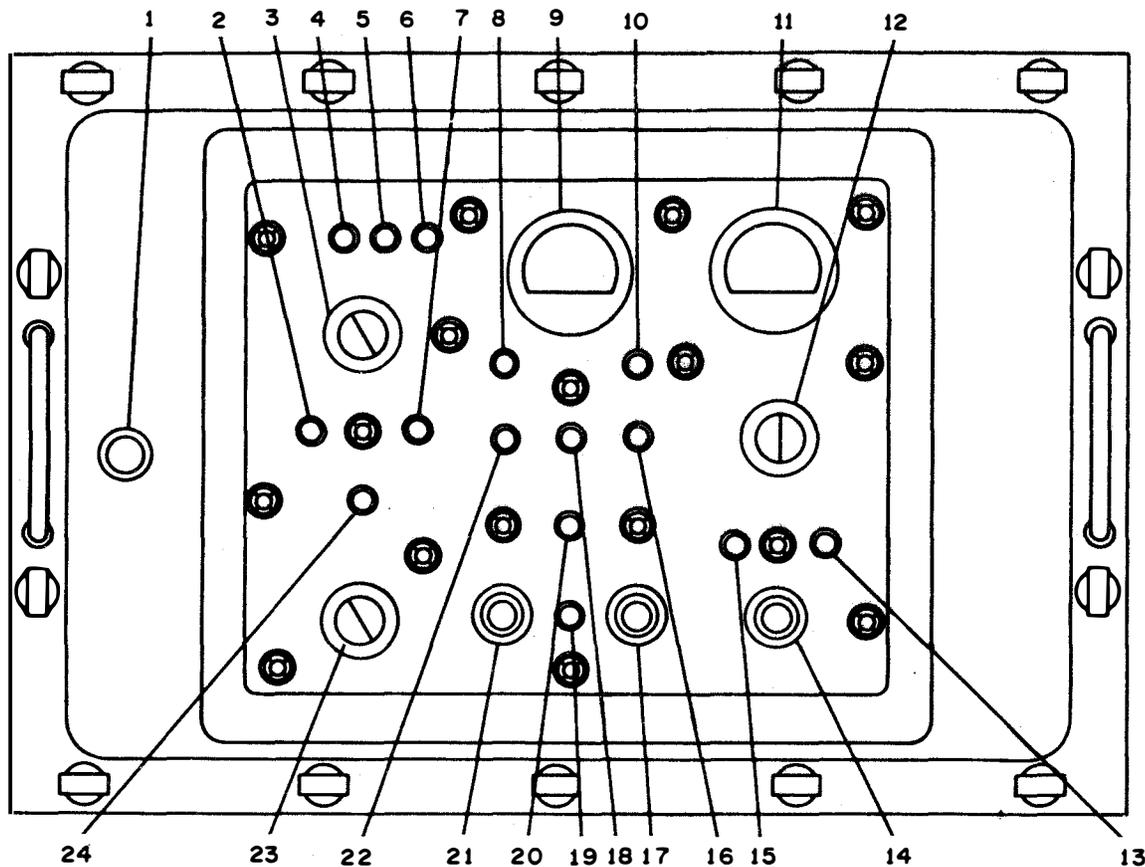


Figure 2-14.— Equipment illustration showing relationship of all units.

32.172(162A)



- | | |
|--|--|
| <ul style="list-style-type: none"> 1. PHONE BUZZ buzzer 2. POWER INTERLOCKS lamp 3. POWER switch 4. STDBY lamp 5. READY lamp 6. TEST lamp 7. CW ILLUMINATOR INTERLOCKS lamp 8. RF POWER DRIVE lamp 9. RF POWER meter 10. RF POWER RADIATED lamp 11. DEVIATION meter 12. DEVIATION switch | <ul style="list-style-type: none"> 13. FM NOISE ALARM lamp 14. NME RESET button 15. AM NOISE ALARM lamp 16. ILLUMINATOR STATUS NO GO lamp 17. RADIATE OFF button 18. ILLUMINATOR STATUS MARGINAL lamp 19. RADIATE lamp 20. HT MODE lamp 21. RADIATE ON button 22. ILLUMINATOR STATUS FAULT lamp 23. DIRECTOR LOUVERS switch 24. DIRECTOR LOUVERS OPEN lamp |
|--|--|

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Figure 2-15.—Equipment controls and indicators.

The reference designation prefix 3A1A2, shown on figure 2-19, identifies the unit, assembly, and subassembly associated with the parts shown on the schematic. Reference designations are discussed in chapter 5 of this manual.

Other diagrams include PIPING DIAGRAMS, that show the interconnections of components by piping, tubing or hoses, and MECHANICAL DIAGRAMS, that show the operational sequence and arrangement of mechanical devices.

| RADIO RECEIVER R-XXX/URR NAVSHIPS | | | |
|--|--|---------------|--|
| INSTALLATION STANDARDS SUMMARY | | | |
| Input Voltage _____ Vac Input Frequency _____ Hz (When reference standard tests are made) | Date _____ Serial Number _____ of Model _____ Installed in (ship or station) _____ Length of transmission line _____ | | |
| Record on this summary sheet the test indications which have been obtained during the installation verification test. | | | |
| Paragraph No. | Ref. Std. | Paragraph No. | Ref. Std. |
| 8-10 | a. _____ Check | 8-46 | a. _____ μ V b. _____ μ V |
| 8-21 | a. _____ Vdc b. _____ Vdc c. _____ Vdc d. _____ Vdc | | c. _____ Check d. _____ μ V e. _____ μ V f. _____ μ V |
| 8-33 | a. _____ Check b. _____ Check c. _____ Check d. _____ Check | 8-51 | a. _____ Sec b. _____ Check c. _____ Check d. _____ Hz e. _____ Hz f. _____ Check g. _____ Check |

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Figure 2-16.—Installation standards summary sheet.

Troubleshooting

This chapter contains all information and instructions necessary to locate troubles and conduct tests on each component, assembly, or subassembly of the equipment. Included are the following:

An **INTRODUCTION** explaining the approach and logic of the troubleshooting principles and data and their relationship to each other.

A **TROUBLESHOOTING INDEX** (table 2-2) which lists all equipment and functions with references to the appropriate procedures and diagrams that can be used to troubleshoot a specific function. (See page 46)

RELAY, LAMP, and PROTECTIVE DEVICE INDEXES (table 2-3) which list all relay coils, indicator lamps and protective devices with the item reference designation, function name, voltages, ratings, and a reference to the troubleshooting diagram. (See page 49)

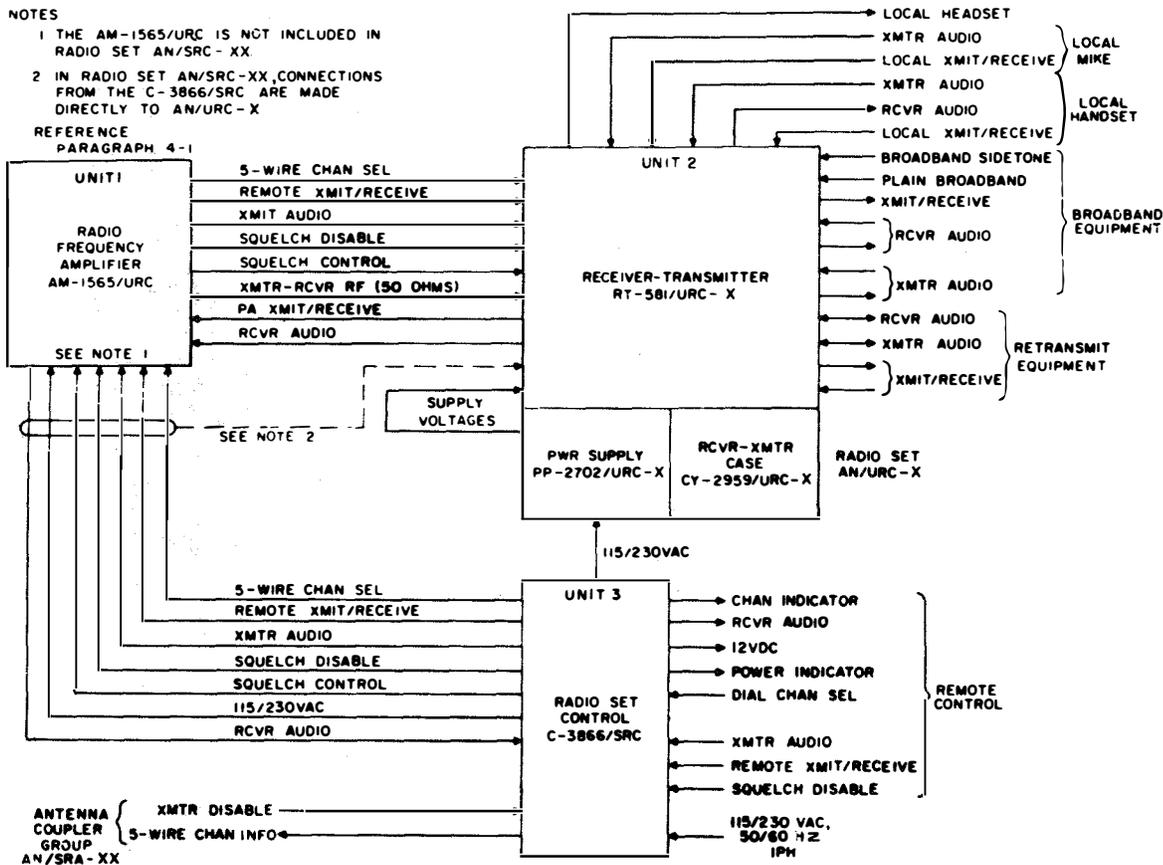
The **MAINTENANCE TURN-ON PROCEDURE** (table 2-4) lists the step-by-step

procedure to energize the equipment with the correct indication for each step and the troubleshooting or corrective action for out-of-tolerance observations. (See page 50)

SIGNAL FLOW DIAGRAMS (Figure 2-20 foldin end of Chapter) are detailed block diagrams which illustrate the functional development of each equipment output from its origin to its measurable output. These diagrams also include test points, test parameters, schematic diagram references, that data for test equipment setup, adjustments, controls, switches, and mechanical couplings.

CONTROL DIAGRAMS (figure 2-21) are used to indicate all control circuits and group them according to their common characteristics.

POWER DISTRIBUTION DIAGRAMS (figure 2-22 foldin end of chapter) depict the distribution of power from the equipment input to the various modules and subassemblies of the equipment. **PIPING DIAGRAMS** are included for fluid cooling, air, gas, and hydraulic systems as needed.



162.21

Figure 2-17.—Overall functional block diagram.

MAINTENANCE SCHEMATIC DIAGRAMS (figure 2-23 foldin end of chapter) completely cover the equipment. These include unit-to-unit interconnection diagrams, intra-unit interconnection diagrams, and unit, assembly, and sub-assembly schematic diagrams.

Scheduled Maintenance

This chapter contains preventative maintenance procedures and performance test instructions to be accomplished on a scheduled basis. NOTE: The scheduled maintenance instructions in this chapter are canceled when PMS is implemented for the appropriate equipment aboard your ship or station.

The sections in this chapter include:

The **INTRODUCTION**, which explains the purpose, scope, and arrangement of the scheduled performance tests and preventive maintenance procedures. **PREVENTIVE MAINTENANCE PROCEDURES** include the information

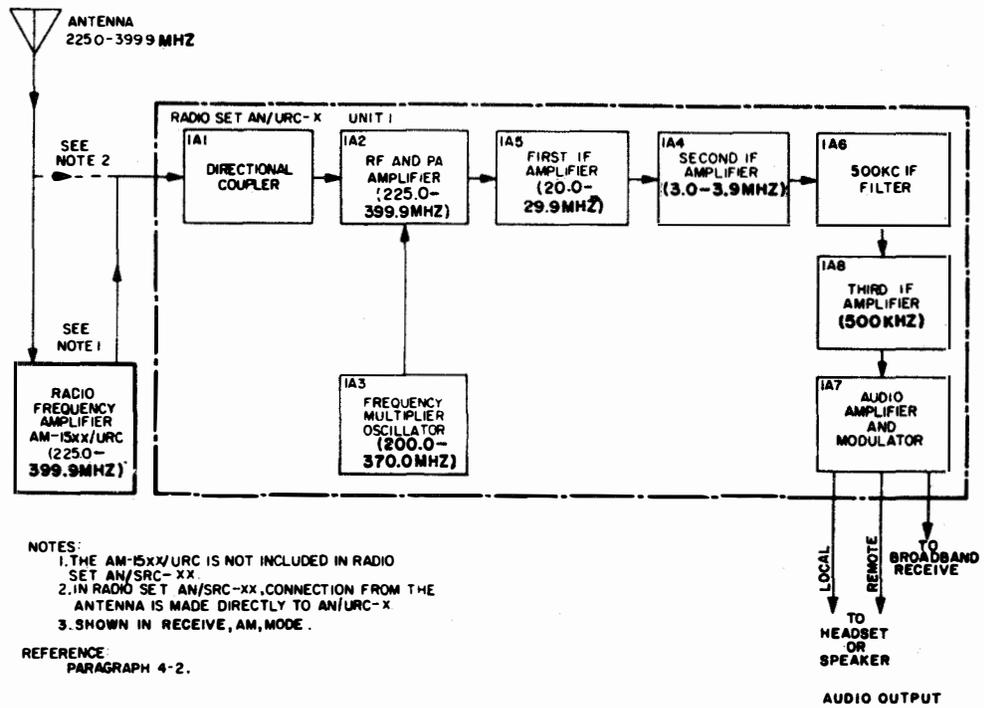
required to inspect, clean, and lubricate the equipment. The **SCHEDULED PERFORMANCE TESTS** which contain step-by-step procedures necessary to verify that the equipment is operating within standards in all modes of operation.

Corrective Maintenance

This chapter contains the instructions required to remove, repair, adjust, and reinstall the circuit elements and mechanical items. Exploded and sectional views and parts placement diagrams are provided as necessary. Information on the use of special tools and test equipment are also included.

Alignment

This chapter provides information for the complete alignment of the system or equipment. It includes all inputs, point of input injection,



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Figure 2-18.— Functional block diagram.

results expected, point of measurement and test equipment required.

Parts List

This chapter lists and identifies all repair parts including the attaching hardware.

The INTRODUCTION explains the scope and arrangement of the parts list, and includes the models and serial numbers of the equipments covered.

The LIST OF MAJOR UNITS lists the units comprising the equipment. The units are listed by unit numbers in numerical order.

The PARTS LISTS is divided and arranged by major units in numerical sequence. Maintenance parts for each unit are listed alphabetically-numerically following the unit designation, for example:

| | |
|----------|------|
| Unit | 1 |
| (Cabinet | 1AT1 |
| parts) | 1B1 |
| | 1C1 |
| | 1CR1 |
| | 1R1 |
| | etc. |

Assembly
(Assembly parts)

- 1A1
- 1A1AT1
- 1A1B1
- 1A1C1
- 1A1CR1
- 1A1R1
- etc.

Subassembly
(Subassembly parts)

- 1A1A1
- 1A1A1AT1
- 1A1A1B1
- 1A1A1C1
- 1A1A1CR1
- 1A1A1R1
- etc.

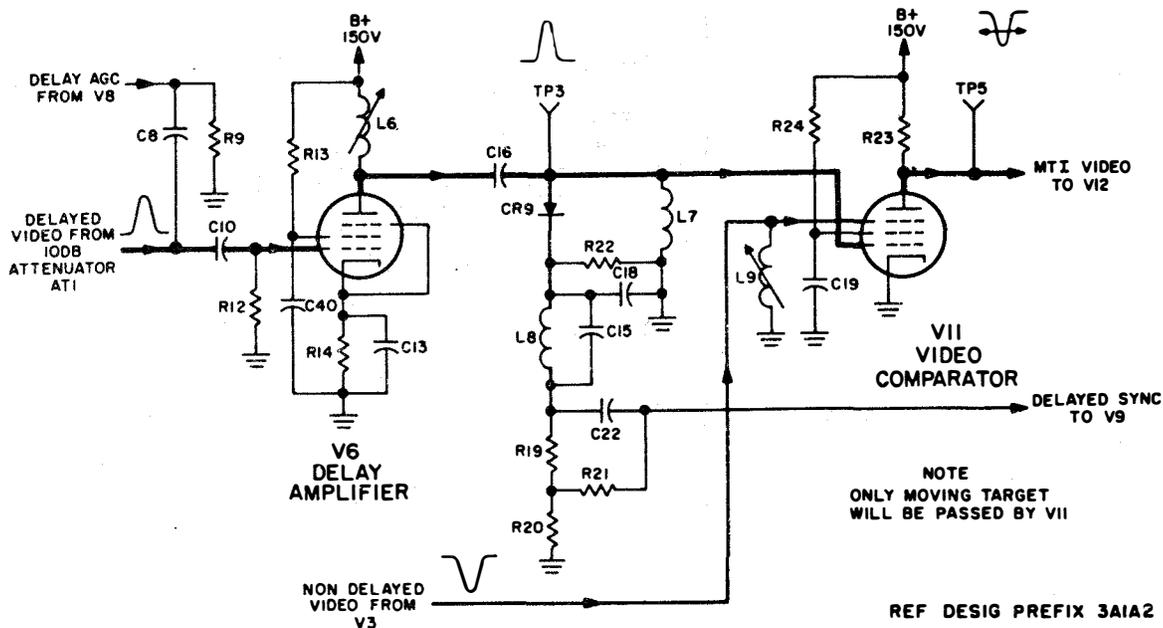
Unit

- 2
- etc.

The LIST OF MANUFACTURERS contains the names, addresses, and code symbols of all manufacturers supplying items for the equipment.

Security Classification

The security classification of the technical manual is printed at the top and bottom of the front and back covers and the title page. If the



162.141

Figure 2-19.—MTI comparator, simplified schematic diagram.

manual is classified (confidential, secret, etc.) the classification is also printed at the top and bottom of every page in the manual. The classification may also be determined from the color of the front and back covers. The covers for manuals prepared according to Military

Specification MIL-M-15071G (NAVY) of 1 August 1969 are: blue-unclassified, green-confidential, yellow-secret, and pink-top secret.

The regulations for the custody, control, and accounting of classified material were presented in chapter 1 of this volume.

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Table 2-2.—Troubleshooting index.

| FUNCTIONAL AREA | TROUBLE SHOOTING PARAGRAPH | TROUBLE SHOOTING DIAGRAM | FUNCTIONAL DESCRIPTION PARAGRAPH | ALIGNMENT/ ADJUST PARAGRAPH |
|--|----------------------------|--------------------------|----------------------------------|-----------------------------|
| AC Power | 5-3 | 5-8 | 3-9a | 6-105, 6-106 |
| DC Power | 5-4 | 5-19 | 3-9b | 6-107 through 6-110, 6-127 |
| Keying | 5-5 | 5-24 | 3-13 | 6-22 |
| Receive RF | 5-8 | 5-1 | 3-4 | 6-112 through 6-115 |
| System Channel and Frequency Selection | 5-9 | 5-16 | 3-10, 3-12 | 6-121 |

WARNING

DANGEROUS VOLTAGES ARE PRESENT EVEN THOUGH CONDITIONS OF NOTES A AND B ARE MET.

GENERAL NOTES

- A. SWITCHES AND RELAY CONTACTS SHOWN IN STOW MODE OF OPERATION.
- B. SWITCHES 8307 AND 8301 ARE SHOWN IN A STOW CONDITION.
- C. 8307 IS LOCATED AGAINST THE FRONT PANEL.

PART LOCATION INDEX

| Ref Des | Zone | Ref Des | Zone | Ref Des | Zone |
|---------|------|-------------|------|-------------|------|
| 83301A | 5A | K3311D | 5B | TB2302-A1DC | 6C |
| 83301B | 6C | K3311E | 4B | TB2303-A2DB | 6A |
| D83214 | 9B | L3304 | 7A | TB2311-A1DB | 7D |
| D83614 | 2B | L3305 | 6A | TB2311-A1DC | 6C |
| D83930 | 2B | L4701 | 1A | TB2311-A1DE | 7C |
| K3301A | 6C | 83906 | 2A | TB2311-A2DB | 7A |
| K3301E | 5D | 83912 | 2B | TB3301-A2DE | 1C |
| K3302 | 3A | 83104 | 7D | TB3001-4B | 1C |
| K3302D | 1D | 83301 | 4A | TB3302-A1DB | 6D |
| K3303 | 3A | 83302 | 6A | TB3302-A1DC | 6C |
| K3303D | 1D | 83303 | 4A | TB3302-A1DE | 7B |
| K3304A | 4A | 83304 | 4A | TB3302-A2DB | 6A |
| K3306A | 4A | 83305A | 3A | TB3303-A1BB | 3D |
| K3306A | 1C | 83305B | 3B | TB3303-A1DD | 5C |
| K3306B | 6D | 83907A | 5C | TB3303-A1EE | 5B |
| K3309A | 1C | 83907B | 6C | TB3303-A1FF | 5B |
| K3309B | 5D | 83907C | 5C | TB3303-A1GG | 4B |
| K3310A | 5A | 83907D | 2C | TB3303-A1HH | 4B |
| K3310B | 5D | 83908 | 3B | TB3303-A1IJ | 4B |
| K3310C | 5B | 84703 | 2A | TB3303-A1KK | 4B |
| K3310D | 5B | 85201J | 1B | TB3303-A1LL | 3B |
| K3310E | 4B | 85201K | 1B | TB3303-A2AA | 2A |
| K3311A | 5A | 85201L | 2B | TB3903-A1BB | 3D |
| K3311B | 5D | 85201M | 1A | TB3903-A1DD | 5C |
| K3311C | 5B | TB2301-A2DE | 1C | TB3903-A1EE | 5B |

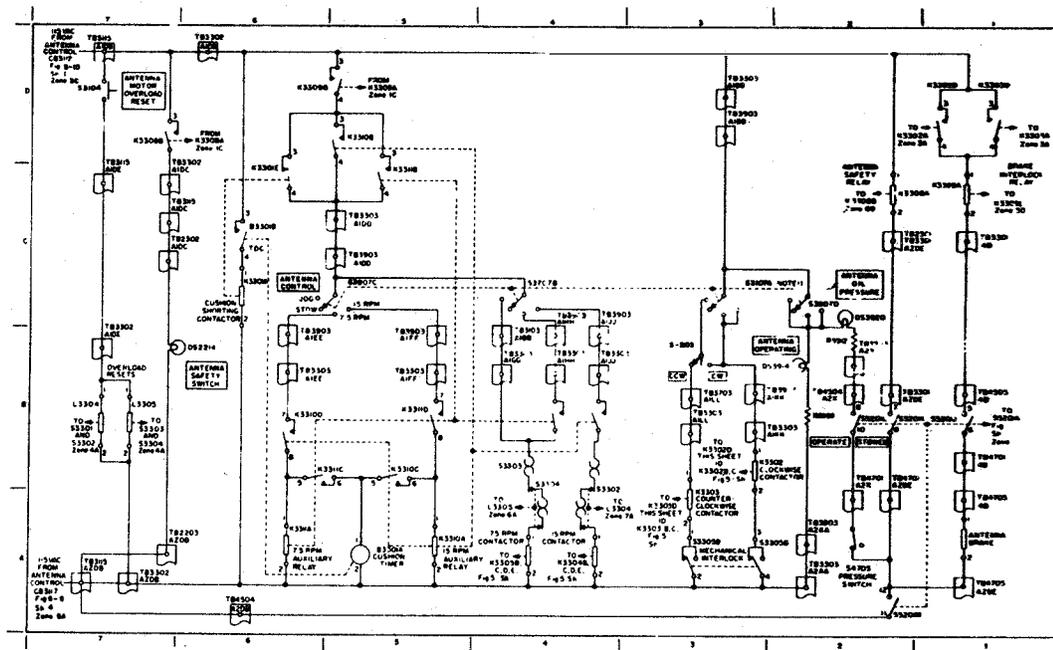
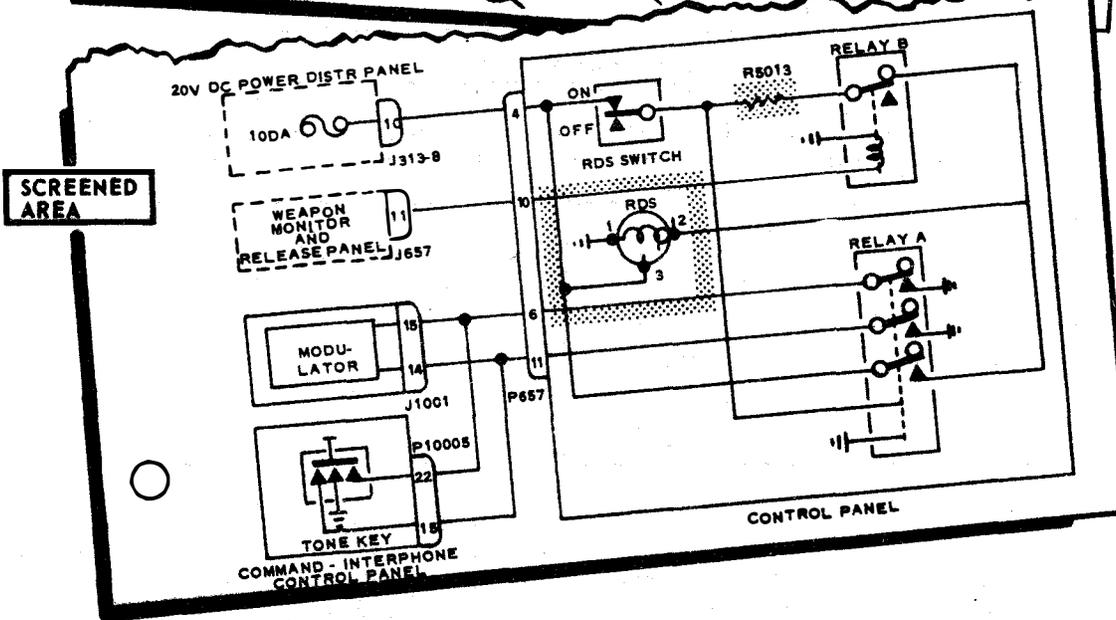
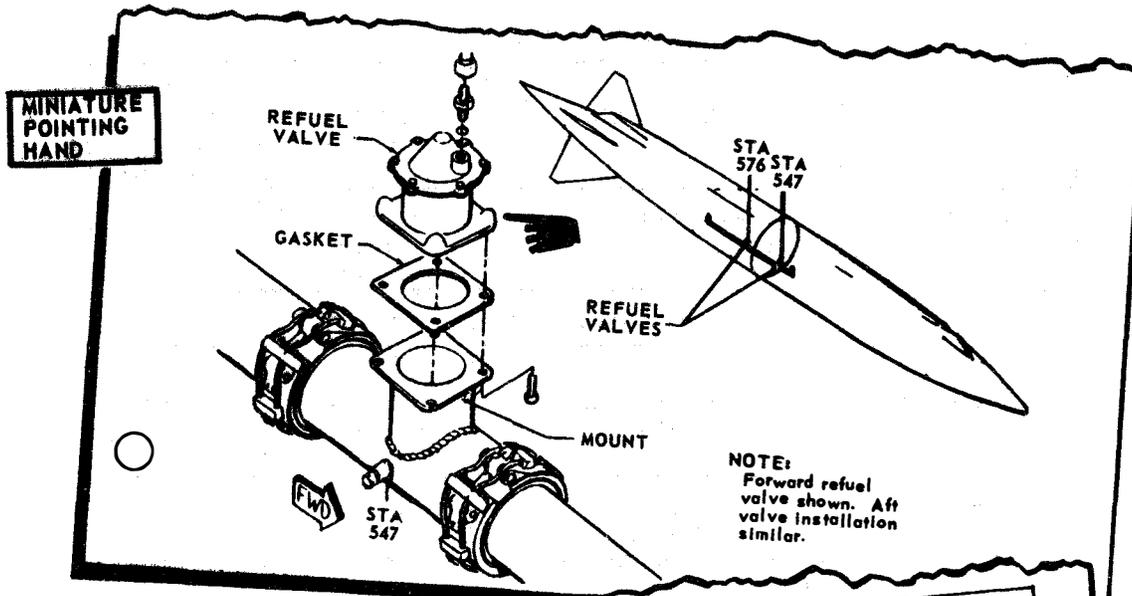


Figure 2-21.—Control diagram.



VERTICAL LINE

8-140. FREE-FALL BOMBING SYSTEM INTERCHANGEABILITY.

8-141. The mission capability of the interchangeable package is determined by the part number of the interchangeable package, the type of release panel (bomb pod control or weapon monitor and release), and the type of ballistic data unit (MBIC or BLU MK) installed in the package. The letters MBIC or BLU MK are decoded on a tab located in the lower right hand corner of the ballistic control panel and indicate the type of ballistic data unit installed in the package. The tab is physically connected by a cord to the ballistic data unit. The following chart indicates mission capabilities for various combinations of components:

Change 1 8-21

Figure 2-24.—Sample of change symbols.

Table 2-3.—Relay, lamp, and protective device indexes

RELAY INDEX

| REFERENCE DESIGNATION | FUNCTIONAL NAME | ENERGIZING VOLTAGE | TROUBLE-SHOOTING DIAGRAM (FIG. NO.) |
|-----------------------|-------------------|--------------------|-------------------------------------|
| 6A4K9 | HV Door Interlock | 115 Vac | 5-21 |
| 6A4K10 | Cabinet Interlock | 28 Vdc | 5-22 |
| 6A4K11 | Buzzer Relay | 28 Vdc | 5-22 |

INDICATOR LAMP INDEX

| REFERENCE DESIGNATION | FUNCTIONAL NAME | ENERGIZING VOLTAGE | TROUBLE-SHOOTING DIAGRAM (FIG. NO.) |
|-----------------------|---------------------------------------|--------------------|-------------------------------------|
| 9A8DS15 | HV INTERLOCK CONFIDENCE-VSWR TRIP-OUT | 28 Vdc | 5-22 |
| 9A8DS16 | HV INTERLOCK CONFIDENCE-HVPS | 28 Vdc | 5-22 |

CIRCUIT BREAKER AND FUSE INDEX

| REFERENCE DESIGNATION | FRONT PANEL MARKING | RATING | | CIRCUIT PROTECTED | TROUBLE-SHOOTING DIAGRAM (FIG. NO.) |
|-----------------------|------------------------------------|--------|------|---|-------------------------------------|
| | | VOLTS | AMPS | | |
| 9A8F1 | KLYSTRON FILAMENT FUSE ALARM 5 AMP | 250 | 5 | Klystron filament control circuit and filament transformer 9A1T106. | 5-32 |
| 14A2F1 | CONTROL | 125 | 3 | Voltage sensor bridge power supply consisting diodes 13A2CR1 through CR4. | 5-2 |

CHANGES

Changes in equipment design, alignment procedures, and maintenance procedures will require that the technical manual be changed to keep pace.

There are two types of changes: temporary changes which are often listed in the EIB and major changes which are issued by the command in charge of the equipment or by the manufacturer. These changes consist of various types: pen and ink, where the technician writes in the change, paste in, where a new item is placed over the old item; and complete pages, where the old page is removed from the book and the new pages are inserted.

New pages will frequently have the changed section marked by a symbol. Refer to figure 2-24 for an example of these symbols.

The miniature pointing hand denotes the changed part on a pictorial diagram. The screened area encloses a changed circuit or part on a schematic diagram. Vertical lines enclose changes in the text.

All corrections and changes must be made in the manuals. If corrections are not made, much time may be lost in attempting to repair an equipment by use of an obsolete schematic diagram. Upon completion of the change, the Change Record in the Front Matter must be filled in to indicate that the manual has been updated. The CHANGE INSTRUCTION (figure

Table 2-4.—Maintenance turn-on procedure

| STEP | OBSERVE | REFERENCE | | | | | | | | |
|--|---|---|-------|-----|--------------|-----|------|--------------|--|--------------------------------|
| <p>1. Preliminary Procedure.</p> <p>a. Position the following switches on rear deck assembly 1A210A1 as indicated.</p> <table border="0"> <tr> <td><u>Switch</u></td> <td><u>Position</u></td> </tr> <tr> <td>POWER</td> <td>OFF</td> </tr> <tr> <td>BATTLE SHORT</td> <td>OFF</td> </tr> <tr> <td>STOW</td> <td>BRAKES APPLY</td> </tr> </table> <p>b. Position POWER switch on console, 1A220A20 (see figure 5-2) to OFF.</p> <p>c. Check to ensure that all chassis or subassemblies in the four compartments of electronic rack assembly, 1A70 are in the retracted position and all covers are secured.</p> <p>d. Remove all obstructions from the rotational paths of the director main antenna assembly.</p> <p>2. Power Off.</p> <p>a. At power control panel perform the following.</p> <p>(1) Check convenience lamp indicators.</p> | <u>Switch</u> | <u>Position</u> | POWER | OFF | BATTLE SHORT | OFF | STOW | BRAKES APPLY | <p>Covers Secured</p> <p>Director Clear</p> <p>Lighted</p> | <p>Schematic, figure 5-233</p> |
| <u>Switch</u> | <u>Position</u> | | | | | | | | | |
| POWER | OFF | | | | | | | | | |
| BATTLE SHORT | OFF | | | | | | | | | |
| STOW | BRAKES APPLY | | | | | | | | | |
| <p>e. At track meter panel, 1A340-02, check COOLANT FAILURES lamp.</p> | <p>Extinguished (Depress RESET button if lamp is lighted)</p> | <p>Relay diagram, figure 5-77, SH 4(4B)</p> | | | | | | | | |

2-25) explains the purpose of the change, the coverage of the change, specific instructions for the insertion of the change and the effective date of the change. After the changes have been made to the manual, the change instruction is inserted in the manual immediately behind the front cover, before all previous changes.

SIMM MANUALS

Although the SIMM manual (fig. 2-13) is prepared to fulfill the same purpose as conventional manuals, it is constructed differently

and uses different methods of organizing and presenting the information. The SIMM manual is organized on a functional basis in three major groupings: the hardware group, the major functions group, and the overall equipment function group. The hardware group (the lowest group) includes all major hardware assemblies. Each of these hardware assemblies is further subdivided into subassemblies. Separate diagrams, text, part location and identification information with related maintenance and troubleshooting data are included for each assembly and subassembly.

UNCLASSIFIED

Interim Change T-1

NAVSHIPS 0967-173-6011

INSTRUCTION SHEET

Interim Change T-1 to Technical Manual for Teletypewriter Set AN/UGC-16 NAVSHIPS 0967-173-6011 (formerly NAVSHIPS 94104)

General Instructions:

This interim change revises the manual to reflect the equipment changes made by Field Change 5-AN/UGC-16. When this change is included in the manual, the manual shall cover the equipment as though Field Change 5, NAVSHIPS 0967-173-6050, has been accomplished on the equipment. This change does not supersede any other changes or corrections.

Maintenance support activities shall make this change in the technical manual immediately but shall keep the superseded data intact for support of equipments that have not been modified.

HOLDERS of equipment accompanied by technical manuals shall not make this change in the manual until accomplishment of the field change referenced above.

Insert this interim change in the manual immediately after the front cover preceding the title page, prior changes, or interim corrections in effect.

Specific Instructions:

1. Remove the following pages and insert the corrected T-1 pages:

REMOVE

8-16
8-18

INSERT

8-16 T-1
8-18 T-1

2. Add the following page:

Insert 6-2A between pages 6-2 and 6-3.

DATED: 1 July 1969

UNCLASSIFIED

162.150

Figure 2-25.—Sample of instruction sheet of temporary and permanent changes.

The major functions group arranges the assemblies and subassemblies according to major functions such as transmitting, receiving, displaying data, etc.

The highest group ties the major functions together to represent the overall equipment function.

For example, in the case of radio set AN/SRC-20, 21, the hardware group would consist of the RF Amplifier (AM-1565/URC), radio set (AN/URC-9), and the Radio Set Control (C-3866/SRC). The major functions group would include the transmitting function, the channel and frequency select function, and the power distribution function. The overall equipment function is a UHF transceiver capable of sending and receiving amplitude modulated voice and CW signals.

The SIMM manual presents the necessary data for the installation, operation, and maintenance of electronics equipment by the use of various diagrams and charts. These are the blocked schematic, blocked text, precise access block diagram, overall functional block diagram, maintenance dependency chart, and parts data chart.

The Blocked Schematic Diagram

The **BLOCKED SCHEMATIC DIAGRAM** (fig. 2-26) identifies each circuit element (switch, resistor, capacitor) or functional entity (amplifier, oscillator) according to its functional level. This diagram distinguishes between the functions and hardware by using shaded areas of blue and gray. Blue shaded areas indicate functional groupings of components or circuits. Darker shades of blue indicate circuits within the functional circuits. Each area of blue includes all circuit elements that are involved in accomplishing the circuit function. These areas are called functional entities. Gray shaded areas indicate physical packaging of equipment. Darker shades of gray indicate subpackaging within the lighter shades of gray. These shades of blue and gray are not shown in the illustrations used in this manual.

Note in figure 2-26 that the parts that work together to perform a basic function (such as amplifying, generating, gating, etc.) are blocked together. These blocks are shaded and coded with a mnemonic code which ties them to the identical blocks on other diagrams. This allows the technician to readily determine precisely what parts work together to perform a particular

function. This is a marked improvement over the schematics in conventionally prepared manuals in which the parts that work together are, in many cases, not readily apparent. The technician, in this case, has to rely on his training, experience, and knowledge of the equipment to find the parts that work together.

The Blocked Text Diagram

The **BLOCKED TEXT** diagram (fig. 2-27) is blocked off and shaded identically to the respective blocked schematic diagram. In lieu of parts in the blocks, however, the blocked text describes what action takes place within the particular block.

Precise Access Block Diagram

The **PRECISE ACCESS BLOCK** diagram (PABD, fig. 2-28) shows all the circuits and hardware assemblies that make up a major function. It identifies the assemblies and depicts the nature and direction of signal flow through the assemblies. Shading is done in the same manner as on the blocked schematic. The PABD also serves as an interconnection diagram, as the signal paths are shown as they pass in and out of each assembly, drawer, and cabinet.

In order to present the various functional entities that make up a major function on a single page, the PABD uses three basic symbols: the triangle, trapezoid, and square.

The triangle represents a circuit that changes the voltage or power level of an incoming signal such as voltage or power amplifiers, cathode followers, etc. These circuits always contain active elements.

The trapezoid depicts a circuit which generates a signal or processes an incoming signal in some manner other than a changing voltage or power level. Examples are oscillators, multi-vibrators, and mixers. These circuits always contain one or more elements which may be active (electron tube or transistor) or passive (semiconductor diode).

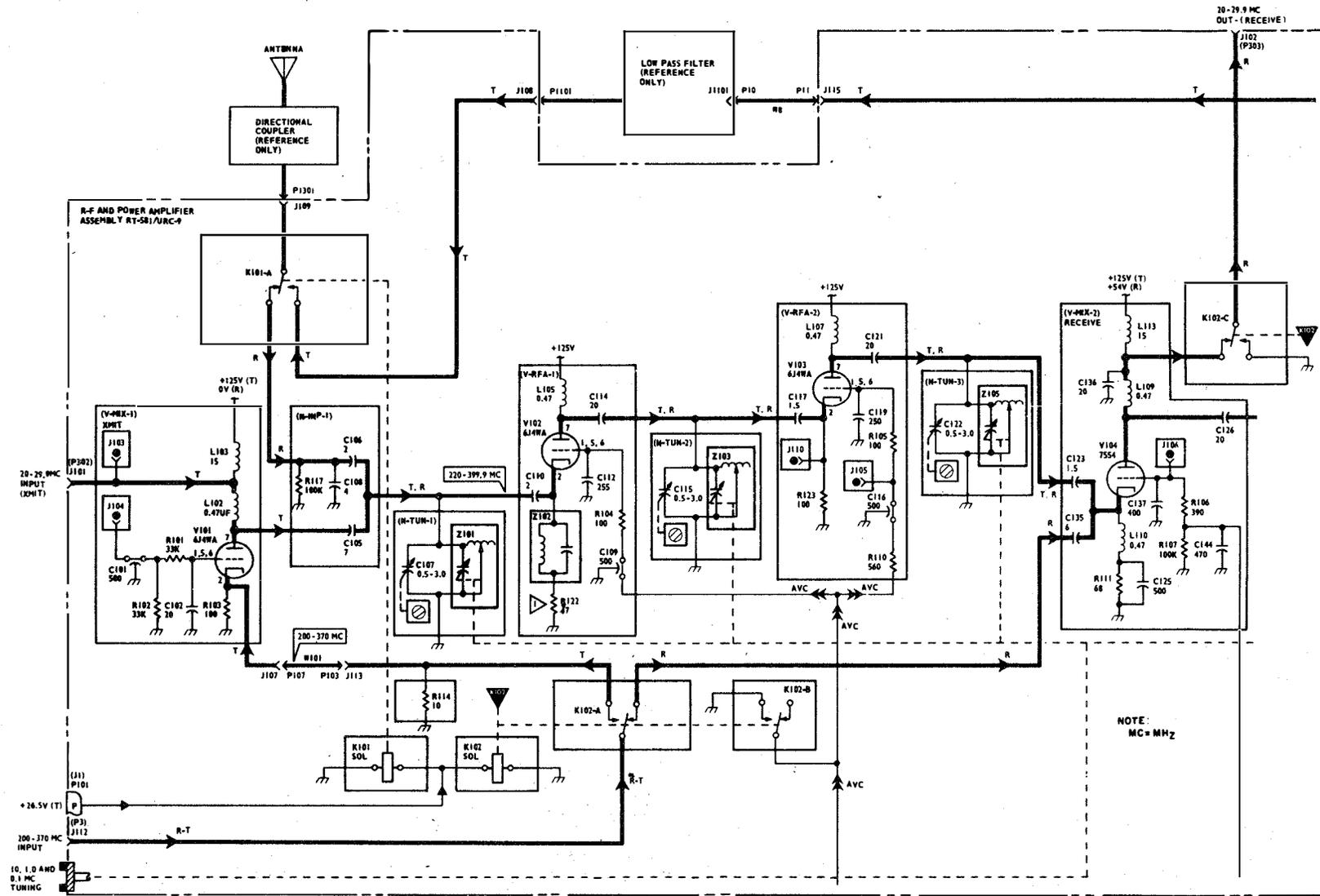
The rectangle represents a circuit that is made up of purely passive elements, such as resistors, capacitors, and inductors.

Like the blocked schematic, the PABD is augmented by an identically blocked and shaded facing page of blocked text (fig. 2-29).

Overall Block Diagram

The **OVERALL BLOCK** diagram (fig. 2-30) shows and describes the relationships between

CS



Chapter 2 - MAINTENANCE

Figure 2-26.—Blocked schematic.

the major functions, thus presenting the overall equipment function. The SIMM overall block diagram differs from those in the conventional manuals in that the SIMM diagram shows cable connections, intraconnections, and graphic representations of certain controls and electronic parts. The function relating to each block is included in the block and shaded gray. Again, the relationship of the gray functional blocks to the hardware is shown by the blue of the hardware area.

Maintenance Dependency Chart

The SIMM manual uses a new approach to the task of troubleshooting. By analogy, if a lamp is to light (Event), its switch must work, and it must be connected to a 115V a.c. receptacle. In the simplest form of SIMM language, this analogy and its equivalent equipment statement, "if a specified source of energy is available, and a particular functional part is working, an event will occur," can be shown by the SIMM expression of a rectangle, dependency triangle, dot and rectangle connected in series as shown in figure 2-31. (See page 59)

The dependency triangle, the dot, and the rectangle are the basic symbols used in the SIMM approach to troubleshooting. They represent dependency upon the functional part or circuit, and event, respectively. Every piece of equipment in its normal operation has many events. Many of these events are determined by the particular mode of operation or switch position the equipment operator selects. Each event depends upon a source of energy or the normal occurrence of another event in addition to the normal operation of a part, a circuit, or a series of parts or circuits. Often, one part or circuit might be involved in the occurrence of more than one event. In practice, the technician is taught to troubleshoot by looking for the fault between the last good event and the first bad event. The entire relationship between an equipment's operation, its event, its functioning parts and circuits, and the dependencies which make the events occur are presented on a Maintenance Dependency Chart.

The MAINTENANCE DEPENDENCY CHART (fig. 2-32) is a symbolic representation of signal flow through the equipment. The chart presents events, as they occur, in a scheme that points out the interdependent relationship between the

functional entities in the equipment, with the dependency relationship clearly outlined. The format used combines turn-on and checkout procedures with fault isolation. Through the use of the chart, fault isolation may be obtained at any level down to the circuit stage. The chart then provides direct access to a schematic for a detailed diagnosis or to a component replacement procedure. The chart is composed of four parts: the procedure column (on the left), the heading (across the top), the body, and the notes and specifications (on the right).

The procedures column specifies the operator actions required to turn on and check out the equipment. The turn-on procedure must be performed in the order given, top to bottom, since each step is dependent upon the proper execution of the preceding step. The checkout steps, indicated by the lettered steps within the numbered step (as shown by letter A in step 1 of figure 2-32) provide a means of checking portions of the equipment that are not checked out under normal operating conditions.

Checkout steps need not be performed, and it is not necessary to perform them in any sequence. However, if they are performed, they must be performed with the equipment set up for the proper turn-on steps, i.e., if checkout step A is performed, it is necessary to complete turn-on steps 1 through 3. Checkout steps may also provide a means of exercising certain self-test features of the equipment.

The heading (figure 2-32) uses alphanumeric or symbol designators to identify the action indicators, available test points, circuit elements, functional entities, and functional devices, i.e., P1307-A/B, K10-A, T1. The physical location of the indicators or entities is identified at the top of the column heading, including a reference to the schematics. Indicators that are recognizable from outside the equipment (front panel indicators, front panel test points) are shown in solid black background with white lettering. The signal specification numbers, located in the box at the base of the column heading are keyed to the notes and specifications located to the right of the chart. The signal specification number references the specification or description of an event that should be present at the check point.

The body of the chart contains symbols that are divided into three general categories: Events, Dependencies, and Function Symbols.

An event is either an action that can be detected by sight or sound (a motor running, lamp

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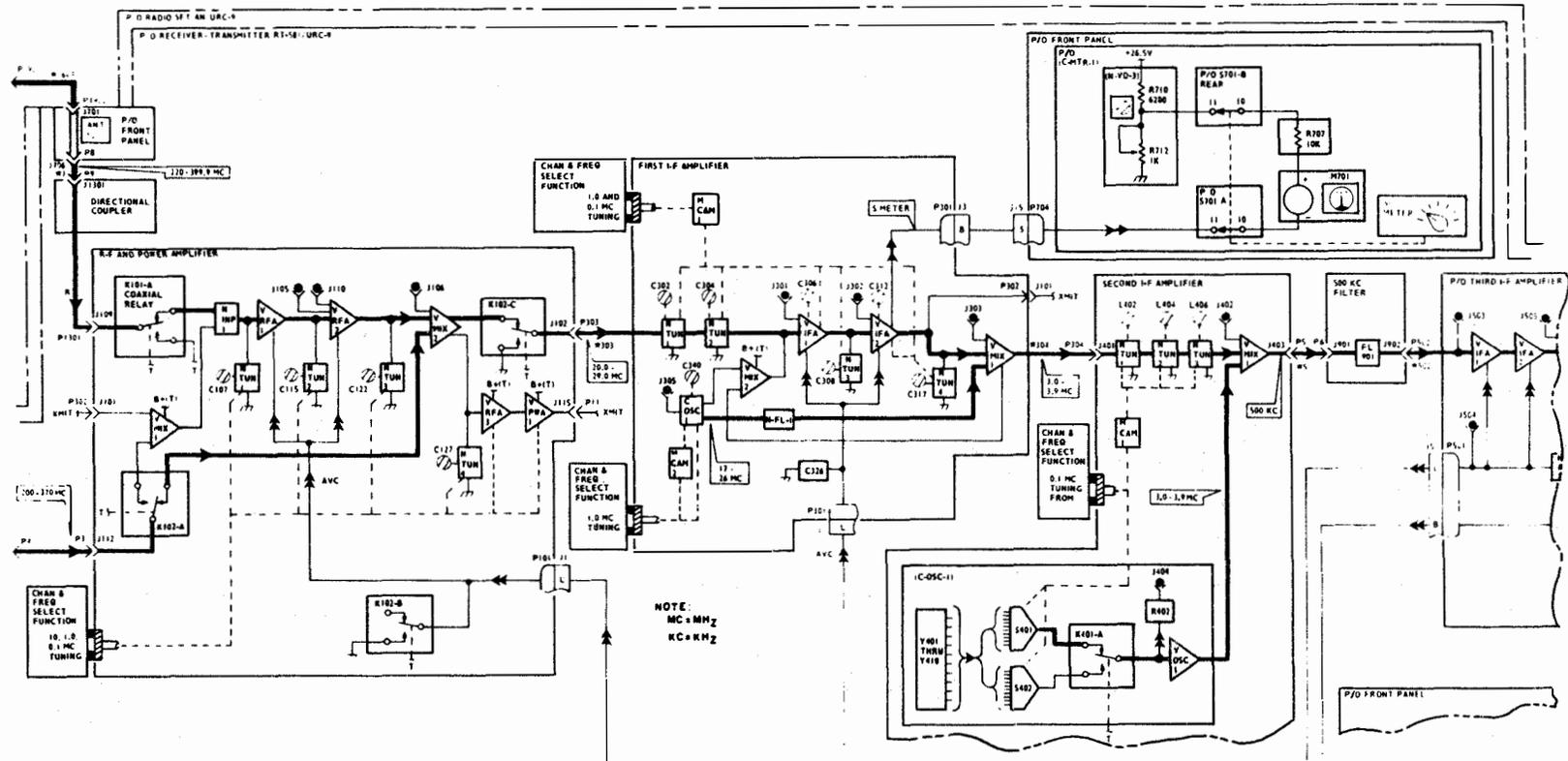


Figure 2-28.—Precise access block diagram (PABD).

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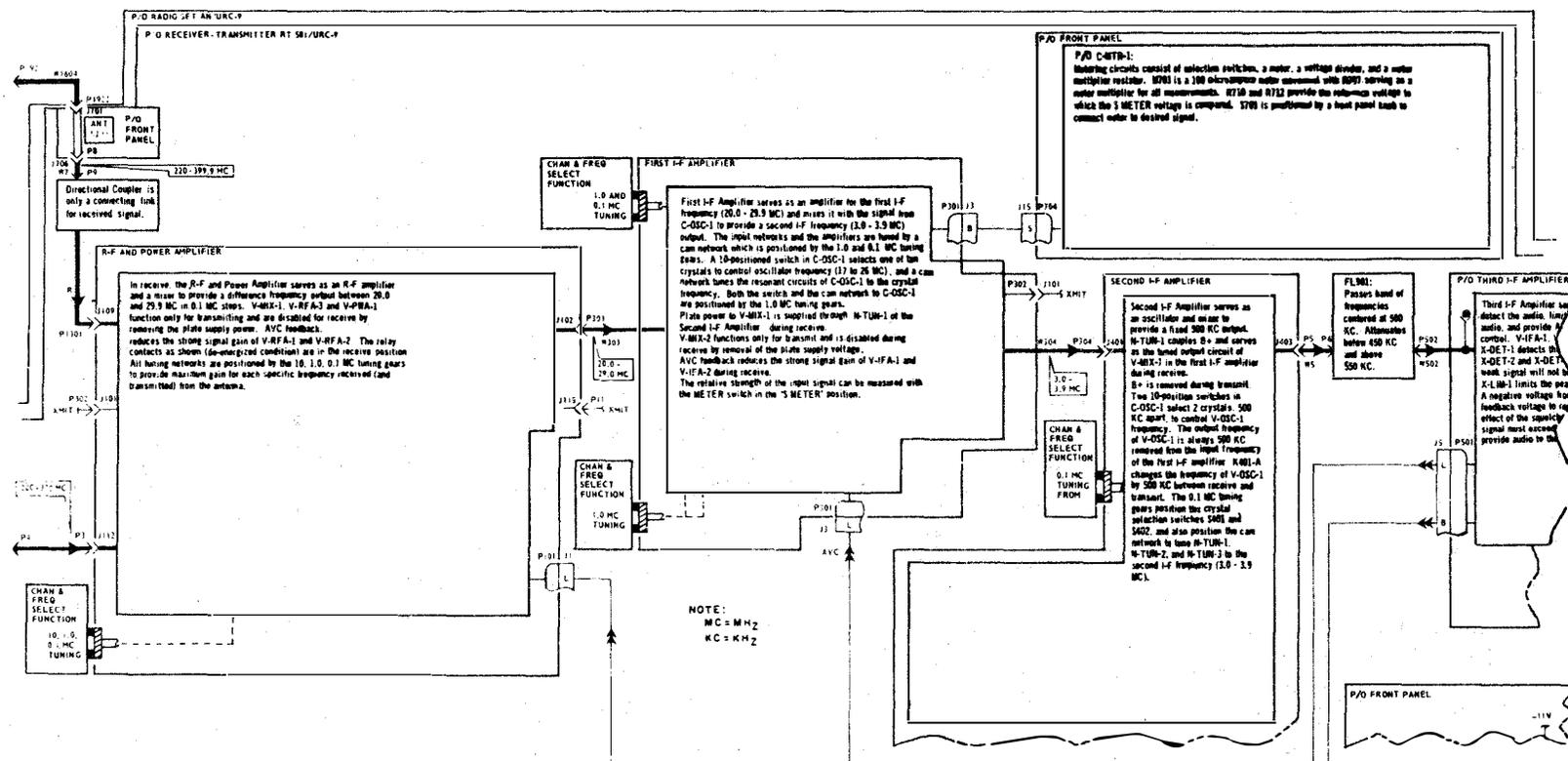
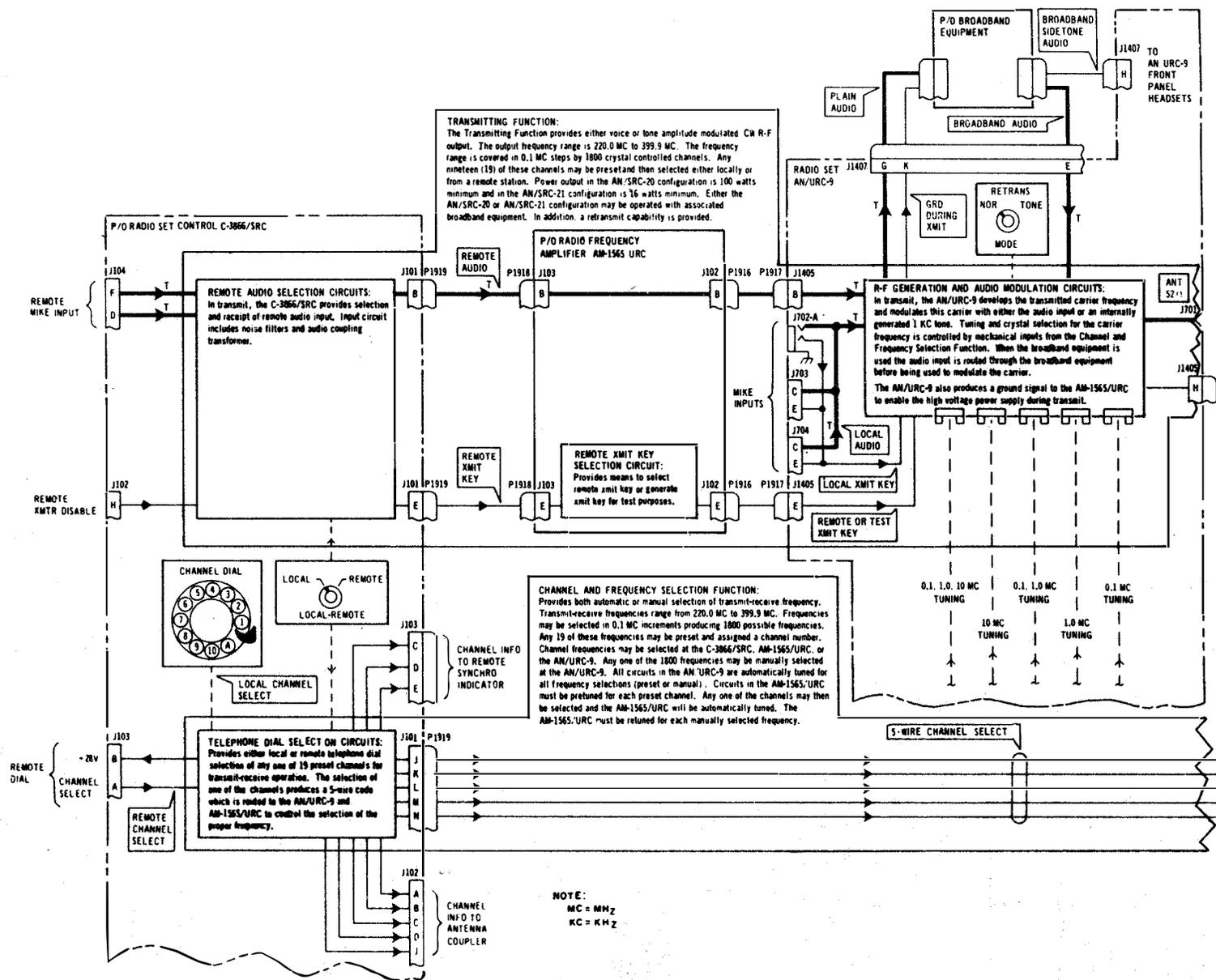


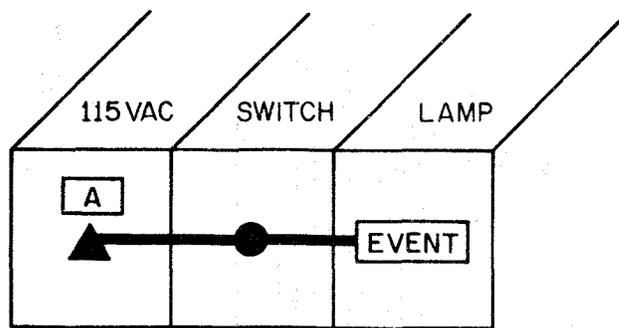
Figure 2-29.—Precise access block diagram text.

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Figure 2-30.—Overall block diagram.



162.156

Figure 2-31.—Simplified maintenance dependency chart.

lighting, meter indicating) or is an availability of a signal that can be determined by a measurement. As shown in figure 2-31, the Action Event Symbol is a rectangular area which encloses an indication of the action. There are three types of Action Event symbols used to represent the degree to which the event is accessible: (1) External, (2) Internal, and (3) Indirect.



A front panel indicator or an event recognizable from outside the cabinet. (black background)



Internal test points that are readily accessible. (gray background)



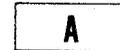
A circuit point at which a measurement might at some time be made. This point is not necessarily readily accessible. (white background)

Abbreviations used to indicate Action Events are listed below:

- EN — Energized (Relay and Contactors)
- LIT — Lighted (Lights, Filaments, VR Tubes)
- RUN— Run (A motor operating.)
- TD — Time Delay (Time-delay sequence is initiated.)
- IND — Indication (A meter is energized and is displaying a voltage or current.)
- OUT— Lamp is not Lit.
- NA — Not Available (Specified voltage, current, or signal is not available.)
- DE — De-energized (Relay is de-energized.)

The Availability Event symbol is a rectangular area with the letter A inside as shown below. The "A" denotes Availability and indicates

that a voltage, signal or other data is present at a specified value. The Availability symbol represents a special type of event that requires an externally applied multimeter, or oscilloscope or other test equipment to determine if the proper voltage or signal is available.



Availability Event Symbol

This symbol is used to show the technician where in the circuit he can expect a voltage, current, or waveform to exist to prove that an event has happened elsewhere or that events should be happening which are dependent upon a signal at the particular point of availability. The background shading of this symbol also indicates the accessibility of the point in the equipment.

The Dependency Symbol is a black triangle as shown below.



Dependency Symbol

The black triangle means that the Event on the same horizontal line is dependent upon occurrence of the Action or Signal Availability Event directly above the triangle in the same vertical column.

The Dependency Symbol is used to show dependency on the Maintenance Dependency Chart. It is not an EVENT symbol but shows the dependency relationships between series or parallel circuit branches. The Dependency Symbol is the only symbol that shows connection or relationship in the vertical direction. Figure 2-33 shows the action event, availability event, and dependency symbols on a maintenance dependency chart.

Function Symbols represent a circuit or a circuit element and are identified at the top of the vertical column. These Symbols are used to show relationship and connecting links between other symbols along a horizontal circuit path. The Symbols take several forms to describe different conditions but the circuit elements they represent must be operating properly or be "good" before any action on the line can occur. Such Symbols represent fuses, relay contacts, power supplies, switches and circuit breakers, oscillator stages, amplifier stages, etc. The

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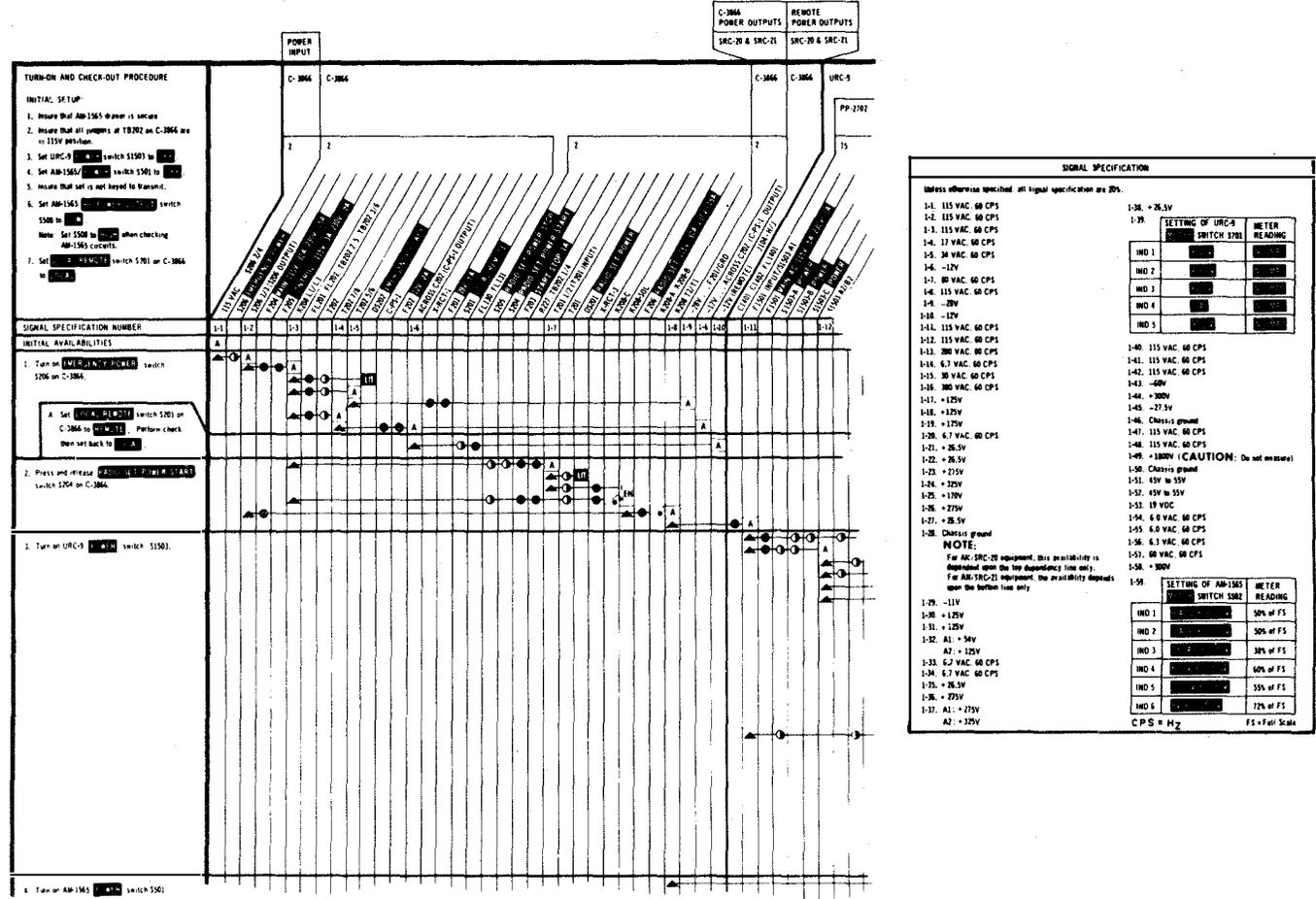
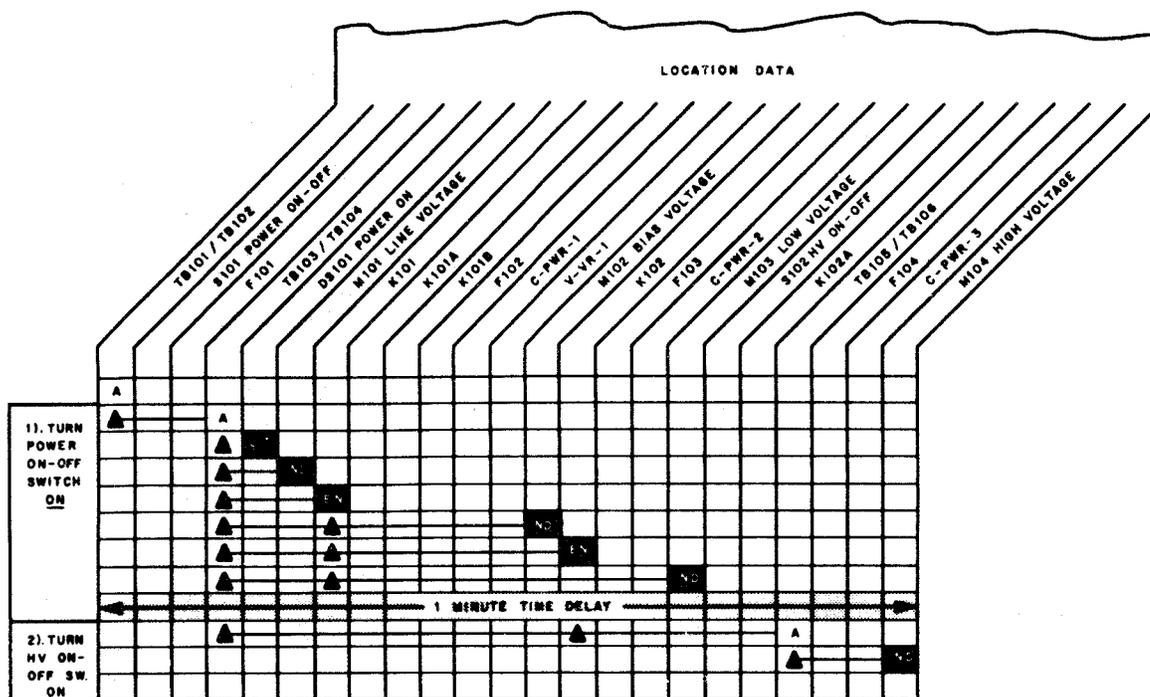


Figure 2-32.—Maintenance dependency chart (MDC).

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162.158

Figure 2-33.—Action event, availability event, and dependency symbols on the MDC.

function Symbols used in Maintenance Dependency Charts are shown below:

- The functional entity or circuit element shown in the column heading above the symbol must be "good" for an Action or an Availability Event shown on the same horizontal line to occur.
- /● The relay contacts provide continuity only when the relay coil is energized.
- / The relay contacts provide continuity only when the relay coil is not energized.
- ⓪ One aspect of the circuit or circuit element is proven good by the occurrence of an Action or Availability Event in the same line (This symbol does not prove a functional entity or a circuit element wholly good.)

Figure 2-34 shows the use of some Function symbols on the maintenance dependency chart.

To use the Maintenance Dependency Chart for troubleshooting, assume that in figure 2-35 black dots (●) represent the basic circuits (oscillator stages, amplifier stages, etc.) or circuit elements (relay contacts, relay coils,

switches, etc.) employed to provide an action LIT at the end of the event line. The black triangle (▲) is a dependency marker.

The action LIT is dependent upon an availability of a power source at the A block and on the proper operation of each of the circuit or circuit elements (●) represented along the event line. If the lamp which indicates the action fails to light, any item along the event line, as well as the source A, is suspected.

In the case of multiple event lines, many entities listed in the heading are common to more than one event line while others are unique to a single line.

In figure 2-36 assume that the lamp does not light on line 4 but does light on lines 1, 2, 3, and 5. It becomes readily apparent that the circuit and circuit element represented by the black dots in columns 4 and 18 are the only ones that can be suspect as faulty since they are unique to line 4. All items represented by dots in the other columns are common to lines 1, 2, 3, or 5, and are proven good because the indicators at the end of the event line light.

Examination of the Partial Maintenance Dependency Chart, in figure 2-37 will show that

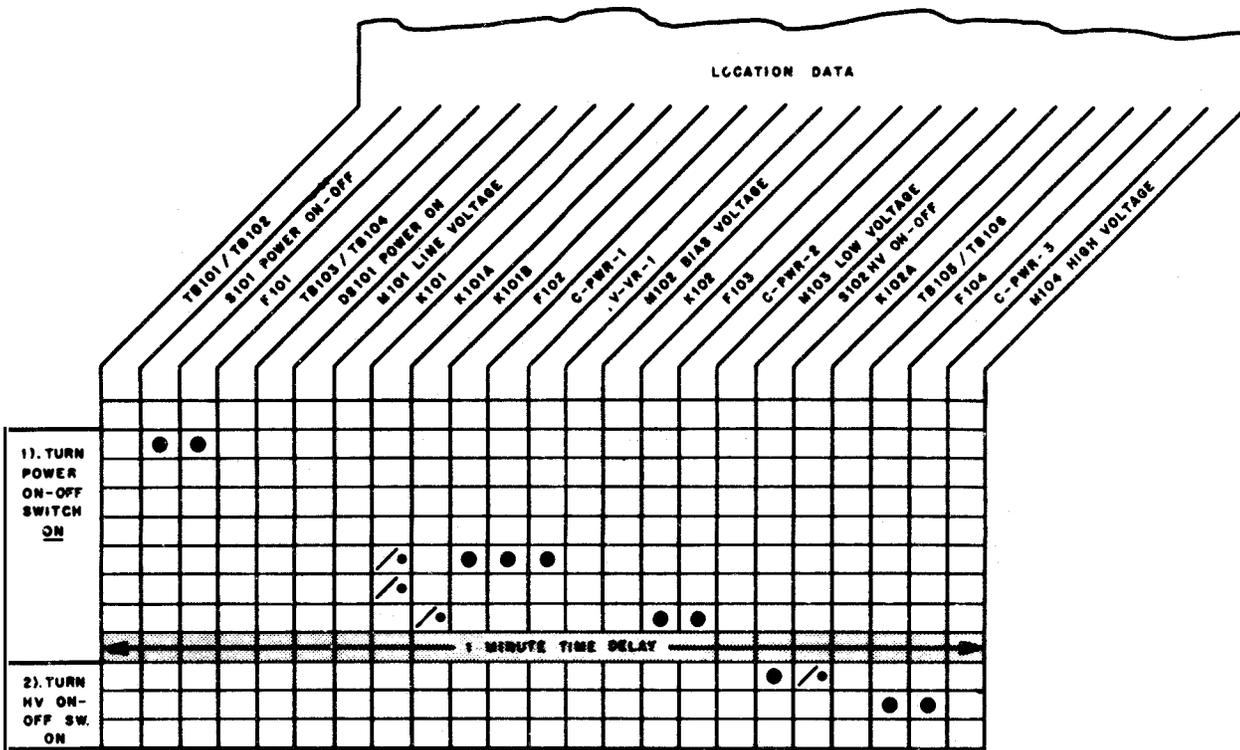


Figure 2-34.—Function symbols on the MDC.

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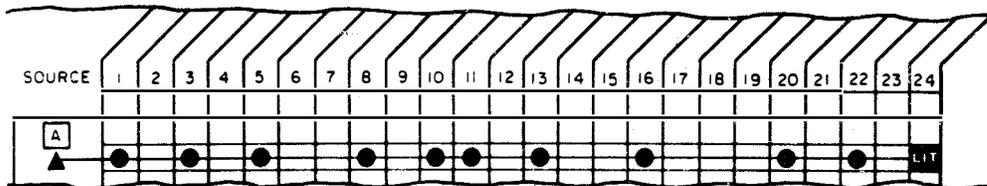


Figure 2-35.—Single event line.

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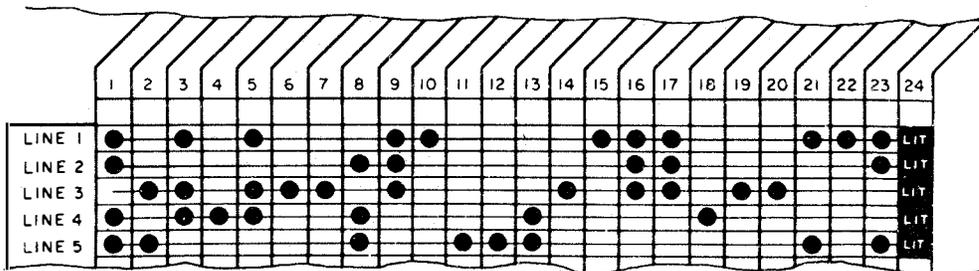
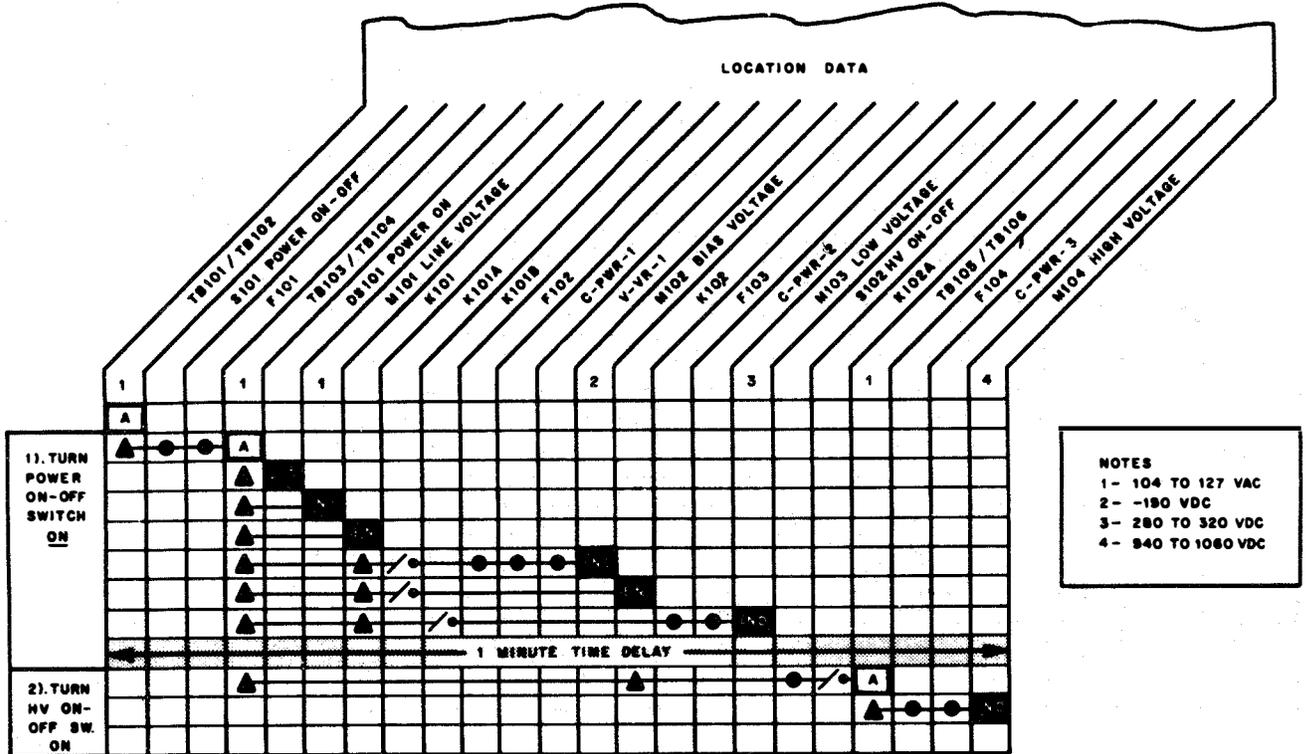


Figure 2-36.—Multiple event lines.

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162.162

Figure 2-37.—Partial MDC.

there are 10 Events, which occur as indicated by the white and black rectangles. You will note that there is only one Event on each horizontal line. The Availability [A] at TB101/TB102 is termed the Input Event, and the other Events are dependent Events, i.e., dependent upon the Input Event. You will also note that Availabilities are usually specified at important junction points.

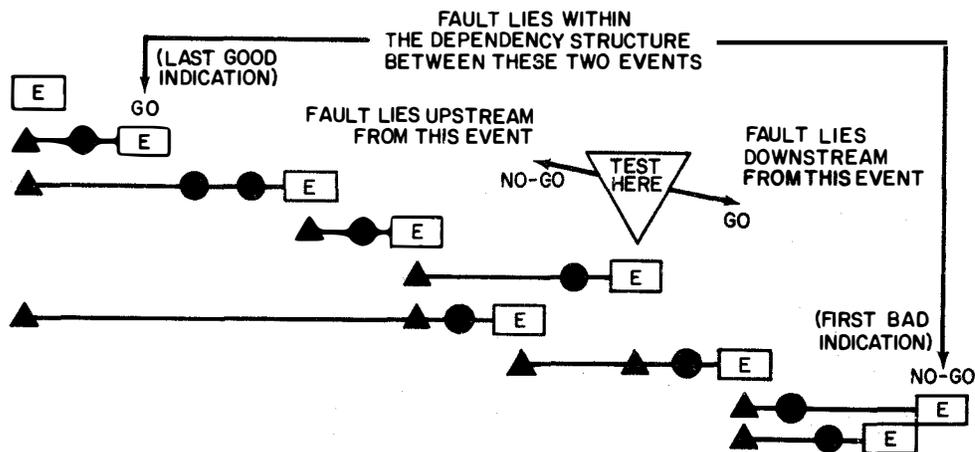
To show how this chart reads, the fact that M102 indicates -150 VDC proves:

1. V-VR-1 is good.
2. C-PWR-1 is good.
3. F-102 is good.
4. Contacts K101A are providing continuity.
5. K-101 is energized.
6. The correct voltage is available at TB103/104.
7. F101 is good.
8. S101 is good.
9. The input voltage is available.

The chart in figure 2-38 illustrates the fault isolation process on a Maintenance Dependency Chart. The technician simply makes note of the

equipment's front panel indicators which have "out-of-spec" indications. The events are then marked for reference, and the first bad indication and the last good indication of the dependency structure are established. The dependency structure between these two events contains the faulty element. To further narrow the area of concern, split-half diagnostics are used. The next event to be tested is located midway within the dependency structure defined by the last good and first bad indications. This event should be chosen for its ease of access as indicated by the event symbol's background. If the event is GO, the fault lies within the dependency structure downstream from the event. If the event is NO-GO, the fault lies upstream from the event. This procedure is repeated until a single dependency line is isolated whose input event is good and whose output event is bad. The fault lies on this line, and the functional entity identified by the dot contains the fault.

An important rule in using the Maintenance Dependency Charts—if an Event is proven good for one Dependent Event, it is proven good for all Dependent Events. In a like manner, if a



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Figure 2-38.—Fault isolation.

functional entity or circuit element has been proven good in connection with an Event; then, it is good in connection with all other Events with which it is associated.

Isolation of a faulty functional entity or circuit element alone is important; also, knowledge of the physical location of the suspected circuit is important. Accordingly, along the top of the Maintenance Dependency Chart the assembly and the cabinetry in which the suspect circuit or circuit element is located is also indicated. Information and details on the suspect circuit or element can be readily ascertained by using the Functional Index to locate the data package for the assembly containing the suspect item. The suspect item's location can be determined (insofar as the assembly and cabinet are concerned) from the Maintenance Dependency Chart. Knowing the piece of hardware in which the assembly and its suspect item is contained, one can find all pertinent data in the assembly data packages listed in the index.

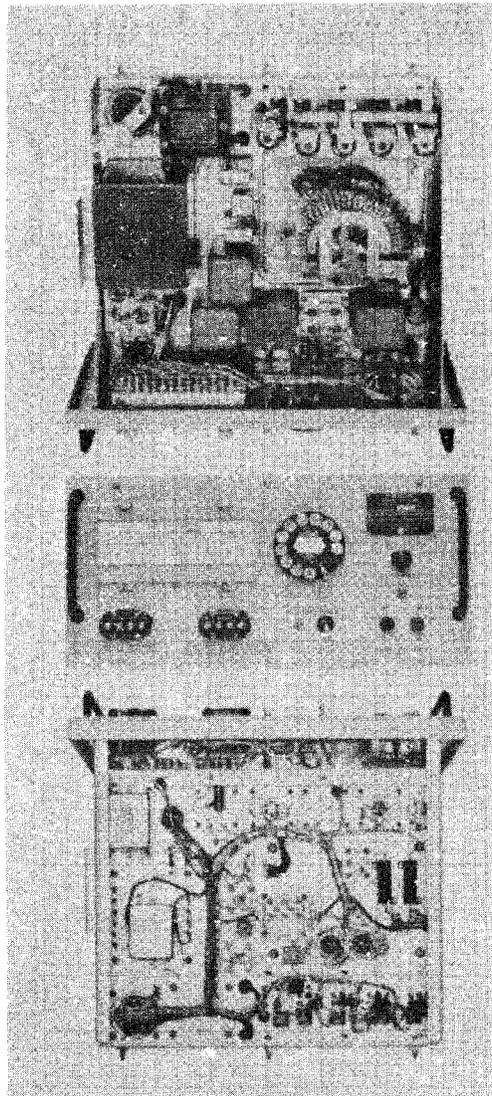
Parts List and Functional Index

Another one of the principal features of SIMM is its method of indexing. Each hardware assembly (unit, major assembly, and subassembly, as required) is fully treated in a four-part data package. All data packages are arranged so that the same type of information is located in the same sequence in every package. Each pack-

age includes a parts list and parts location illustrations (2-39); blocked text; blocked schematic; and related technical maintenance data. All information at the hardware assembly level is provided in four pages or less. Hence, the index for assemblies lists only four page numbers for each assembly. Indexing the higher level PABD's and text, and the system block diagram, the functional coverage page, the instructional page (how to use the manual), the maintenance dependency charts, installation and operation information, by page number is the only other requirement. This eliminates the need for long lists of contents, illustrations and tables. The indexing of a SIMM manual (fig. 2-40) permits the finding of pertinent information in seconds.

Improvements

As this training manual goes to press, various improvements are being made to the SIMM technical manual. Current SIMM manuals will use a keyed-text technique instead of the blocked text. In the keyed-text, the text material is arranged in tabular format and keyed to the diagram by circled numbers as shown by figure 2-41. This method of presentation permits significantly more text material to be presented than the blocked text method. In addition to the schematic diagrams, the keyed-text will also be used with the precise access block diagrams (called functional block diagrams), and the overall block diagram (called the functional description diagram).



SLIDE MOUNTED ASSEMBLY

| REF DESIG | LOCATING COORD | NAME AND DESCRIPTION | REF DESIG | LOCATING COORD | NAME AND DESCRIPTION |
|-----------|----------------|---|-----------|----------------|---|
| C201 | C.2/5.3 | CAPACITOR, SPRAGUE ELECTRONIC CO. PART NO. 16P16M4T15 | R316 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C202 | D.3/4.4 | CAPACITOR, MIL TYPE CL32C-132PF3 | R317 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C203 | D.3/3.3 | CAPACITOR, MIL TYPE CL32C-132PF1 | R318 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C204 | F.2/4.1 | DIODE, MIL TYPE 1N518 | R319 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C205 | F.2/4.2 | DIODE, MIL TYPE 1N518 | R320 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C206 | E.5/4.1 | DIODE, MIL TYPE 1N518 | R321 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C207 | E.5/4.2 | DIODE, MIL TYPE 1N518 | R322 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C208 | B.2/4.1 | DIODE, MIL TYPE 1N249B | R323 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C209 | B.2/4.4 | DIODE, MIL TYPE 1N249B | R324 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C210 | B.2/4.5 | DIODE, MIL TYPE 1N249B | R325 | G.1/3.5 | RESISTOR, IBC INC. PART NO. G8T1-222M5 |
| C211 | B.4/5.4 | DIODE, MIL TYPE 1N249B | R326 | G.2/7.2 | RESISTOR, RESISTORS, INC. PART NO. 10A-400-00 |
| C212 | B.4/5.1 (0) | DIODE, MIL TYPE 1N249B | R327 | G.2/7.2 | RESISTOR, DALE ELECTRONICS INC. PART NO. RNS5-15000C |
| C213 | F.1/4.2 (0) | DIODE, MIL TYPE 1N518 | R328 | G.2/7.2 | RESISTOR, DALE ELECTRONICS INC. PART NO. RNS5-15000C |
| C214 | F.2/5.1 (0) | DIODE, MIL TYPE 1N518 | R329 | B.4/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C215 | E.4/4.2 (0) | DIODE, MIL TYPE 1N518 | R330 | B.5/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C216 | E.4/5.2 (0) | DIODE, MIL TYPE 1N518 | R331 | C.2/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C217 | E.5/5.5 | DIODE, MIL TYPE 1N518 | R332 | C.4/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C218 | E.5/5.6 | DIODE, MIL TYPE 1N518 | R333 | C.5/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C219 | E.5/5.7 | DIODE, MIL TYPE 1N518 | R334 | G.2/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C220 | E.5/5.8 | DIODE, MIL TYPE 1N518 | R335 | B.3/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C221 | E.4/4.2 (0) | DIODE, MIL TYPE 1N518 | R336 | B.5/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C222 | E.4/5.2 (0) | DIODE, MIL TYPE 1N518 | R337 | C.1/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C223 | E.5/5.5 | DIODE, MIL TYPE 1N518 | R338 | C.2/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C224 | E.5/5.6 | DIODE, MIL TYPE 1N518 | R339 | C.4/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C225 | E.5/5.7 | DIODE, MIL TYPE 1N518 | R340 | D.1/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C226 | E.5/5.8 | DIODE, MIL TYPE 1N518 | R341 | D.2/7.2 | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C227 | E.5/5.9 | DIODE, MIL TYPE 1N518 | R342 | B.3/7.2 (0) | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C228 | E.5/6.0 | DIODE, MIL TYPE 1N518 | R343 | B.5/7.2 (0) | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C229 | E.5/6.1 | DIODE, MIL TYPE 1N518 | R344 | C.2/7.1 (0) | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C230 | E.5/6.2 | DIODE, MIL TYPE 1N518 | R345 | C.4/7.1 (0) | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C231 | E.5/6.3 | DIODE, MIL TYPE 1N518 | R346 | C.5/7.1 (0) | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C232 | E.5/6.4 | DIODE, MIL TYPE 1N518 | R347 | D.2/7.1 (0) | RESISTOR, VARIABLE, MIL TYPE RVALATAS50B |
| C233 | E.5/6.5 | DIODE, MIL TYPE 1N518 | R348 | G.4/7.1 | RESISTOR, MIL TYPE RV20V-D1 |
| C234 | E.5/6.6 | DIODE, MIL TYPE 1N518 | R349 | G.4/5.4 | RESISTOR, P O K26 |
| C235 | E.5/6.7 | DIODE, MIL TYPE 1N518 | RV201 | G.4/7.3 | RESISTOR, VOLTAGE SENSITIVE, AUTOMATIC ELECTRIC CO. PART NO. 8754 |
| C236 | E.5/6.8 | DIODE, MIL TYPE 1N518 | RV202 | F.1/5.3 | RESISTOR, VOLTAGE SENSITIVE, AUTOMATIC ELECTRIC CO. PART NO. 8754 |
| C237 | E.5/6.9 | DIODE, MIL TYPE 1N518 | RV203 | G.1/4.3 | RESISTOR, VOLTAGE SENSITIVE, AUTOMATIC ELECTRIC CO. PART NO. 8754 |
| C238 | E.5/7.0 | DIODE, MIL TYPE 1N518 | RV204 | F.2/4.3 | RESISTOR, VOLTAGE SENSITIVE, AUTOMATIC ELECTRIC CO. PART NO. 8754 |
| C239 | E.5/7.1 | DIODE, MIL TYPE 1N518 | RV205 | E.4/1.3 | RESISTOR, VOLTAGE SENSITIVE, AUTOMATIC ELECTRIC CO. PART NO. 8754 |
| C240 | E.5/7.2 | DIODE, MIL TYPE 1N518 | RV206 | E.3/4.2 | RESISTOR, VOLTAGE SENSITIVE, AUTOMATIC ELECTRIC CO. PART NO. 8754 |
| C241 | E.5/7.3 | DIODE, MIL TYPE 1N518 | RV207 | E.1/1.4 (0) | RESISTOR, VOLTAGE SENSITIVE, AUTOMATIC ELECTRIC CO. PART NO. 8754 |
| C242 | E.5/7.4 | DIODE, MIL TYPE 1N518 | S201 | G.2/4.5 | SWITCH, 0A5 WEG. CO. PART NO. 2325M3 |
| C243 | E.5/7.5 | DIODE, MIL TYPE 1N518 | S202 | E.4/7.3 | DIAL, TELEPHONE, AUTOMATIC ELECTRIC CO. PART NO. 2327J-1 |
| C244 | E.5/7.6 | DIODE, MIL TYPE 1N518 | S203 | --- | NOT USED |
| C245 | E.5/7.7 | DIODE, MIL TYPE 1N518 | S204 | F.2/4.5 | SWITCH, ARBOR-MART AND HEGEMAN ELECTRIC CO. PART NO. B-48LACE |
| C246 | E.5/7.8 | DIODE, MIL TYPE 1N518 | S205 | G.3/4.4 | SWITCH, ARBOR-MART AND HEGEMAN ELECTRIC CO. PART NO. B-02ED |
| C247 | E.5/7.9 | DIODE, MIL TYPE 1N518 | S206 | B.5/7.1 | SWITCH, MIL TYPE H5300-2 |
| C248 | E.5/8.0 | DIODE, MIL TYPE 1N518 | T201 | D.5/4.1 | TRANSFORMER, COLLINS RADIO CO. PART NO. 94-070047 |
| C249 | E.5/8.1 | DIODE, MIL TYPE 1N518 | T202 | B.1/4.3 | TRANSFORMER, COLLINS RADIO CO. PART NO. 87-40117-00 |
| C250 | E.5/8.2 | DIODE, MIL TYPE 1N518 | T203 | G.4/4.1 | TRANSFORMER, STANCOR ELECTRONICS INC. PART NO. 2951 |
| C251 | E.5/8.3 | DIODE, MIL TYPE 1N518 | T204 | G.3/4.2 | TRANSFORMER, AUDIO FABRIQUIN, AOC PRODUCTS INC. PART NO. A121H |
| C252 | E.5/8.4 | DIODE, MIL TYPE 1N518 | T205 | F.4/1.2 | TERMINAL BOARD, COLLINS RADIO CO. PART NO. 57-4002-002 |
| C253 | E.5/8.5 | DIODE, MIL TYPE 1N518 | T206 | E.3/1.2 | TERMINAL BOARD, COLLINS RADIO CO. PART NO. 57-4004-002 |
| C254 | E.5/8.6 | DIODE, MIL TYPE 1N518 | T207 | F.2/5.4 | TERMINAL BOARD, COLLINS RADIO CO. PART NO. 57-4005-002 |
| C255 | E.5/8.7 | DIODE, MIL TYPE 1N518 | T208 | F.2/5.5 | TERMINAL BOARD, COLLINS RADIO CO. PART NO. 57-4006-002 |

(0) DENOTES HIDDEN

Figure 2-39.—Parts data.

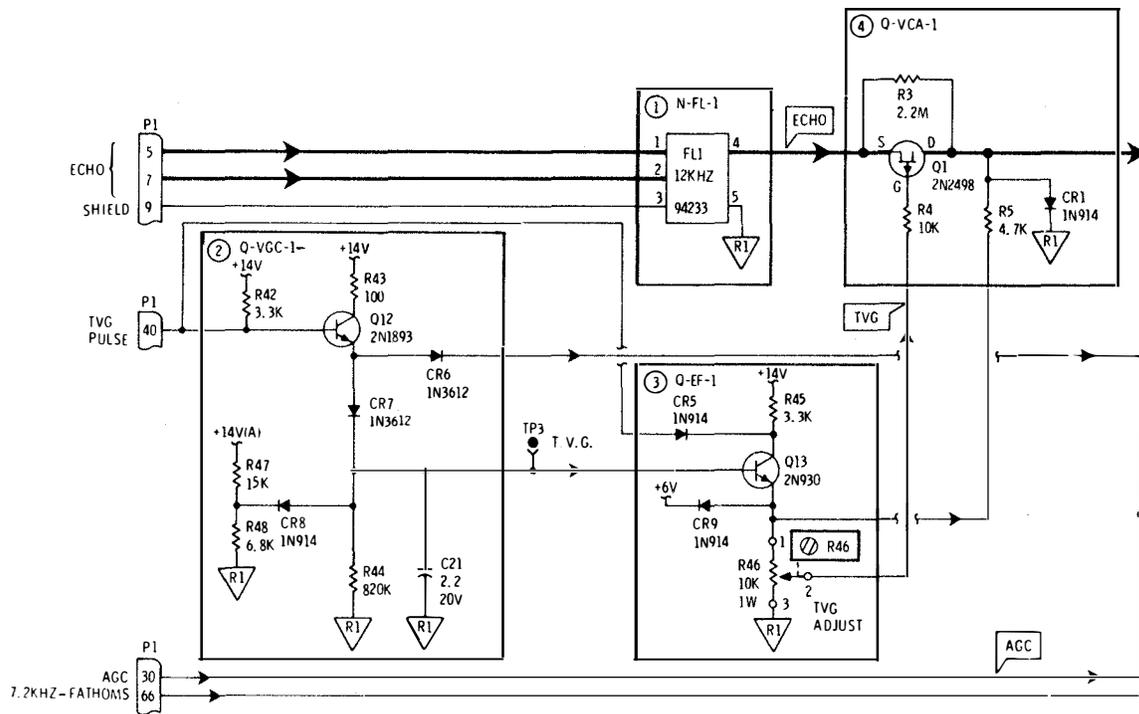
66

| EQUIPMENT DATA | | PAGE | ASSEMBLY DATA | | | | |
|--|--|---------------------------------|---|-------------------|------------------------|-----------------------|--|
| Manual Description | | 3 | ASSEMBLY NOMENCLATURE | | | | |
| Radio Sets AN/SRC-20 and AN/SRC-21 Equipment Description | | 4 | PARTS DATA PAGE | BLOCKED TEXT PAGE | BLOCKED SCHEMATIC PAGE | MAINTENANCE DATA PAGE | |
| Operating Instructions & Turn-on and Checkout Chart | | 5 | Radio Frequency Amplifier AM-1565/URC | | | | |
| Radio Sets AN/SRC-20 and AN/SRC-21 Block Diagram | | 6 | 200 Series: Power Amplifier | | | | |
| Transmitting and Receiving Functions | Transmitting and Receiving Functions Assembly Data | 7 | 21 | 22 | 23 | 24 | |
| | Receiving Function Blocked Text | 8 | | | | | |
| | Receiving Function Precise Access Block Diagram | 9 | 500 Series: Front Panel and Autopositioner | | | | |
| | Transmitting Function Blocked Text | 10 | Radio Set AN/URC-9 (RT-581/URC-9 and PP-2702/URC-9) | | | | |
| | Transmitting Function Precise Access Block Diagram | 11 | 100 Series: R-F and Power Amplifier | | | | |
| Channel and Frequency Select Function | Transmitting and Receiving Functions Maintenance Data | 12 | 29 | 30 | 31 | 32 | |
| | Channel and Frequency Select Function Assembly Data | 13 | | | | | |
| | Channel and Frequency Select Function Blocked Text | 14 | 33 | 34 | 35 | 36 | |
| | Channel and Frequency Select Function Precise Access Block Diagram | 15 | | | | | |
| Channel and Frequency Select Function Maintenance Data | 16 | 500 Series: Third I-F Amplifier | | | | | |
| Power Distribution Function | Power Distribution Function Assembly Data | 17 | 37 | 38 | 39 | 40 | |
| | Power Distribution Function Text | 18 | | | | | |
| | Power Distribution Function Diagram* | 19 | 600 Series: Relay-Filter Assembly | | | | |
| | Power Distribution Function Maintenance Data | 20 | 700 Series: Front Panel | | | | |
| Maintenance Dependency Chart (MDC) | How to Use | 61 | 41 | 42 | 43 | 44 | |
| | Part 1: Power Distribution Function | 62 | | | | | |
| | Part 2: Channel and Frequency Select Function | 63 | 45 | 46 | 47 | 48 | |
| | Part 3: Transmitting Function | 64 | | | | | |
| | Part 4: Receiving Function | 65 | 800 Series: Audio Amplifier and Modulator | | | | |
| Radio Set AN/SRC-20 Installation | 66 | 900 Series: 500 k Hz Filter | | | | | |
| Radio Set AN/SRC-21 Installation | 67 | 1000 Series: Centrifugal Fan | | | | | |
| Preventive Maintenance | 68 | 1100 Series: Low-Pass Filter | | | | | |
| Performance Check Chart | 69 | 1200 Series: Frequency Selector | | | | | |
| | | | 1300 Series: Directional Coupler | | | | |
| | | | 1500 Series: Power Supply (PP-2702/URC-9) | | | | |
| | | | 1600 Series: Broadband Sidetone Amplifier | | | | |
| | | | Radio Set Control C-3866/SRC | | | | |
| | | | 100 Series: Case | | | | |
| | | | 200 Series: Slide Mounted Assembly | | | | |
| | | | 57 | 58 | 59 | 60 | |

*Includes power schematic for AM-1565/URC

162.165

Figure 2-40.— Functional index.

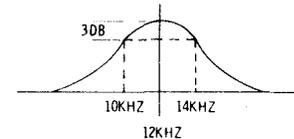


1A4A1 RECEIVER ASSEMBLY

AMPLIFIES THE LOW LEVEL RECEIVED ECHO. CONVERTS THE TVG PULSE (TIME VARIABLE GAIN) INTO A DECREASING EXPONENTIAL VOLTAGE TO BLANK THE RECEIVER AT TRANSMIT TIME AND ALLOW IT TO RECOVER SLOWLY. AGC IS ALSO PROVIDED TO REDUCE THE GAIN OF THE RECEIVER WHEN THE NOISE LEVEL HAS INCREASED (NOISE CAUSED BY RECEIVED ACOUSTIC ENERGY OTHER THAN THE ECHO).

① N-FL-1 FILTER

PROVIDES IMPEDANCE MATCHING BETWEEN THE FILTER IN THE TRANSMIT-RECEIVE NETWORK AND THE INPUT AMPLIFIER. HAS A CENTER FREQUENCY OF 12KHZ WITH A BANDPASS 2KHZ EITHER SIDE OF CENTER (3DB POINTS).



FILTER INPUT IMPEDANCE IS 120 OHMS, OUTPUT IMPEDANCE IS 240 OHMS.

② Q-VGC-1 VOLTAGE GAIN CONTROL

EMITTER FOLLOWER CONFIGURATION. NORMALLY BIASED OFF, CONDUCTS UPON RECEIPT OF TVG PULSE. DIVIDER R47 AND R48 ALONG WITH DIODE CR8 LIMIT THE TVG VOLTAGE AT TP3 TO APPROXIMATELY +3.8V. THE TVG PULSE HAS THE SAME PULSE WIDTH AS THE TRANSMIT PULSE AND IS APPLIED TO C11 THRU CR6.

③ Q-EF-1 Emitter Follower

COUPLES TVG PULSE TO Q-VCA-1. AMPLITUDE CONTROLLED BY R46 IN EMITTER CIRCUIT.

④ Q-VCA-1 VOLTAGE CONTROLLED ATTENUATOR

ACTS AS VARIABLE RESISTOR BETWEEN OUTPUT OF N-FL-1 AND INPUT TO Q-AMP-1. PINCHED OFF BY THE POSITIVE TVG VOLTAGE APPLIED TO GATE DURING TRANSMIT TIME.

Figure 2-41.—Blocked schematic with keyed text.

162.179

Another area of the manual to be improved is the maintenance dependency chart. Instead of only one MDC for each major function, future manuals will have additional MDCs for the functional block and schematic diagrams. MDCs will also be provided with an acetate or Mylar overlay so that the technician can use a grease pencil

to mark his progress when troubleshooting. Also, the manual will be smaller than the 15"x35" shown in figure 2-13. New SIMM manuals will be 11"x27". This gives them a folded dimension of 9"x11", which is the same size as conventional manuals.

TEST DATA

GENERAL NOTES

- A. Test Equipment Required
 Signal Generator AN/USM-44 or equivalent
 RF Millivoltmeter CCVO-31-DA or equivalent
 20-db, 50ohm attenuator (part of Power Measuring Set AN/USM-177B)
 6-db, 50-ohm attenuator Microlab Type AA-06N or equivalent
 Multimeter AN/PSM-4B or equivalent
 Oscilloscope AN/USM-1400 or equivalent

- B. If necessary, refer to paragraph 5-6.7 for troubleshooting sequence and figure 5-15 for physical location of test points.

SPECIFIC NOTES

1. Make the following preliminary control settings:

| UNIT | CONTROL | POSITION |
|--|-----------------------------|------------------------|
| Switch Box SAXXX/SP | STOW-OPERATE switch 17S1 | OPERATE |
| Radio Frequency Transmission Line Line Switch SA-XXX/U | DUMMY-NORMAL 1A1S3 | Dummy load position |
| Electron Tube Liquid Cooler HD-XXX/SP | POWER switch 10S1 | ON |

2. Monitor scope set-up:

POWER switch - ON
 OPERATION switch - REMOTE
 TRIGGER SELECT switch - EXT
 DELAY MULTIPLIER switch - OFF
 VERTICAL GAIN control - CAL position

3. Test Steps:

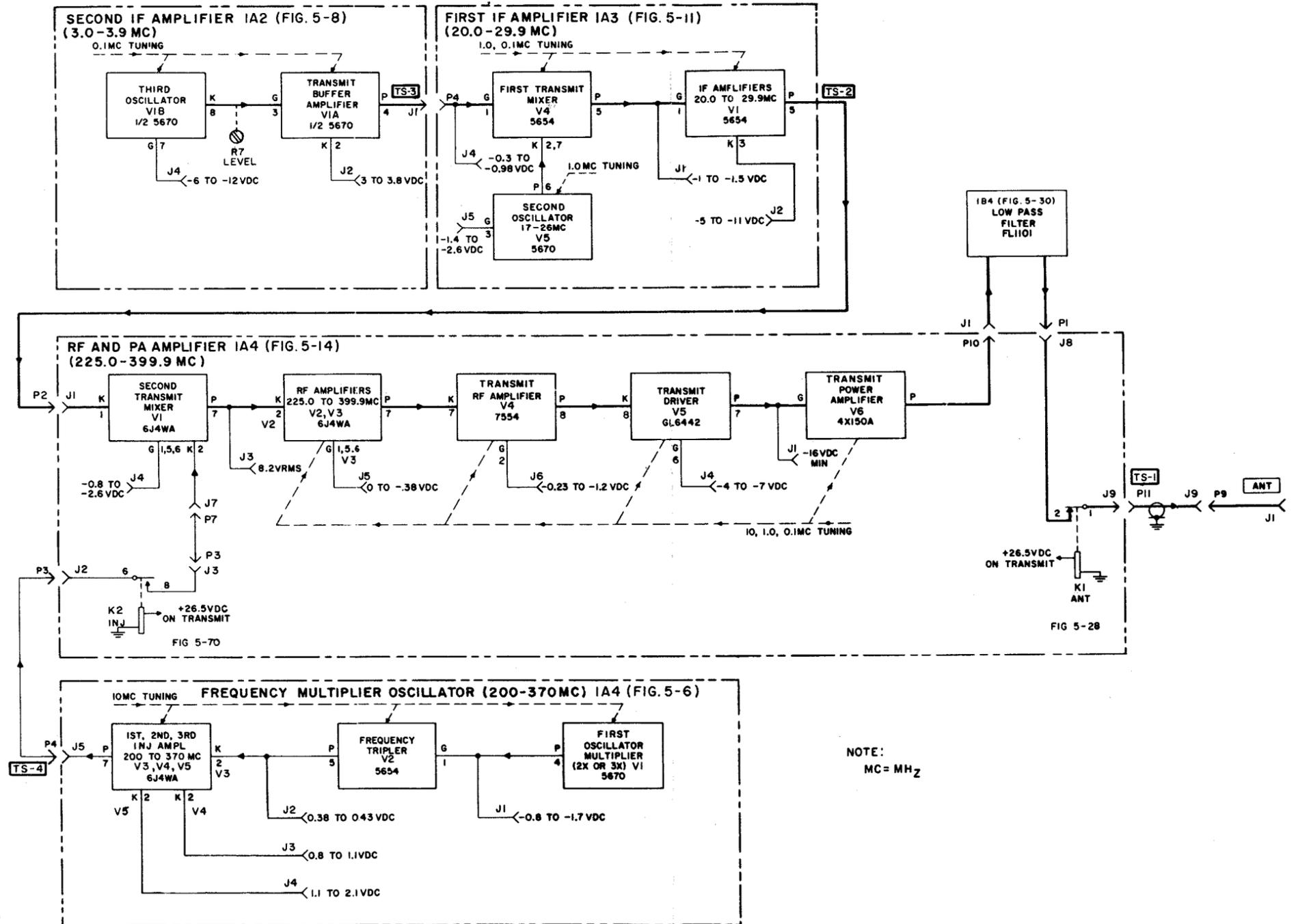
(For steps out of tolerance, refer to paragraph 5-6.7.)

TS1 Refer to note 1 before performing test, except ignore pulse generator cabinet settings. Open outer door of receiver. Then open inner door while holding MOMENTARY INTERLOCK BYPASS switch 4S2 closed; engage PULLOUT TO BYPASS INTLK switch 4S1 before releasing switch 4S2. Connect tee-adaptor between 4A3P1 and 4A3CP1. Connect probe of rf millivoltmeter to open end of tee-adaptor. At control monitor, successively select each of the 20 channels using CHANNEL SELECTOR switch 6A3S2. Input measured on rf millivoltmeter should be at least 0.7 volt rms for each channel.

TS2 Same as TS1, except connect tee-adaptor between 9A1P5 and 4A1J5.

TS3 Refer to note 1 before performing test, except ignore pulse generator cabinet settings. Set up control-monitor cabinet monitor scope per note 2. Place CONTROL POSITION switch 6A3S6 in LOCAL position. Place MONITOR DISPLAY SELECTOR switch 6A1S1 in DxBIAS PULSE position.

TS4 Refer to note 1 before proceeding. Connect sync input of Oscilloscope AN/USM-140D to a tee-adaptor connected between 20A1A1P1 and 20A1A1J1 (A trigger). Connect oscilloscope probe to test point via tee-adaptor.



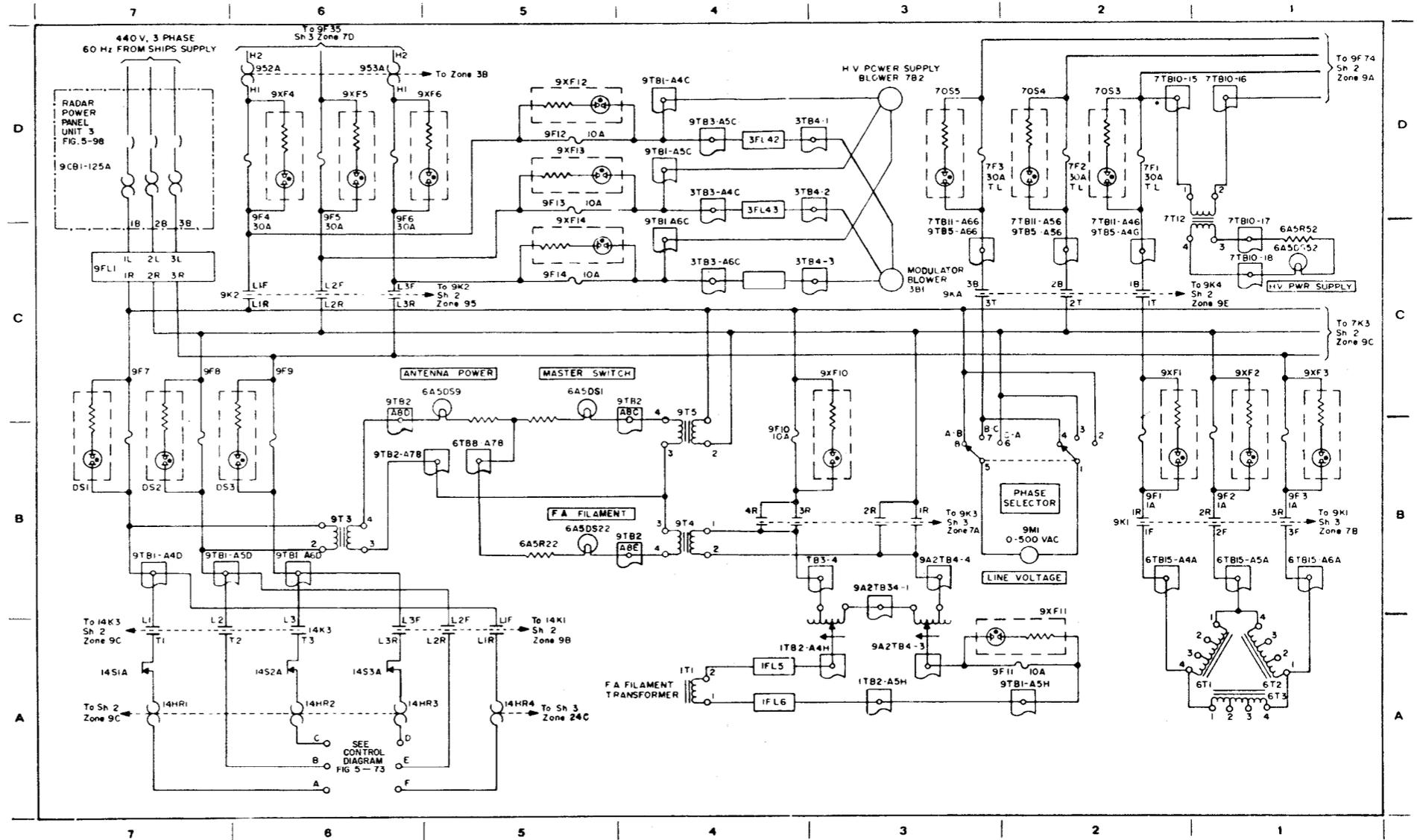
162.145

Figure 2-20.— Functional signal flow diagram.

NOTE:
A. ALL RELAYS AND SWITCHES ARE SHOWN IN OPERATING POSITION.

PART LOCATION INDEX

| Ref Des | Zone | Ref Des | Zone | Ref Des | Zone | Ref Des | Zone |
|-----------|------|----------|------|----------|------|------------|------|
| DS1 | 7B | 7DS3 | 2C | 9K2-L2F | 6C | 9TB1-A6D | 6B |
| DS2 | 7B | 7DS4 | 3C | 9K2-L2R | 6C | 9TB2-A7B | 5B |
| DS3 | 7B | 7DS5 | 3C | 9K2-L3F | 6C | 9TB2-A8C | 5B |
| 1FL5 | 4A | 7F1 | 2C | 9K2-L3R | 6C | 9TB2-A8D | 6B |
| 1FL6 | 4A | 7F2 | 3C | 9K3-1F | 3B | 9TB2-A8E | 5B |
| 1T1 | 4A | 7F3 | 3C | 9K3-1R | 3B | 9XF1 | 2B |
| 1TB2-A4H | 4A | 7T12 | 2C | 9K3-2F | 3B | 9XF2 | 2B |
| 3B1 | 3C | 7TB10-15 | 2C | 9K3-2R | 3B | 9XF3 | 2B |
| 3FLA2 | 4D | 7TB10-16 | 2C | 9K3-3F | 4B | 9XF4 | 6D |
| 3FLA3 | 4C | 7TB10-17 | 2C | 9K3-3R | 4B | 9XF5 | 6D |
| 3FLA4 | 4C | 7TB10-18 | 2C | 9K3-4F | 4B | 9XF6 | 6D |
| 3TB3-A4C | 4C | 9CB1 | 7C | 9K3-4R | 4B | 9XF10 | 4B |
| 3TB3-A5C | 4D | 9F1 | 2B | 9K4B-1B | 2C | 9XF11 | 3A |
| 3TB3-A6C | 4C | 9F2 | 2B | 9K4B-1T | 2C | 9A2T1 | 4A |
| 3TB4-1 | 4D | 9F3 | 2B | 9K4C-2B | 3C | 9A2T2 | 3A |
| 3TB4-2 | 4C | 9F4 | 7C | 9K4C-2T | 3C | 9A2TB3-4 | 4A |
| 3TB4-3 | 4C | 9F5 | 6C | 9K4D-3B | 3C | 9A2TB3-4-1 | 4A |
| 6T1 | 2A | 9F6 | 6C | 9K4D-3T | 3C | 9A2TB4-3 | 3A |
| 6T2 | 2A | 9F7 | 7B | 9M1 | 3A | 9A2TB4-4 | 3A |
| 6T3 | 2A | 9F8 | 7B | 9S1A | 3B | 10B1 | 5D |
| 6TB8-A78 | 5B | 9F9 | 6B | 9S1B | 3B | 10S1 | 6D |
| 6TB15-A4A | 2A | 9F10 | 4B | 9S2A | 7D | 10T1 | 5D |
| 6TB15-A5A | 2A | 9F11 | 3A | 9S3A | 6D | 10TB1-2 | 5D |
| 6TB15-A6A | 2A | 9F12 | 5D | 9T3 | 6B | 10TB1-A7A | 4D |
| 6A5DS1 | 5B | 9F13 | 5C | 9T4 | 4B | 10TB1-A8A | 4D |
| 6A5DS9 | 6B | 9F14 | 5C | 9T5 | 4B | 10TB2-2 | 5D |
| 6A5DS19 | 4D | 9FL1 | 7C | 9TB1-A4B | 7D | 10TB2-3 | 5D |
| 6A5DS2 | 5B | 9K1A-1F | 2B | 9TB1-A4G | 5D | 10A2F1 | 4D |
| 6A5DS22 | 1C | 9K1A-1R | 2B | 9TB1-A4D | 7B | 10A2T1 | 4D |
| 6A5R1 | 5B | 9K1B-2F | 2B | 9TB1-A5B | 6D | 10A2TB1-1 | 4D |
| 6A5R9 | 5B | 9K1B-2R | 2B | 9TB1-A5C | 5C | 10A2TB1-2 | 4D |
| 6A5R19 | 4D | 9K1C-3F | 2B | 9TB1-A5D | 7B | 14HR1 | 7A |
| 6A5R22 | 5B | 9K1C-3R | 2B | 9TB1-A5H | 3A | 14HR2 | 6A |
| 6A5R2 | 1C | 9K2-L1F | 7C | 9TB1-A6B | 6D | 14HR3 | 6A |
| 7B2 | 3D | 9K2-L1R | 7C | 9TB1-A6C | 5C | 14HR4 | 5A |



162.147

Figure 2-22.—Power distribution diagram.

GENERAL NOTES

- UNLESS OTHERWISE SPECIFIED:
 A. ALL RESISTANCE VALUES ARE IN OHMS, 1/4W, ±5%.
 B. ALL CAPACITANCE VALUES ARE IN MICROFARADS.
 C. ALL DIODES ARE 1N916.
 D. ALL TRANSISTORS ARE 2N718.
 E. ← FEEDBACK

PART LOCATION INDEX

| REF DES | ZONE |
|---------|------|---------|------|---------|------|---------|------|
| C1 | 6C | CR12 | 2C | R2 | 6C | R32 | 2B |
| C2 | 6C | CR13 | 2B | R3 | 6C | R33 | 2B |
| C3 | 6C | CR14 | 1C | R4 | 6C | R34 | 2B |
| C4 | 5C | CR15 | 1C | R5 | 6C | R35 | 3B |
| C5 | 5C | CR16 | 1C | R6 | 6C | R36 | 3B |
| C6 | 5C | CR17 | 2C | R7 | 6C | R37 | 6C |
| C7 | 4C | CR18 | 2C | R8 | 6C | R38 | 5B |
| C8 | 6A | | | R9 | 5C | R39 | 5B |
| C9 | 4C | DL1 | 2C | R10 | 5C | R40 | 5B |
| C10 | 4C | | | R11 | 5C | R41 | 5B |
| C11 | 3C | J102 | 6C | R12 | 5C | R42 | 5B |
| C12 | 3C | | | R13 | 5C | R43 | 4B |
| C13 | 3C | Q1 | 6C | R14 | 5B | R44 | 4B |
| C14 | 6A | Q2 | 5C | R15 | 4C | R45 | 2C |
| C15 | 2B | Q3 | 5C | R16 | 4C | R46 | 1C |
| C16 | 2B | Q4 | 4C | R17 | 6A | R47 | 6B |
| C17 | 3B | Q5 | 4C | R18 | 4C | R48 | 6B |
| C19 | 5B | Q6 | 3C | R19 | 4C | R49 | 5B |
| CR1 | 5C | Q7 | 2B | R20 | 4C | R50 | 5B |
| CR2 | 5C | Q8 | 2B | R21 | 4C | R51 | 6A |
| CR3 | 4C | Q9 | 3B | R22 | 4C | | |
| CR4 | 3C | Q10 | 6B | R23 | 4C | T1 | 6C |
| CR5 | 3C | Q11 | 5B | R24 | 3C | T2 | 5C |
| CR6 | 3C | Q12 | 5B | R25 | 3C | T3 | 5C |
| CR7 | 3C | Q13 | 4B | R26 | 3C | T4 | 3C |
| CR8 | 3C | Q14 | 2C | R28 | 3C | T5 | 2C |
| CR9 | 2B | Q15 | 1C | R29 | 2B | T6 | 1C |
| CR11 | 4B | R1 | 6C | R31 | 2B | 1AP1 | 1C |

CAUTION

Use ohmmeter on highest usable scale to avoid damage to transistors.

VOLTAGE CHART

| | E | B | C | | E | B | C |
|----------------|-----|-------|------|-----------------|------|------|------|
| Q ₁ | +2V | +1V | +10V | Q ₁₁ | +.5V | +.1V | +20V |
| Q ₂ | +3V | +2.8V | +17V | Q ₁₂ | +.6V | +.8V | +17V |

SPECIFIC NOTES:

- All voltage readings taken with equipment in STANDBY.

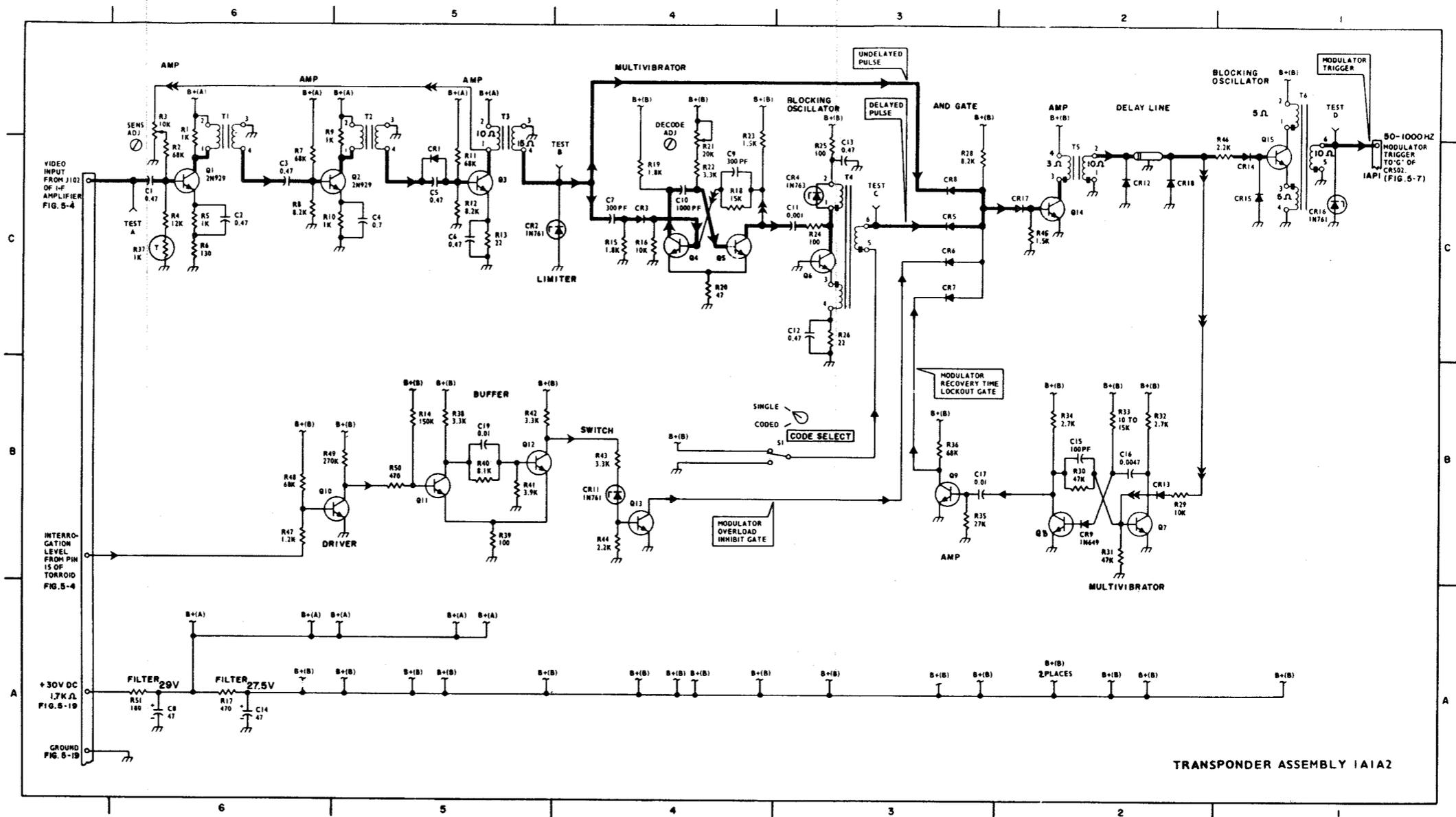


Figure 2-23.—Maintenance Schematic diagram.

CHAPTER 3

MICROELECTRONICS

Microelectronics is the technology of constructing electronic circuits and devices in extremely small packages by various techniques. This technology is also sometimes referred to as microminiaturization.

The increasing complexity of military electronics system over the past 30 years has made the evolution of microelectronics inevitable. During this period, the electron tubes used in the early electronic systems have been replaced by solid state discrete devices and integrated circuitry, and these in turn are giving way to medium-and large-scale integrated circuitry.

INTEGRATED CIRCUITS

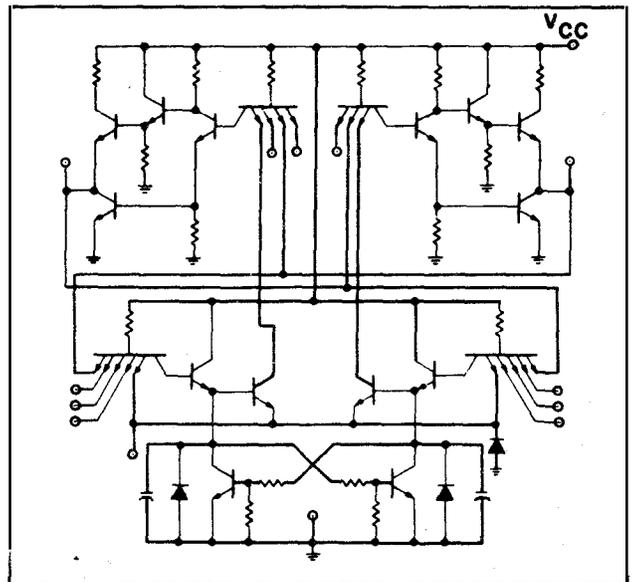
Microelectronics technology today encompasses thin-film, thick-film, hybrid, and integrated circuits. These circuits (and combinations of them) are being applied in digital, analog and other types of electronic circuits.

The current trend of producing a number of circuits on a single chip will further increase the packaging density of electronic circuits while reducing the size, weight, and number of connections in individual systems. Improvements in reliability, logistics, and system capability are also to be expected.

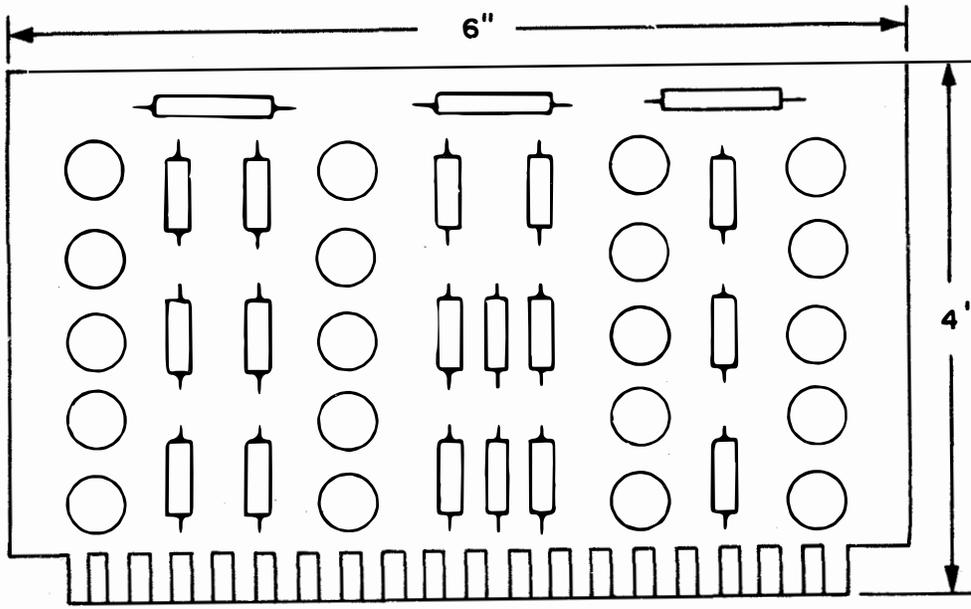
Integrated circuits can be produced that combine all the elements of a complete electronic circuit in a single chip of silicon. The implications of this in the microelectronic evolution are demonstrated by a comparison of a conventional J-K flip-flop circuit incorporating solid state discrete devices and the same type of circuit employing integrated circuitry. The conventional circuit depicted schematically in figure 3-1 would require approximately 40 separate discrete elements, 200 connections, 40 hermetic seals, and 300 separate processing operations—with each operation, seal, and connection representing a possible source of failure. However,

if all the elements of this circuit are integrated in one chip of silicon, the number of connections drops to approximately 14, because all circuit elements are intraconnected inside the package by a process known as vapor metalization; instead of 40 hermetic seals there is 1, and the 300 processing operations are reduced to approximately 30. Figure 3-2 presents a size comparison of a discrete J-K flip-flop circuit and an integrated circuit of the same type.

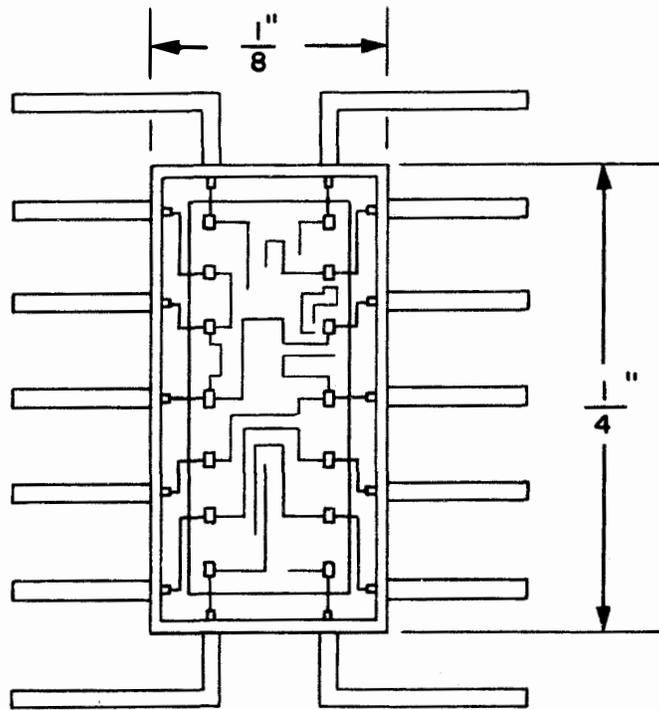
Before the actual fabrication of the integrated circuit begins, the silicon crystal must be sliced into paper-thin wafers (fig. 3-3A). The wafers must be lapped and polished on the side that is to be used for the active elements. Unless special processing is involved, the back side of the wafer is left in the lapped state.



162.82
Figure 3-1.—Schematic of a J-K flip-flop.



(A) DISCRETE CIRCUIT



NOTE:
NOT TO
SCALE

(B) INTEGRATED CIRCUIT

162.83

Figure 3-2.—Size comparison between a discrete and an integrated circuit of a J-K flip-flop.

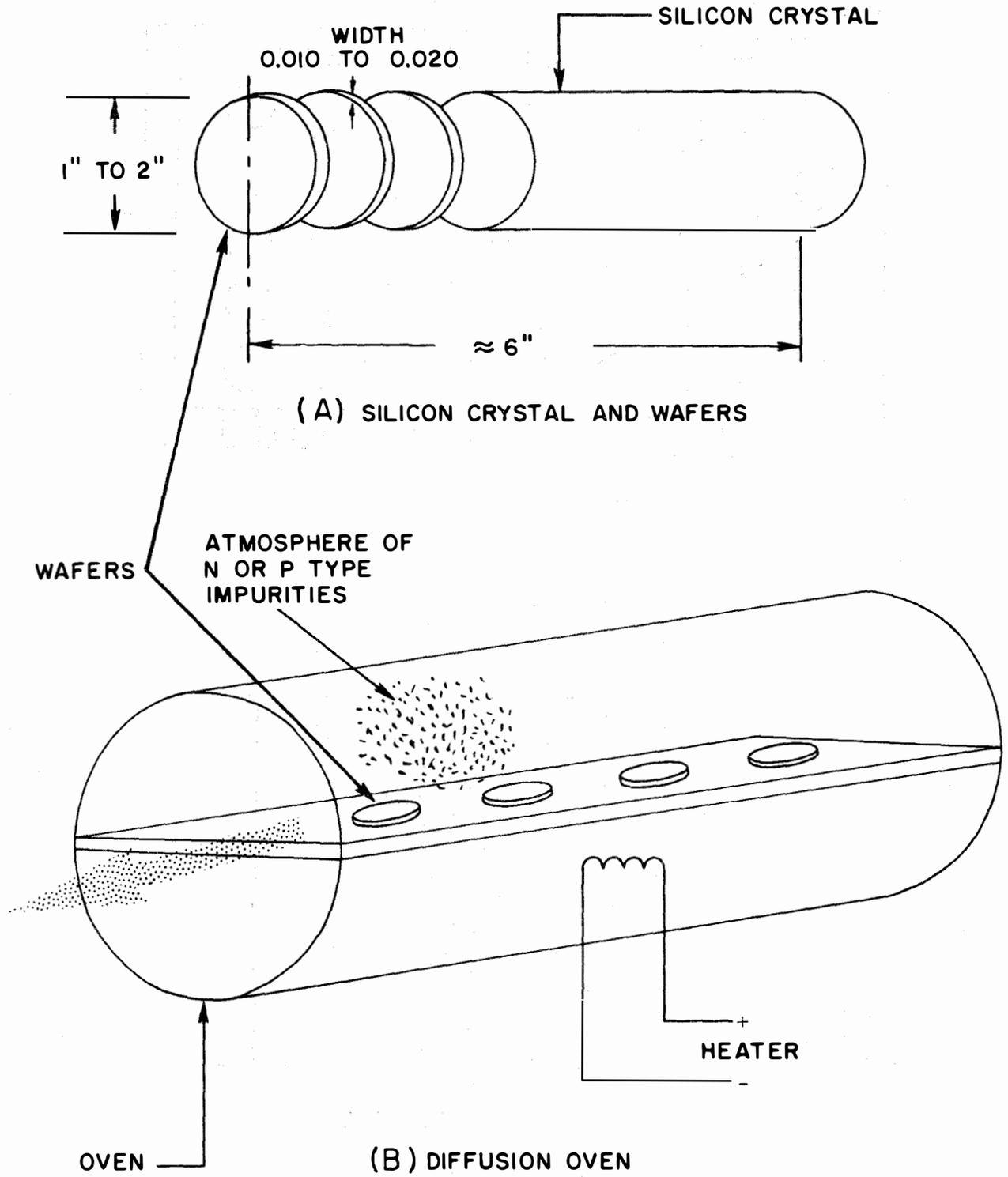
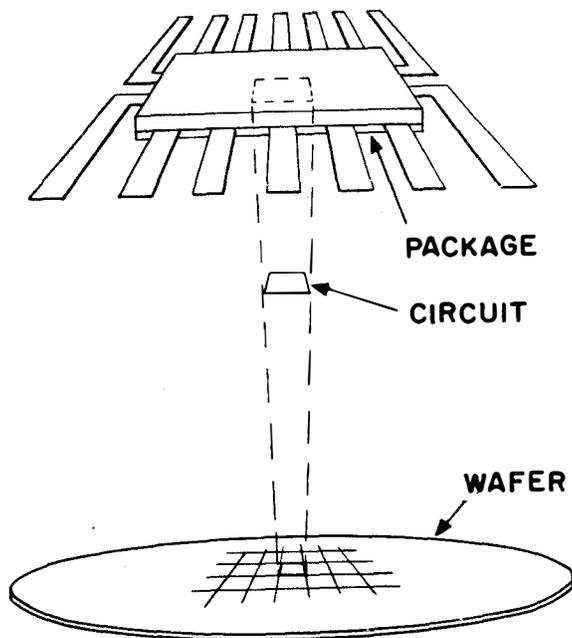


Figure 3-3.—Diffusion method.



162.85

Figure 3-4.—Steps in producing and packaging integrated circuits.

Both sides of the wafer are lapped simultaneously with an abrasive (usually aluminum oxide) until all visible traces of the saw cuts are removed. One side of the wafer is then polished several times with slurries of abrasive grits. A grit of smaller size is used for each succeeding polishing step. Finally, the wafer is chemically etched to remove any irregularities in the surface resulting from the last polishing step.

The diffusion process begins when the highly polished silicon wafer is placed in an oven, fig. 3-3B, containing impurity atoms which yield the desired electrical characteristics. The concentration of impurity atoms diffused into the wafer can be controlled by controlling the temperature of the oven and the time that the silicon wafer is allowed to remain in the oven. When the wafer has been uniformly doped the fabrication of semiconductor devices may begin. Several hundred circuits are produced simultaneously on the wafer by the method shown in figure 3-4.

THIN AND THICK FILM CIRCUITS

Film circuits differ from the integrated circuits described in the preceding paragraph in that instead of being diffused into the substrate, components are layered on the substrate material (usually ceramic) by deposition, screening

and etching, or a combination of these processes.

Only passive devices are produced by this technique since it does not lend itself to the production of active components. Active components are attached and interconnections between components made in much the same way as leads are bonded to integrated circuits (ICs) or transistors.

HYBRID CIRCUITS

A hybrid microcircuit is one that is fabricated by combining two or more circuit types (i.e. film circuits and semi-conductor circuits) or a combination of one or more circuit types and discrete elements (fig. 3-5). The primary advantage of hybrid microcircuits over other microcircuits is design flexibility. Hybrid microcircuits find wide application in specialized applications, such as low-volume and high-frequency circuits.

Several elements and circuits are available for hybrid applications. These include discrete components that are electrically and mechanically compatible with integrated circuits. They may be used to perform functions supplementary to ICs and can be handled, tested, and assembled with essentially the same technology and tools.

Complete circuits are available in the form of uncased chips (unencapsulated IC dice). These chips are usually identical to those sold as part of the manufacturer's regular production line. They must be properly packaged and connected by the user if a high-quality final assembly is to be obtained.

The circuits are usually sealed in a package to protect them from mechanical and environmental stresses. One-mil (.001") gold wire leads are connected to the appropriate pins which extend out of the package to allow external connections.

MICROELECTRONIC DEVICE PACKAGING

Integrated Circuit packages have evolved from the still-used transistor type (modified to include more leads), to the widely used flat pack, to the dual in-line package (DIP). Generally, these packages are limited to 14 leads, but some configurations are available with many more. Packages with up to 160 leads are being developed for large-scale integrated devices.

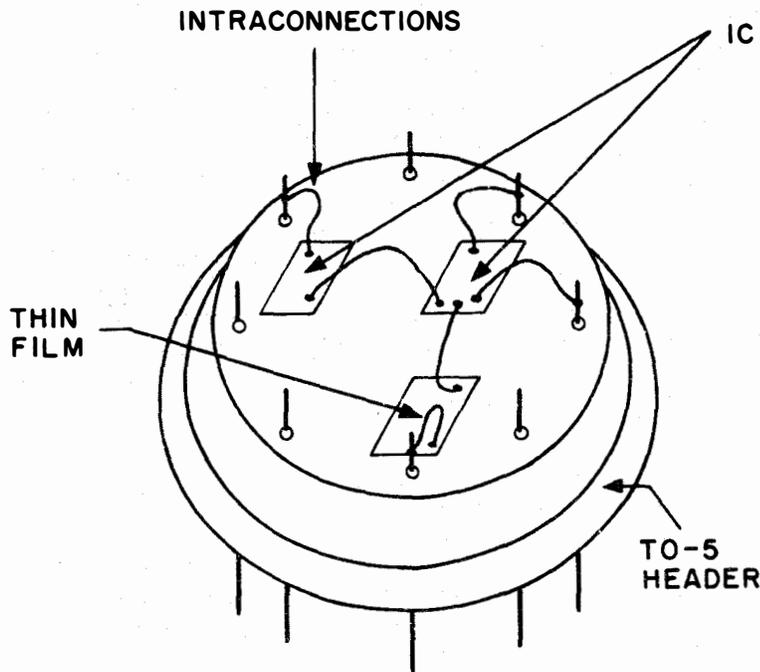
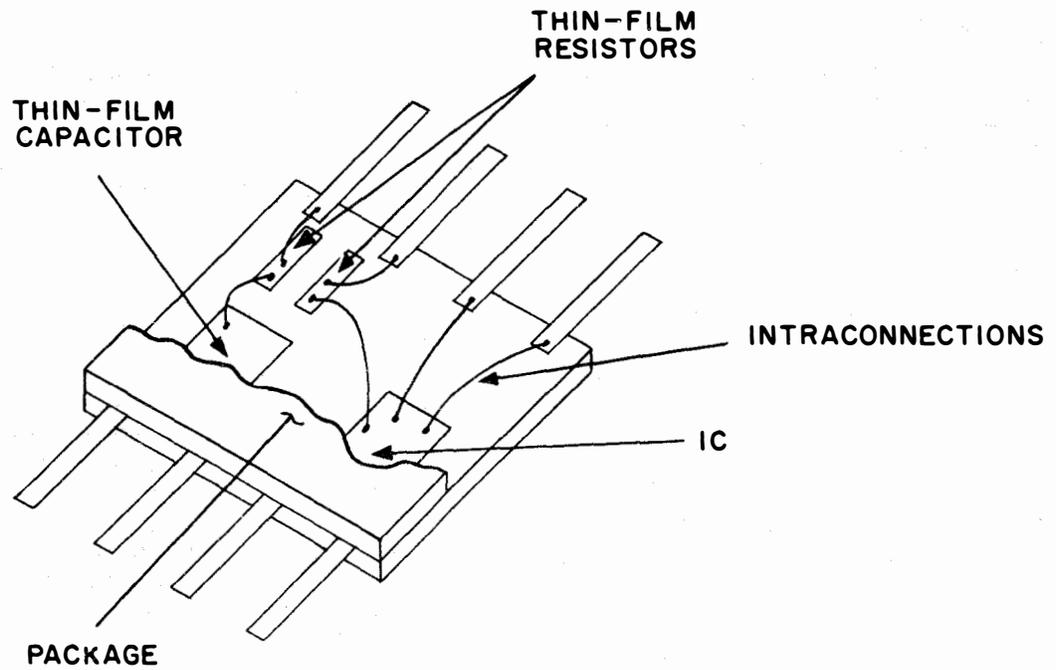


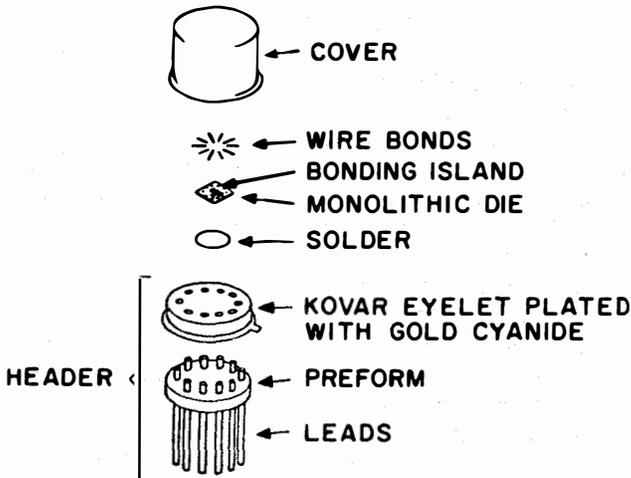
Figure 3-5.—Hybrid circuit configuration.

MODIFIED TO-5 PACKAGE

"Modified TO-5" is a term used to describe a package having the same general appearance as a standard TO-5 transistor package but which has been modified by increasing the number of external leads and the dimensions of the package.

Modified TO-5 assembly methods are extensions of the techniques used in the production of standard transistor packages. Since the modified TO-5 package typically has 10 leads, compared with the 3 or 4 leads of the standard transistor package, its pincircle diameter is slightly larger (0.230 inch vs. 0.200 inch). The modified TO-5 package is shown in figure 3-6. Kovar, a nickel-iron alloy, is used for the leads and eyelet, and 7052 glass for the preform. The cover may be German silver, kovar, or nickel, but kovar is used most frequently because its coefficient of thermal expansion is similar to that of the glass preform, thus allowing a matched seal.

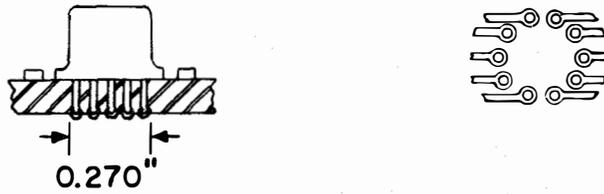
The glass preform and eyelet are assembled as shown in figure 3-6, and then sealed by fusion in a 1000 °C oven. After it is sealed, the entire assembly, called the header, is cleaned and the leads are clipped to the desired length. The header is then plated with 0.001 inch of gold cyanide. The IC die is bonded to the header by (1) inserting a solder preform between the die and the header, (2) placing a weight on top of the assembly, and (3) heating the entire header to approximately 395 °C so that the die, solder, and header are fused together.



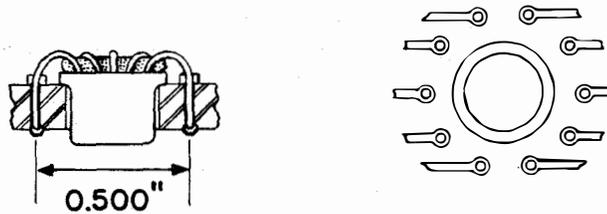
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Figure 3-6.—Exploded view of modified TO-5 package.

PLUG-IN MOUNTING



EMBEDDED CAN
(LEADS PLUGGED IN)



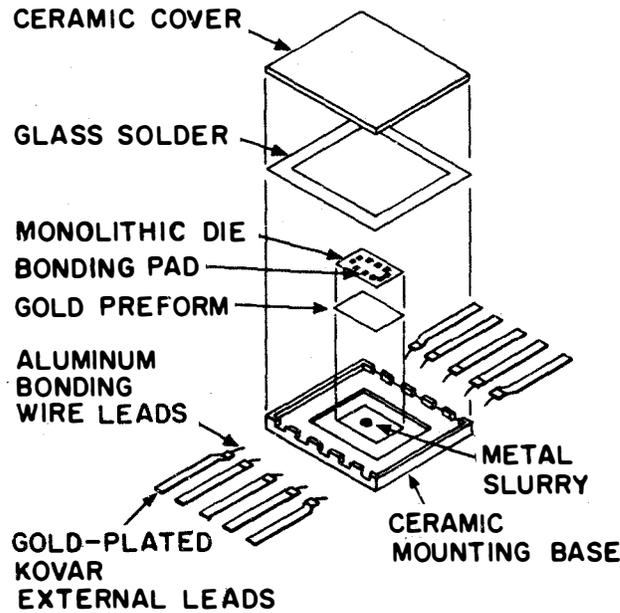
162.88

Figure 3-7.—Mounting for TO-5 packages.

Because the elements of integrated circuits (transistors, diodes, etc.) are so small, it would be impossible to attach wires directly to points in the circuit. For this reason a series of relatively large bonding islands are placed around the edges of the die during its fabrication and these are connected by metalization to appropriate points in the circuit. During packaging, the bonding islands are connected to the package leads by fine lead wires (0.001 inch to 0.003 inch). These wires may be either gold or aluminum and are attached by thermocompression or ultrasonic bonding techniques.

As the final step in TO-5 packaging, the cover is welded to the header in a controlled atmosphere.

The modified TO-5 package can be either plugged into or embedded in a board (fig. 3-7). The latter method is preferred, but whether the package is plugged in or embedded, the interconnection area of the package leads must not be impinged by other printed conductors on either side of the board. The plug-in method does not provide sufficient clearance between the pads to route additional circuitry, but when the packages are embedded there is sufficient space between the pads (because of the increased diameter of the interconnection pattern) for additional conductors.



162.89

Figure 3-8.—Exploded view of ceramic flat pack.

Flat Pack

Many types of integrated circuit flat packages are being produced in various sizes and materials. These packages are available as square, rectangular, oval, and circular configurations with 10 to 60 external leads and may be fabricated of metal, ceramic, epoxy, glass, or combinations thereof. Only the ceramic flat pack (fig. 3-8) will be discussed here, since it is representative of all flat packs with respect to general package requirements.

After the package leads are sealed to the mounting base, a rectangular area on the inside bottom of the base is treated with metal slurry to provide a surface suitable for bonding the monolithic die to the base. The lead frame is then cut away from the secured leads, and these leads and the metalized area in the bottom of the package are gold-plated. The die is then attached by gold-silicon eutectic (easily melted) bonding.

The die bonding step (fig. 3-4) is followed by bonding gold or aluminum wires between the bonding island on the integrated circuit die and the inner portions of the package leads.

Following the wire bonding, a glass-solder preformed frame is placed on top of the mount-

ing base. One surface of the ceramic cover is coated with Pyrocera glass, and the cover is placed on top of the mounting base. The entire assembly is placed in an oven at 450° C. This causes the glass solder and Pyrocera to fuse and seal the cover to the mounting base.

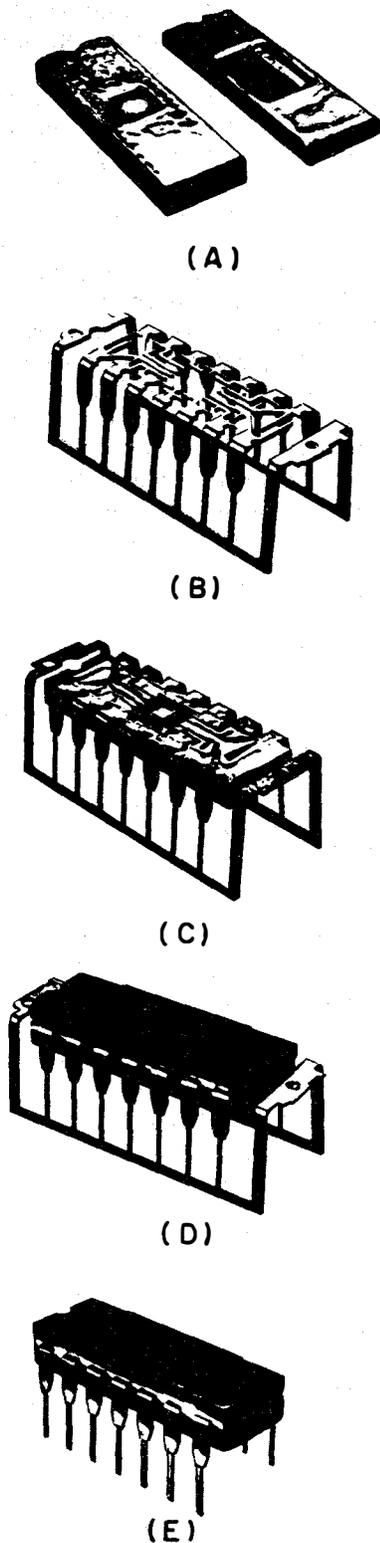
DUAL IN-LINE PACKAGE

The dual in-line package (DIP) was designed primarily to overcome the difficulties associated with handling and inserting packages into mounting boards. Dual in-line packages are easily inserted by hand or machine and require no spreaders, spacers, insulators, or lead-forming. It is also possible to field-service the devices with standard hand tools and soldering irons. Plastic dual in-line packages are finding wide use in commercial applications, and a number of military systems incorporate ceramic in-line packages.

The progressive stages in the assembly of a ceramic dual in-line package are illustrated in figure 3-9. The integrated-circuit die is sandwiched between the two ceramic elements (A). The element on the left is the bottom half of the sandwich and will hold the integrated circuit die.

The ceramic section on the right is the top of the sandwich; the large well protects the integrated circuit die from mechanical stress during sealing operations. Each of the ceramic elements is coated with low-melting-temperature glass for subsequent joining and sealing. The kovar lead frame is shown stamped and bent into its final shape (B). The excess material is intended to preserve pin alignment. The holes at each end are for the keying jig used in the final sealing operation. The lower half of the ceramic package is inserted into the lead frame (C). The die is mounted in the well and leads are attached. The top ceramic element is bonded to the bottom element (D) and the excess material is removed from the package (E).

The ceramic dual in-line packages are processed individually while plastic dual in-line packages are processed in quantities of two or more, in chain fashion. After processing, the packages are sawed apart. The plastic package also uses a kovar lead frame, but the leads are not bent until the package is completed. Because molded plastic is used to encapsulate the integrated circuit die, there may be no void between cover and die as is the case with ceramic packaging.



At present, ceramic dual in-line packages are the most common of the two package types to be found in Navy microelectronics systems.

The trend in microelectronic packaging is toward still higher circuit density. Complex arrays are already available to a limited degree, and research and development are being performed on extremely complex devices that will incorporate the required intraconnections on silicon wafers. This approach, called Large-Scale Integration (LSI), has as its objective the intraconnection of hundreds of undiced circuits packaged in containers comparable in size to a silver dollar.

Considerable effort is being directed toward increasing the upper frequency limit associated with microelectronics. The practicality of microwave integrated circuits has been demonstrated and this type of circuit is currently being fabricated by a number of laboratories.

MAINTENANCE

Microelectronic developments have had a great impact on the test equipment, tools, and facilities that are necessary to maintain systems incorporating these developments.

TEST EQUIPMENT

Early electronic systems could be completely checked-out with general purpose test equipment (GPTE), but the time required to individually test the components in one of today's very complex systems would probably exceed the design life of the system. One improvement in system testing was accomplished by designing systems so that testing could be performed at various functional levels. This allows groups of components to be tested as a whole, thus reducing the time required to test components individually. One other advantage of this method is that complete test plans can be written to provide optimum sequencing of tests and wave shapes of voltage output for each function level.

This method of testing also leads to the development of special support equipment or test sets capable of simulating operating conditions of the system under test. Appropriate voltages or signals are applied by the equipment to the various functional levels of the system and the output of each level is monitored. Testing sequences are prewritten and steps are switched in manually. The limits for each function level are preprogrammed to give a go/no-go indication.

162.90

Figure 3-9.—Dual in-line package assembly.

Another significant breakthrough for improved systems testing was the design of modular subassemblies equipped with input and output terminals that allow quick isolation of faults and easy location of defective parts. These modules are designed for easy removal from the system.

Although functional-level testing and modular design have been successfully applied to most systems in use today, the trend toward increasing the number of subassemblies within a module by incorporating microelectronics will make this method of testing less and less effective.

This has led to the present trend of developing both on-line and off-line automatic test systems. The on-line systems are being designed to continuously monitor performance and to automatically isolate faults to removable assemblies. Off-line systems automatically check out removable assemblies and isolate faults to the component part level.

When no automatic means of accomplishing fault isolation is available, general-purpose test equipment and good troubleshooting procedures may be employed, but such fault diagnosis should be attempted only by experienced technicians. Misuse of electrical probes or soldering irons may permanently damage printed circuit boards (PCBs) or microelectronic devices attached to them. The proximity of leads to one another and the effects of the interconnecting wiring makes the testing of printed circuit boards extremely difficult, and drift or current leakage measurements practically impossible.

Printed circuit boards that have been conformally coated are difficult to probe because the coating is often too thick to penetrate for a good electrical contact and must be removed for electrical probe testing. Test leads with sharp needle points are available; these points easily penetrate the conformal coating to permit testing. Many printed circuit boards, however, are designed with special test points that can be monitored either with special test sets or general purpose test equipment. Another method of obtaining access to a greater number of test points is to use extender cards or cables.

If none of the test aids described above are available, each suspect device or component lead must be probed manually. However, special care must be exercised when probing integrated circuits since the circuits may be easily damaged by excessive voltages or currents and leads may be physically damaged.

Precautions concerning the use of test equipment for troubleshooting equipments containing integrated circuits are similar to those that must be observed when troubleshooting equipments containing semiconductor devices. To prevent possible circuit damage when testing microelectronic circuits with a VTVM or VOM, the meter should have a sensitivity of more than 20,000 ohms per volt on the voltage scales, and should not pass more than 1 milliamperes of current through the circuit being tested.

Static d.c. and resistive tests are usually effective in locating catastrophic failures or defects that exhibit large deviations from normal characteristics, but these methods are time-consuming, and sometimes inadequate when the defect is drift in device characteristics. The suspect device in this case must be desoldered, then retested to verify the fault. If the defect is not verified, the device must be resoldered, to the board again. If it is necessary to repeat this procedure several times, or if the printed circuit board is conformally coated, the defect may never be located. In fact, the circuit may be further damaged by the attempt to locate the fault.

FOR THESE REASONS, THE DEVICE SHOULD NEVER BE DESOLDERED UNTIL ALL POSSIBLE IN-CIRCUIT TESTS ARE PERFORMED AND THE DEFECT VERIFIED.

TOOLS

Because of the smallness and susceptibility to damage of microelectronic devices, the repair of modules incorporating them may be accomplished, in many instances, only with special tools designed expressly for that purpose. The following paragraphs describe some of these special tools which are also included in the recommended tool list (table 3-1). The table is divided into three sections: Part I lists the special tools, and Part II the chemicals that are required to perform maintenance on Navy systems incorporating microelectronic devices. Part III lists tools that generally are available to Electronics Technicians. Figure 3-10 shows some of the tools that are normally kept in the Electronics Technician's toolbox.

The most important tool used in removing and replacing microelectronic packages is the soldering iron. Improper choice of a soldering iron or tip may result in severe damage to microelectronic devices and/or printed circuit boards. Only a low wattage pencil soldering iron and tin diameter solder with rosin core flux and a tin-to-lead ratio of 63/37 should be used.

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Table 3-1.—Recommended tools and materials

| Part I Special Tools | | | |
|--|----------|----------------------|-------------------------------|
| Item | Quantity | FSN or Mfg. Part No. | Manufactured by or Equivalent |
| Ungar Universal Handle | 1 | 777 | Ungar |
| Thread-in Element, 23 1/2 Watts | 1 | 535 | Ungar |
| Thread-in Element, 37 1/2 Watts | 1 | 1235 | Ungar |
| Thread-in Element, 47 1/2 Watts | 1 | 4045 | Ungar |
| Pencil Tip | 1 | PL331 | Ungar |
| Pencil Offset Tip | 1 | PL332 | Ungar |
| Chisel Tip Long Taper | 1 | PL333 | Ungar |
| Tapered Needle Tip | 1 | PL338 | Ungar |
| Stepped Pencil Tip | 1 | 7154 | Ungar |
| Ungar Hot Knife Tip | 1 | 4025 | Ungar |
| Offset Slotted Tip | 1 | 862 | Ungar |
| Straight Slotted Tip | 1 | 857 | Ungar |
| Hollow Cube Tip | 1 | 863 | Ungar |
| Cup Tip, 5/8" Dia. | 1 | 856 | Ungar |
| Cup Tip, 3/4" Dia. | 1 | 855 | Ungar |
| Cup Tip, 1" Dia. | 1 | 854 | Ungar |
| Desoldering Tip (DIP) | 1 | 859 | Ungar |
| Desoldering and Cleaning Tool | 1 | 7800 | Ungar |
| Soldering Iron Holder | 1 | 8000 | Ungar |
| Kleen-Tip Sponge and Tray | 1 | 400 | Ungar |
| Low Voltage Soldering Iron | 1 | 6970 | Ungar |
| Printed Circuit Card Holder | 1 | 371 | Henry Mann Co. |
| Steel Bench Clamp | 1 | 356 | Henry Mann Co. |
| Miniature Vise | 1 | 353 | Henry Mann Co. |
| Illuminated Magnifier, 3 Power | 1 | LFM-1 | Henry Mann Co. |
| Clip-on Lens, 4 Power | 1 | No. 1 | Henry Mann Co. |
| Desoldering and Cleaning Tip, 0.033" | 1 | 7812 | Ungar |
| Hemostat | 1 | 8-907 | Fisher Scientific Co. |
| Hand tool - lead trimmer (TO type package) | 1 | | Henry Mann Co. |
| Desoldering and Cleaning Tip, 0.057" | 1 | 7806 | Ungar |
| Desoldering and Cleaning Tip, 0.069" | 1 | 7813 | Ungar |
| High Intensity Lamp | 1 | 5975 | Tensor |
| Lead Forming Tool | 1 | ATH-3260 | Astro Tool Co. |
| DIP Package Puller | 1 | 6982 | Ungar |
| 45° Chain-Nose-Tip Cutter | 1 | A119 | Henry Mann Co. |
| Tooth Picks, Round | 1 Box | | |
| Wooden Dowels, 1/4" x 6" | 10 | | |
| Triceps Tweezer, 8" | 1 | T8 | Henry Mann Co. |

Chapter 3—MICROELECTRONICS

Table 3-1.—Recommended tools and materials—Continued.

| Item | Quantity | FSN or Mfg. Part No. | Manufactured by or Equivalent |
|---|-------------|----------------------|---|
| Part II Required Chemicals and Materials | | | |
| Insulating Varnish | 1 Pt. | 5970-280-4920 | Fishman Furane Plastics Henry Mann Co. Conap, Inc. |
| Epoxy-Resin Compound | 1 Kit | 8040-777-0631 | |
| Potting Syringes | 12 | E-602 | |
| Epibond | 1 Kit | H-1331 | |
| Acid Brushes | 12 | | |
| Solvent Dispensers | 4 | 613 | |
| Polyurethane Coating | 1 Kit | CE-1155 | |
| Isopropyl Alcohol | 1 Pt. | TT-1-735 | |
| Methyl-Ethyl Ketone | 1 Pt. | TT-M-261 | |
| Acetone | 1 Qt. | 6810-281-1864 | |
| Copper Shim Stock | .003" | | |
| Aluminum Oxide Abrasive Paper | 10 Shts/Box | 5350-967-5080 | |
| Cotton Swabs | | | |
| Teflon Tape - 1" | 1 Roll | | |
| Part III Standard Tools | | | |
| Soldering Aid Tool | 1 | G5120-629-2697 | XCelite/ Henry Mann Co. |
| End Nippers, 4 1/2" | 1 | G5110-221-1503 | |
| Diagonal Pliers, 4" | 1 | G5110-541-4079 | |
| Long-Nose Pliers, 4 1/2" | 1 | G5120-541-4078 | |
| Round-Nose Pliers, 4 1/2" | 1 | G5120-239-8252 | |
| Phillips Screwdriver, 3" | 1 | G5120-240-8716 | |
| Phillips Screwdriver, 4" | 1 | G5120-234-8913 | |
| Phillips Screwdriver, 6" | 1 | G5120-234-8912 | |
| Phillips Screwdriver, 10" | 1 | X1010 | |
| Flat Tip Screwdriver, 2" | 1 | G5120-227-7377 | |
| Flat Tip Screwdriver, 4" | 1 | G5120-278-1283 | XCelite/ Henry Mann Co. |
| Flat Tip Screwdriver, 5" | 1 | G5120-278-1271 | |
| Flat Tip Screwdriver, 10" | 1 | R31610 | |
| Jeweler's Screwdrivers | 1 Set | G5120-288-8739 | |
| Swiss File Set | 1 Set | G5110-288-7685 | |
| Allen Wrenches | 1 Set | G5120-288-8732 | |
| Allen Wrenches | 1 Set | G5120-315-3358 | |
| Spin Tite, 1/4" | 1 | 5120-770-0016 | |

Table 3-1.—Recommended tools and materials—Continued.

| Part III Standard Tools (Continued) | | | |
|--------------------------------------|----------|----------------------|-------------------------------------|
| Item | Quantity | FSN Mfg. Part No. | Manufactured by or Equivalent |
| Spin Tite, 5/16" | 1 | 5120-770-0017 | |
| Spin Tite, 3/8" | 1 | 5120-770-0025 | |
| Spin Tite, 7/16" | 1 | 5120-770-0030 | |
| Tweezers, Curved | 1 | G5120-288-9685 | |
| Tweezers, Straight | 1 | G5120-247-0867 | |
| Tweezers, Lock | 1 | G5120-293-0149 | |
| Drill Bit Set #33 to #80 | 1 | 20-087 | Hunter Tools |
| Hand Drill | 1 | F-223 | Hunter Tools |
| Brass Wire Brush | 1 | | |
| Heat Sinks, Medium | 6 | 51F | Hunter Tools |
| Nylon Brush | | | |
| X-acto Knife (with Blades) | 1 | 5110-595-8400 | |
| Material Loot | 1 Box | | Johnson & Johnson |
| Solder Eutectic, 63/37 Rosin Core | 1 Lb. | | |
| Tool Box | 1 | 7817 | Union Steel Chest Corp. |
| Primary Page | | | |
| Teflon Tape, 1" | 1 Roll | | |
| Forceps, Straight, 5" | 1 | G6515-334-5600 | |
| Forceps, Curved, 5" | 1 | G6515-334-4900 | |
| Forceps, Straight, 9" | 1 | L6515-334-9900 | |
| Forceps, Curved 8" | 1 | L6515-334-4100 | |
| "C" Clamp - 3 inch | 1 | 5-810 | Fisher Scientific Co. |
| Wire Stripper | 1 | 101-S | Henry Mann Co. |

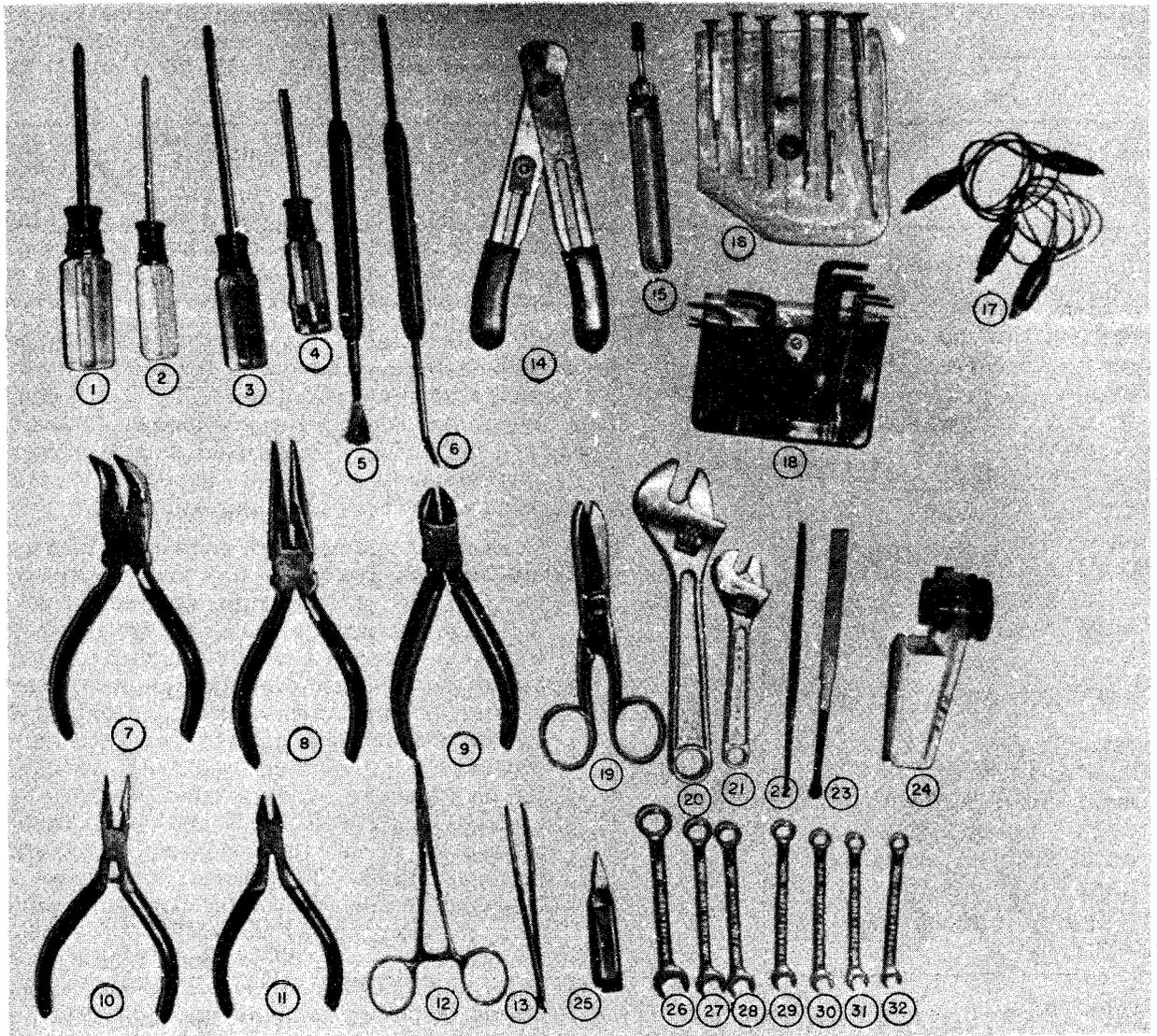
Repair work on modules containing micro-electronic devices usually involves both desoldering and resoldering. For desoldering, a soldering iron with interchangeable tips is recommended (fig. 3-11).

One tip designed specifically for heating and removing solder from leads has a hollow point through which molten solder is drawn. The vacuum for the point may be provided manually (i.e., suction ball) or mechanically (by means of a vacuum pump). The manually operated attachment is recommended because it requires no special equipment.

The wicking (capillary) method is an effective method for removing solder when no special equipment is available. In this method, a piece of copper braid is applied to the melted solder then removed. Due to capillary attraction the copper braid acts as a wick absorbing the melted solder.

The other desoldering tips and heating elements shown in the figure are compatible with various types of microelectronic packages. The best way to remove a microelectronic package from a printed circuit board is to desolder all leads simultaneously, but this can be accomplished only if a tip is available to accommodate the lead configuration of the package. Many tips are required because of the lack of standardization of microelectronic packaging.

Resoldering should be performed with a miniature isolated low voltage soldering system. Preferably, the heat of the tip should be variac-controlled to provide the correct amount of heat to form a good solder joint. The small mass of the tip will assure that only the lead being soldered is effected by the heat from the iron. All soldering irons used in repair of modules

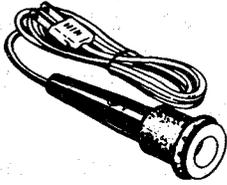


| <u>TOOL</u> | <u>DESCRIPTION</u> | <u>TOOL</u> | <u>DESCRIPTION</u> |
|-------------|--|-------------|---|
| 1. | PHILLIPS SCREWDRIVER, MEDIUM POINT | 14. | INSULATION STRIPPER |
| 2. | PHILLIPS SCREWDRIVER, SMALL POINT | 15. | PRECISION OILER |
| 3. | STRAIGHT SCREWDRIVER, 3/16" x 4" | 16. | JEWELER'S SCREWDRIVERS |
| 4. | STRAIGHT SCREWDRIVER, 1/8" x 2" | 17. | JUMPER LEADS WITH MINIATURE ALLIGATOR CLIPS |
| 5. | SOLDERING AID, WIRE BRUSH AND POINT | 18. | ALLEN AND BRISTOL (SPLINE) WRENCH SET |
| 6. | SOLDERING AID, ANGLED POINT AND SLOTTED TIP | 19. | ELECTRICAL SCISSORS |
| 7. | LONG NOSE PLIERS, ANGLED | 20. | CRESCENT WRENCH, 6" |
| 8. | LONG NOSE PLIERS, WITH WIRE CUTTER | 21. | CRESCENT WRENCH, 4" |
| 9. | DIAGONAL CUTTING PLIERS | 22. | TRIANGULAR FILE |
| 10. | NEEDLE NOSE PLIERS WITH WIRE CUTTER, MINIATURE | 23. | IGNITION FILE |
| 11. | DIAGONAL CUTTING PLIERS, MINIATURE | 24. | 12 X MAGNIFIER |
| 12. | HEMOSTATS | 25. | CLIP-ON HEAT SINK |
| 13. | TWEEZERS | 26-32. | COMBINATION (OPEN-END/BOX-END) WRENCH SET |

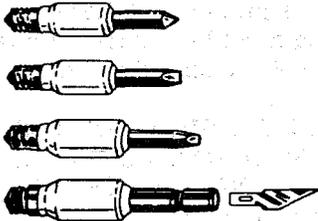
Figure 3-10.—Tools for Microelectronics repair.

162.92.1

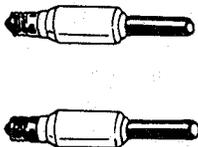
UNGAR UNIVERSAL HANDLE



INTERCHANGEABLE TIPS



HEATING TIPS



THREAD-IN UNITS FOR SUBMINIATURE SOLDERING



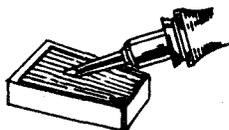
DESOLDERING UNITS



SOLDER SUCKER ATTACHMENT



TIP CLEANER



containing microelectronic devices should be powered by isolated power supplies or be equipped with ground straps to eliminate stray voltages.

Another major item is a fixture for holding printed circuit boards while they are being repaired. This fixture should provide good support to the printed circuit board but should also be easy to rotate since the technician during the performance of maintenance actions must often inspect or apply heat to both sides of the board.

In some cases, the complete desoldering and resoldering operation and final inspection of a repair must be conducted under an illuminated magnifier. Soldering operations should be performed under a magnifier with a power of approximately 3x. Final inspection should be made with a 12x power magnifier.

Special tools are also required for lead forming. Most integrated circuits are shipped in carriers or special lead frames to protect the devices against damage during handling or testing. Before the packages may be attached to a printed circuit board, they must be removed from the carrier, and the leads trimmed and formed. This may be accomplished in any of several ways. One way is to place the integrated circuit and carrier flat on a block of wood and to cut the leads to the desired length with an X-acto knife. Another method is to cut the leads with scissors or diagonal pliers. The physical shock of a lead being cut by a diagonal cutter may be transmitted along the lead causing damage to the interior of the microelectronic device and causing an early failure. With either of these methods, however, stress is placed on the integrated circuit leads that may eventually cause the device to fail.

An Integrated Circuit Cutting and Forming Tool is recommended for use in removing integrated circuits from their carriers. This tool has special cutting and forming dies that allow precise cutting and forming of leads in one operation with a minimum amount of stress on the integrated circuit leads.

After desoldering, most microelectronic devices can be removed from printed circuit boards with tweezers, but dual in-line packages require special extractor tools. The extractor tool listed in table 3-1, part I, is recommended to remove dual in-line packages and to prevent lead damage.

Dual in-line packages are also difficult to insert if leads are bent.

162.93

Figure 3-11.—Recommended tools.

FACILITIES

The shipboard work area in which maintenance and repair of systems incorporating microelectronic devices is accomplished need not include special clean room facilities or an exceptionally large work space.

The main requirement is a clean, sturdy workbench approximately the size of a standard desk and solid enough to accommodate such special support equipment as a printed circuit card holder, magnifier, small vise, etc. A riser shelf should be provided for storage of general test instruments to be used for simple continuity tests. Tool holders should also be provided for larger tools. The more delicate instruments, such as tweezers, should be kept in a special tray or drawer.

Proper lighting is also important because of the extremely small size of integrated circuit packages and the close tolerance requirements for lead alignment. Shadows or glare will cause eye fatigue.

REMOVAL AND REPLACEMENT OF CONFORMAL COATINGS

Many manufacturers of equipments to be used in military applications apply protective conformal coatings to their equipments. These conformal coatings include epoxies, silicones, polyurethanes, varnishes, and lacquers. Most of them consist of a synthetic resin dissolved in a volatile solvent. When properly applied to a clean surface, the solvent evaporates, leaving a continuous layer of solid resins. After curing, the coating protects against environmental stress, corrosion, moisture, and fungus. However, these coatings must be removed from any surface to be properly cleaned before maintenance can be performed on the equipment.

Conformal coatings can be removed either by chemical or mechanical means. However, the application of chemical solvents may cause damage to printed circuit boards by dissolving the adhesive materials that bond the circuits to the boards. The application of solvents may also dissolve the potting compounds used on other parts or assemblies.

Most polyurethane conformal coatings can be removed by applying heat to the area to be cleaned and gently scraping the conformal coating with an X-acto knife. Detailed procedures for removing coatings by this method are presented in the following paragraphs:

Place the printed circuit board to be repaired in the printed circuit card holder as shown in figure 3-12.

Mask the area that is not to be stripped of conformal coating.

EXCESSIVE HEAT MAY DAMAGE THE PRINTED CIRCUIT BOARDS OR SURROUNDING PARTS.

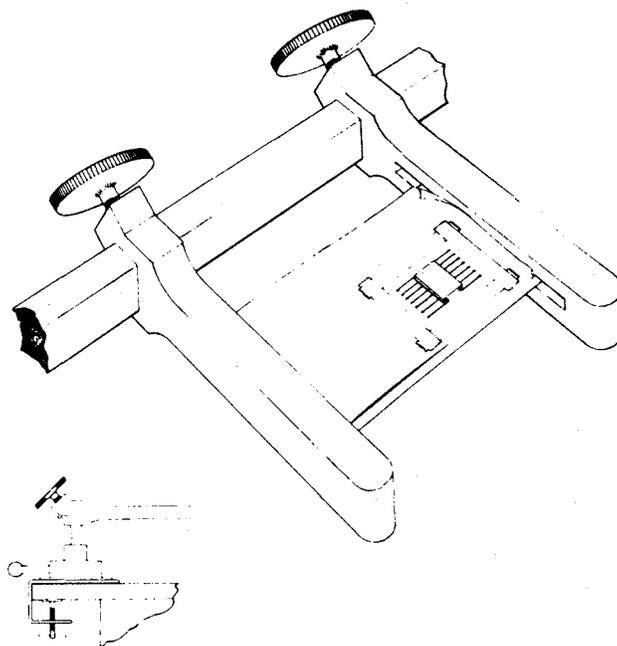
Heat a small area of the coating to be removed by holding a soldering iron close to the surface, but do not touch the board with the iron.

DO NOT APPLY EXCESSIVE PRESSURE DURING SCRAPING AS THIS MAY CAUSE NICKS ON THE LAND OF THE PRINTED CIRCUIT BOARD OR DAMAGE TO THE LEADS OF OTHER PARTS.

When the conformal coating softens, gently scrape it away from the surface with an X-acto knife.

Remove loosened particles of conformal coating by gently brushing. Assure that loose particles of coating do not contaminate any moving parts.

Repeat these steps until all coating has been removed from the area exposed by the mask.



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Figure 3-12.—Printed circuit card holder.

Cleanse the area with a cotton swab that has been dipped in alcohol to remove all loose particles of conformal coating that remain after brushing.

Remove the mask.

Cleanse the area with a cotton swab and alcohol—ensuring that no loose particles of coating remain on the perimeter of the stripped area.

With a 12x viewer (magnifier) visually examine the cleansed area to assure that the area is clean and that no damage was done during the cleaning operation.

To replace the coating after repair proceed as follows.

With a 12x viewer, visually inspect the repaired board for foreign particles.

Clean area to be coated with a cotton swab that has been dipped in alcohol.

Allow the PCB to dry thoroughly. Drying time will depend on the cleaning agent used (alcohol is recommended).

Mask the area that is not to be coated. The unmasked area should be large enough to allow some overlapping with the old coating to assure adequate protection.

Spray the exposed area with three layers of conformal coating material, allowing sufficient time for curing between successive coats. Several thin coats are more effective than one heavy coat. If the coating material has a tendency to porosity, it is unlikely that the pinholes will occur in exactly the same positions on successive coats.

Remove the mask and inspect the reworked area for any voids or pinholes, using a 12x viewer. If any voids or pinholes are observed, add another coat of conformal coating.

Conformal coatings may affect the capacitance (air dielectric capacitors, distributed capacitance between leads) and Q of inductors in RF assemblies. Refer to the appropriate maintenance procedures manual concerning alignment procedures and the use of conformal coatings for RF assemblies.

REPAIR OF PRINTED CIRCUIT BOARDS

Printed circuit assembly wiring patterns are formed in three basic ways, by painting, chemical deposit, and stamped or etched metal foil.

Organizational-level repair of painted and chemically deposited printed wiring patterns is not recommended because specialized equipment is not always available at organizational repair facilities.

The metal foil printed wiring pattern consists of a thin metal foil bonded to a nonconductive base. The wiring pattern is produced by stamping the foil before bonding it to the base, or by chemically etching away unwanted portions of the metal foil after bonding to the base.

Because the metal foil is the most readily repairable and most commonly used type of printed wiring board, the repair techniques described in this Section apply to metal foil printed circuits only.

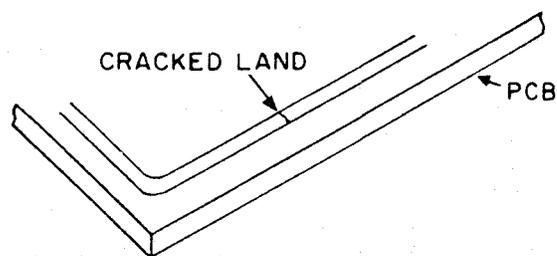
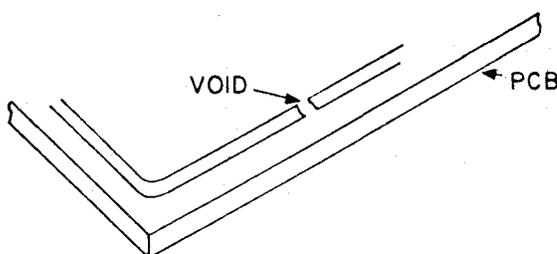
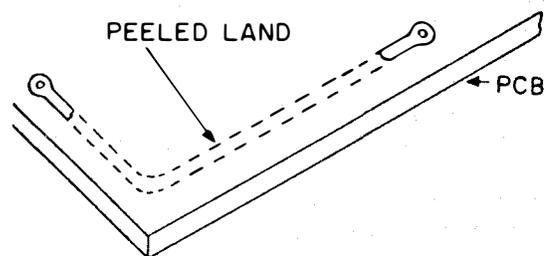
The major cause of printed circuit board failures attributable to maintenance actions is mishandling during the fault isolation and replacement of parts. It is important, therefore, that care be exercised in performing maintenance.

After isolation of a fault to a printed circuit board, the board should be visually examined to determine the possible cause of the fault. If the cause is not really apparent, the lands on the board should be checked for continuity with an ohmmeter and needle probes. Place the probes at each end of the land. If the land is open, move one probe along the board until continuity is observed on the meter. Then locate the break in the land with the 12x viewer.

The three major types of circuit failures are caused by cracks, voids, or peeling of the lands. During the visual examination, it may be observed that the copper laminate used for the contact fingers has separated or peeled away from the board as shown in figure 3-13. A cracked land on a printed circuit board may indicate that the board itself is cracked. The board should be inspected under magnification. This type of damage can be repaired by following the procedures described in the following paragraphs.

The following tools and materials are required:

- Miniature low voltage soldering iron
- General-purpose adhesive such as Hysol
- Epoxy or Epibond H-1331
- Alcohol, Isopropyl
- Acetone
- Cotton swabs
- Teflon Tape
- "C" clamp
- Flat file (Swiss File)
- Copper shim material
- X-acto knife
- Aluminum oxide sandpaper
- Ohmmeter
- Teflon-coated hook-up wire, AWG 22
- 3x viewer
- Potting syringe

CRACKED LANDVOID IN THE LANDPEELED LAND

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Figure 3-13.—Examples of broken conductor lands.

Repair Of Cracked Lands

If the land has been covered with a conformal coating, remove it in accordance with the procedure described earlier.

Flow solder the cracked sections together as shown in figure 3-14.

Clean all residue from the boards with a cotton swab that has been dipped in alcohol.

With a 3x viewer, visually inspect the area for solder flux and solder splashes and remove any residue.

Replace conformal coating as described earlier.

Check continuity.

ENSURE THAT SOLDER DOES NOT FLOW OVER THE EDGES OF THE LAND AS THIS WILL REDUCE THE SPACING BETWEEN LANDS AND AFFECT THE ELECTRICAL PERFORMANCE CHARACTERISTICS OF THE BOARD.

Repair of Small Voids

Remove the conformal coating as stated previously. With an X-acto knife, trim each end of the broken land at a 45-degree angle (fig. 3-15A). Ensure that the remaining end of each land is firmly attached to the board.

Strip the insulation from a small piece of AWG 22 hook-up wire and solder as shown in figure 3-15B.

Clean the soldered areas with cotton swabs that have been dipped in alcohol.

With a 3x viewer, visually inspect the area for solder flux and solder splashes and remove any residue.

Check continuity.

Replace conformal coating as described previously.

EXCESSIVE HEAT MAY CAUSE THE ENDS OF THE CONDUCTOR TO LIFT FROM THE BOARD.

Repair of Peeled Conductors

Remove the conformal coating as described previously. With an X-acto knife, trim each end of the land at a 45-degree angle. Ensure that the remaining end of each land is firmly attached to the board.

Obtain a length of AWG 22 hook-up wire with Teflon insulation that will span the void in the conductor. Strip both ends and tin.

Position the wire as shown in figure 3-16 and solder ends to terminals.

Pot the wire to the board with general-purpose adhesive to prevent breakage during handling of the board.

With a 3x viewer, visually inspect the area for solder flux and solder splashes and remove any residue.

Check continuity.

Replace conformal coating as described previously.

Repair of Loose Connector Tabs

Place the edge of an X-acto knife between the board and the loose tab, lifting the tab as shown in figure 3-17.

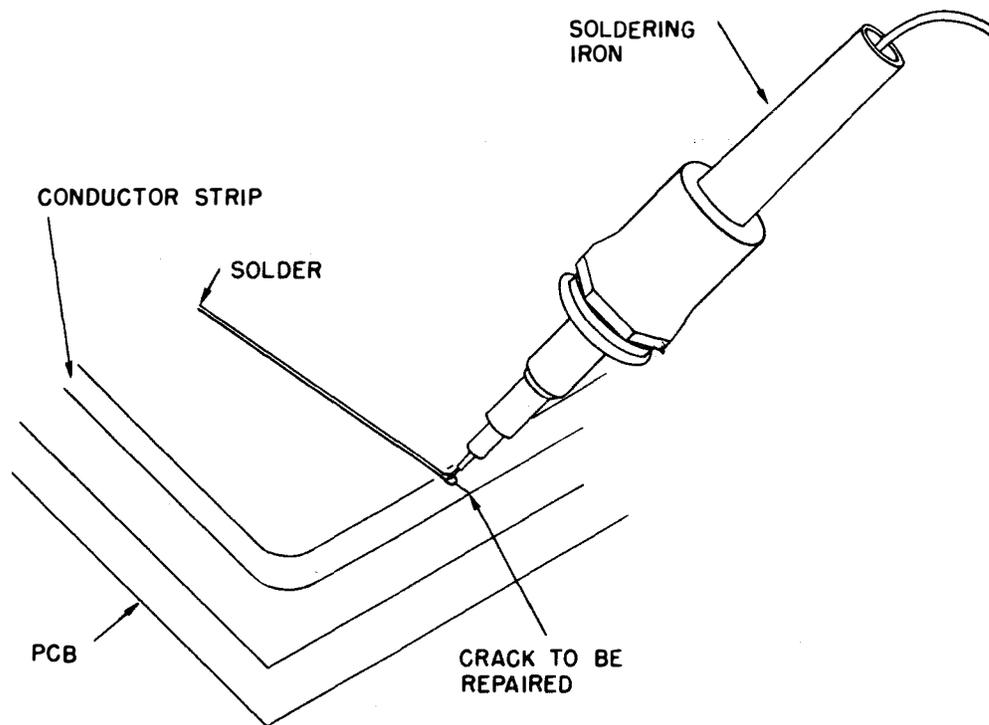


Figure 3-14.—Repair of cracked lands.

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Place a piece of Teflon on the top part of the tab and clean the underside of the tab with aluminum oxide sandpaper until it is a bright color.

Remove all old adhesive from the board by gently scraping with an X-acto knife.

Gently wipe the underside of the tab and board with cotton swabs that have been dipped in acetone.

Using potting syringe, apply adhesive to tab and board surfaces.

DO NOT ALLOW THE TAB TO CURL OR FORM RIGHT ANGLE BENDS AS THIS WILL DAMAGE THE TAB. ACETONE IS FLAMMABLE.

Place Teflon on top of the tab and clamp both to the board with "C" clamp.

Allow adhesive to cure in accordance with the manufacturer's specifications.

Remove "C" clamp and Teflon.

Gently scrape the board with an X-acto knife to remove excess adhesive.

Clean tab by wiping with a cotton swab that has been dipped in acetone.

Assure that the repaired contact fits into the connector.

Check continuity.

Repair of Broken Connector Tabs

With an X-acto knife, cut off the rough edge of the broken tab by making a 45-degree angle cut as shown in figure 3-18.

Ensure that the undamaged section of the tab is still bonded to the board.

Clean the board by scraping off any residue and wiping with a cotton swab that has been dipped in acetone.

Cut a replacement contact from a piece of copper foil stock 0.002 inch thick of the same dimensions as the tab to be replaced, allowing 1/4 inch for a lapjoint at the point of contact with the existing copper land.

Clean the replacement contact by holding it with tweezers and dipping it in acetone. Place the cleaned contact on a clean piece of paper.

Use the potting syringe to prepare adhesive in accordance with the manufacturer's directions and apply it to the board. Align the replacement

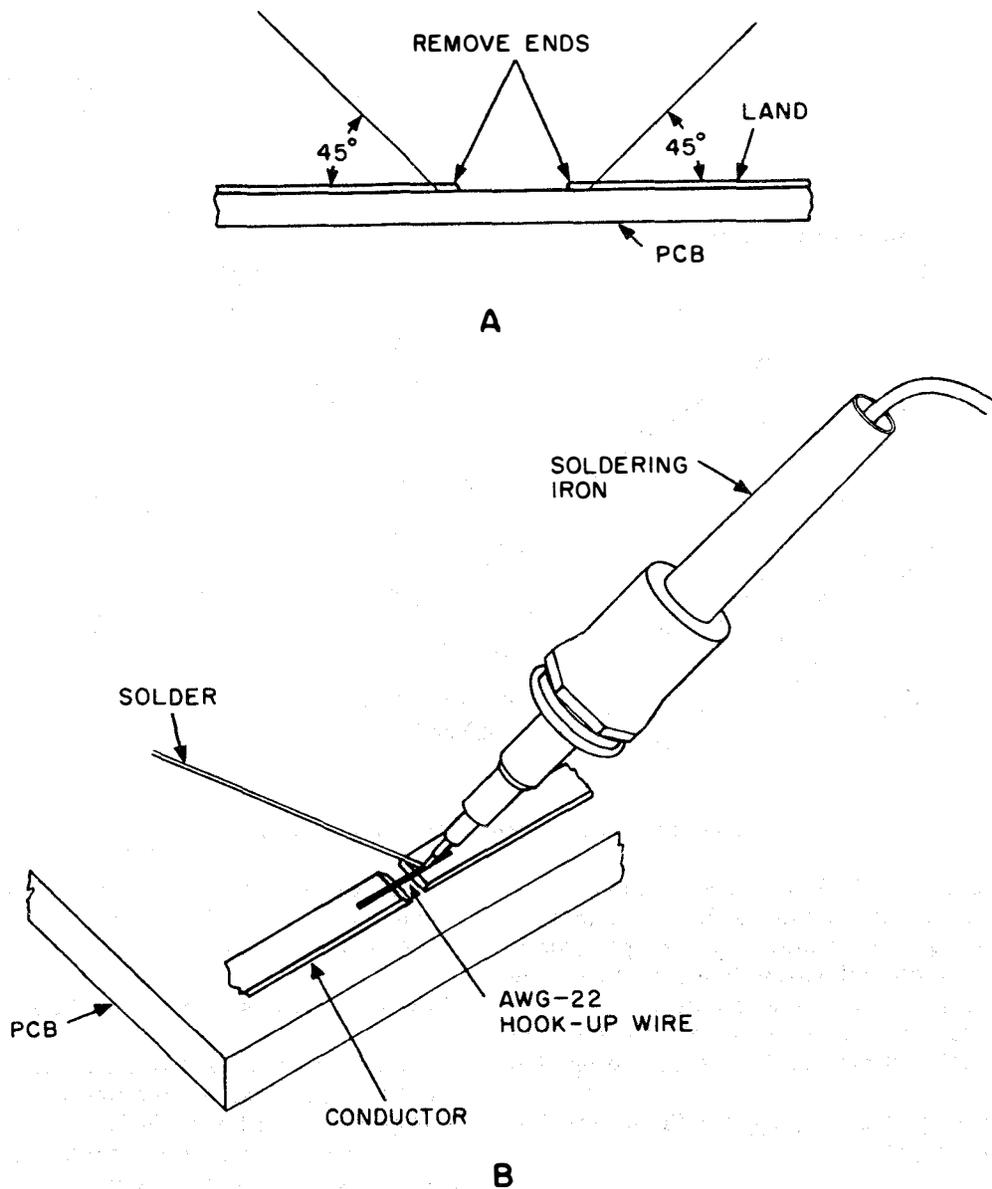


Figure 3-15.—Repair of land with void.

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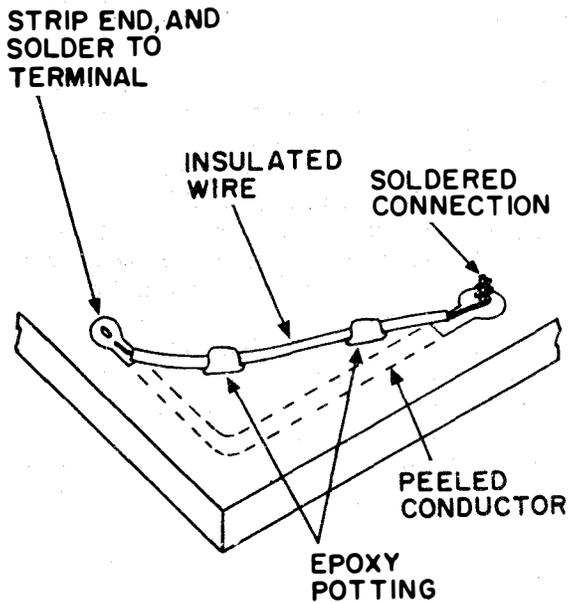
contact with tweezers, and press flat. Using an X-acto knife, scrape off excess adhesive, leaving a thin film on the board. Place a piece of Teflon over the replaced tab and clamp with a "C" clamp as shown in figure 3-19A. Do not move Teflon or rotate clamp while tightening, as the movement may result in improper orientation of the tab.

Allow adhesive to cure in accordance with the manufacturer's specification. To decrease

curing time, place a lamp (60 to 100 watts) approximately 5 inches from the board.

Remove "C" clamp and Teflon. Solder at the point of overlap between the new and original circuitry, using a miniature low voltage soldering iron.

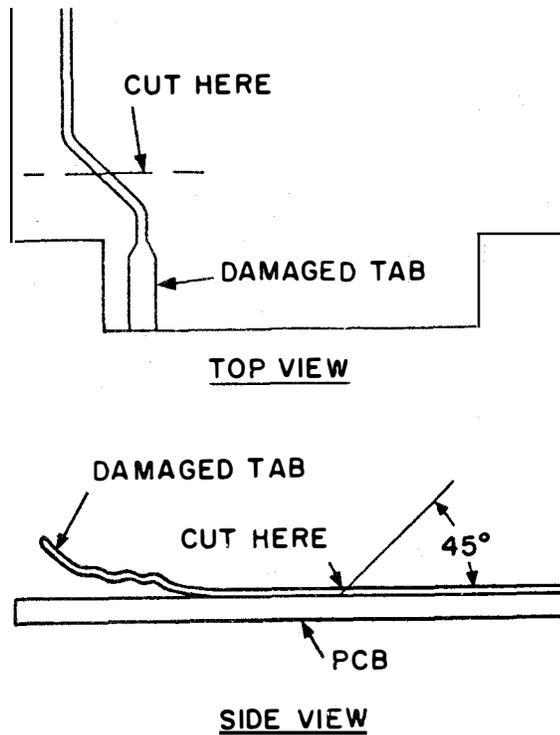
With a small, flat file, bevel the edge of the tab at a 45-degree angle to conform to the bevel of the board (fig. 3-19B). Gently scrap the board with an X-acto knife to remove excess adhesive.



162.98

Figure 3-16.—Repair of lifted land.

Clean contact and soldered joint by wiping with a cotton swab that has been dipped in alcohol. Assure that the repaired contact mates evenly with the proper connector. Check continuity.



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Figure 3-18.—Damaged Connector tab.

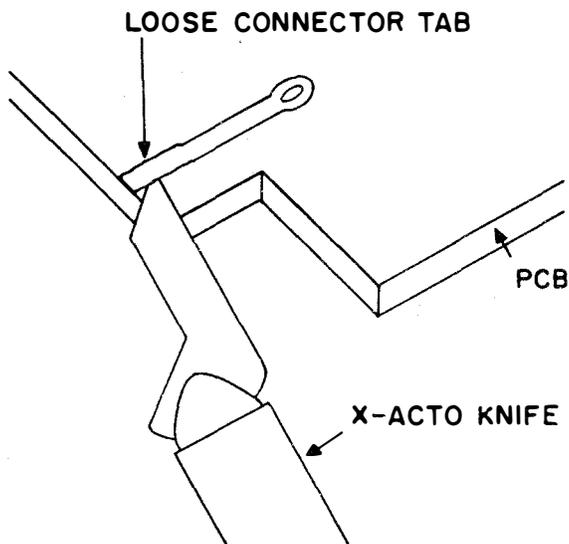
REMOVAL AND REPLACEMENT OF FLAT PACKS

Because of their small size, extreme care must be exercised in soldering and unsoldering flat-pack leads. Careless work may cause damage to the mounting surfaces, circuits, or both.

Orientation of the flat pack with respect to the mounting surface is also of major importance. All flat packs have index points, usually located in one corner or on the package centerline. Before removing any flat pack, the board to which it is attached should be marked or a sketch made of the location of the index point so that the replacement device may be properly oriented (fig. 3-20).

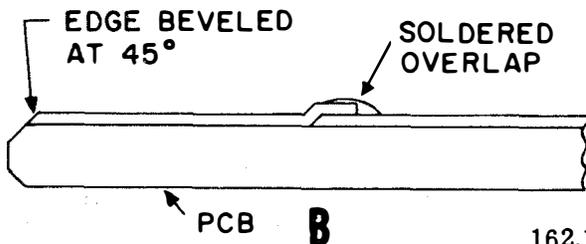
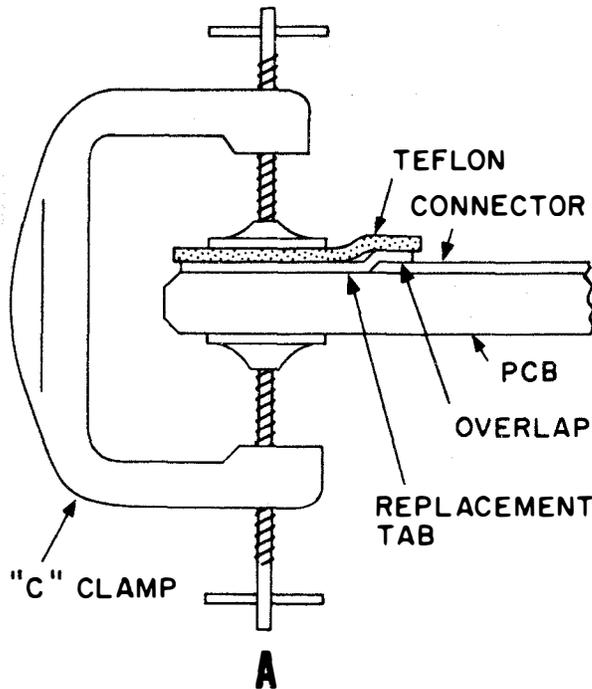
The following tools and materials are required:

- 45-degree chain nose tip cutter
- Desoldering and cleaning tool (solder sucker)
- Low voltage soldering iron
- X-acto knife
- Printed circuit card holder
- Teflon tape
- Epoxy resin compound



162.99

Figure 3-17.—Peeled Connector tab.



162.101

Figure 3-19.—Connector tab replacement.

- 3x and 4x viewers
- Alcohol, Isopropyl
- Cotton swabs
- Tricep tweezers
- Lead cutting and forming tool (or wooden form)
- Potting syringe

Soldered-In Flat Packs

Upon completion of subsystem checkout and the localization of the defective flat pack, the following removal and replacement procedures are recommended.

Insert the printed circuit board in a printed circuit card holder with the flat pack face up as shown in figure 3-12.

SOLVENTS AND ABRASIVES MAY DAMAGE THE BOARD OR SURROUNDING PARTS AND ARE NOT RECOMMENDED FOR FIELD MAINTENANCE. THEY SHOULD BE USED ONLY UNDER CONTROLLED CONDITIONS.

If the flat pack has been covered with a conformal coating, remove the coating as described for printed circuit boards.

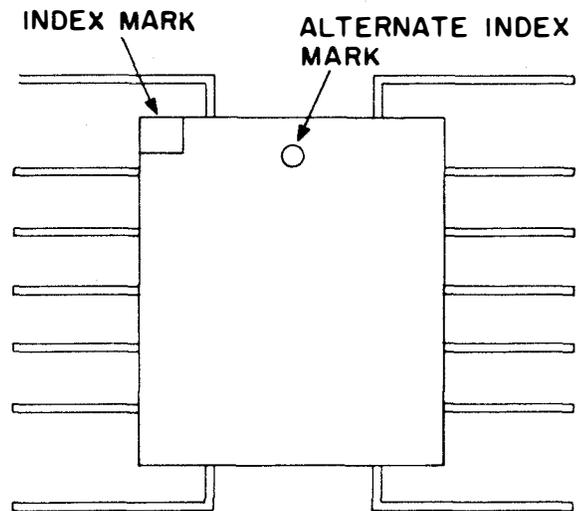
Mark board to show the location of the index mark on the flat pack (fig. 3-21).

With a pair of sharp chain-nose-tip cutters, cut the flat pack leads halfway between the soldered joints and the body of the flat pack as shown in the figure.

If thermally conductive adhesive has been used between the flat pack and the board, hold the device with tricep tweezers and place the heated blade of an X-acto knife between the flat pack and the printed circuit board on one side of the flat pack and gently move the knife back and forth in a cutting motion. Repeat this process on all four sides until the flat pack has been loosened.

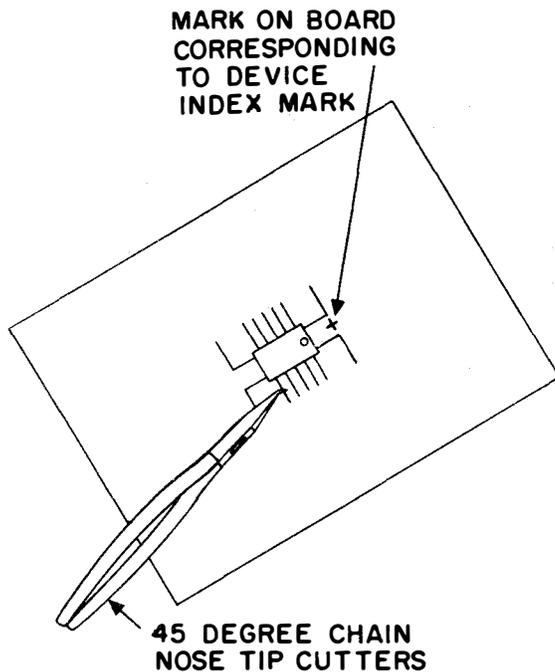
DO NOT TAP BOARD TO REMOVE EXCESSIVE SOLDER AS THIS MAY CAUSE BRIDGING OF LANDS ON OTHER PARTS OF THE BOARD.

Unsolder the remaining leads, one at a time, using a desoldering iron and solder sucker attachment to remove excess solder.



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Figure 3-20.—Flat pack index markings.



162.103

Figure 3-21.—Cutting flat pack leads.

After removing the flat pack, remove mask and visually examine the printed circuit board with a 12x viewer. Remove all residue (conformal coating, solder flux and solder splashes) and clean the board with a cotton swab that has been dipped in alcohol.

ASSURE THAT CLEANING SOLVENT IS DRY BEFORE APPLYING A HOT SOLDERING IRON—ALCOHOL IS FLAMMABLE.

Examine the replacement device for damage. Review applicable circuit specifications and test circuit in accordance with the applicable technical manual.

Remove the flat-pack from the handling container. If a suitable lead cutting and forming tool is not available, place the flat pack on a wooden form and cut the leads to the proper length, one at a time, with a sharp X-acto knife (fig. 3-22).

ASSURE THAT THE REPLACEMENT FLAT PACK CIRCUIT IS PROPERLY ORIENTED WITH RESPECT TO THE INDEX MARK PREVIOUSLY SCRIBED ON THE PRINTED CIRCUIT BOARD.

Using the potting syringe, apply epoxy resin compound to the underside of the flat pack and place the package in position, using tricep tweezers.

Allow the adhesive to cure in accordance with the manufacturer's requirements.

USE A MINIATURE LOW VOLTAGE SOLDERING IRON. EXCESSIVE HEAT WILL DAMAGE THE FLAT PACK AND/OR THE PRINTED CIRCUIT BOARD.

Flow solder the flat pack leads to the board, one at a time. Use a miniature low voltage soldering iron (fig. 3-23).

With a 12x viewer, visually examine the area surrounding the replaced device for bad solder joints, bridging of solder between the leads, flux residue, or excessive adhesive.

Clean all residue from the leads and PCB with a cotton swab that has been dipped in alcohol.

If the system is available, place the printed circuit board in it for final test and checkout. If the system is not available, the proper inputs should be duplicated in accordance with specified test procedures and the output monitored using bench test equipment and procedures in the appropriate equipment test and checkout manual.

Replace conformal coating as described previously.

Welded-In Flat Packs

Welded-In flat packs are removed and replaced by following the same procedures as for the soldered-in flat packs. Those portions of the leads remaining on the printed circuit board after removal of the package are clipped as closely as possible to the welded joint to facilitate soldering of the lapped joint of the replacement leads.

REMOVAL AND REPLACEMENT OF DUAL IN-LINE PACKAGES

Because of their smallness, extreme care must be exercised in soldering and unsoldering dual in-line package leads. Careless work may damage the mounting surface and/or the circuits.

Orientation of the dual in-line package with respect to the mounting surface is also of major importance. All dual in-line packages have index points, usually located in one corner or on the package centerline. Before moving any dual in-line packages, the board to which it is attached

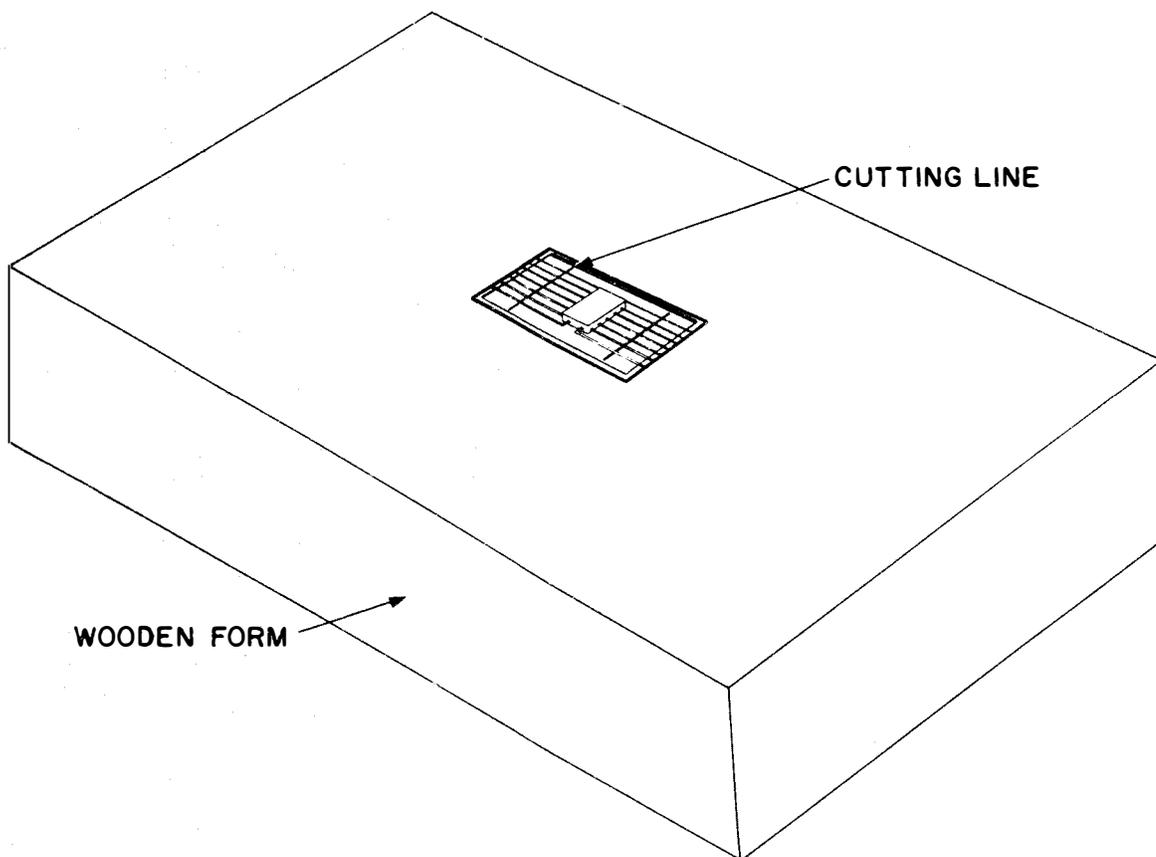


Figure 3-22.—Flat pack lead trimming.

162.104

should be marked or a sketch made of the location of the index point so that the replacement device may be properly oriented (fig. 3-24).

The following tools and materials are required:

- 45-degree chain-nose tip cutter
- Desoldering and cleaning tool (solder sucker)
- Low voltage soldering iron
- Solder sucker attachment
- X-acto knife
- Printed circuit card holder
- Teflon tape
- Epoxy resin compound
- 3x and 4x viewers
- Alcohol, isopropyl
- Cotton swabs
- Tweezers, straight
- Insulating varnish
- Dual in-line package puller
- Toothpicks

Dual in-line packages With Conformal Coating

Insert the printed circuit board in a printed circuit card holder as shown in figure 3-12.

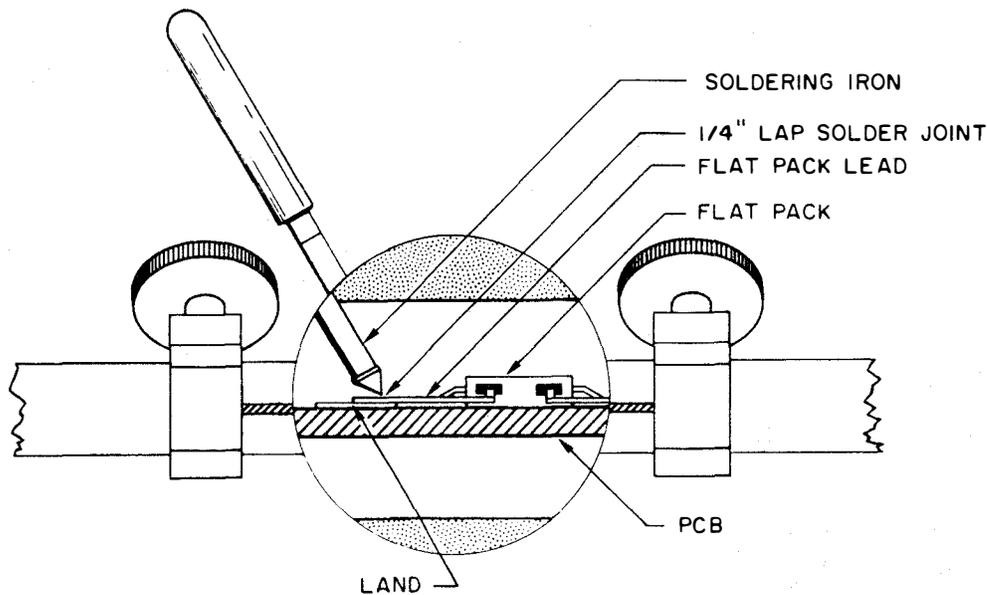
Construct a Teflon tape mask over the circuit board, exposing the dual in-line package to be removed. Remove the conformal coating.

Mark board or make sketch indicating location of the index mark on the dual in-line package.

With a pair of 45-degree chain nose tip cutters, cut the package leads, one at a time (fig. 3-25).

Lift the portion of the leads attached to the package, one at a time, with tweezers; bending the leads upward.

DO NOT APPLY A PRYING OR LIFTING MOTION WITH X-ACTO KNIFE AS THIS MAY DAMAGE THE PRINTED CIRCUIT BOARDS.



162.105

Figure 3-23.—Lap soldering of flat pack leads.

Using a heated X-acto knife blade, loosen the conformal coating beneath the package and gently lift the package.

Remove the remaining conformal coating from the board.

Remove solder from each lead remaining in the board, using soldering iron and solder sucker and heater. Simultaneously remove leads with tweezers.

Clean holes in the printed circuit board with a toothpick.

Remove all residue (conformal coating, solder flux, and solder splashes) and clean board with a cotton swab that has been dipped in alcohol.

Examine the replacement device for damage. Review the applicable circuit specification and test circuit in accordance with the applicable technical manual.

Upon completion of the visual and electrical tests, align the circuit pins.

ASSURE THAT THE CIRCUIT IS PROPERLY ORIENTED. IMPROPER POSITIONING OF THE PACKAGE MAY RESULT IN DESTRUCTION OF THE CIRCUIT.

Insert dual in-line package in the board and solder leads individually. Use a low-voltage soldering iron.

Use a 12x viewer to visually inspect the area surrounding the replaced device for bad solder joints, bridging of solder between leads, and flux residue.

Clean all leads and surrounding areas with a cotton swab that has been dipped in alcohol.

Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and the outputs monitored using bench test equipment and procedures in the appropriate equipment test and checkout manual.

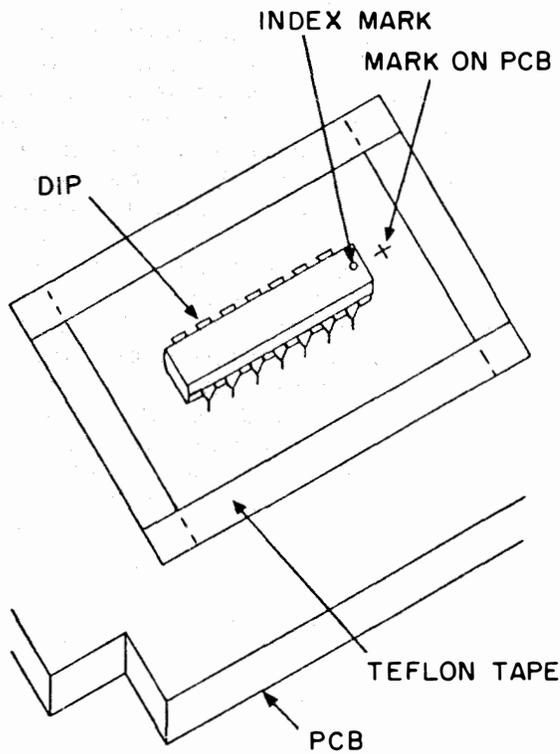
Dual in-line packages Without Conformal Coating

Mark printed circuit board, showing location of the index mark on the dual in line package.

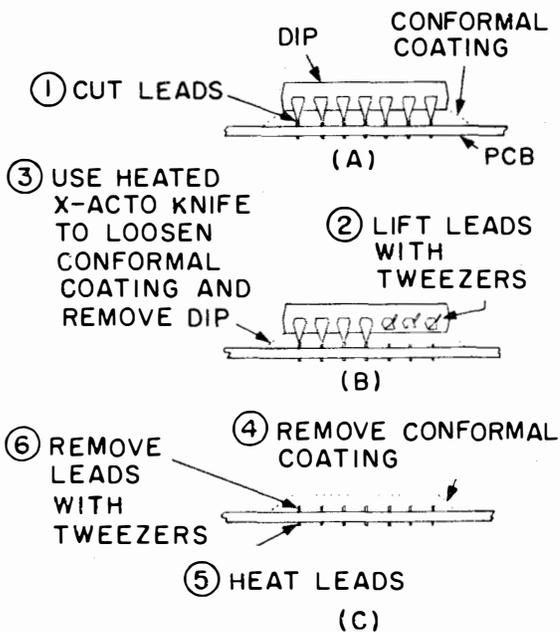
Heat solder at each lead, individually, and remove the molten solder from top of board with a solder sucker or wicking tool.

DO NOT APPLY TWISTING OR PRYING FORCES AS THIS MAY DAMAGE THE PRINTED CIRCUIT BOARD OR BREAK DUAL IN-LINE PACKAGE PINS WITHIN THE BOARD

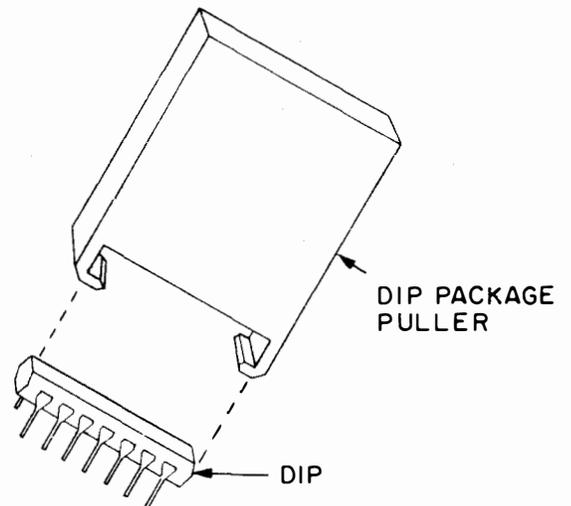
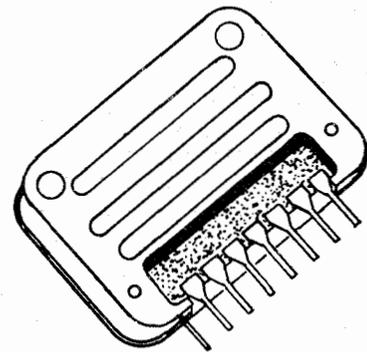
Grasp the dual in-line package with the dual-in-line puller illustrated in figure 3-26. Heat all



162.106
Figure 3-24.—Dual in-line package masking and alignment



162.107
Figure 3-25.—Dual in-line package lead cutting and package removal.



162.108
Figure 3-26.—Dual in-line package puller.

leads simultaneously, using the dual in-line package desoldering tip. Gently pull the dual in-line package away from and perpendicular to the board. The dual in-line package should be easily freed from the printed circuit board.

Clean holes in the printed circuit board with a toothpick.

Remove all residue (solder flux, and solder splashes) and clean board with a cotton swab that has been dipped in alcohol.

Examine the replacement device for damage. Review the applicable circuit specification and test circuit in accordance with the applicable technical manual.

Upon completion of the visual and electrical tests, align the circuit pins. ASSURE THAT THE CIRCUIT IS PROPERLY ORIENTED. IMPROPER POSITIONING OF THE PACKAGE MAY RESULT IN DESTRUCTION OF THE CIRCUIT.

Insert the dual in-line package in the board and solder leads individually, using low-voltage soldering iron.

With a 12x viewer, visually inspect the area surrounding the replaced device for bad solder joints, bridging of solder between leads, and flux residue.

Clean all leads and surrounding area with a cotton swab that has been dipped in alcohol.

Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and the outputs monitored using bench test equipment and procedures in the appropriate equipment test and checkout manual.

REMOVAL AND REPLACEMENT OF TO PACKAGES

TO packages containing integrated circuits are available with 8 to 12 leads. The leads are usually arranged in a symmetrical pattern and mounted directly to lands on the printed circuit board. Two of the most common mounting techniques, embedded and plug-in, are shown in figure 3-27.

The procedures currently used to remove and replace transistor TO packages also apply to modified TO packages containing integrated circuits. The major difference between the two packages is that the number of leads on modified TOs is greater and the space between leads is less than on standard TOs, thus limiting the space available for lead clipping, desoldering, and soldering. The smaller packages also require greater manual dexterity on the part of repair personnel. Other constraints such as spacing of lands on the printed circuit board, removal of conformal coatings, etc., present additional problems to the maintenance man.

Protective conformal coatings contribute to the difficulty in unsoldering leads, removing devices from the mounting surface, and preparing the mounting surface for device replacement. After the protective coating has been removed, device leads must be disconnected and the device removed, but the procedure to be followed in removing the TO will depend on the mounting configuration. If the package to be removed is embedded or plugged in without a spacer (fig. 3-27), the leads should be clipped and the package removed before those segments of the leads remaining in the board are unsoldered. If this is not possible—as would be the case with packages that are flush mounted or plugged-in with a spacer—all leads should be heated simultaneously to allow package removal.

Procedures for removing embedded, plug-in, and flush-mounted packages are presented in the following paragraphs.

Replacement TO circuits should be electrically tested in accordance with the applicable detailed specifications and sub-system operating requirements.

The following tools and materials are required:

- Teflon tape
- Desoldering and cleaning tool (solder sucker)
- Low voltage soldering iron
- 45-degree chain nose tip cutter
- Long-nose pliers
- Printed circuit card holder
- Toothpick
- Hemostat
- Alcohol, isopropyl
- Cup tip
- Cotton swabs
- 3x and 4x viewers

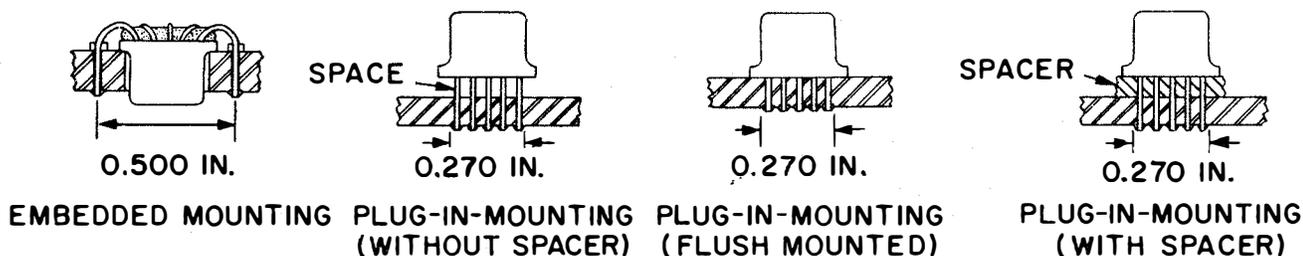


Figure 3-27.—Embedded and plug-in mountings.

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Embedded TOs and TOs Without Spacers

Place the printed circuit board in the printed circuit card holder. If the printed circuit board has been covered with a conformal coating, mask all portions of the board except for the TO that is to be removed.

EXCESSIVE HEAT MAY DAMAGE THE TO PACKAGE AND/OR PRINTED CIRCUIT BOARD. SOLVENTS OR ABRASIVES SHOULD NOT BE USED. THEY MAY DAMAGE THE PRINTED CIRCUIT BOARD OR SURROUNDING PARTS.

Remove coating from the terminal areas and area where the package is inserted into the board. This can best be accomplished by holding a soldering iron close to the printed circuit board and gently scraping the conformal coating with an X-acto knife.

Clip leads near the TO package with a 45-degree chain nose tip cutter.

Apply pressure to top of TO package with a wooden dowel to remove TO from the board (fig. 3-28).

Heat terminals with a desoldering iron and remove molten solder with a solder sucker attachment.

DO NOT FORCIBLY PULL OR APPLY TWISTING MOTION TO LEADS. THIS MAY DAMAGE TERMINALS.

Remove those segments of leads remaining in the board by applying the desoldering iron to the printed circuit board land and gently pulling downward on the lead with long-nose pliers.

WAIT UNTIL ALCOHOL IS DRY BEFORE USING SOLDERING IRON—ALCOHOL IS FLAMMABLE.

Clean all terminal areas with a cotton swab that has been dipped in alcohol.

With a 12x viewer, inspect terminals for loose solder, solder flux residue, and damage to terminals.

Visually examine replacement device for damage, review applicable circuit specifications, and test replacement circuit in accordance with

- ① CLIP LEADS
- ② PUSH OUT TO-5 WITH DOWEL
- ③ UNSOLDER LEADS
- ④ PULL OUT LEAD ENDS WITH LONG-NOSE PLIERS

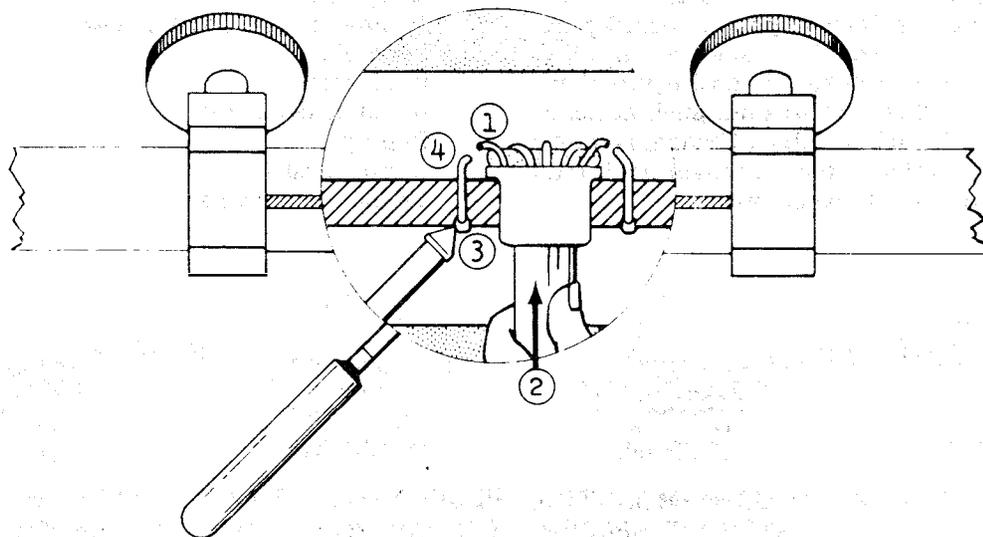


Figure 3-28.—Removal of embedded TO package.

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requirements of the appropriate operational specification.

Align leads and insert new TO package into printed circuit board.

Solder leads individually with a miniature low-voltage soldering iron, using a heat sink or long-nose pliers as a heat sink.

Inspect repaired area with a 12x viewer and remove any solder splashes or foreign materials with a cotton swab that has been dipped in alcohol.

If required by the applicable equipment maintenance manual, apply conformal coating.

Place the repaired printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and the outputs monitored using bench test equipment and following procedures in the appropriate equipment test and checkout manual.

Flush-Mounted TOs And Plugged-In TOs With Spacers

Place the printed circuit board in printed card circuit holder. If the printed circuit board is covered with a conformal coating, mask all portions of the board except for the TO that is to be removed.

Heat each lead individually and remove molten solder from the printed circuit board with the solder sucker attachment.

DO NOT APPLY TWISTING MOTION TO PACKAGE. THIS MAY DAMAGE PRINTED CIRCUIT BOARD OR TERMINALS.

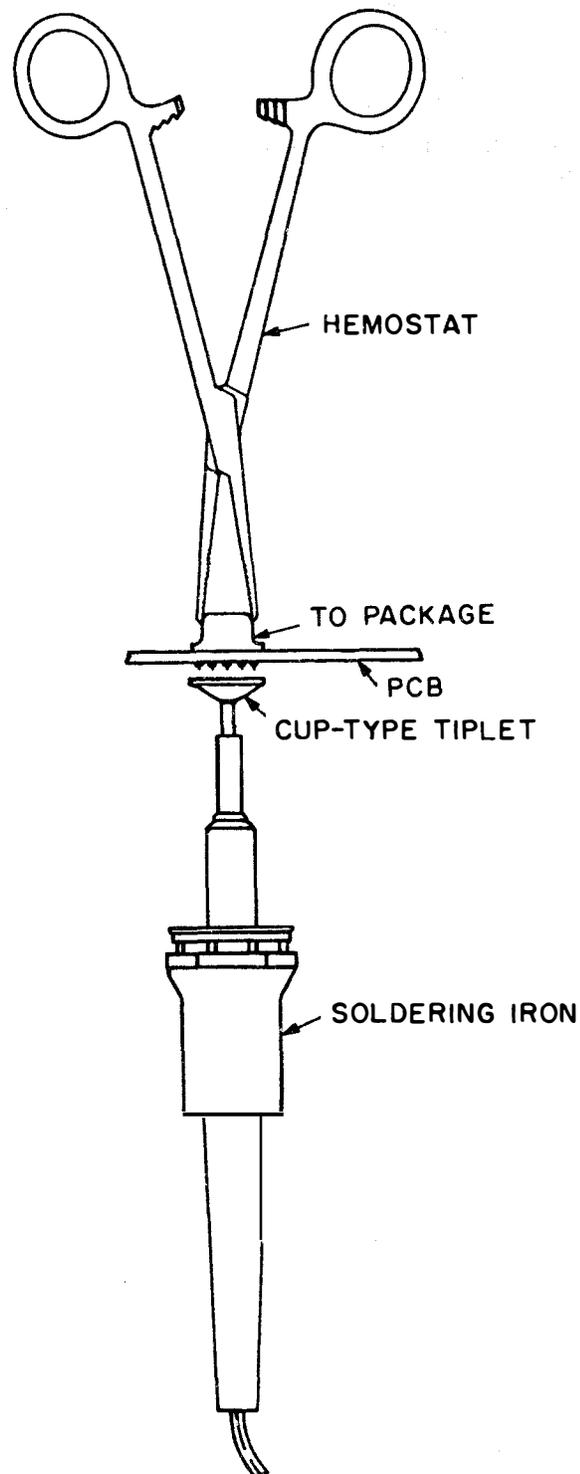
Heat all leads simultaneously with the cup-type tiplet adapter to the desoldering iron shown in figure 3-29. With hemostats, gently grasp the package and remove from the printed circuit board.

WAIT UNTIL ALCOHOL IS DRY BEFORE USING SOLDERING IRON—ALCOHOL IS FLAMMABLE.

Clean all terminal areas with a cotton swab that has been dipped in alcohol.

With a 12x viewer, inspect terminals for loose solder, solder flux residue, and damage to terminals.

Visually examine replacement device for damage. Review applicable circuit specifications and test circuit in accordance with requirements of the appropriate operational specification.



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Figure 3-29.—Removal of flush-mounted TO package.

Align leads and insert new TO package in printed circuit board.

Solder leads, one at a time, with a miniature low voltage soldering iron.

Inspect repaired area with a 12x viewer and remove any solder splashes or foreign materials with a cotton swab that has been dipped in alcohol.

If required by the applicable equipment maintenance manual, apply conformal coating.

Place the printed circuit board in the system, if the system is available, for final test and checkout. If the system is not available, the proper inputs should be duplicated and the outputs monitored using bench test equipment and following procedures in the appropriate equipment test and checkout manual.

CHAPTER 4

USE OF TEST EQUIPMENT

As discussed in chapter 2 of this manual, all maintenance of Navy electronics equipment is divided into two main categories—preventive maintenance and corrective maintenance. As illustrated in figure 4-1, testing is the major function performed by the ET in carrying out maintenance.

Testing or test procedures may sometimes be referred to as tests, measurements, or checks. These terms are sometimes used interchangeably and overlap in meaning depending upon their use and the results obtained. For example, a power output MEASUREMENT and a frequency CHECK may constitute a TEST for the proper operation of a transmitter.

Basic testing procedures and some of the general purpose test equipment used by the ET are discussed in volumes 1 and 2 of Basic Electronics, NAVPERS 10087-C. This chapter builds upon this information by presenting some of the safety precautions to be observed when using test equipment, and discussing additional test equipments and procedures.

TEST EQUIPMENT SAFETY PRECAUTIONS

The electrical measuring instruments included in portable test equipment are delicately constructed and require certain precautions when they are handled to avoid damaging them. In addition, there are precautions that must be observed while using portable test equipment to avoid injury to personnel.

Three precautions that apply to all electrical measuring instruments to avoid damage are as follows:

1. Avoid mechanical shock. Instruments contain permanent magnets, meters, etc., which are sensitive to shock. Heavy vibrations or shock can cause loss of calibration to the instruments.

2. Avoid exposure to strong magnetic fields. Strong magnetic fields may permanently impair the accuracy of an instrument by leaving residual magnetic effects in the magnet, iron parts, or in the magnetic materials used to shield the instruments. Locations subjected to strong magnetic fields include regions near the pole pieces of large motors and generators, degaussing coils, electrical propulsion cables, submarine main storage battery leads, and radar magnetrons.

3. Avoid excessive current flow. This includes various precautions, depending on the type of instrument. When in doubt, use the maximum scale range of the instrument. Connections should be made while the circuit is deenergized if possible and then all connections checked to ensure that the instrument will not be overloaded before energizing.

Precautions to be observed to avoid instrument damage include the following:

1. Keep in mind that the coils of wattmeters, frequency meters, and power meters may be carrying excessive current even when the meter pointer is on scale.

2. Secondaries of current transformers should never be short-circuited when the primary is energized.

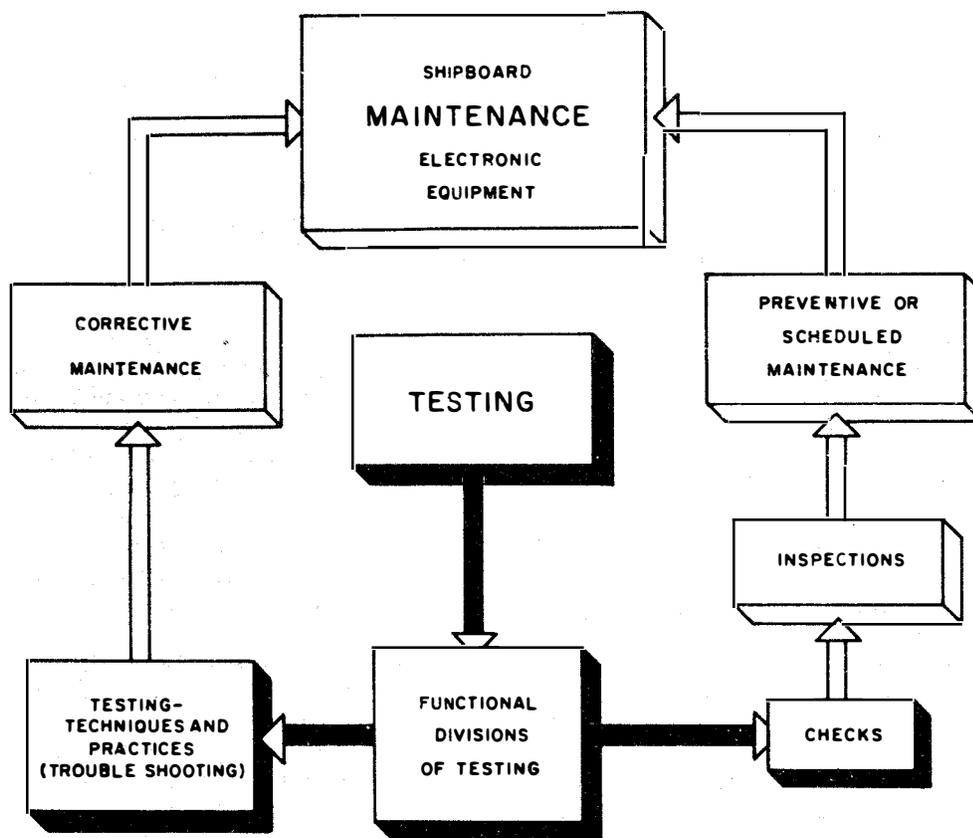
3. Secondaries of potential transformers should never be short-circuited when the primary is energized.

4. Ensure that meters in motor circuits can handle the motor starting current which may be as high as 6 or 8 times normal running current.

5. Never leave an instrument connected with its pointer off-scale or deflected in the wrong direction.

6. Never attempt to measure the internal resistance of a meter movement with an ohmmeter, as the movement may be damaged by the current required to operate the ohmmeter.

7. Never advance the intensity control of an oscilloscope to a position which causes an excessively bright spot on the screen or permits a



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Figure 4-1.—Electronic maintenance functional diagram.

sharply focused spot to remain stationary for any length of time.

8. When checking electron tubes with a tube tester always perform the inter-element short test first. If the tube is shorted, no further tests should be made.

9. Before measuring resistance, always discharge capacitors in the circuit to be tested. Note and record any points not having bleeder resistors or discharge paths for capacitors.

10. Always disconnect voltmeters from field circuits or other highly inductive circuits before the circuit is opened.

Situations can arise during the use of portable test equipments that are extremely dangerous to personnel. For example, you may have an oscilloscope plugged into one receptacle, and electronic voltmeter plugged into another, and a soldering iron in still another, using an extension cord, or many other combinations. Some of the hazards presented by situations such as these are coming into contact with live terminals

or test leads, or accidentally throwing the equipments to the deck due to a sudden roll or pitch of the ship, which may possibly entangle personnel in the leads or cords and cause severe or fatal shocks. In addition, the situation may be such that a potential difference exists between the metal cases of two or more instruments sufficient to cause harmful shocks.

Wires attached to portable test equipment should extend from the back of the instruments away from the observer if possible. If this is not possible, they should be clamped to the bench or table near the instruments.

When used in places where vibration is present, the instruments should be placed on pads of folded cloth, felt, or similar material. Additional precautions are necessary when using portable test equipment during heavy seas.

Precautions to be observed to avoid injury to personnel include the following:

1. Ensure that the metal cases of all instruments are grounded.

2. Ensure that one side of the secondary of external instrument transformers is also grounded.

3. If equipment must be energized for testing after removal from its normal rack or mounting, ensure that all parts normally at ground potential are securely grounded.

4. Avoid testing voltages in excess of 300 volts when holding test probes in the bare hands.

BASIC MEASUREMENTS

Basic electrical and electronic measurements involve the fundamental electrical quantities (voltage and current) and the inherent circuit characteristics (resistance, capacitance, and inductance).

VOLTAGE AND CURRENT

Voltage measurements, when compared with voltage charts, provided for a specific piece of equipment, are a valuable aid in locating trouble quickly and easily. However, if the sensitivity of the test voltmeter differs from that of the voltmeter used in preparing the chart, the voltage measurements must be evaluated before the true circuit conditions can be determined. It should be kept in mind that in certain cases a voltmeter, particularly one of low sensitivity used on a low range, may disturb some circuits to such a degree as to render them inoperative.

Since many troubles encountered in equipments and systems result from or cause abnormal voltages, voltage measurements are considered indispensable in locating trouble. Testing techniques that utilize voltage measurements have the advantage over other tests of not interrupting circuit operation. Point-to-point voltage measurement charts, which contain the normal operating voltages encountered in the various stages of the equipment, are available to the technician. These voltages are usually measured between the indicated points and ground, unless otherwise stated. When voltage measurements are taken, it is considered good practice to set the voltmeter on the highest range initially, so that any excessive voltages existing in a circuit will not cause overloading of the meter. To obtain increased accuracy, the voltmeter may then be set to the designated range for the proper comparison with the representative value given in the voltage charts. When checking voltages, it is important to remember that a voltage reading can be obtained across a resistance, even if that

resistance is open. The resistance of the meter (and the multipliers) forms a circuit resistance when the meter prods are placed across the open resistance. Thus, the voltage across the part may appear to be approximately normal, as read on the meter, but may be abnormal when the meter is disconnected from the circuit. Therefore, to avoid unnecessary delay in troubleshooting, it is good practice to make a resistance check on a "cold" circuit (before applying power) to determine whether the resistance values are normal.

If the internal resistance of the voltmeter and multiplier is approximately comparable in value to the resistance of the circuit under test, it will indicate a considerably lower voltage than the actual voltage present when the meter is removed from the circuit. The sensitivity (in ohms-per-volt) of the voltmeter used to prepare the voltage charts is always given on those charts, therefore, if a meter of similar sensitivity is available, it should be used, so that the effects of loading will not have to be considered.

The following precautions are general safety measures, pertinent to the measurement of voltages, that you should follow when working with electronic equipment. You should constantly keep in mind that almost all voltages are dangerous and can possibly be fatal if contacted. When it is necessary to measure high voltages, the following precautions should be observed:

1. Connect the ground lead of the voltmeter first. While making measurements, place one hand in a pocket or behind the back.

2. If the voltage to be measured is less than 300 volts, place the end of the test probe on the point to be tested, which may be either positive or negative with respect to ground.

If the voltage to be measured is more than 300 volts, proceed as follows: shut off the circuit power, discharge any filter capacitors, and pulse forming networks several times, and temporarily ground the point to be measured; then connect (clip on) the proper test lead to the high potential point, and move away from the voltmeter. Turn on the circuit power and read the voltmeter. Turn off the circuit power again and discharge any capacitors and pulse forming networks several times before disconnecting the meter.

Current measurements, as a rule, are not often taken in the course of testing, unless the ammeter (or other current-measuring meter)

is an integral part of the equipment being tested. Current measurements are infrequently used because in most cases the circuit must be opened (unsoldered) for the necessary series connection of the ammeter. Usually, a voltage measurement and a calculation by means of Ohm's law are sufficient to determine the circuit current. In a circuit of extremely high resistance, a current measurement is inadvisable because the current may be so low that it cannot be measured accurately with ordinary test equipment.

RESISTANCE

Resistance measurements are valuable in locating trouble. Hence, many maintenance handbooks contain resistance charts which are referenced to accessible points (usually tube sockets) within the equipment. Without these charts, making resistance measurements in a complex circuit is a slow process, sometimes necessitating the unsoldering of one side of a particular resistor or group of resistors in order to prevent erroneous readings as a result of shunting circuits. It is important that the operation of ohmmeters and the calibration of their scales be understood, especially on the high ranges, since often it is impossible to attain reasonable accuracy when the meter is operated at its maximum range. For best results select a range that will indicate a near mid-scale reading on the meter.

For an ohmmeter to be used for troubleshooting, portability, convenience, and speed are considered of greater importance than extreme accuracy. Resistor tolerances vary so widely that approximate resistance readings are adequate for most jobs, with the exception of bridge circuits, voltage dividers, and balanced circuits. Two precautions to be observed when an ohmmeter is used are: (1) the circuit under test (including heaters of tubes) must be completely deenergized; (2) and any meters, tubes, or transistors which may be damaged by the ohmmeter current must be removed before any measurement is made. It is not practicable to measure very low values of resistance with an ohmmeter, because of the effect of lead and contact resistance and the possibility of damage to the electronic parts under test. For precision measurement of low values of resistance, a special type of bridge instrument must be used.

CAPACITANCE

Capacitance measurements are usually accomplished by either a bridge-type or a reactance-type capacitance meter. For accuracy, the former equipment is comparable to the resistance bridge, and the latter instrument is comparable to the ohmmeter. Capacitance tolerances vary even more widely than resistance tolerances, being dependent upon the type of capacitor, the value of the capacitance, and the voltage rating. The results of capacitance tests must be evaluated to determine whether a particular capacitor will fulfill the requirements of the circuit in which it is used. The power factor of a capacitor is important because it is an indication of the various losses attributable to the dielectric, such as current leakage and dielectrical absorption. Current leakage is of considerable importance, especially in electrolytic capacitors. The measurement of capacitance is very simple; however, you must make the important decision of whether to reject or continue to use a certain capacitor after it has been tested.

INDUCTANCE

Inductance measurements are seldom required in the course of troubleshooting. However, in some cases inductance measurements are useful and instruments are available for making this test. Many capacitance test sets can be used to measure inductance. Most manufacturers of capacitance test sets furnish inductance conversion charts if the test equipment scale is not calibrated to read the value of inductance directly.

CAPACITANCE-INDUCTANCE-RESISTANCE BRIDGES

Capacitance, inductance, and resistance are measured for precise accuracy by alternating current bridges which are composed of capacitors, inductors, and resistors in a wide variety of combinations. These bridges operate on the principle of the Wheatstone bridge, in which an unknown resistance is balanced against known resistances. The unknown resistance is calculated in terms of the known resistance after the bridge has been balanced. One type of capacitance bridge circuit is shown in simplified form in figure 4-2. When the bridge is balanced by adjusting the variable resistor R_c , there is no

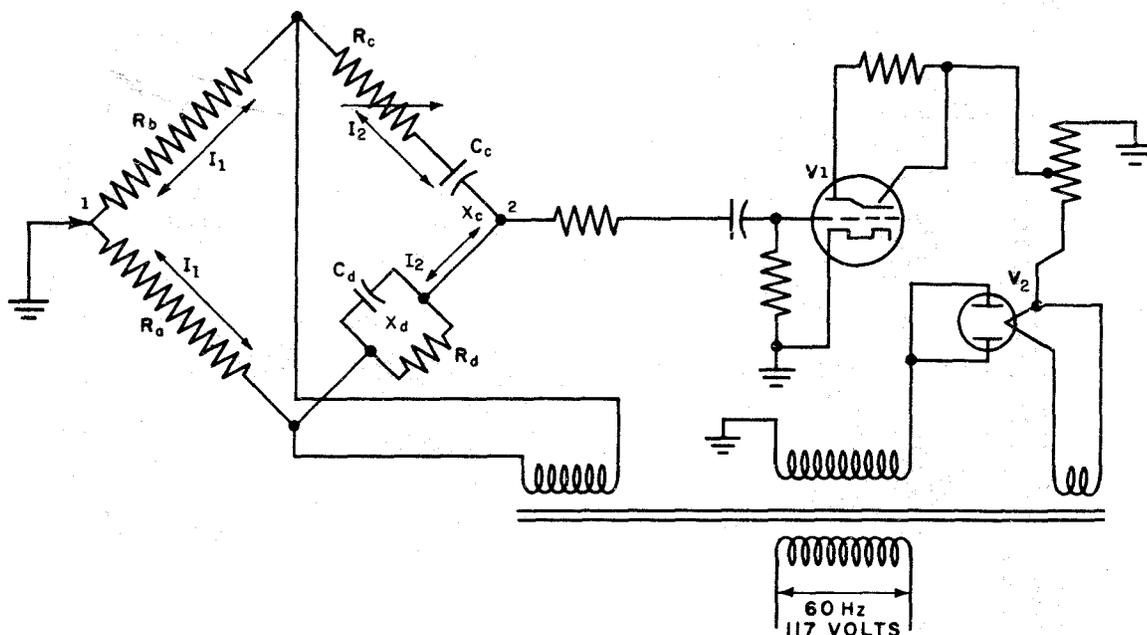


Figure 4-2.—Simplified schematic of capacitance checker.

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a.c. voltage developed across the input of the indicator tube, V1, and the shadow angle is maximum. (V1 is an electron-ray tuning indicator tube.) Any slight unbalance produces an a.c. voltage, which, in turn, develops a grid-leak bias and lowers the plate current of V1, reducing the shadow angle. The following relations exist when the bridge is balanced:

$$\frac{C_d}{C_c} = \frac{R_b}{R_a} - \frac{R_c}{R_d}$$

and

$$\omega^2 = \frac{1}{R_d R_c C_d C_c}$$

where R_a , R_b , R_c , and R_d are the resistances indicated in the figure; C_c is the standard capacitance; and C_d the unknown capacitance. $\omega = 2\pi f$, where f is the frequency of the voltage applied across the bridge.

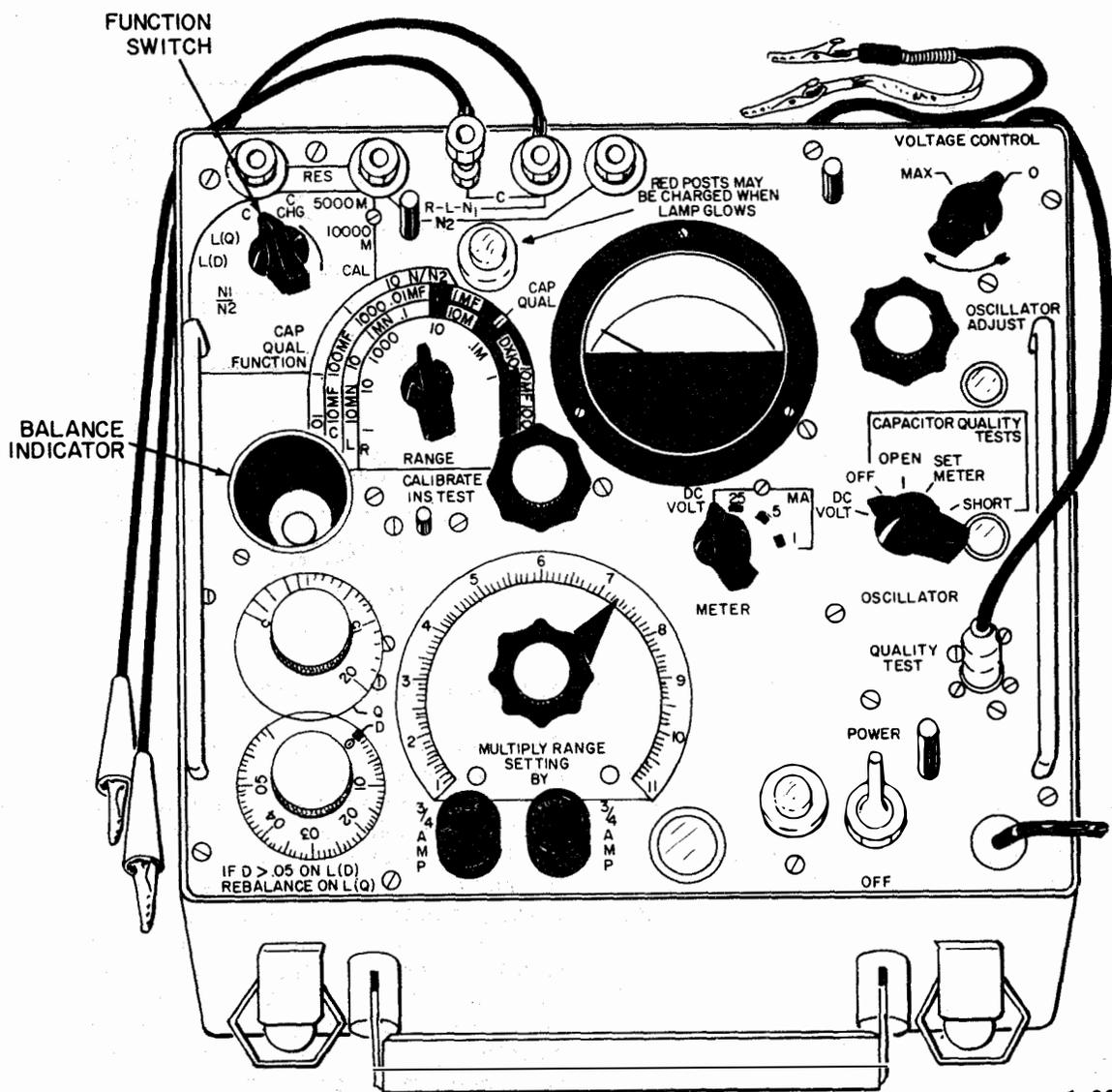
In the basic Wheatstone bridge circuit, using d.c. voltages and simple resistances, the balance is obtained when the voltage drops across the ratio arms are equal. In the a.c. capacity bridge it is not sufficient to have equality of voltage

drops in the ratio arms, but, in addition, the phase angle between current and voltage in the two arms containing the capacitors must be equal in order to obtain a balance. When a balance is obtained, the current in R_a is equal to that in R_b , and the current in C_c is equal to the current in the parallel circuit of C_d and R_d .

The capacitance-inductance-resistance bridge shown in figure 4-3 is used to measure C, L, and R values in addition to special tests, such as the turns ratio of transformers and capacitor quality tests. This instrument is self-contained except for a source of line power, and has its own source of 1000 Hz bridge current with a sensitive bridge balance indicator, and adjustable source of direct current for electrolytic capacitor and resistance testing. The bridge also contains a meter with suitable ranges for leakage current tests on electrolytic capacitors.

Resistance Measurements

To make resistance measurements with the bridge tester (fig. 4-3), set the FUNCTION switch to the R position and connect the resistor to be measured to the R posts (second and fourth posts from the left, fig. 4-3). Select an appropriate range on the R scale of the RANGE switch; then turn the MULTIPLY BY dial until



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Figure 4-3.—Capacitance-Inductance-Resistance Bridge (ZM-11A/U).

the indicator tube (a type 6E5 electron-ray tube) shows the maximum opening, indicating balance on the BALANCE INDICATOR.

If balance is indicated at either extreme of the MULTIPLY BY dial, change the setting of the RANGE switch and rebalance. Multiply the RANGE switch reading by the MULTIPLY BY dial reading to obtain the unknown resistance reading.

Capacitance Measurements

Connect the capacitor to be tested to the C posts (third and fourth from left, fig. 4-3) and

set the FUNCTION switch to position C. Select a suitable range on the C scale of the RANGE switch. Obtain a balance by turning the MULTIPLY BY dial and simultaneously adjusting the D dial. When balance is achieved, multiply the range setting by the MULTIPLY BY dial reading to obtain the unknown capacitance. The D dial reading indicates the loss factor of the capacitor. Multiply the D dial reading by ten when using any range in the colored section of the RANGE Switch.

Inductance Measurements

Connect the inductor to be measured to the L

posts (second and fourth posts from left, fig. 4-3), and set the FUNCTION switch to the L(D) or L(Q) position, depending upon the probable loss of the coil to be tested. Usually coils used in the AF ranges will fall within the loss range of L(D), while RF and IF coils will fall within the loss range of L(Q).

Select a probable range setting on the L scale of the RANGE switch and obtain a balance by turning the MULTIPLY BY dial and simultaneously adjusting the Q or D dial. Read the range setting and multiply it by the MULTIPLY BY dial reading to obtain the unknown inductance. Read the Q or D dial to obtain the coil loss factor.

POWER MEASUREMENTS

It is often necessary to check the power consumption and the input and output signal power levels of communication and electronic equipment. The determination of d.c. power is comparatively simple; the unit of power, the watt, is the product of the potential in volts and the current in amperes.

As discussed in Basic Electricity, NAVPERS 10086-B, to make accurate a.c. power measurements, the phase angle of the voltage and current must be considered. The measurement of a.c. power is further complicated by the frequency limitations of various power meters. If there is no phase difference, a.c. power may be computed in the same manner as d.c. power, by determining the average value of the product of the voltage and current.

Electric power at a line frequency of approximately 60 Hz may be measured directly by a dynamometer-type wattmeter. This type of meter indicates the actual power, and, therefore, the phase angle of the voltage and current does not have to be determined. Normally, the exact power consumption of equipment is not necessary for maintenance, and a current measurement is sufficient to permit you to decide whether the power consumption is within reason.

In the audio-frequency range, power levels have to be determined in the course of routine checks and during corrective maintenance procedures. When working with audio-frequency amplifiers, it is ordinarily easier and more convenient to measure voltage, current, and

impedance and then compute the power than it is to measure power directly. Power measurements for audio-frequency circuits are usually indicated in terms of decibels (db), decibels referenced to one milliwatt (dbm), or volume units (vu). The power gain of an amplifier can be expressed in db. The power level of a sinusoidal signal compared to a 1-milliwatt reference is indicated in dbm. The power level of a complex signal, such as voice, music, or multiplexed information, compared to a reference level of 1 milliwatt, is indicated in vu. Many a.c. voltmeters have scales calibrated in decibels or volume units. Such meters are useful for making measurements where direct indication in decibels is desired. However, it must be remembered that these are voltmeters, and that power measurements are not meaningful unless the circuit impedance is known.

At radio frequencies below the UHF range, power is usually determined by voltage, current, and impedance measurements. One common method, used to determine the output power of RF oscillators and radio transmitters, consists of connecting a known resistance to the equipment output terminals, measuring the current flow through the resistance, and then calculating the power as the product of I^2R . Since the power is proportional to the current squared, the meter scale can be calibrated to indicate power units directly. A thermocouple ammeter is usually used for this measurement of RF current. The resistor used to replace the normal load is usually specially designed to have low reactance, and has the ability to dissipate the required amount of power. Such resistors are commonly called dummy loads or dummy antennas.

In the UHF and SHF portion of the radio-frequency spectrum, it is usually difficult to accurately measure the voltage, current, and impedance. These basic measurements may change greatly at slightly different points in a circuit, and are appreciably affected by small changes in the placement of parts in the vicinity of the tuned circuits. To measure the output of microwave radio or radar transmitters, test instruments which convert RF power to another form of energy, such as light or heat, can be used to indirectly measure the power. A method which measures the heating effect of a resistor load on a stream of passing air can be used. Accurate measurement of large-magnitude power can be achieved by measuring the

temperature change of a water load. The most common type of power meter for use in this frequency range employs a bolometer. The bolometer is a loading device that undergoes changes of resistance as changes in the power dissipation occur. Resistance is measured before and after RF power is applied, and power can be determined by the change in resistance.

STANDING WAVE MEASUREMENTS

A transmission line which is not terminated in its characteristic impedance is subject to a condition known as "standing waves." Reflection of energy at the load end of a transmission line gives rise to a wave that travels toward the generator end. This reflected wave varies continuously in phase in much the same way that the incident wave varies in phase. At certain points, one-half wave-length apart, the two waves are exactly in phase, and the resultant voltage is maximum. At points a quarter wave-length from the maximums, the two waves are in continuous opposition, and voltage nodes are produced. The ratio of maximum to minimum voltage at such points is called the "standing wave ratio" (SWR) or "voltage standing wave ratio" (VSWR). The ratio of maximum to minimum current along a transmission line will have the same value as the VSWR. A high SWR indicates that the characteristic impedance of a transmission line differs greatly from the terminating impedance, and a low SWR indicates that there is a good impedance match between a transmission line and the terminating impedance. If it is desired to terminate a transmission line in its characteristic impedance, a SWR of 1.0 is optimum.

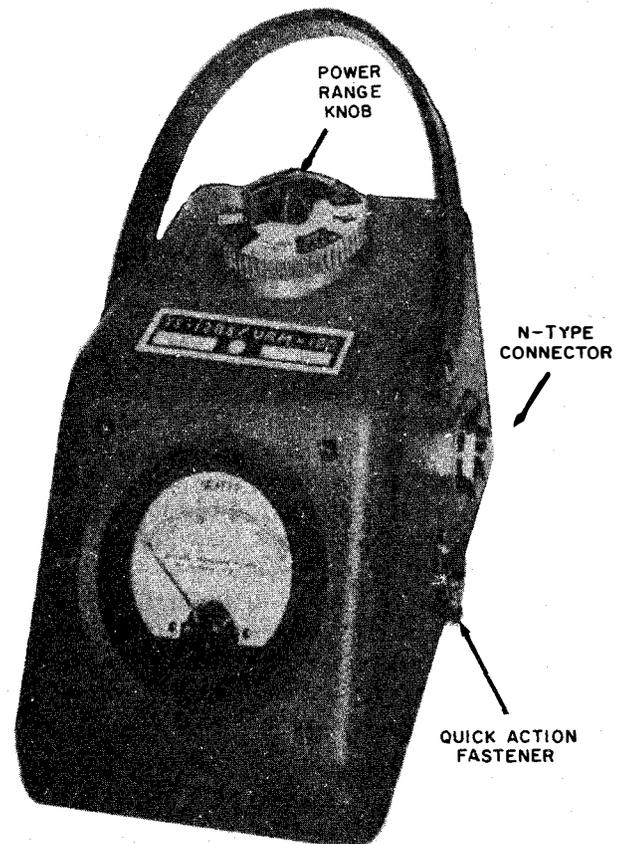
Transmission line SWR measurements are often made during installation, tuning, and maintenance of communication equipment. Radio antenna transmission lines can be constructed to have the correct length and wire spacing to provide impedance matching for transmitter and receiver equipment. For maximum transfer of energy, the transmission line characteristic impedance should match the terminating impedance. However, unmatched (resonant) transmission lines are useful as impedance-matching devices. In many situations it is not necessary to determine the actual SWR. As an example, loading devices, such as antennas are often adjusted for the condition of minimum SWR. Absorption wavemeters or neon-lamp indicators are capable of providing a rough check of the

SWR and the location of standing waves for an open-wire transmission line. Slotted coaxial lines or waveguides in conjunction with an indicator are used for standing-wave measurements in the VHF to SHF range.

Standing wave measurement for radar equipment are discussed in volume 2 of this manual.

RF WATTMETER

Wattmeter AN/URM-120 (fig. 4-4) is designed to measure incident and reflected RF power from 10 to 1000 watts with a frequency range of 2 to 1000 MHz. Three coupler-detectors, each rated to cover a portion of the frequency and power ranges, are provided with the wattmeter. Each coupler-detector has a knurled knob which projects through a hole in the top of the wattmeter case as shown in figure 4-4. A nameplate on the knurled knob indicates the power range. Centered on the nameplate is



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Figure 4-4.—RF in-line wattmeter.

the power range knob, which can be rotated 360° to any desired power range. The coupler-detector rotates only 180° along the coaxial primary line inside the metal case. Also located inside the metal case are the indicating meter and cable for interconnecting the meter to the coupler-detector.

Two N-type connectors (1 male and 1 female) are located on either side of the instrument case for connecting the wattmeter between the power source and the load. The upper and lower parts of the instrument are held together with quick action fasteners, which permit easy access to the coupler-detector, the coaxial primary line, and the indicating meter.

Power measurements are made by inserting the proper coupler-detector and connecting the wattmeter in the transmission line between the load and the RF power source. To determine incident power, the arrow on the coupler-detector knurled knob is rotated toward the load, and the power range knob is positioned for peak meter reading. To determine reflected power, the arrow is positioned toward the RF power source. In effect, rotation of the coupler-detector (which is a directional coupler) causes the coupler to respond only to a wave traveling in a particular direction while being unaffected by a wave traveling in the opposite direction. A diode rectifier in the coupler rectifies the energy picked up by the coupler, and this energy is measured across a known impedance to obtain the incident or reflected power.

Operation

Insert the proper coupler-detector for the RF power being measured into the wattmeter case. Remove the wire shunt from the meter terminals. Deenergize and tag the RF power source and connect the wattmeter in the transmission line, either at the load or the RF source. Ensure that all connections are tight.

Position the power range knob to a position higher than the rated power of the RF source. **IF THE RATED POWER IS NOT KNOWN, PLACE THE POWER RANGE KNOB IN THE HIGHEST POWER POSITION BEFORE THE POWER SOURCE IS TURNED ON.**

To measure incident power, rotate the coupler-detector so that the arrow indicating power flow points toward the load. Apply RF power to the transmission line under test. Rotate the power range knob to the proper range for measuring and observe the point at which the

indicating meter peaks. This is the incident power.

Reflected power is measured in the same manner as described for incident power, except that the coupler-detector is rotated so that the arrow points toward the RF source. After power measurements have been completed, deenergize the RF source, disconnect the wattmeter from the transmission line, and replace the wire shunt on the meter terminals.

Interpreting Power Measurements

The RF power measurements made by the wattmeter are used to determine the VSWR of the load and the power absorbed by the load. The VSWR may be determined from a chart provided in the wattmeter technical manual, or it may be calculated by the following formula:

$$VSWR = \frac{\sqrt{P_i} + \sqrt{P_r}}{\sqrt{P_i} - \sqrt{P_r}}$$

where P_i is the incident power and P_r is the reflected power as measured by the wattmeter.

The RF power absorbed by the load may be determined by subtracting the reflected power reading from the incident power reading.

FREQUENCY MEASUREMENTS

Frequency measurements are an essential part of preventive and corrective maintenance for electronics equipment. Frequency measurements for radio equipment are made during tuning, preventive maintenance, and corrective maintenance procedures. The type of test equipment selected depends on the frequency to be measured and the required accuracy. Signal frequencies of radio transmitters which operate in the low-frequency to the very-high-frequency range are normally measured by absorption-type wavemeters, reaction-type wavemeters, heterodyne-type frequency meters, or calibrated radio receivers. Where accuracy is not of prime importance, in making preliminary adjustments, or for general experimental work, rapid frequency checks may be made by the absorption-type wavemeter. Since the wavemeter is relatively insensitive, it is very useful in determining the fundamental frequency in a circuit generating multiple harmonics.

The signal frequencies of radio and radar equipment which operate in the ultra-high-frequency and super-high-frequency range can be measured by resonant-cavity-type wavemeters, resonant-coaxial-line-type wavemeters, or

Lecher-wire devices. When properly calibrated, resonant-cavity and resonant-coaxial-line wavemeters are more accurate and have better stability than wavemeters used for measurements in the low-frequency to very-high-frequency range. These frequency-measuring instruments are often furnished as part of communication and electronic equipment, but are also available as general-purpose test sets.

Frequency measuring equipment and devices, particularly those used to determine radio frequencies constitute a distinct class of test equipment, because of the important and critical nature of such measurements. The requirement of precise calibration is extremely important in all frequency measuring work. In order to provide accurate measurements, every type of frequency meter must be calibrated against some frequency standard.

Frequency standards are divided into two general categories: primary and secondary standards. The primary frequency standard is determined and maintained by the U.S. Bureau of Standards. It has long-term stability and accuracy that are determined by comparison with a standard interval of time. A secondary frequency standard is a highly stable and accurate standard that has been calibrated against the primary standard.

The accuracy of a secondary frequency standard is maintained only when periodic calibration checks are made against a primary standard, or against standard frequency transmissions of WWV or WWVH. These transmissions are broadcast continuously, and are monitored for agreement with the National Primary Frequency Standard, which is maintained by the Bureau of Standards, Time and Frequency Division, Boulder, Colorado.

FREQUENCY COUNTER

The AN/USM-207 is a portable, solid-state electronic counter for precisely measuring and displaying on an 8-digit numerical readout the frequency and period of a cyclic electrical signal, the frequency ratio of two signals, the time interval between two points on the same or different signals, and the total number of electrical impulses (totalizing). The counter also provides the following types of output signals:

1. Standard signals from 0.1 Hz to 10 MHz in decade steps derived from a 1 MHz frequency standard, frequency dividers, and a frequency multiplier

2. Input signals divided in frequency by factors from 10 to 10^8 by a frequency divider

3. Digital data of the measurement in four-line binary-coded-decimal form with decimal point and control signals for operation of printers, data recorders, or control devices

4. A 1 MHz output from a frequency standard

General Description

The AN/USM-207 (fig. 4-5) consists of a major counter assembly, two plug-in assemblies installed in recesses on the front and rear panel, and a group of accessory cables and connectors stored in the detachable front cover.

The major assembly Digital Readout Electronic Counter CP-814/USM-207 contains the input amplifiers, gate control, display, reset and transfer control, frequency multipliers, time base dividers, decade and readout boards, numerical display tubes, decimal point and units indicators, power supply and regulator, and controls associated with these circuits.

The Radiofrequency Oscillator O-1267/USM-207 plug-in assembly develops a 1 MHz signal and includes its own power supply. The oscillator includes the 1 MHz output receptacle which may be used as a source of that frequency when the oscillator is connected to a.c. power through the basic counter or when connected to the power line independently of the counter. The counter may be operated without the oscillator in totalizing, scaling the input signal, time interval with external clock, and frequency ratio measurements. For other measurements the counter does not require the oscillator when a separate external 100 kHz or 1 MHz signal is connected. In either of these two situations, the oscillator may be left in the counter or removed. The oscillator plugs into the right rear of the counter.

The Electronic Frequency Converter CV-1921/USM-207 plug-in assembly permits measurement of frequencies up to 500 MHz, using the heterodyne principle. The unit consists of the broadband amplifier, mixer, multiplier, and controls and indicators associated with these circuits. When measurements other than heterodyne frequency measurements are made, the converter is not required, but need not be removed. The converter also permits the measurement of signals from 35 MHz to 100 MHz with a greater sensitivity than available with the basic counter. The converter plugs into the right front of the counter.

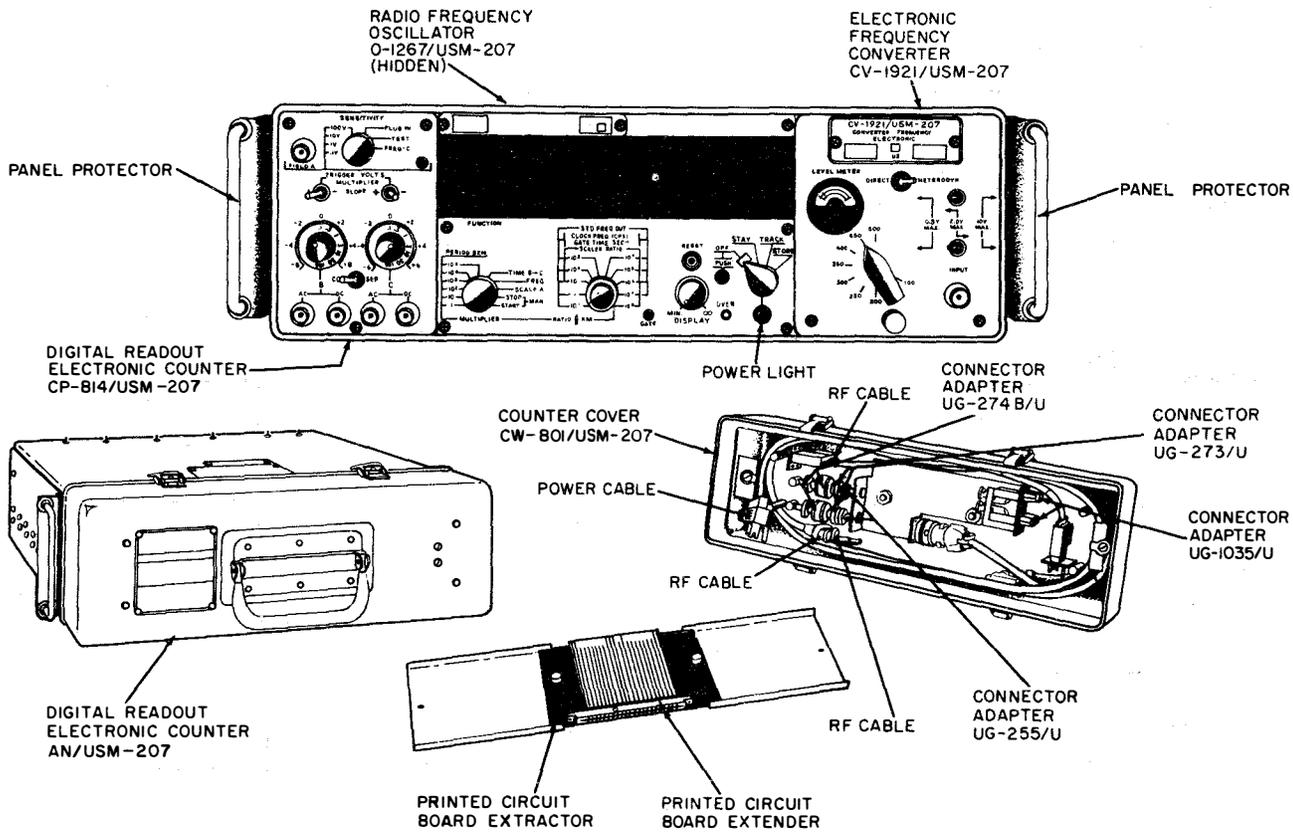


Figure 4-5.—Digital Readout Electronic Counter (AN/USM-207).

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Functional Description

Figure 4-6 is the overall functional block diagram of the counter. To make a measurement requires two types of information; a count signal, and a gate control signal. These two signals may be generated within the instrument, or they may be supplied from outside sources. The type of measurement the counter will make depends upon the relationship of these two signals. In any function the instrument counts the count signal for a period of time determined by the gate control signal. Routing of these signals within the instrument is accomplished by logic circuits. These logic circuits are controlled by means of the front panel controls.

The radio frequency oscillator (0-1267/USM-207) generates a signal of precise frequency for use throughout the counter or to provide a precise 1 MHz signal for use outside the equipment.

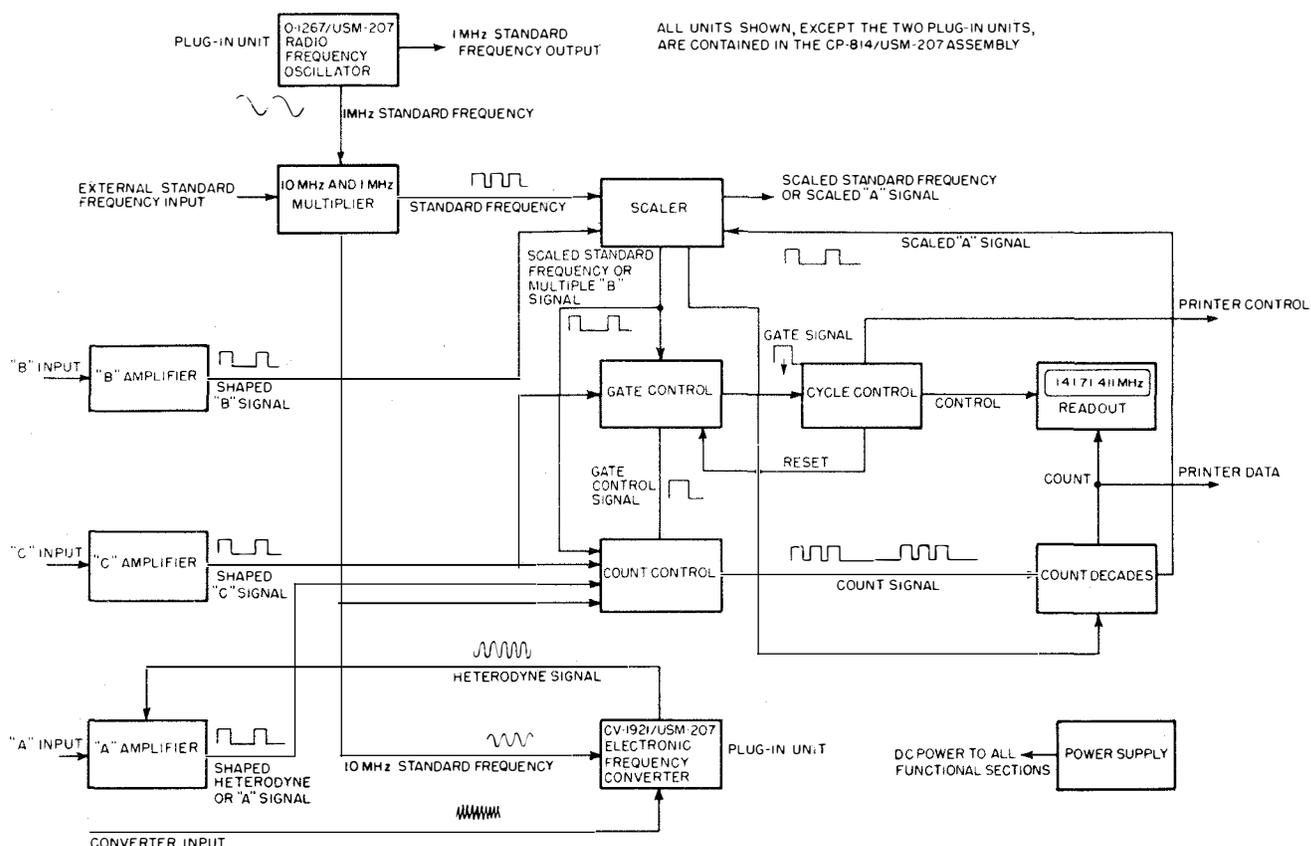
The electronic frequency converter accepts radio frequencies between 100 MHz and 500 MHz and converts them to radio frequencies between 5 MHz and 100 MHz for measurement by the basic counter.

The "A", "B", and "C" amplifiers amplify and shape the respective input signals for use throughout the counter.

The 10 MHz and 1 MHz multiplier multiplies the frequency and shapes the signal generated by the radio frequency oscillator. It also provides precise timing signals to the various functional sections of the basic counter and to the frequency converter.

The scaler consists of a series of decade dividers and gating systems which provide divided standard frequencies and control signals depending on the type of measurement the instrument is making.

The gate control generates the gate control signal. This signal determines the length of time that the count decades will count the count signal.



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Figure 4-6.—Digital readout electronic counter overall block diagram.

The count control provides the proper count signal to the count decades, as selected by the setting of the front-panel switches.

The cycle control produces all signals necessary to display the measurement results on the readout and to recycle the counter.

The count decades count the count signal when permitted to do so by the gate control.

The result of their counting becomes the final reading displayed by the readout at the end of each measurement.

The readout receives binary-coded-decimal (BCD) data from the count decades, decodes this data into decimal form and drives the readout indicator tubes. The readout also contains memory circuits which function when the counter is operated in the "Store" mode.

The power supply supplies all d.c. power required by the basic instrument and the converters and consists of seven d.c. supplies. Five of these supplies (+18 volts, +12 volt, +6

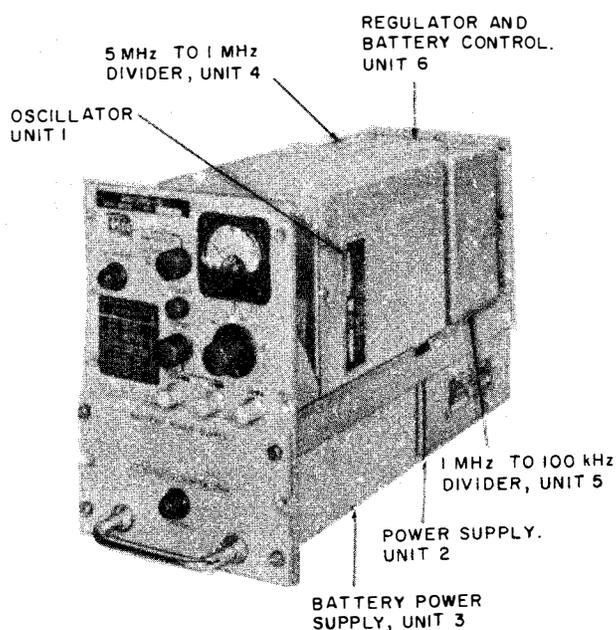
volt, -6 volt, and -12 volt) are regulated, and two (+180 volt and +45 volt) are unregulated.

FREQUENCY STANDARD

Frequency Standard AN/URQ-10 (fig. 4-7) is a compact, multipurpose secondary frequency standard designed for continuous duty operation aboard ship or at shore facilities. The standard operates from a 115 volt, 50 to 400 Hz single-phase a.c. source, and provides three highly stable output frequencies (100 kHz, 1 MHz, and 5 MHz). Frequency Distribution Amplifier AM-2123 (not shown) provides for distributing these frequencies to remote locations aboard ship. A battery is provided in the frequency standard which automatically supplies the power for operation in the event the external power source fails.

Functional Description

The functional block diagram of the AN/URQ-10 is shown in figure 4-8. The standard consists



162.114
Figure 4-7.—Frequency Standard (AN/URQ-10)
cover removed.

of two basic sections, the section which actually produces the frequency outputs, and the power supply section with its control circuits.

The section which actually produces the frequency outputs consists of the oscillator module, unit A1; the 5-MHz to 1 MHz frequency divider module, unit A4; and the 1-MHz to 100-kHz frequency divider module, unit A5. The power supply section consists of the power supply module, unit A2; the battery power supply, unit A3; and the regulator and battery control module, unit A6.

The basic 5-MHz signal, from which all other frequencies are derived, is generated in the oscillator module by the 5-MHz crystal oscillator (fig. 4-8). The signal from the oscillator is amplified by the AGC amplifier and then by the output amplifier. The output amplifier increases the signal to the level necessary for the 5-MHz output signal and also provides the 5-MHz internal signal which is utilized by the 5-MHz to 1-MHz frequency divider module. An inner oven and an outer oven, located within the oscillator module, maintain constant temperature control for the 5-MHz crystal oscillator and the AGC amplifier. The oven temperature circuits, the crystal oscillator, and the AGC

amplifier are a single potted assembly which is contained in the oscillator module along with the 5-MHz output amplifier. The 5-MHz to 1-MHz frequency divider consists of the frequency divider proper and the 1-MHz output amplifier. The 5 MHz to 1-MHz frequency divider circuit utilizes the internal 5-MHz signal to produce two separate 1-MHz outputs. One output is applied to the 1-MHz amplifier, and the other is applied to the 1-MHz to 100-kHz frequency divider module. The output amplifier increases the signal level to provide the 1-MHz output signal. The 1-MHz to 100-kHz frequency divider module, which consists of a frequency divider and a 100-kHz output amplifier, accepts the 1-MHz internal signal to provide the 100-kHz signal. The signal is then increased to the required level for the final 100-kHz output signal.

The power supply module uses the primary a.c. power to provide unregulated d.c. for recharging the battery and for the operation of the other circuits in the frequency standard. The battery charging current passes through the battery charging control circuitry and the battery disconnect circuitry, located in the regulator and battery control module, before reaching the battery power supply. The battery charging control circuitry maintains a full charge for the battery power supply as long as primary a.c. power is present. The battery disconnect circuitry removes the battery from the load before its terminal voltage drops to a potential at which the battery could be damaged. The other unregulated d.c. supply line provides power for the outer oven heater in the oscillator module and for the regulator which supplies all regulated operating power for the frequency generation circuits. The line status circuitry detects a loss of primary a.c. power.

Operation

The front panel controls and indicators for the frequency standard are shown in figure 4-9. Some of these controls (as shown by table 4-1) are not operator controls but are used only by laboratory technicians for calibration purposes.

DO NOT OPERATE ANY CONTROLS UNNECESSARILY. UNNECESSARY CONTROL MANIPULATION CAN DISRUPT THE OUTPUT FREQUENCIES OF THE UNIT REQUIRING LABORATORY CALIBRATION.

When normal a.c. power is supplied to the standard, it automatically reverts to a.c.

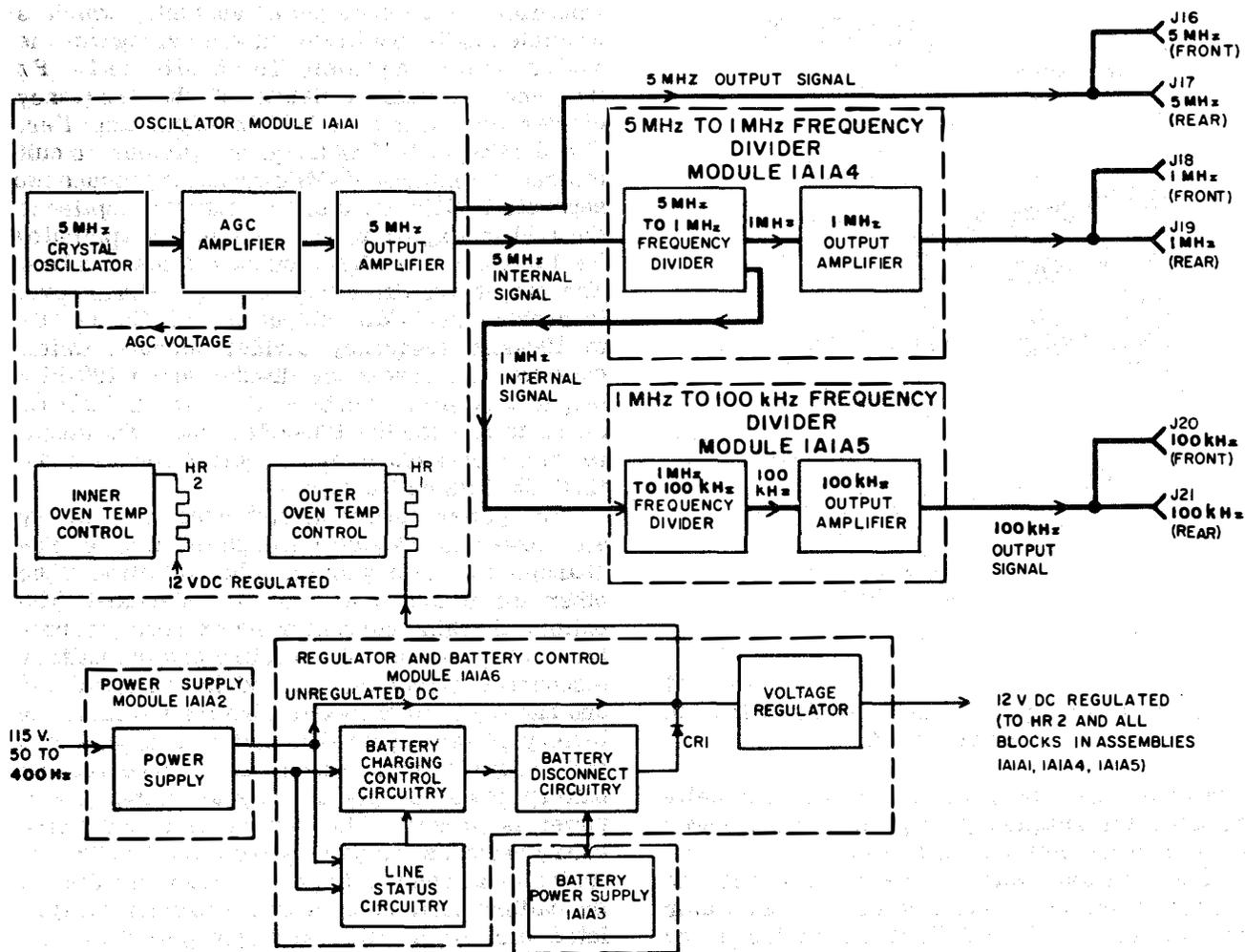


Figure 4-8.—Frequency Standard (AN/URQ-10) block diagram.

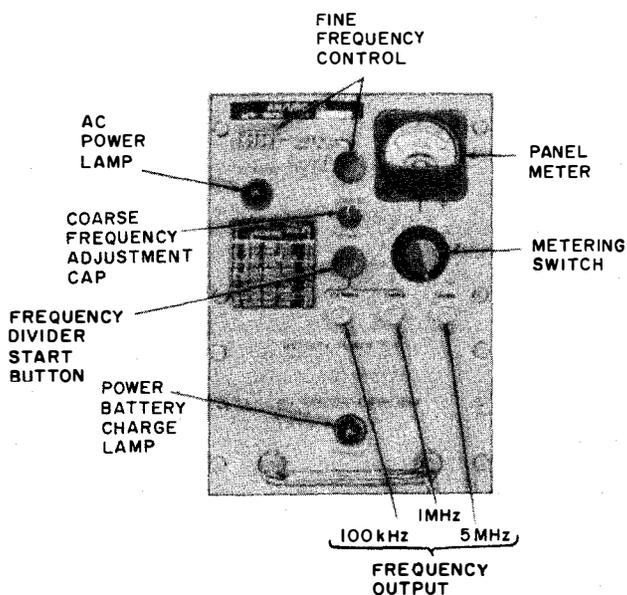
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operation and continues to operate automatically as long as the power is available. If the a.c. power fails, operation will be maintained by the standby battery for a minimum of eight hours, provided the battery is fully charged.

DO NOT ALLOW THE FREQUENCY STANDARD TO BE SHUT OFF EXCEPT IN AN EMERGENCY OR UNLESS IT REQUIRES MAJOR REPAIR. COOLING OF THE CRYSTAL WILL ALTER ITS FREQUENCY CHARACTERISTICS, MAKING LABORATORY CALIBRATION NECESSARY. DO NOT REMOVE THE BATTERY POWER SUPPLY FROM THE SET UNLESS THE STANDARD IS PLUGGED INTO THE NORMAL A.C. SOURCE.

When the standard is operating from battery (emergency operation), both indicator lamps on the front panel (fig. 4-9) are off. No special precautions are necessary during emergency operation. If the normal a.c. supply is not restored, however, the set must be connected to an alternate supply source or shut down before the battery becomes discharged. If it becomes necessary to shut down the standard, it must be disconnected from the a.c. source and the battery removed.

Normal operation for the standard is determined by the use of the panel meter and metering switch. Normal meter readings for the various switch positions are listed in the equipment technical manual.



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Figure 4-9.—Front panel controls and indicators.

TESTING ELECTRON TUBES

Electron tube failures are responsible for a large percent of troubles that occur in electronic equipments or systems. However, if a particular system uses a great number of tubes, it is obviously impracticable, as well as poor policy, for you to attempt to locate faults by general tube checking. Only when the fault has been traced to a particular stage should any tubes be tested, and then only those associated with the improperly functioning circuits.

The condition of a tube can be determined by substituting a tube known to be good for the questionable one. However, indiscriminate substitution of tubes is to be avoided, as detuning of circuits may result. In addition, a tube may not operate properly in a high-frequency circuit, although it performs well in a low-frequency circuit. Therefore, if you are to service electronic equipment, a knowledge of tube-testing devices and their limitations, as well as correct interpretation of the test results obtained, is indispensable for accurate and rapid job performance.

TYPES OF TESTS

In-order to determine the condition of an electron tube, some method of testing is necessary. Because the operating capabilities (and

design features) of a tube are shown by its electrical characteristics, a tube is tested by measuring its characteristics and comparing them with representative values established as standard for that type of tube. Tubes which read abnormally high or low with respect to the standard are subject to suspicion. Practical considerations, which take into account the limitations of the tube test in predicting actual tube performance in a particular circuit, make it unnecessary to employ complex and costly test equipment having laboratory accuracy. For most applications the testing of a single tube characteristic suffices to determine whether a tube is performing satisfactorily.

Testing the emission characteristic of the cathode or filament is perhaps the simplest method of determining the condition of a tube. Since emission normally decreases as the tube ages, low emission is indicative of the end of tube serviceability. This test, however, is subject to limitations, because it tests the tube under static conditions and does not consider the actual circuit operation of the tube. Furthermore, coated cathodes or filaments may develop highly emissive spots, so that the relatively small grid area adjacent to these spots cannot control the electron stream. Under these conditions, testing the total emission may indicate the tube to be satisfactory, while in reality it is defective.

The transconductance (G_m) of a tube used in an amplifier stage is normally a more useful characteristic to measure than the emission. Transconductance is the change of plate current which results from a change in grid voltage; this characteristic, therefore, indicates the ability of the tube to amplify a.c. signals. The most common military tube testers provide dynamic transconductance measurements, although some of the testers are limited to static measurements of this characteristic.

It should be kept in mind that a tubetesting device only compares the characteristic of a given tube with a standard for that particular type of tube. Since the operating conditions imposed upon a tube may vary over wide limits, it is not possible for the tube tester to evaluate a tube in terms of performance capability for all applications. Therefore, the tube tester is not considered the final authority in deciding whether or not a tube is always satisfactory. Substituting a good tube in the equipment, and observing the performance of the equipment, provides the most reliable evidence concerning the condition of the

Chapter 4—USE OF TEST EQUIPMENT

Table 4-1.—Controls and indicators

| OPERATOR CONTROLS AND INDICATORS | | |
|--|--|---|
| Control or Indicator | Function | Normal Status |
| AC POWER lamp (figure 4-9). | Lights when ac input is supplied to the frequency standard. Extinguishes when ac input is interrupted. | Remains lighted during normal operation. |
| Battery CHARGE lamp | Indicates that battery is being charged in the manual mode of operation or in the higher (not trickle) automatic charge mode. | Lamp remains extinguished during normal operation, except after interruption of ac input. |
| Battery charge switch (Not shown) | Selects either manual or automatic battery charging mode. MANUAL CHARGE position causes constant, higher rate charging. AUTO CHARGE position causes higher rate charging only when required to restore battery to full charge, automatically decreasing to trickle charge to maintain battery in full charge position. | Switch remains in AUTO position except at initial start or when battery power supply is replaced. |
| Frequency output connectors | Provides 5-MHz, 1-MHz, and 100-kHz frequencies. | Frequencies are available at connectors whenever frequency standard is operating. |
| Panel meter | Indicates circuit conditions of circuit selected by metering switch. | Indicates zero when metering switch is set at normal unmarked position. |
| Metering switch | Selects circuit to be checked on panel meter. | Remains in unmarked, lower position. |
| CALIBRATION LABORATORY CONTROLS AND INDICATORS | | |
| COARSE frequency adjustment cap | Provides access to coarse frequency control. Coarse frequency control provides coarse adjustment of oscillator output. This must be adjusted with special insulated tool. Tool is stored in clips mounted directly above battery power supply. | Screwed into panel to prevent adjustment of coarse control. |
| Fine frequency adjustment indicator | Indicates in parts per 10^{10} the amount of adjustment provided by the operation of the fine frequency control. | Varies for each unit. |
| Fine frequency control | Provides a fine frequency control, changing frequency of oscillator output by the amount, in parts per 10^{10} indicated on fine frequency adjustment indicator. | Screwed in to lock control and associated indicator. |
| Frequency divider START button | Starts operation of frequency dividers at initial operation or after shutdown. | Remains in undepressed position. |

tube in question. Substitution is also the only method by which you may test many high-power tubes used for transmitter applications. Nevertheless, the tube tester plays a very important function, since in most cases it provides a quick and satisfactory check on tube serviceability.

TUBE TESTER

A representative field type electron tube tester designed to test all common low power tubes is shown in figure 4-10. The tube test conditions (which are as close as possible to the actual tube operating conditions) are programmed on a prepunched card. The card switch (S101, fig. 4-10) automatically programs the tube test conditions when it is actuated by a card. A card compartment on the front panel of the tester provides storage for the most frequently used cards. The cover of the tester (not shown) contains operating instructions, brackets for storing the technical manual, the power cord, a calibration cell for checking the meter and short tests, calibration cards, blank cards, and a steel hand punch.

Front Panel

When a prepunched card is fully inserted into the card switch (S101), a microswitch is actuated which energizes a solenoid, causing the card switch contacts to complete the circuit. The card switch has 187 single pole single throw switches arranged in 17 rows with 11 switches in each row. The card is used to push the switches closed; thus, the absence of a hole in the card is required to actuate a switch.

The meter (M301 fig. 4-10) contains four scales. The upper scale is graduated from zero to 100 for direct numerical readings. The three lower scales, numbered 1, 2, and 3, are read for LEAKAGE, QUALITY, and GAS respectively. Each numbered scale includes green and red areas marked GOOD and REPLACE. Inside a shield directly in front of the meter are five neon lamps (DS301 through DS305), which indicate shorts between tube elements.

The pushbutton marked 2 (MP6) is used for transconductance, emission, and other quality tests described later. The pushbutton marked 3 (MP7) is used to test for the presence of gas in the tube envelope. The pushbutton marked 4 (MP8) is used for tests on dual tubes. A neon lamp (DS203) lights when pushbutton number 4 is to be used. Eleven tube test sockets are

located on the panel plus tube pin straighteners for the 7 and 9-pin miniature tubes.

The power ON-OFF spring return toggle switch (S105) turns the tester on by energizing a line relay. Pilot light (DS107) lights when this relay closes. Above the power ON-OFF switch are five fuses. Fuses F101, F201, and F202 protect circuits in the tester not protected by other means and have neon lamps to indicate when they have blown. Fuses F102 and F103 protect both sides of the power line.

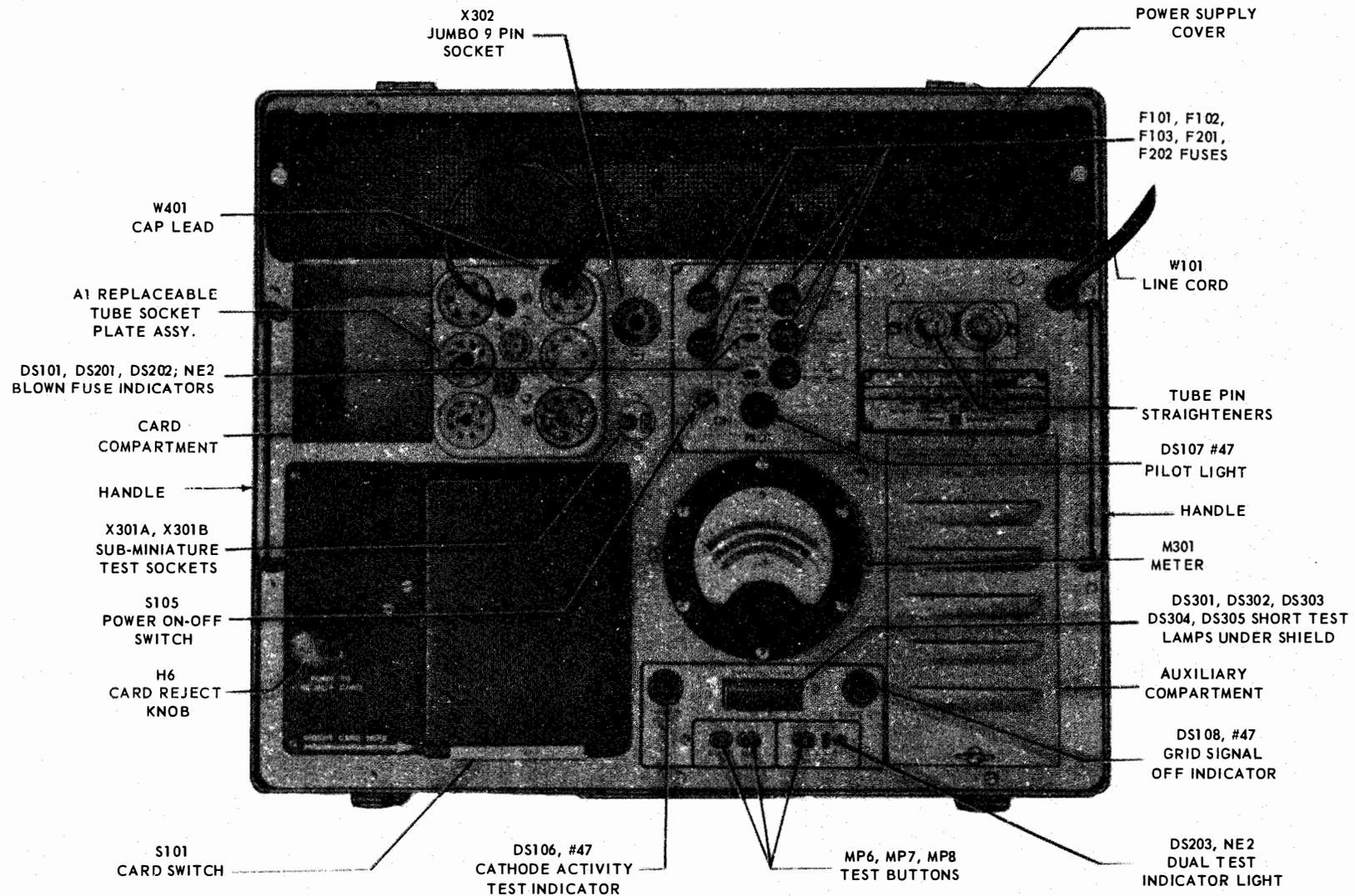
Auxiliary Compartment

A group of auxiliary controls covered by a hinged panel are used for special tests and for calibration of the tester. Two of these controls labeled SIGNAL CAL (R152 and R155, fig. 4-11) are used with special test cards for adjusting the regulation and amplitude of the signal voltage. A pushbutton labeled CATH ACT (S302D) is used for making cathode activity tests. When this button is pressed, DS106 on the front panel (fig. 4-10) lights, and the filament voltage of the tube under test is reduced by 10 percent. Results of the test are read as a change in reading on the numerical meter scale.

Pushbutton S302E and potentiometers R401 and R405 (fig. 4-11) are used for balancing the Gm bridge circuit under actual tube operating current. Pressing S302E removes the grid signal and allows a zero balance to be made with one potentiometer or the other, depending upon whether the tube under test is passing high or low plate current. Lamp DS108 on the front panel lights when S302E is pressed. Pushbutton S302C is used for checking grid to cathode shorts at a sensitivity much higher than the normal tests. Results of this test are indicated by the short test lamps on the front panel.

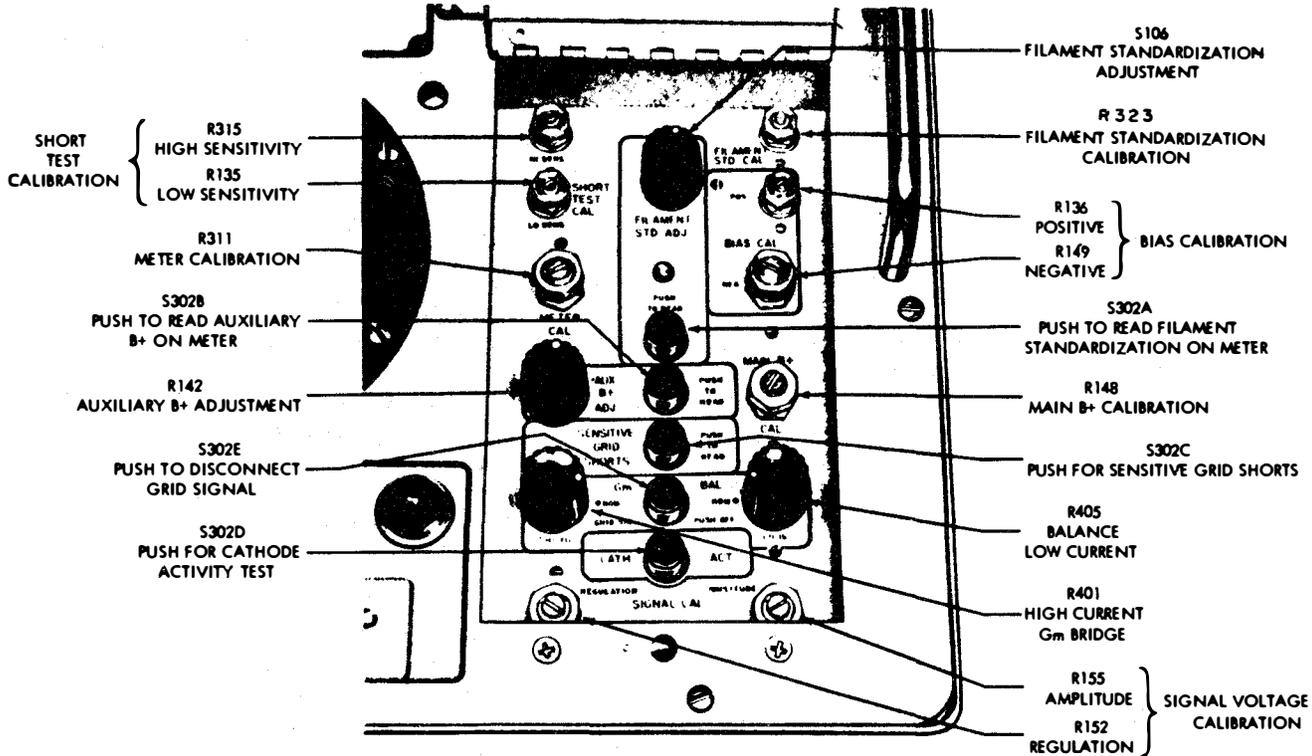
Certain special tests require the use of a continuously adjustable auxiliary power supply. By pressing pushbutton S302B, meter M301 may be used to read the voltage of the auxiliary power supply. This voltage may be adjusted by the use of potentiometer R142. The rest of the potentiometer controls are calibration controls and are adjusted by the use of special calibration cards and a calibration test cell.

All circuits in the tester except the filament supply are electronically regulated to compensate for line voltage fluctuations. The filament supply voltage is adjusted by pressing pushbutton S302A and rotating the filament standardization adjustment switch S106 until meter M301 reads midscale.



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Figure 4-10.—Tube Tester (AN/USM-118B).



20.346(162A)

Figure 4-11.—Auxiliary compartment.

Program Cards

As stated previously, the circuits to be used in testing are selected by a prepunched card. These cards are made of a tough vinyl plastic material. The tube numbers are printed in color on the tabs of the cards and also at the edge of the card for convenience in filing. A special card is provided to use as a marker when a card is removed for use. Blank cards are provided so that additional test cards may be punched for new tubes that are developed or to replace cards that have become unserviceable (fig. 4-12).

Operation

Before operating for the first time, and periodically thereafter, the tester should be calibrated using the calibration test cards as described in the equipment technical manual.

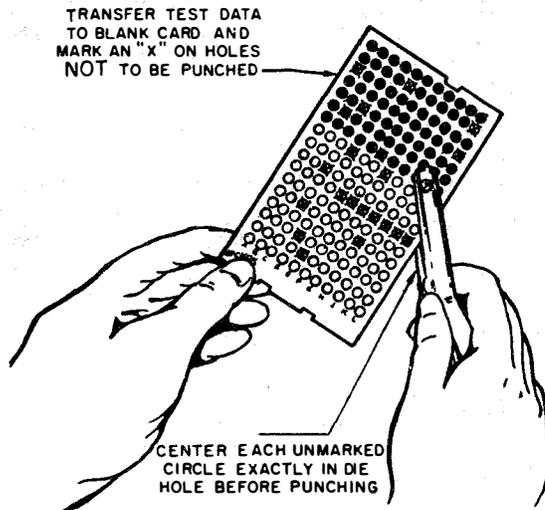
NORMAL TEST.—The tester is equipped with a three-conductor power cord, one wire of which is chassis ground. It should be plugged

into a grounded 105-125 volt 50-400 Hz outlet.

Before operating the tester, open the auxiliary compartment and ensure that the FILAMENT STD ADJ, and the Gm BAL knobs are in the NOM position. The GRID SIG and CATH ACT buttons (S302E and S302D) should be up and lamps DS108 and DS106 on the front panel out.

Turn on the tester and allow it to warm up for five to ten minutes, then press the PUSH TO REJECT CARD knob down until it locks. If a nontest card is installed in the card switch, remove it. This card is used to keep the switch pins in place during shipment and should be inserted before transporting the tester.

Plug the tube to be tested into its proper socket. (Use the pin straighteners before plugging in 7 and 9-pin miniature tubes.) Select the proper card or cards for the tube to be tested. Insert the card selected into the slot in the card switch until the PUSH TO REJECT knob pops up. The card will operate the tester only if it is fully inserted, and the printing is up and toward the operator. DO NOT put paper or objects other



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Figure 4-12.—Punching new or replacement tube test code cards.

than program cards into the card switch as they will jam the switch contacts. If the overload shuts off the tester when the card is inserted in the switch, check to see that the proper card is being used for the tube under test, and if the tube under test has a direct interelectrode short.

As soon as the card switch is actuated, the tube under test is automatically subjected to an interelement short test and a heater to cathode leakage test. A blinking or steady glow of any of the short test lamps is an indication of an interelement short. If the short test lamps remain dark, no interelement shorts exist within the tube. If a short exists between two or more elements, the short test lamp or lamps connected between these elements will remain dark, and the remaining lamps will light. The abbreviations for the tube elements are located on the front panel just below the short test shield so that the neon lamps are between them. This enables the operator to tell which elements are shorted. Heater to cathode shorts are indicated as leakage currents on the #1 meter scale. If the meter reads above the green area, the tube should be replaced. A direct heater to cathode short will cause the meter to read full scale.

To make the **QUALITY** test, push the number 2 button (fig. 4-10) and read the number 2 scale on meter M301 to determine if the tube is good. (This test may be one of various types, such as transconductance, emission, plate current, or voltage drop, depending upon the type of tube under test.)

To test the tube for **GAS**, press the number 3 button and read the number 3 meter scale. The number 2 button also goes down when number 3 is pressed. If a dual tube having two identical sections is being tested, the neon lamp (DS203) will light, indicating that both sections of the tube may be tested with one card. To do this, check the tube for shorts, leakage, quality, and gas as described previously, then hold down button number 4 and repeat these tests to test the second section of the tube. Dual tubes with sections that are not identical require two cards for testing. A second card is also provided to make special tests on certain tubes.

AUXILIARY TESTS.—As mentioned previously, two special tests (cathode activity and sensitive grid shorts) may be made by use of controls located in the auxiliary compartment (fig. 4-11). The cathode activity test (CATH ACT) is used as an indication of the amount of useful life remaining in the tube. By reducing the filament voltage by 10 percent and allowing the cathode to cool off slightly, the ability of the cathode as an emitter of electrons can be estimated. This test is made in conjunction with the normal quality test.

To make the CATH ACT test, allow the tube under test to warm up, press button number 2 (fig. 4-10) and note the reading of scale number 2 on meter M301. Note also the numerical scale reading on M301. Next, lock down the CATH ACT button (fig. 4-11), wait for about 1.5 minutes, then press button number 2 (fig. 4-10) again and note the numerical and number 2 scale readings on meter M301. The tube should be replaced if the numerical reading on M301 differs from the first reading by more than 10 percent, or if the reading is in the red area on the number 2 scale.

It is sometimes desirable to check certain tubes for shorts at a sensitivity greater than normal. To make the **SENSITIVE GRID SHORTS** test, push S302C (fig. 4-11) and note if any short test lamps (fig. 4-10) light.

TESTING SEMICONDUCTOR DEVICES

Because of the reliability of semi-conductor devices, servicing techniques developed for

transistorized equipment differ from those normally used for electron tube circuits. Electron tubes are usually considered to be the circuit component most susceptible to failure, and are, therefore, normally the first components to be tested. Transistors, however, are capable of operating in excess of 30,000 hours at maximum rating without failure and are often soldered in the circuit in much the same manner as resistors and capacitors.

Substitution of a semiconductor diode or transistor known to be in good condition is a simple method of determining the quality of a questionable semiconductor device. This technique should be used only after you have made voltage and resistance measurements to make certain that there is no circuit defect that might damage the substitution semiconductor device. If more than one defective semiconductor is present in the equipment section where trouble has been localized, this method becomes cumbersome, since several semiconductors may have to be replaced before the trouble is corrected. To determine which stages failed and which semiconductors are not defective, all of the removed semiconductors must be tested. This can be accomplished by observing whether the equipment operates correctly as each of the removed semiconductor devices is reinserted into the equipment.

TESTING DIODES

Semiconductor diodes, such as general purpose germanium and silicon diodes, power silicon diodes, and microwave silicon diodes may be tested most effectively only under actual operating conditions. However, crystal rectifier testers are available to determine direct-current characteristics which provide an indication of crystal-diode quality.

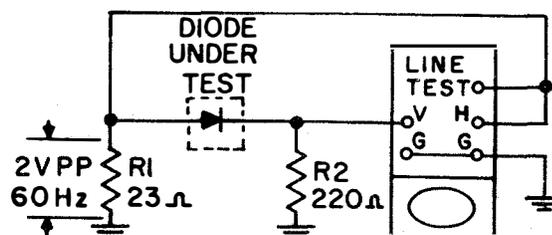
A common type of crystal diode test set is a combination ohmmeter-ammeter. Measurements of forward resistance, back resistance, and reverse current may be made with this equipment. The condition of the diode under test can then be determined by comparison with typical values obtained from test information furnished with the test set or from the manufacturer's data sheets. A check which provides a rough indication of the rectifying property of a diode is the comparison of the diode's back and forward resistance at a specified voltage. A typical back-to-forward-resistance ratio is on the order of 10:1, and a forward-resistance value of 50 to 80 ohms is common.

Testing With Ohmmeter

A convenient test for a semiconductor diode requires only an ohmmeter. The forward and back resistance can be measured at a voltage determined by the battery potential of the ohmmeter and the resistance range at which the meter is set. When the test leads of the ohmmeter are connected to the diode, a resistance will be measured which is different from the resistance indicated if the leads are reversed. The smaller value is called the forward resistance, and the larger value is called the back resistance. If the ratio of back-to-forward resistance is greater than 10:1, the diode should be capable of functioning as a rectifier. However, you should keep in mind that this is a very limited test that does not take into account the action of the diode at voltages of different magnitudes and frequencies.

Testing With An Oscilloscope

An oscilloscope can be used to graphically display the forward and back resistance characteristics of a crystal diode. A circuit used in conjunction with an Oscilloscope to make this test, is shown in figure 4-13. This circuit uses the oscilloscope line test voltage as the test signal. A series circuit composed of resistor R1 and the internal resistance in the line test circuit decreases the 3-volt open circuit test voltage to a value of approximately 2 volts, peak to peak. The test signal applied to the crystal diode is also connected to the horizontal input of the oscilloscope. The horizontal sweep will then represent the voltage applied to the diode under test. The voltage developed across current-measuring resistor R2 is applied to the vertical input of the oscilloscope. Since this voltage is proportional to the current through



162.117

Figure 4-13.—Testing semiconductor diode with oscilloscope.

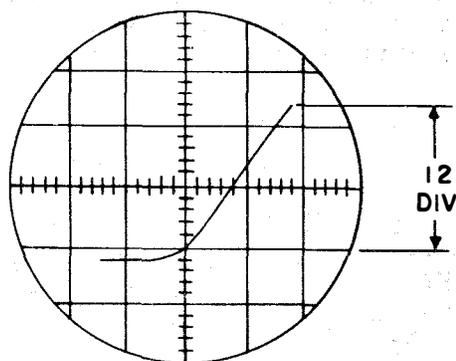
the diode under test, the vertical deflection will indicate crystal current. The resulting oscilloscope trace for a normal diode will be similar to the curve shown in figure 4-14.

To test Zener diodes, a higher voltage than the oscilloscope line test signal must be used. This test can be made with a diode test set or with the circuit shown in figure 4-15. In this circuit, rheostat R1 is used to adjust the input voltage to a suitable value for the Zener Diode being tested, and resistor R2 limits the current through the diode. The signal voltage applied to the diode is also connected to the horizontal input of the oscilloscope. The voltage developed across current-measuring resistor R3 is applied to the vertical input of the oscilloscope. Therefore, the horizontal sweep will represent the applied voltage, and the vertical deflection will indicate the current through the diode under test. Figure 4-16 shows the characteristic pattern of a Zener diode; note the sharp increase in current at the Zener voltage (avalanche) point. For the Zener diode to be acceptable, this voltage must be within the limits specified by the manufacturer.

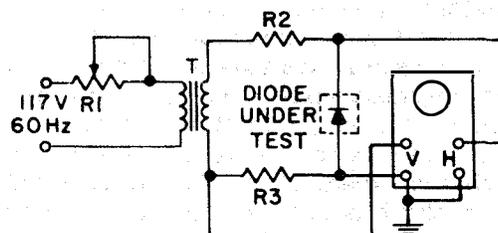
Instructions for constructing a simple in-circuit semiconductor diode and transistor tester (used in conjunction with an oscilloscope) are contained in EIB 815 of 15 November 1971.

TESTING TRANSISTORS

When trouble occurs in transistorized equipment, power supply voltage measurement, waveform checks, signal substitution or signal tracing methods are normally the first tests made. If a faulty stage is isolated by one of these test methods, voltage, resistance, and current measurements can be made to locate defective parts.



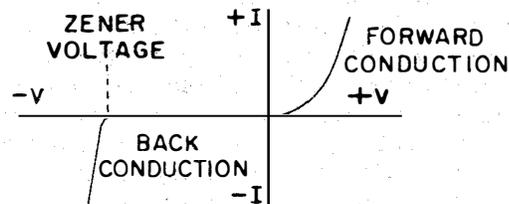
162.118
Figure 4-14.—Characteristic curve of a semiconductor diode.



162.119
Figure 4-15.—Testing Zener diode.

When making these measurements, you must make certain that the voltmeter resistance is high enough to have no appreciable effect upon the voltage being measured, and that current from the ohmmeter will not damage the transistor. If the transistors are not soldered into the equipment, it is usually advisable to remove the transistors from their sockets during a resistance test. Transistors should be removed from or reinserted into their sockets only after power has been removed from the stage, since damage by surge currents may otherwise result.

Transistor circuits other than pulse and power amplifier stages are usually biased so that the emitter current is from 0.5 to 3 milliamperes, and the collector voltage is from 3 to 15 volts. The emitter current can be measured by opening the emitter connector and inserting a milliammeter. When making this measurement, you should expect some change in bias due to the meter resistance. The collector current can often be determined by measuring the voltage drop across a resistor in the collector circuit and calculating the current. If the transistor itself is suspected, it can be tested with an ohmmeter or transistor tester as described in the following paragraphs.



162.120
Figure 4-16.—Zener diode characteristic curve.

Resistance Test

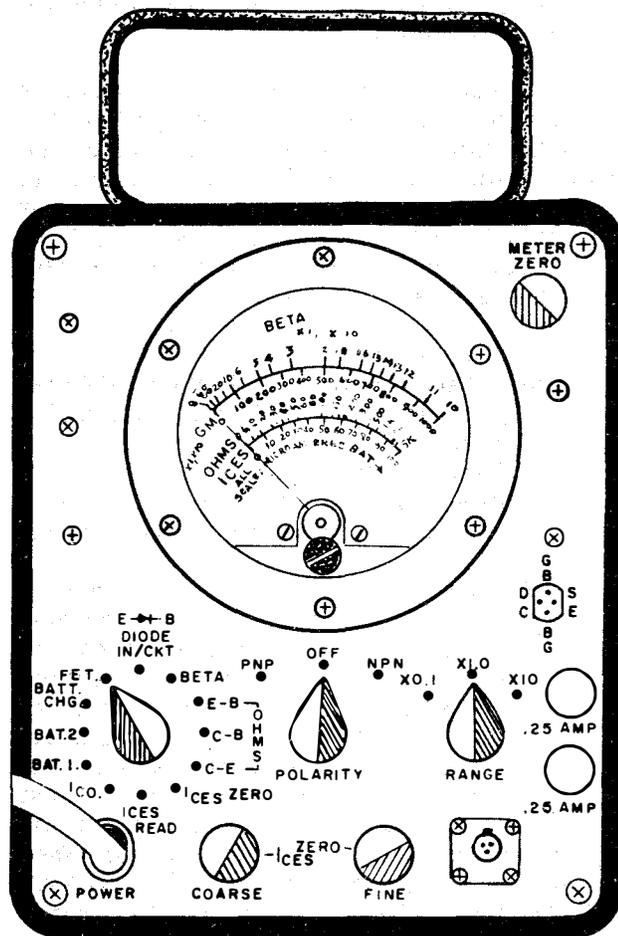
An ohmmeter can be used to test transistors by measuring the emitter-collector, base-emitter, and base-collector forward and back resistances. A back-to-forward resistance ratio on the order of 500:1 should be obtained for the collector-to-base and emitter-to-base measurements. The forward and back resistances between the emitter and collector should be nearly equal. All three measurements should be made for each transistor tested, since experience has shown that transistors can develop shorts between the collector and emitter and still have good forward and reverse resistances for the other two measurements.

Because of shunting resistances in transistor circuits, you will normally have to disconnect at least two transistor leads from the associated circuit for this test. You must exercise caution during this test to make certain that current during the forward resistance tests does not exceed the rating of the transistor. Ohmmeter ranges which require a current of more than 1 milliamperere should not be used for testing transistors. Many ohmmeters are designed so that on the RX1 range 100 milliamperes or more can flow through the electronic part under test.

Transistor Tester

Laboratory transistor test sets are used in experimental work to test all characteristics of transistors. For maintenance and repair, however, it is not necessary to check all of the transistor parameters. A check of two or three performance characteristics is usually sufficient to determine whether a transistor needs to be replaced. Two of the most important parameters used for transistor testing are the transistor current gain (Beta) and the collector leakage or reverse current (I_{CO}). These are discussed in Basic Electronics, Vol. 1, NAVPERS 10087-C.

Semiconductor test set AN/USM-206-A (fig. 4-17) is a rugged field type tester designed to test transistors and semiconductor diodes. The set will measure the Beta of a transistor, the resistance appearing at the electrodes and the reverse current of a transistor or semiconductor diode, a shorted or open condition of a diode, the forward trans-conductance of a field effect transistor, and the condition of its own batteries.



162.121
Figure 4-17.—Semiconductor Test Set
(AN/USM-206A).

In order to assure that accurate and useful information is gained from the transistor tester, the following preliminary checks of the tester should be made prior to testing any transistors:

With the POLARITY switch (fig. 4-17) in the OFF position the meter pointer should indicate exactly zero. (When required, rotate meter adjust screw on front of meter to fulfill this requirement). The POLARITY switch must always be left in the OFF position, when measurements are not actually being made, to prevent battery drain.

Always check the condition of the test set batteries by disconnecting the test set power cord, placing the POLARITY switch in the PNP position and placing the FUNCTION switch first to BAT.(1) then to BAT.(2). In both BAT positions

the meter pointer should move so as to indicate within the red BAT box.

BETA MEASUREMENTS.—If the transistor is to be tested out of the circuit, plug it into the test jack located on the right hand side below the meter shown in figure 4-17. If the transistor is to be tested in the circuit it is imperative that at least 300 OHMS exists between E-B, C-B, and C-E for accurate measurement. Initial setting of the test set controls is:

- (a) Function Switch to BETA
- (b) Polarity Switch to PNP or NPN (dependent on type of transistor under test.)
- (c) Range Switch to X10
- (d) Adjust meter zero for zero meter indication (transistor disconnected.)

NOTE: The polarity switch should remain OFF while transistor is connected to or disconnected from the test set. If it is determined that the Beta reading is less than 10, reset the range switch to X1 and reset the meter to zero.

After connecting the yellow test lead to the emitter, the green test lead to the base and the blue test lead to the collector, plug the test probe (not shown) into the Jack located at the lower right hand corner of the test set. When testing grounded equipment, unplug the 115 VAC line cord and use battery operation. Beta reading is attained by multiplying the meter reading times the range switch setting. Refer to the Transistor Characteristics book provided with the tester to determine if the reading is normal for the type of transistor under test.

ELECTRODE RESISTANCE MEASUREMENTS.—Connect the in-circuit probe test leads to the transistor with the yellow lead to the emitter, the green lead to the base, and the blue lead to the collector. Set the function switch to the OHMS E-B position and read the resistance between the emitter and base electrode on the center scale of the meter.

To read the resistance between the collector and base and the collector and emitter, set the function switch to OHMS C-B and OHMS C-E. These in-circuit electrode resistance measurements are used to correctly interpret the in-circuit Beta measurements. The accuracy of the BETA X1, X10 range is $\pm 15\%$ only when the emitter to base load is equal to or greater than 300 ohms.

ICO MEASUREMENTS.—Adjust meter zero control for zero meter indication. Plug the transistor to be tested into the Jack or connect test leads to the device under test. Set the PNP/NPN switch to correspond with the transistor under test. Set the function switch to ICO, the range switch to X0.1, X1 or X10 as specified by the transistor data book for allowable leakage. Read leakage on bottom scale, and multiply by the range setting figure as required.

DIODE MEASUREMENTS.—Diode qualitative in-circuit measurements are attained by connecting the green test lead to the cathode and the yellow test lead to the anode. Set the function switch to Diode IN/CKT and the range switch to X1. (Insure that the meter has been properly zeroed on this scale). If the meter reads down scale reverse the polarity switch. If the meter reads less than mid-scale the diode under test is either open or shorted. The related circuit impedance of this test is less than 25 ohms.

PRECAUTIONS.—Transistors, although generally more rugged mechanically than electron tubes, are susceptible to damage by excessive heat and electrical overload. The following precautions should be taken in servicing transistorized equipment:

1. Test equipment and soldering irons must be checked to make certain that there is no leakage current from the power source. If leakage current is detected, isolation transformers must be used.
2. Ohmmeter ranges which require a current of more than 1 milliampere in the test circuit should not be used for testing transistors.
3. Battery eliminators should not be used to furnish power for transistor equipment because they have poor voltage regulation and, possibly, high ripple voltage.
4. The heat applied to a transistor, when soldered connections are required, should be kept to a minimum by using a low-wattage soldering iron and heat shunts, such as long-nose pliers on the transistor leads.
5. All circuits should be checked for defects before a transistor is replaced.
6. The power should be removed from the equipment before replacing a transistor or other circuit part.
7. When working on equipment with closely spaced parts, conventional test probes are often the cause of accidental short circuits between

adjacent terminals. Momentary short circuits, which rarely cause damage to an electron tube, may ruin a transistor. To avoid accidental shorts, the test probes can be covered with insulation for all but a very short length of the tips.

SIGNAL GENERATORS

In the maintenance of electronic equipment, it is often necessary to employ standard sources of a.c. energy, both audio-frequency and radio frequency. These sources are called signal generators. They are used in testing and aligning radio transmitters, receivers, and amplifiers, they are also used when troubleshooting various electronic devices, and sometimes for measuring frequency.

The principal function of a signal generator is the production of an alternating voltage of the desired frequency and amplitude which has the necessary modulation for the test or measurement concerned. It is very important that the amplitude of the generated signal be correct. In many generators, output meters are included in the equipment so that the output may be adjusted and maintained at a standard level over a wide range of frequencies.

When using the generator, the output test signal is coupled into the circuit being tested, and its progress through the equipment is traced by the use of high-impedance indicating devices such as vacuum tube voltmeters or oscilloscopes. In many signal generators, calibrated networks of resistors, called attenuators, are provided. These are used to regulate the voltage of the output signal and also provide correct impedance values for matching the input impedance of the circuit under test. Accurately calibrated attenuators are used, as the signal strength must be regulated to avoid overloading the circuit receiving the signal.

There are many types of signal generators. They may be classified roughly by frequency into audio generators, video signal generators, radio-frequency generators, frequency-modulated RF generators, and special types which combine all of these frequency ranges.

AUDIO AND VIDEO SIGNAL GENERATORS

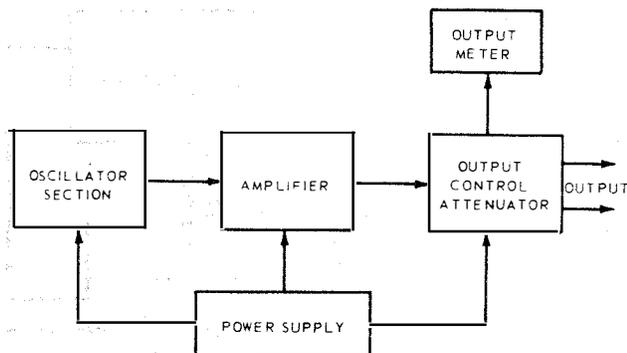
Audio signal generators produce stable audiofrequency signals used for testing audio equipment. Video signal generators produce signals which include the audio range and extend

considerably further into the RF range. These generators are used in testing video amplifiers and other wideband circuits. In both audio and video generators, the major components include a power supply, an oscillator (or oscillators), one or more amplifiers, and an output control. Voltage regulation circuits are necessary to insure stability of the oscillator in generators which derive power from 115-volt, a.c. sources. In portable generators, battery power supplies are usually used, and these require no voltage regulation.

In the audio and video generators of the beat-frequency type the output frequency is produced by mixing the signals of two radio-frequency oscillators, one of which is fixed in frequency and the other variable. The difference in frequency of the two is equal to the desired audio or video frequency.

Audio signal generators often include RC oscillators in which the audiofrequency is directly produced. In these, a resistance-capacitance circuit is the frequency determining part of the oscillator. The frequency varies when either the resistance or the capacitance is changed in value. In commercial generators, however, the capacitance alone is often chosen as the variable element. The change in frequency which can be produced by this method is limited, and it is usually necessary to cover the entire range of the generator in steps. This is accomplished by providing several RC circuits, each corresponding to a portion of the entire range of frequency values. The circuits in the oscillator are switched one at a time to give the desired portion of the audio range.

The amplifier section of the block diagram (fig. 4-18 usually consists of a voltage amplifier



20.482

Figure 4-18.—Block diagram of audio or video signal generator.

and one or two power amplifiers. These are coupled by means of RC networks, and the output of the final power amplifier is often coupled to the attenuator, or output control, by means of an output transformer.

The output control section provides a means of matching the output signal to the input of the equipment under test and regulating the amplitude of the signal.

RADIOFREQUENCY SIGNAL GENERATORS

A typical radiofrequency signal generator contains, in addition to the necessary power supply, three main sections; an oscillator circuit, a modulator, and an output control circuit. The internal modulator modulates the radio frequency signal of the oscillator. In addition, most RF generators are provided with connections through which an external source of modulation of any desired waveform may be applied to the generated signal. Metal shielding surrounds the unit to prevent the entrance of signals from the oscillator into the circuit under test by means other than through the output circuit of the generator.

A block diagram of a representative RF signal generator is shown in figure 4-19. The function of the oscillator stage is to produce a signal which can be accurately set in frequency at any point in the range of the generator. The type of oscillator circuit used depends on the range of frequencies for which the generator is designed. In low-frequency signal generators, the resonating circuit consists of one of a group of coils combined with a variable capacitor. One of the coils is selected with a range selector

switch which attaches it to the capacitor to provide an LC circuit which has the correct range of resonant frequencies.

The function of the modulating circuit is the production of an audio (or video) voltage which can be superimposed on the RF signal produced by the oscillator. The modulating signal may be provided by an audio oscillator within the generator (internal modulation), or it may be derived from an external source. In some signal generators, either of these methods of modulation may be employed. In addition, a means of disabling the modulator section is used whereby the pure unmodulated signal from the oscillator can be used when it is desired.

The type of modulation used depends on the application of the particular signal generator. The modulating voltage may be either a sine wave, a square wave, or pulses of varying duration. In some specialized generators, provision is made for pulse modulation in which the RF signal can be pulsed over a wide range of repetition rates and at various pulse widths.

Usually the output circuit of the generator contains a calibrated attenuator and often an output level meter. The output level meter gives an indication of, and permits control of, the output voltage of the generator by indicating arbitrary values of output read in tenths through the value of one. The attenuator selects the amount of this output. The attenuator, a group of resistors forming a voltage-dropping circuit, is controlled by a knob which is calibrated in microvolts. When the control element is adjusted so that the output meter reads unity (1.0), the reading on the attenuator knob gives the exact value (no multiplication factor) of the output in microvolts. If output voltage is desired at a lower

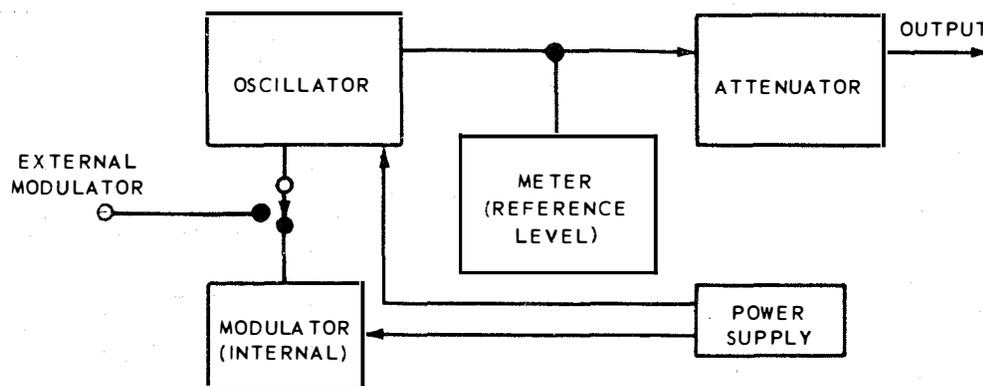


Figure 4-19.—Block diagram of RF signal generator.

value, the control is varied until the meter indicates some decimal value less than one, and this decimal is multiplied by the attenuator reading to give the output in microvolts.

Frequency-modulated RF signal generators are widely used for testing frequency-modulated receivers and for visual alignment (using an oscilloscope) of AM receivers. A frequency-modulated signal is an alternating voltage in which the frequency varies above and below a given center frequency value. The overall frequency change is called the frequency swing.

There are several methods by which the frequency of the oscillator in the signal generator may be frequency modulated. In one type of FM generator, use is made of a vibrating plate which forms one of the elements of the tuning capacitor of the oscillator to be modulated. The plate is driven by a device similar

to a magnetic loudspeaker. The audio modulating voltage is applied to the driving coil which moves in the field of a permanent magnet and vibrates the plate of the capacitor at the applied audio frequency. Movement of the plate causes variation of the capacitance in the oscillator tuning circuit with the result that the frequency of the oscillator is periodically raised or lowered.

Another method of producing frequency modulation is based on the action of a reactance tube which is connected in parallel with the tuning circuit of the oscillator to be modulated.

In signal generators of microwave frequencies, frequency modulation is accomplished in the oscillator by applying the modulating voltage to the repeller plate of the reflex klystron tube, which is usually employed in these generators.

CHAPTER 5

INTRODUCTION TO COMMUNICATION SYSTEMS

Until recently, the term "radio communications" brought to mind either telegraphy (CW), voice (AM), or possibly teletype (RATT) communications. Today, radio communications has become a highly sophisticated field of electronics. Even the small Navy ships have the capabilities for "coming up" on the commonly used ship-to-ship, ship-to-air, and ship-to-shore communications circuits. These circuit operations are accomplished through the use of compatible and flexible communication systems.

A communication system (as will be seen later) consists of two or more sets, each having its own separate identity, arranged and interconnected to perform a circuit operation that cannot be performed by any one of the individual sets alone. Navy communication systems vary from simple to the very complex, depending upon the circuit operations involved. Each system requires the integrated use of various types of equipments. Thus, a large number of sets, groups and units are involved when several systems must be operated separately and simultaneously. The concept of shipboard efficiency not only dictates where these sets, groups and units will be located physically, but also that they be installed in a manner permitting operating flexibility for the various system applications. This flexibility is provided through a complex arrangement of interconnections which allows the physically separated sets, groups and units to be selectively switched (patched) into the different circuit configurations.

Most shipboard communications equipment is, at one time or another, used in one or more different system operations. Therefore, it is important for the Electronics Technician to know how to perform maintenance at a system level as well as on the individual equipments.

This chapter begins by defining a system and explaining how it is broken down into the various subdivisions, then continues by presenting a

brief discussion of Navy CW, voice, teletype, satellite, and facsimile communication systems. These systems are discussed further in subsequent chapters of this manual.

INTRODUCTION TO SYSTEMS

As naval electronics has grown in capabilities, complexity, and extent, an orderly plan of designations has been adopted. The largest designator, SYSTEM, describes equipments that work together for a specific function. For example, a ship's radar system includes every item of electronics equipment used for or with a radar on board that ship. The smallest designator, PART, describes one single piece, such as a bolt, or a resistor.

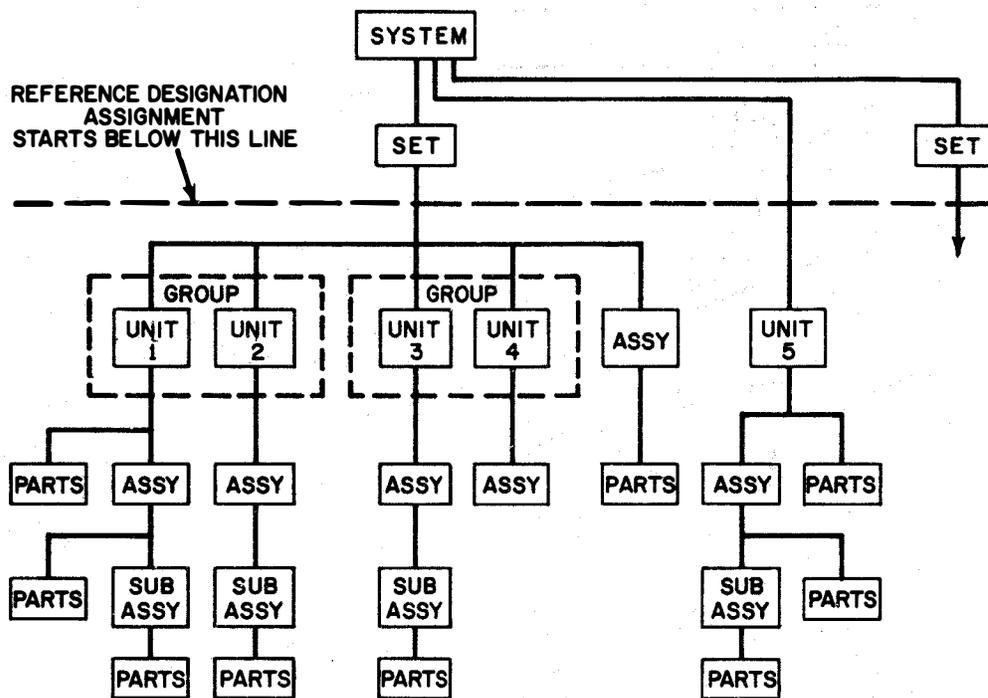
You will find that the majority of your troubleshooting will be system oriented. A system is subdivided into sets, groups, units, assemblies, subassemblies, and parts as shown in figure 5-1.

SYSTEM

A system is a combination of parts, assemblies, and sets joined together to perform a specific operational function or functions, such as a communications system, a radar system, or a navigation system. Figure 5-2 is a pictorial view of a typical communications system containing the necessary components for transmission and reception of voice, CW and teletype signals. Figure 5-3 is a block diagram of the same communication system with the arrows showing the direction of signal flow.

SET

A set consists of a unit or units and the necessary assemblies, subassemblies and parts connected or associated together to perform an

EQUIPMENT DIVISIONS FOR
REFERENCE DESIGNATIONS

REFERENCE DESIGNATIONS ARE ALWAYS ASSIGNED DOWN TO LOWEST
LEVEL (PARTS). THE FINAL WIRED CABINET IS THE UNIT.

162.122

Figure 5-1.—System subdivision.

operational function, such as a radio receiving set, or a radio transmitting set.

Figure 5-4 is a block diagram of a radio transmitting set which consists of a radio frequency amplifier unit (1), a radio transmitter unit (2), a power supply unit (3), and an antenna coupler group.

GROUP

A group is a collection of units, assemblies or subassemblies, which is a subdivision of a set or system, but is not capable of performing a complete operational function. The antenna coupler group in figure 5-4 requires power and signals from the radio frequency amplifier unit for operation.

UNIT

A unit is an assembly or any combination of parts, subassemblies and assemblies mounted together, normally capable of independent operation in a variety of situations.

ASSEMBLY

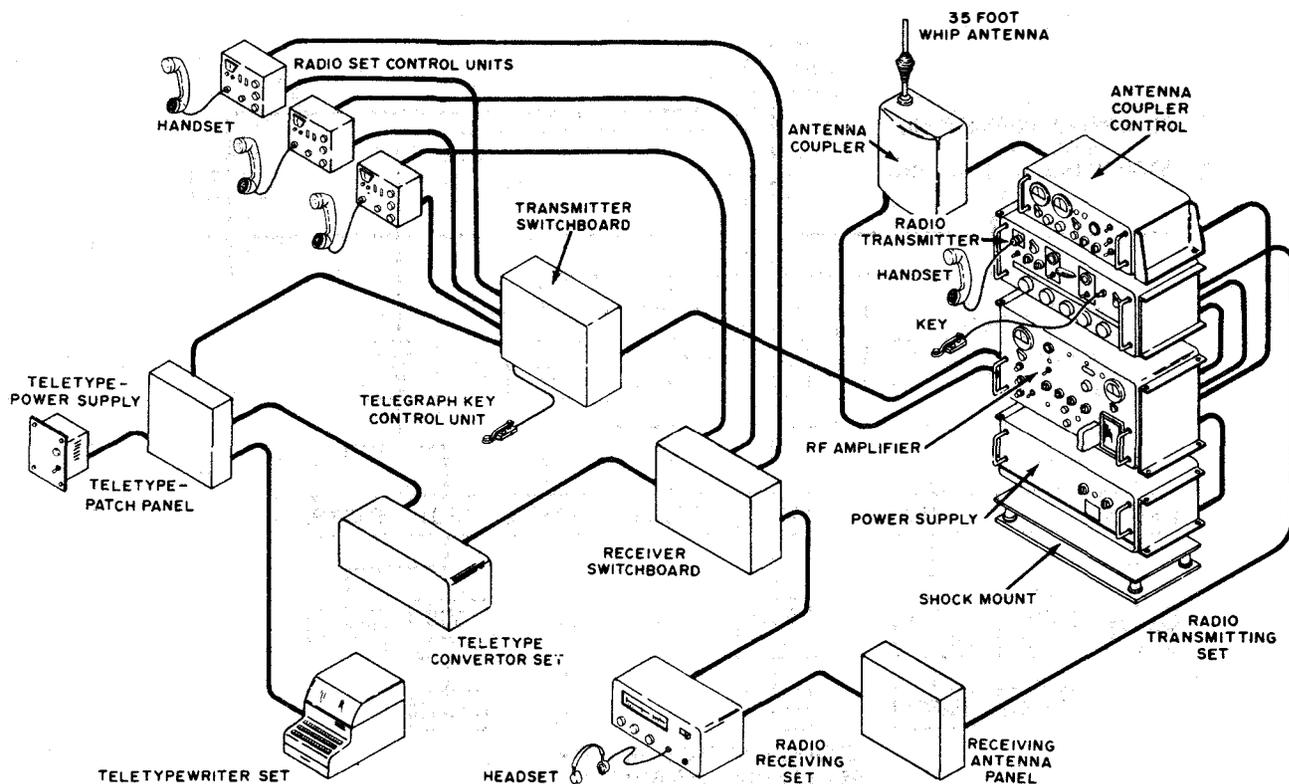
An assembly is a number of parts or subassemblies, or any combination thereof joined together to perform a specific function. Figure 5-5 shows a unit (2) consisting of six assemblies and an assembly (A6) which consists of six subassemblies.

SUBASSEMBLY

A subassembly consists of two or more parts which form a portion of an assembly or a unit, replaceable as a whole, but having a part or parts which are individually replaceable.

The distinction between an assembly and a subassembly is not always exact; an assembly in one instance may be a subassembly in another when it forms a portion of an assembly.

Figure 5-6 shows a printed circuit board subassembly and some of the parts which may be mounted on it.



120.66

Figure 5-2.—Communication system pictorial view.

PART

A part is one piece, or two or more pieces joined together which are not normally subject to disassembly without destruction of the designed use, such as resistors, capacitors and transistors.

REFERENCE DESIGNATIONS

Each set within a system has an "AN" nomenclature assigned. Each unit, assembly, subassembly and part of a set has an assigned reference designation. The reference designation consists of letters or numbers, or both, used to identify and locate specific units, assemblies, subassemblies and parts.

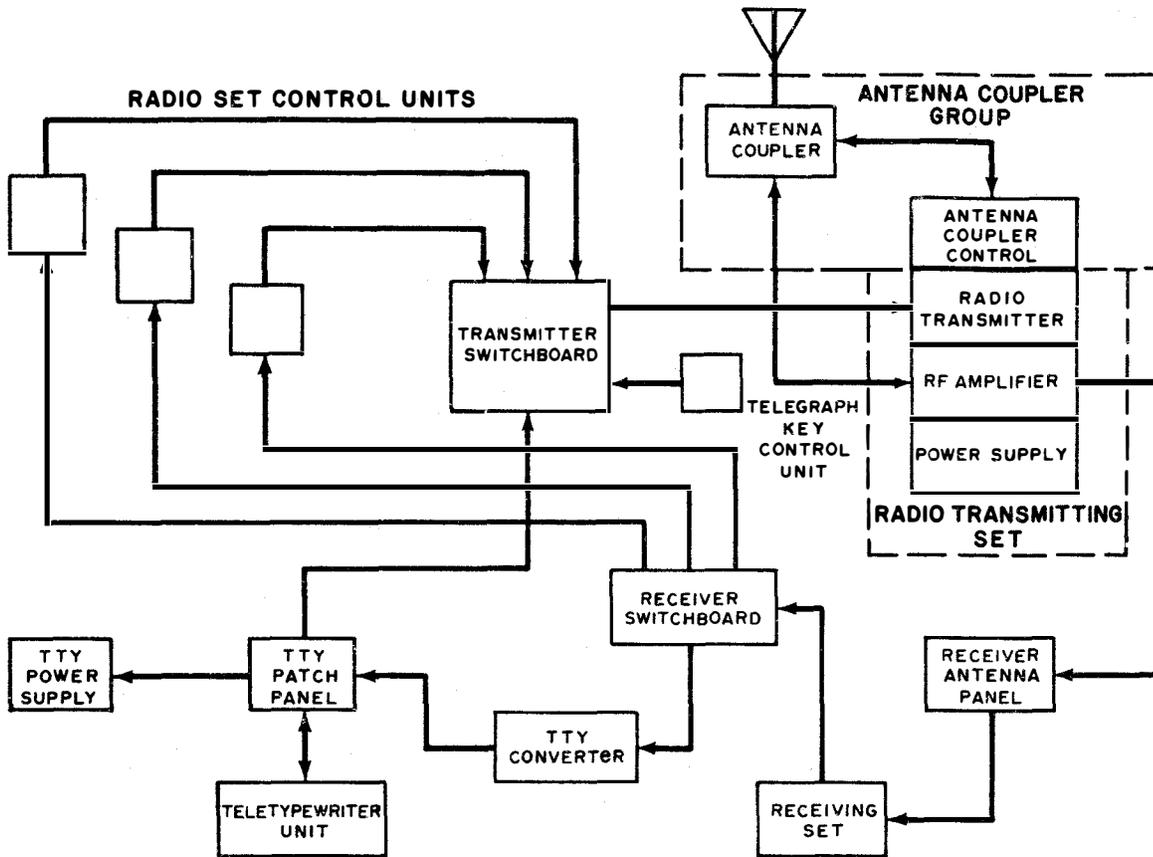
Each unit within a set is assigned an identifying number. This number will begin with one and run consecutively for all units of the set. This number is the reference designation of the unit. Figure 5-3 shows a radio transmitting set AN/URT-xx and the unit numbers (1, 2, 3). Note that the units may also have an AN nomenclature, such as T-xxx/URT.

The reference designation of an item (assembly, subassembly or basic part) which is a portion of an assembly consists of the following, in the order listed:

- (1) the unit number identifying the unit which contains the particular assembly
- (2) the basic reference designation for the particular assembly
- (3) the basic reference designation for the part located in the particular assembly

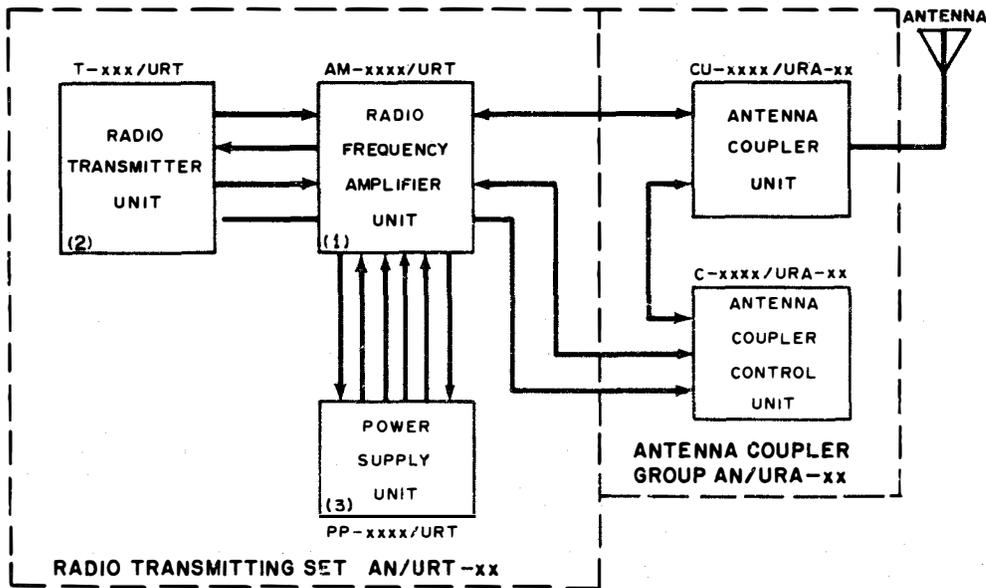
For example, the reference designation 2A4C3 identifies capacitor C3, which is on assembly A4 in unit 2. The actual location can be seen in figure 5-7. The reference designations may be expanded or reduced to as many levels as required to identify a particular part. For example, in figure 5-7 the reference designation 2A2A3C1 locates capacitor C1 on subassembly A3, which is on assembly A2, which is in unit 2; another example is 2J1, which identifies jack J1, which is mounted directly on unit 2.

Partial reference designations are used to save space on diagrams. For example, in figure



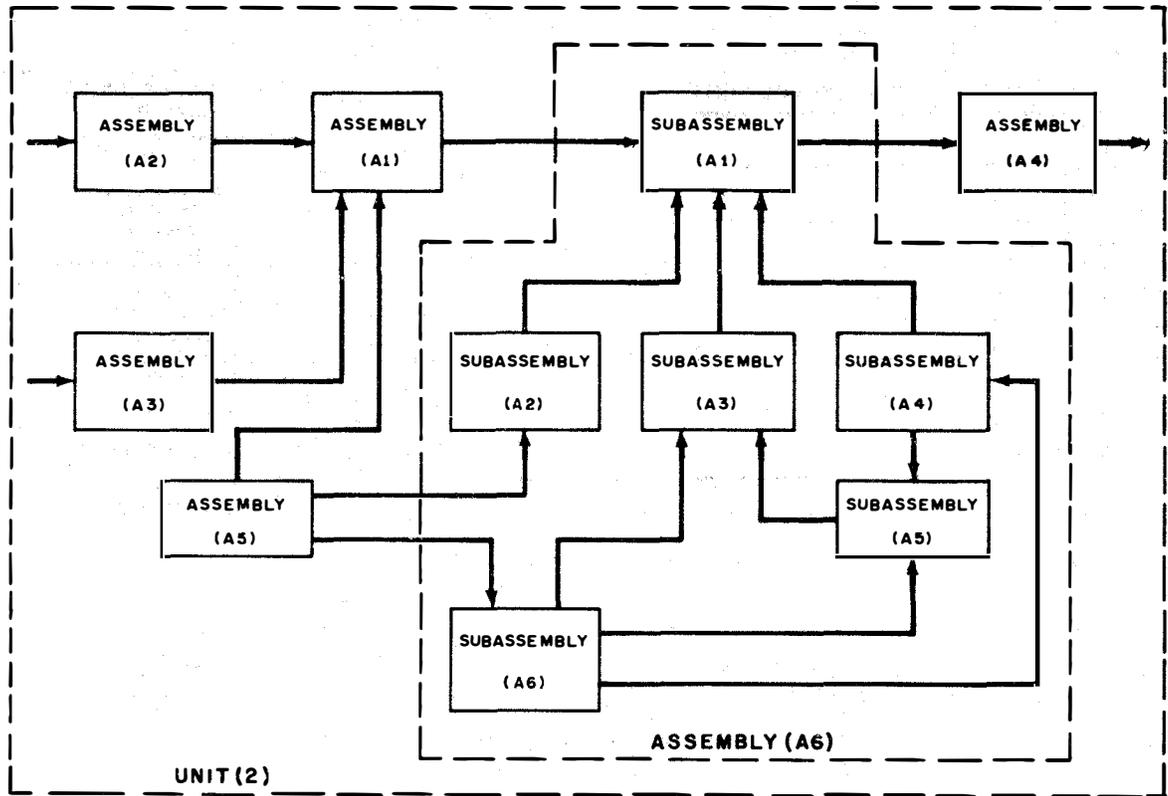
162.123

Figure 5-3.—Communication system block diagram.



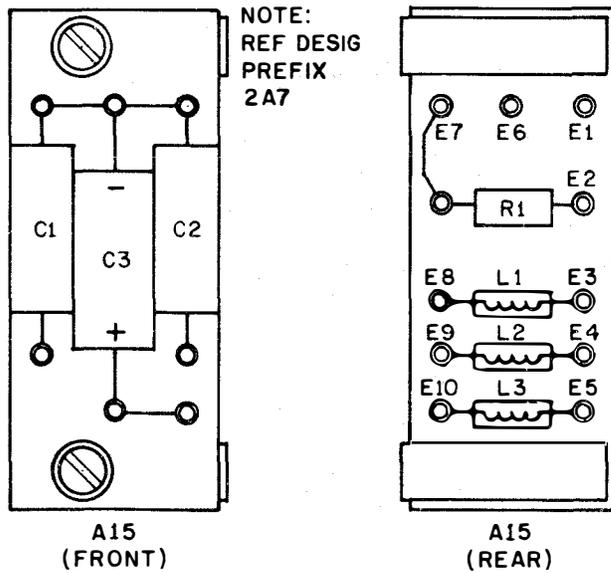
162.124

Figure 5-4.—Radio transmitting set.



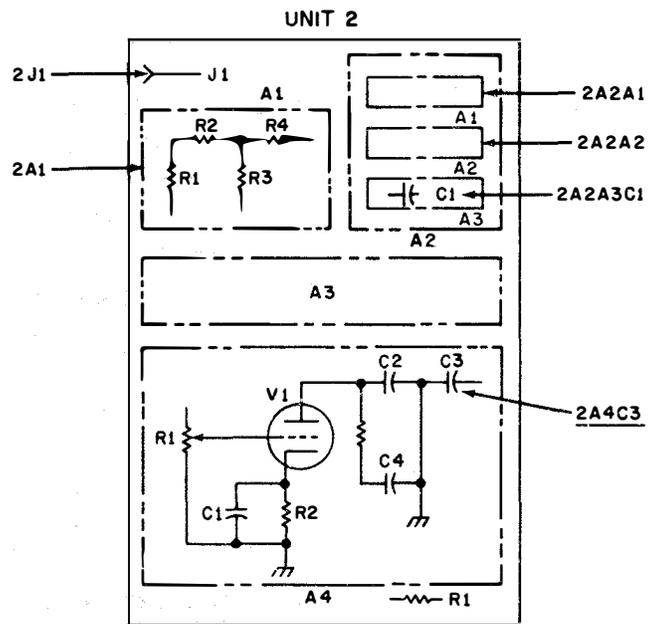
162.125

Figure 5-5.—Unit and assemblies.



162.126

Figure 5-6.—Typical subassembly.



162.127

Figure 5-7.—Reference designations.

5-6 partial reference designations are placed near the parts on subassembly A15 and a note indicating the reference designation prefix is added. To identify capacitor C3 on subassembly A15, the complete reference designation would be 2A7A15C3.

TYPES OF RADIO EMISSIONS

By international agreement, the various types of radio emissions (transmissions) are assigned designations as shown in table 5-1. A designation may be preceded by a numerical value to indicate its necessary bandwidth in kilohertz.

CW SYSTEMS

Continuous wave, is one of the oldest and least complicated forms of radio communications. The system consists of little more than

a transmitter and receiver connected so as to facilitate their control from a central location as shown by figure 5-8.

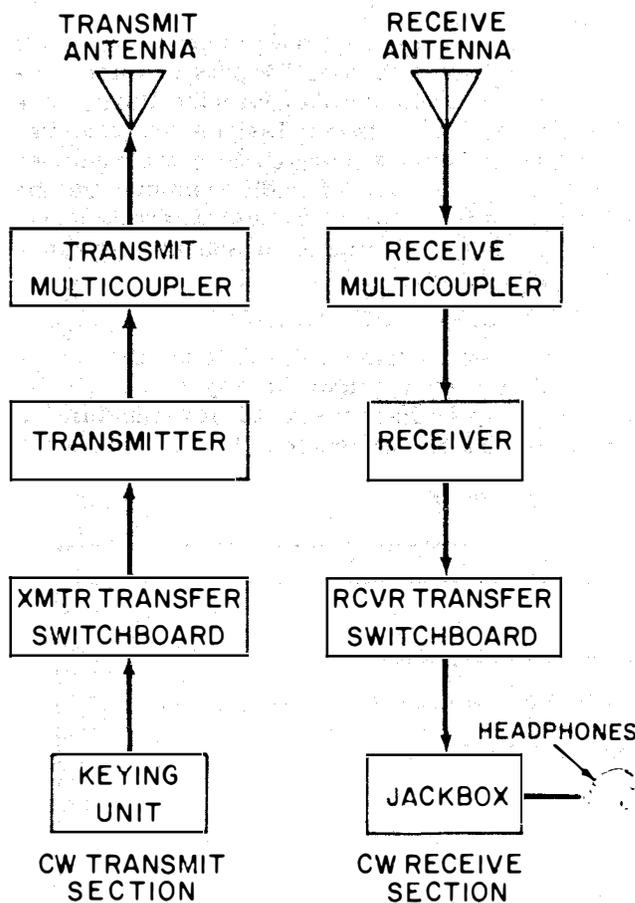
The transmitter (fig. 5-8) is keyed on and off to produce short or long RF pulses which correspond to the dots and dashes of the Morse code characters. These transmissions are received through headphones plugged into the receiver jack box. This type of radio communications (although old) is still in use and at certain times is still the most reliable means of long range communications.

ANTENNAS AND MULTICOUPLERS

The antennas used with CW and other communication systems may be any of the several shipboard types that are suitable for transmitting and receiving RF emissions. Multicouplers (or

Table 5-1.—Types of radio emissions

| AM | FM | MODULATION |
|-----|----|--|
| A0 | F0 | No modulation intended to carry intelligence. |
| A1 | F1 | On-off or mark-space keying without the use of a modulating tone. |
| A2 | F2 | On-off or mark-space keying of a modulating audio frequency, or of the modulated emission. |
| A3 | F3 | Voice-frequency modulating, including simplex AFTS RATT. |
| A3A | | Single-sideband, reduced carrier (SSB). |
| A3B | | Two independent sidebands (ISB). |
| A3H | | Single-sideband, full carrier (compatible SSB). |
| A3J | | Single-sideband, suppressed carrier (SSSC). |
| A4 | F4 | Facsimile, with modulation of main carrier directly or by a frequency-modulated subcarrier. |
| A4A | | Facsimile using single-sideband, reduced carrier. |
| A5 | F5 | Television. |
| A5C | | Television, vestigial sideband. |
| | F6 | Four-frequency duplex telegraphy (RFCS RATT). |
| A7 | | Multi-channel voice-frequency telegraphy (AFTS MUX). |
| A7A | | Multi-channel voice-frequency telegraphy (AFTS MUX) using single-sideband, reduced carrier. |
| A7B | | Multi-channel voice-frequency telegraphy (AFTS MUX) using two independent sidebands. |
| A7J | | Multi-channel voice-frequency telegraphy (AFTS MUX) using single-sideband, suppressed carrier. |
| A9 | F9 | Cases not covered by above (e. g., a combination of telephony and telegraphy). |
| A9B | | Combinations using two independent sidebands. |



162.129

Figure 5-8.—CW systems.

filter assemblies) are used so that several transmitters and/or receivers may be operated from the same antenna.

The specified overall frequency response of an antenna filter assembly, or multicoupler, is divided into several smaller RF ranges, or channels, through the use of tuned circuits or filter subassemblies. All of these channels may be used independently or simultaneously with any of the other channels.

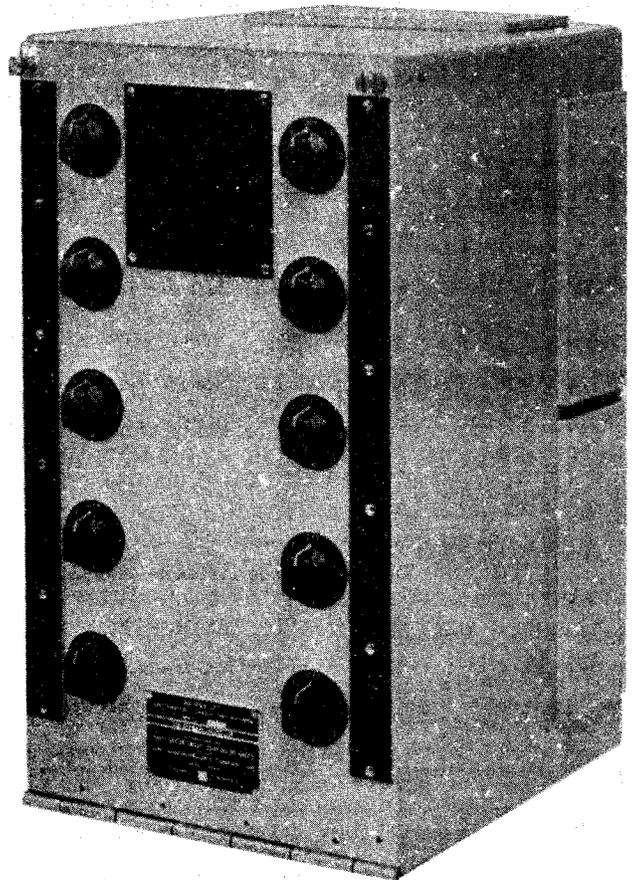
The filters not only guard against interference at frequencies falling outside the channel being used, but also prevent receivers connected to alternate channels from interacting with each other when their tuning or trimming adjustments are made.

A given Navy communications receiver generally operates throughout a frequency range that spans several of the smaller RF bands, or channels, provided by the multicoupler. For operation

on any given frequency, the receiver must be connected to the output of the particular RF channel of the multicoupler or filter that will pass the desired signals. Connection is normally made by means of a coaxial patch cord and a patch panel as discussed later in this manual.

TRANSFER SWITCHBOARDS

The transmitter transfer switchboard provides facilities for selectively transferring remote control station functions and signals to the transmitters. A representative transfer switchboard (fig. 5-9) provides facilities for selectively transferring any one, or all, of ten remote control station functions and signals to any one of six transmitters. The cabinet has ten rotary switches, arranged in two vertical rows of five switches each. Arrangement of the circuitry is such that it is impossible to parallel



70.64

Figure 5-9.—Transmitter Transfer Switchboard (SB-988/SRT)

transmitter control circuits, that is to connect more than one transmitter to any remote control station.

Each switch operating knob corresponds to a remote control station. Each rotary switch position (one through six) corresponds to a controlled transmitter. Rotary position X corresponds to an extension providing for the transfer of all circuits to additional Transmitter Transfer Switchboards when more than six transmitters are installed in the system.

When it is required, for example, that remote control station number two is to have control of transmitter number three; switch knob designated number two is rotated until its pointer indicates position three on its respective dial plate. Any of the remote stations may thus be connected to control any of the transmitters installed in the system.

The receiver transfer switchboard provides for transferring the audio output from the receivers to remote control station audio circuits. A representative receiver transfer switchboard is shown in figure 5-10. This switchboard contains 10 seven-position switches. Each switch relates to a remote control station, and each switch position (1 through 5) relates to a receiver.

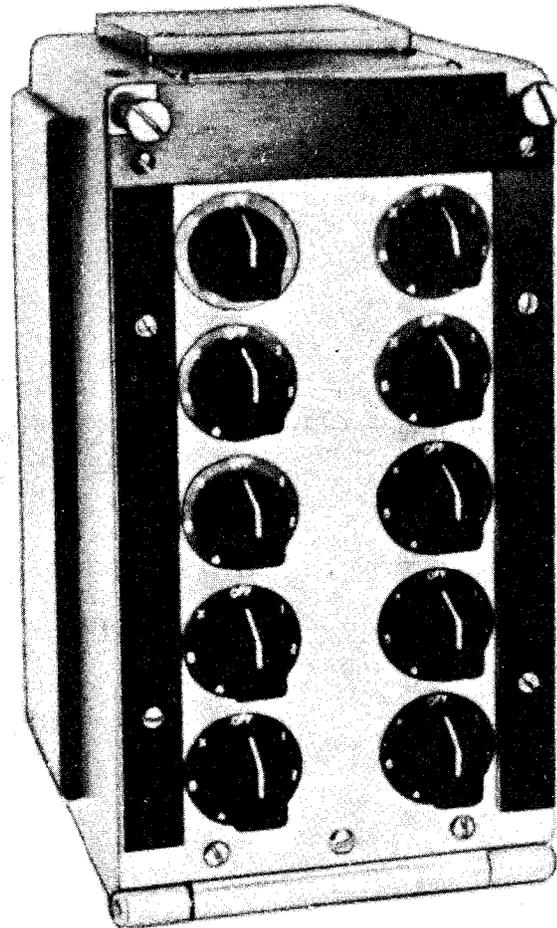
Position X on each switch serves to transfer the circuits to additional switchboards as in the case of the transmitter transfer switchboard.

KEYING UNIT

The keying unit provides control (on/off and keying) of the transmitter selected on the transmitter transfer switchboard. A representative unit is shown in figure 5-11. Located on the plastic control panel are a toggle switch for turning the transmitter on and off, an indicator light that glows red when the transmitter is on, a telegraph key for keying the transmitter, and a key jack that provides for an auxiliary telegraph key.

VOICE SYSTEMS

Voice systems are probably the most used form of radio communications aboard Navy ships. Either amplitude or frequency modulation may be used provided all units in the voice net use the same mode of emissions (all on AM or all on FM). A typical non-secure voice system consists of one or more radio set control units, usually referred to as radiophone or remote



120.16
Figure 5-10.—Receiver Transfer Switchboard (SB-973/SRR).

phone units (RPU), patched to transmitter and receiver sets (or transceivers) via transfer switchboards (fig. 5-12A). If remote channel selection is required the remote channel selector is patched through a separate switch panel (fig. 5-12B).

The push-to-talk button on the handset closes the d. c. keying circuit to the transmitter, (fig. 5-12A) placing the transmitter on the air. The audio signal and d. c. keying voltage from the handset are patched through the transmitter transfer switchboard to the transmitter. The audio signal modulates the RF signal generated by the transmitter, and this modulated RF signal is radiated by the transmitter antenna.

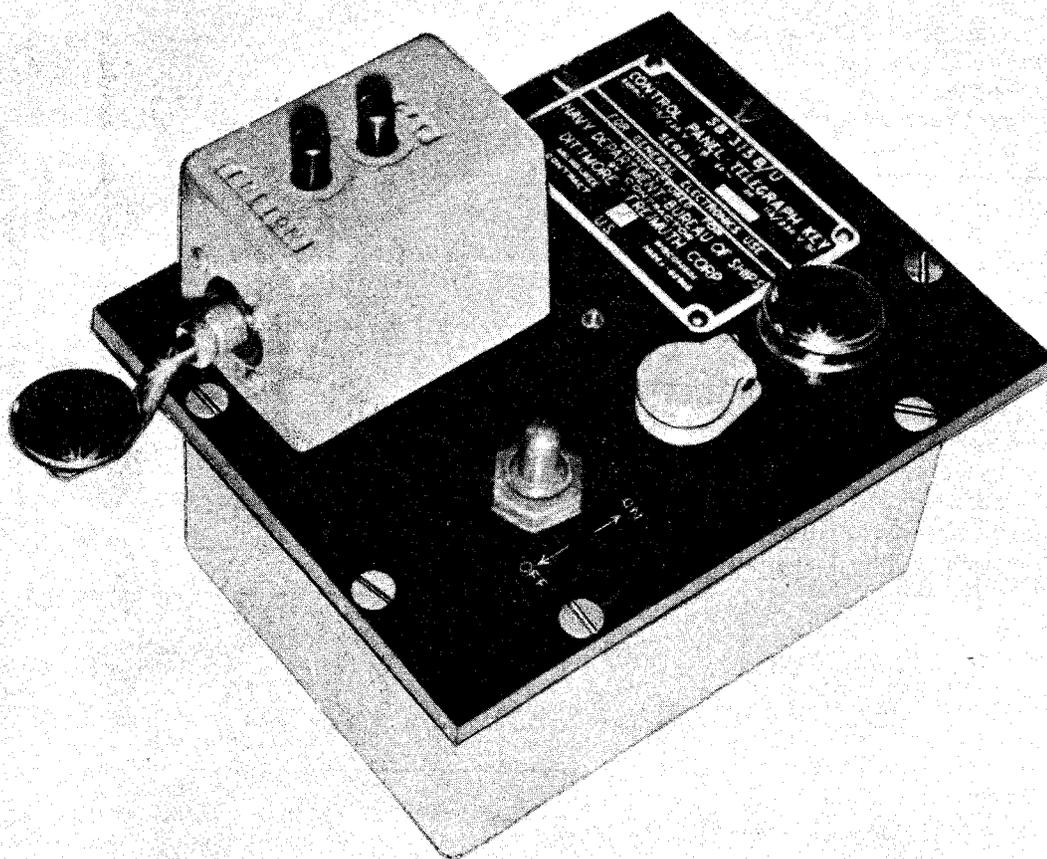


Figure 5-11.—Control Panel Telegraph Key (SB-315B/U).

120.18

On the receive side, the RF signal is picked up by the receiver antenna and fed through the coupler or multicoupler to the receiver where demodulation takes place, resulting in an audio signal output. This audio signal output from the receiver is patched through the receiver transfer switchboard to the RPU and loudspeaker.

The speaker amplifier (fig. 5-12A) is a simple audio amplifier (such as the AM-215/U) which drives one or more speakers. The volume control is adjusted to a comfortable listening level. The transfer switchboards are of the same type and perform the same functions as those described for CW systems.

RADIO SET CONTROL UNIT

The radio set control unit (fig. 5-12A) provides facilities to remotely control certain

radiophone transmitter functions and the receiver output. Circuits are provided for turning the transmitter on and off, for voice modulating the transmission (or keying when CW operation is desired) and for controlling the audio output level of the receiver.

A representative radio set control unit is shown in figure 5-13. Under standard operating conditions, as many as four of these, or similar units, may be paralleled to a single transmitter/receiver group to provide additional operating positions.

SECURE VOICE SYSTEMS

Wideband UHF/VHF secure voice is used extensively for shipboard line-of-sight voice communications. A typical system (fig. 5-14)

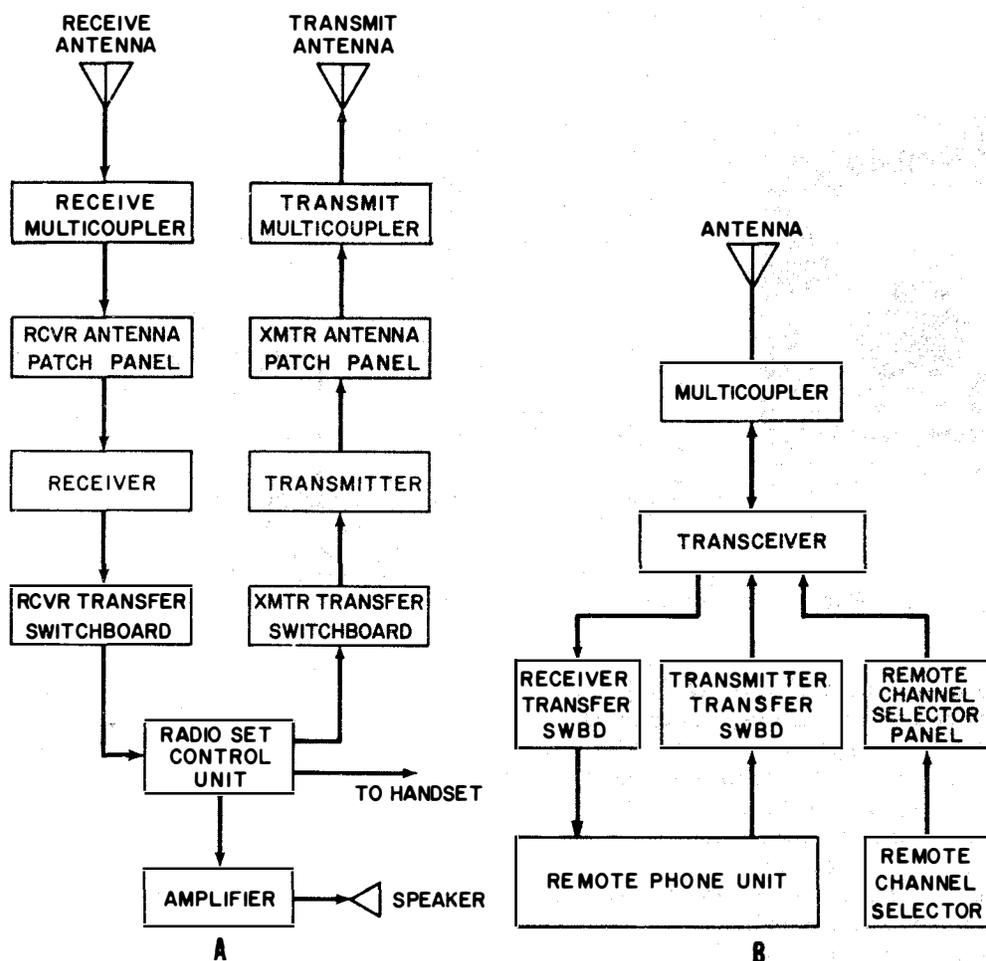


Figure 5-12.—Nonsecure voice systems.

162.130

consists of the antenna connected through a coupler or multicoupler to a transceiver. The transceiver is patched through the switchboards to security (crypto) equipment. The security equipment is connected through a matrix or network to the remote phone units.

When the operator speaks into the handset, the audio signals are patched through the matrix to the security equipment. The security equipment encrypts (scrambles) the audio signals. The encrypted signals are then applied to the transmitter section of the transceiver where they modulate the RF carrier and are radiated by the antenna system.

The modulated RF carrier is received and demodulated by the receiver section of the transceiver, resulting in encrypted audio signals. The encrypted audio signals are then applied to the

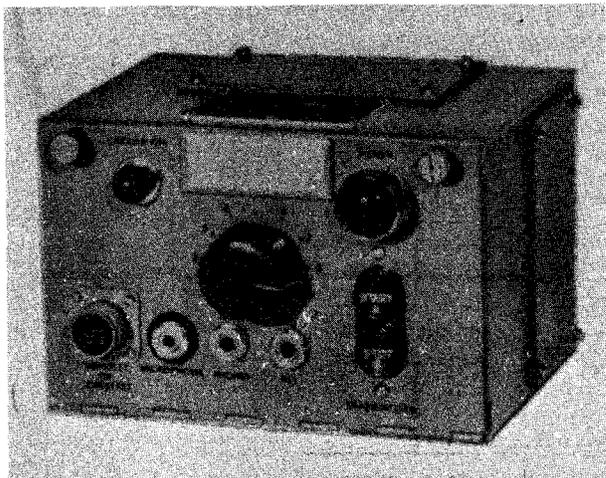
security equipment where they are decrypted (unscrambled) and converted back to audio signals. The audio signals are then patched through the matrix to the remote phone unit.

TELETYPE SYSTEMS

Teletype Communication Systems provide high speed accurate transmission and reception of intelligence over lines and by radio. As an ET you will be concerned with radio teletype (RATT) systems. Teletype messages may be received and cut on tape at the same time, thus enabling the operator to relay a message almost immediately.

BASIC PRINCIPLES

To see how intelligence is sent via teletype, one of the simpler devices for electrical



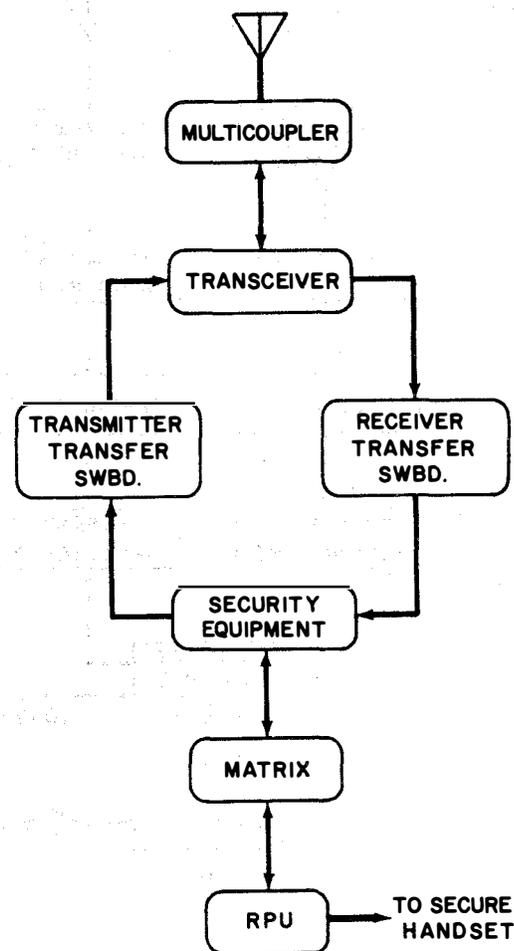
7.40.2A

Figure 5-13.—Radio set control.

communications—the manual telegraph circuit—is first considered. This circuit, shown in figure 5-15, includes a telegraph key, a source of power (battery), a sounder, and a movable sounder armature. If the key is closed, current flows through the circuit and the armature is attracted to the sounder by magnetism. When the key is opened, the armature is retracted by a spring. With these two electrical conditions of the circuit—closed and open—it is possible, by means of a code, to transmit intelligence. These two conditions of the circuit are referred to as MARKING and SPACING. One condition occurs when the circuit is closed, and a current flows; the other condition occurs when it is open, and no current flows.

If the key at station A is replaced by a transmitting teletypewriter and the sounder arrangement at station B is replaced by a receiving teletypewriter, the basic teletypewriter circuit shown in figure 5-16 is formed.

If a teletypewriter signal could be drawn on paper, it would resemble figure 5-17. This is the code combination for the letter R. Shaded areas show intervals during which the circuit is closed, and the blank areas show the intervals during which the circuit is open. There are a total of seven units in the signal. Five of these are numbered, and are called INTELLIGENCE units. The first and last units of the signal are labeled START and STOP. They are named after their functions: the first starts the signal, and last stops it. These are a part of every teletypewriter

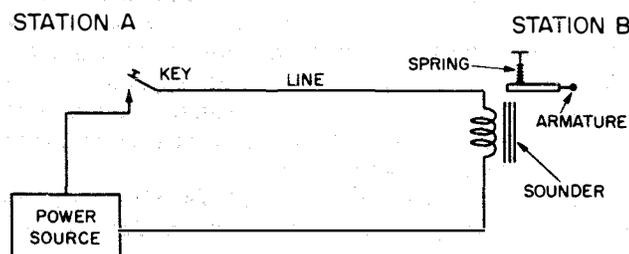


162.131

Figure 5-14.—Secure voice system.

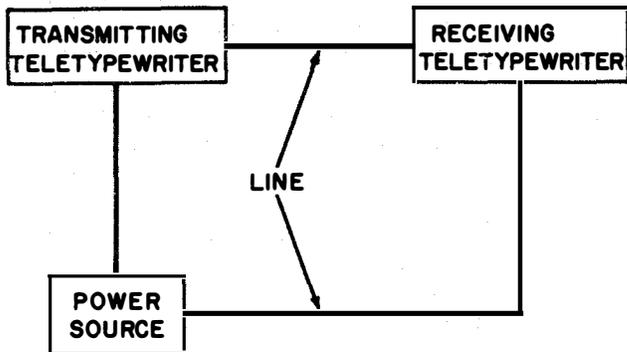
code signal; the START unit is always spacing, and the STOP unit is always marking.

Examine figure 5-17 again. This is theoretically a perfect signal. The time between each unit remains the same during its transmission



1.196

Figure 5-15.—Manual telegraph circuit.



1.200

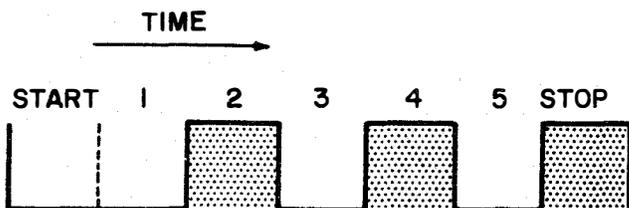
Figure 5-16.—Simple teletype circuit.

and the shift from mark to space (and vice versa) is called a TRANSITION. A transition occurs at the beginning and end of each unit when it shifts from mark to space or space to mark, and there will be only 2, 4, or 6 transitions for each character.

When figuring time duration of a signal character, no allowance for transition time is made as the transition is instantaneous and is considered to have zero time duration. The time duration for each unit is measured in milliseconds.

Codes

In manual telegraphy, the most widely used code is the Morse code. In this code, two distinctive signal elements are employed, the dot and the dash. The difference between a dot and a dash is usually one of time duration, a dash being three times as long in duration as a dot. Each character is made up of a number of dots and/or dashes. The dot and dash elements constituting any character are separated from each other by a time interval equal to the duration of one dot. The time interval between the characters for



1.197

Figure 5-17.—Mark and space signals.

each word is equal to the duration of three dots, and the interval between words is equal to seven dots.

In teletypewriter operation, the code group for each character is of uniform length. Since the Morse code is an uneven length code, it cannot be used in teletypewriter operation, without additional code converters.

The 5-unit (5-level) code has been the most commonly used code in modern printing telegraphy, and is universally employed for teletypewriter operation. The mechanical sending device in the teletypewriter divides the sending time for each character into five short code elements (impulses) of equal duration. The 5-unit code is an example of what is called an even length or constant length code; i.e., one in which the number of signal elements for a character is the same for every character, and the duration of each element is constant. In the 5-unit code, each character consists of a combination of 5-signal elements, and each element may consist of either of two basic signaling conditions (marking or spacing). Thus, a total of 2^5 or 32 combinations of the signal elements is possible with this arrangement.

The 32 possible combinations available from the 5-unit code are insufficient to handle the alphabet and numbers, since 26 combinations are required for the letters of the English alphabet alone. This leaves only six combinations for numerals, symbols, or nonprinting functions. This is obviously inadequate. It was therefore necessary to adopt a plan to enable a larger number of characters to be included, and this was done as follows. Two of the 32 combinations are used as shift-signals, which permit the remaining code combinations in the first case to be used as letters, and in the second case, the combinations are used for numerals, punctuation signs, etc. The shift-signals are often referred to as case-shift signals; i.e., one case is a letter-shift, and the other a figure-shift. When a letter-shift is transmitted, it sets the receiving instrument in a condition to recognize any signal combination subsequently received to be recorded in the letter case, until a figure-shift is received. Then the receiving instrument sets itself in a condition to record any subsequent signal combinations received in the figure case. That is, the interpretation of a signal combination is determined by the previous shift-signal. The use of this plan enables 30 of the available 32 combinations to have two meanings.

Modes of Operation

There are two basic modes of teletypewriter operation: nonsynchronous (start-stop) and synchronous. The most common mode of teletypewriter operation is the start-stop mode. Synchronous operation is used more in high-speed data systems.

In the start-stop mode of operation the receiving device is allowed to run for only one character and is then stopped to await the reception of a start signal indicating that the next character is about to start. In this manner any difference in speed between the transmitting and receiving devices can accumulate only during the duration of one character. However, there is a penalty to pay for this advantage. The length of each character must be increased to include an element to start the receiving device and another added to stop it.

The start element precedes the first code (intelligence) element and is always a space signal. Its purpose is to start the receiving machine. The stop element follows the last code element and is always a mark signal. Its purpose is to stop the receiving machine in preparation for receiving the next character. The start element must be equal to at least one element of the code. The standard mode uses a stop element 1.42 times the length of one code element. It is common practice to refer to a code element as a unit and the duration of a unit as the unit interval.

The length of time required to transmit the entire character is called the character interval. Character interval becomes very important in some transmissions due to certain items of equipment being "character length conscious" or "code conscious." Stop unit intervals of various lengths are used or produced by various equipment, such as 1.0, 1.27, 1.5, 1.96, 2.0, etc. Basically the only difference between them is the length of time required to transmit one character.

Synchronous teletypewriter operation, as opposed to start-stop operation, does not in all cases have to rely upon elements of the transmitted character to maintain proper position in relation to the receiving device. External timing signals may be used, allowing the start and stop elements to be discarded. Then only the elements necessary to convey a character, (and in some cases a reference element,) need to be transmitted.

Synchronous systems have certain advantages over start-stop systems. The amount of

time taken to transmit stop and start elements is made available for information transmission rather than for synchronizing purposes. Only the intelligence elements are transmitted. In start-stop signaling the ability of the receiving device to select the proper line signal condition is dependent upon interference to the start-stop arrival. This means that if the stop to start transition arrives before it should, all subsequent selection positions in that character will appear earlier in time in each code element. A synchronous system, therefore, has a higher capability to accept distorted signals than does a start-stop system.

Modulation Rate

There are several methods of referring to teletypewriter modulation rates or signaling speeds. These include baud, bits per second (BPS) and words per minute (WPM). Baud is the only one that is technically accurate without using additional qualifying terms. The others are either approximations, or require explanation.

The word baud by definition is a unit of modulation rate. It is sometimes used to refer to a signal element but this reference is technically incorrect. Baud rate is the reciprocal of the time in seconds of the shortest signal element. Hence, to find the modulation rate of a signal in bauds, the figure 1 is divided by the time duration of the shortest unit interval present in the signal. For example, 22 milliseconds (.022) is the time interval of the shortest unit in the 5-unit code at 60 words per minute. To find the number of bauds corresponding to 60 WPM, we divide 1 by .022. Rounding off the results of our division, we arrive at the figure 45.5, which is the baud equivalent of 60 WPM. Each increase in WPM will correspondingly decrease the signal unit time interval. (The Defense Communications System standard speed for teletype operation is 100 WPM.)

Words per minute is used only when speaking in general terms for an approximation of speed. The term 100 WPM means that 100 5-letter words with a space between them can be transmitted in a 60 second period. However, it is possible to obtain this nominal words per minute rate in several systems by varying either modulation rate or the individual character interval (length). For this reason, the modulation rate (baud) method of reference rather than words per minute is used.

Formulas for baud and WPM are as follows:

$$\text{Baud} = \frac{1}{\text{Unit interval}}$$

$$\text{WPM} = \frac{\text{Baud}}{\text{Unit code} \times 0.1}$$

The term "bit" is a contraction of the words "binary digit." In binary signals, a bit is equivalent to a signal element. As a result of the influence of computer and data processing upon our language, modulation rate is sometimes expressed as "bits per second" (BPS). When it is expressly understood that all signal elements being transmitted are of equal length, then the modulation rate expressed in bits per second is the same as modulation rate expressed in baud.

D.C. Circuits

It has been pointed out that the two conditions, mark and space, may be represented by any convenient means. The two most common are neutral operation, in which current flow represents the mark and no current flow represents the space, and polar operation, in which current impulses of one polarity represent mark and impulses of the opposite polarity of equal magnitude represent the space.

Neutral circuits make use of the presence or absence of current flow to convey information. These circuits use 60 milliamperes (ma) (or in some cases 20 ma) as the line current value. A neutral teletypewriter circuit is composed of a transmitting device, a battery source to supply current, a variable resistor to control the amount of current, a receiving device, and a line for the transmission medium.

Polar operation differs from neutral, as information is always present in the system, and is either in a positive or negative condition. A polar teletypewriter circuit is composed of the same items as a neutral circuit plus an additional battery source. The reason for having an extra source of battery is that the standard polar circuit uses positive battery for mark and negative battery for space.

The most significant advantage to polar operation is that for all practical purposes it is almost impossible to distort a signal through low line currents, high reactance or random patching of signal circuits or equipment. Another advantage of polar signaling is that a complete loss of current (a reading of ZERO on the milliammeter)

indicates line or equipment trouble, whereas the same conditions with neutral signaling may only indicate that a steady space is being transmitted.

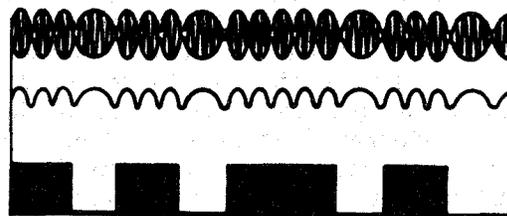
BASIC SYSTEMS

When two teletypewriters are wire-connected, the exchange of intelligence between them is direct. But when the teletypewriters are not joined by wire, exchange of intelligence is more complex. Direct-current mark and space intervals cannot be sent through the air. The gap between the machines must be bridged by radio. To bridge the gap, a radio transmitter and receiver are needed. The transmitter produces a radiofrequency carrier wave to carry the mark and space intelligence. Also, a device such as a **KEYER** is needed to change the d.c. pulses from the teletypewriter into corresponding mark and space modulation for the carrier wave in the transmitter. The radio receiver and a **CONVERTER** are required to change the radio frequency signal back to d.c. pulses.

The Navy uses two basic RATT systems—the tone-modulated system, referred to as audio frequency tone-shift (AFTS), and the carrier frequency-shift system, referred to as radio frequency carrier shift (RFCS). The RFCS system is also called frequency-shift keyed (FSK).

Figure 5-18 shows a modulated carrier wave with audio tone impulses impressed on the radio-frequency carrier wave, with corresponding d.c. mark and space signals.

The RFCS signal can be explained by comparing it to the on-off CW signal. As CW signals are of essentially constant frequency, there is no variation along the frequency axis (fig. 5-19A). The complete intelligence is carried as variations in the signal amplitude. Figure 5-19B



1.226
Figure 5-18.—Modulated carrier wave with audio tone for mark and space.

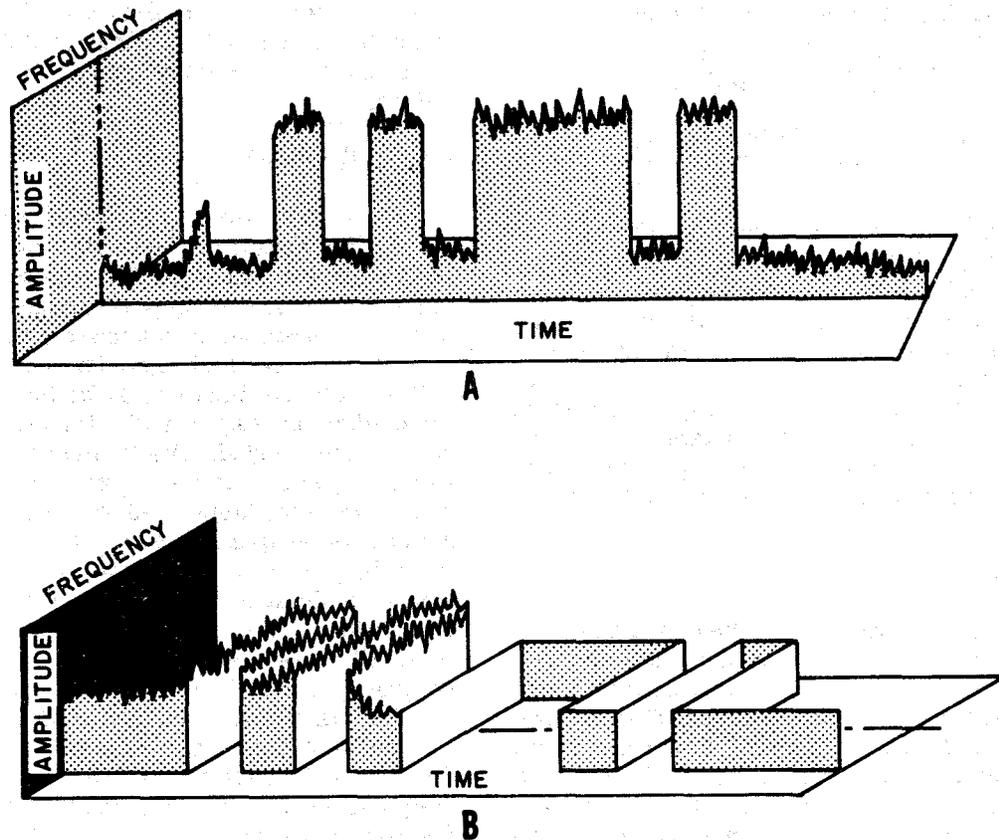


Figure 5-19.—CW and RFCS telegraph signals.

162.132

shows the same signal as a shift in frequency between the mark and space.

Tone-Modulated System

Tone-Modulated (AFTS) Systems use the process of amplitude modulation to change the d.c. mark and space impulses into audio electrical impulses.

Conversion to the audio tones is accomplished by an audio oscillator in the tone converter (such as the AN/SGC-1A) which operates at 700 Hertz (Hz) for a mark impulse and at 500 Hz for a space impulse. This may be reversed subsequent to the printing of this manual (see note below). The rapid varying of the tone according to the characters transmitted from the teletype equipment amplitude modulates the carrier wave in the transmitter. The receiver receives the modulated signal and separates the audio signal from the carrier. This process of separating the

modulated signal is known as detection or demodulation. A basic tone-modulated system is shown in figure 5-20.

Carrier Frequency-Shift System

For Frequency-Shift (RFCS) Systems, a keyer in the transmitter provides a source of radio-frequency excitation which can be shifted below or above the assigned frequency corresponding to the mark or space required to transmit the teletype characters. NOTE: In the past U.S. Navy communications equipment has been set up so that the shift above the assigned frequency represented the mark and the shift below the assigned frequency represented the space. For standardization purposes, this is being reversed so that the high frequency represents the space and the low frequency represents the mark. Normally the keyer is adjusted for an 850 Hz spread, 425 Hz above the assigned

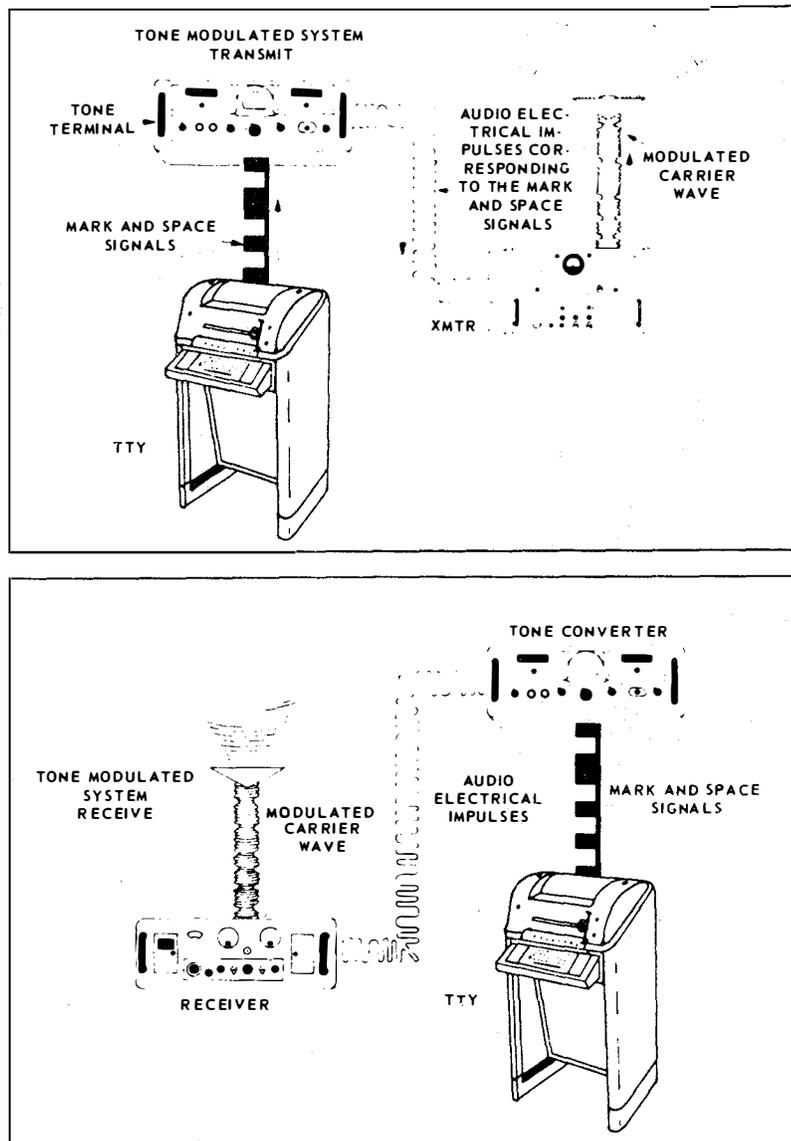


Figure 5-20.—Basic tone-modulated (AFTS) system.

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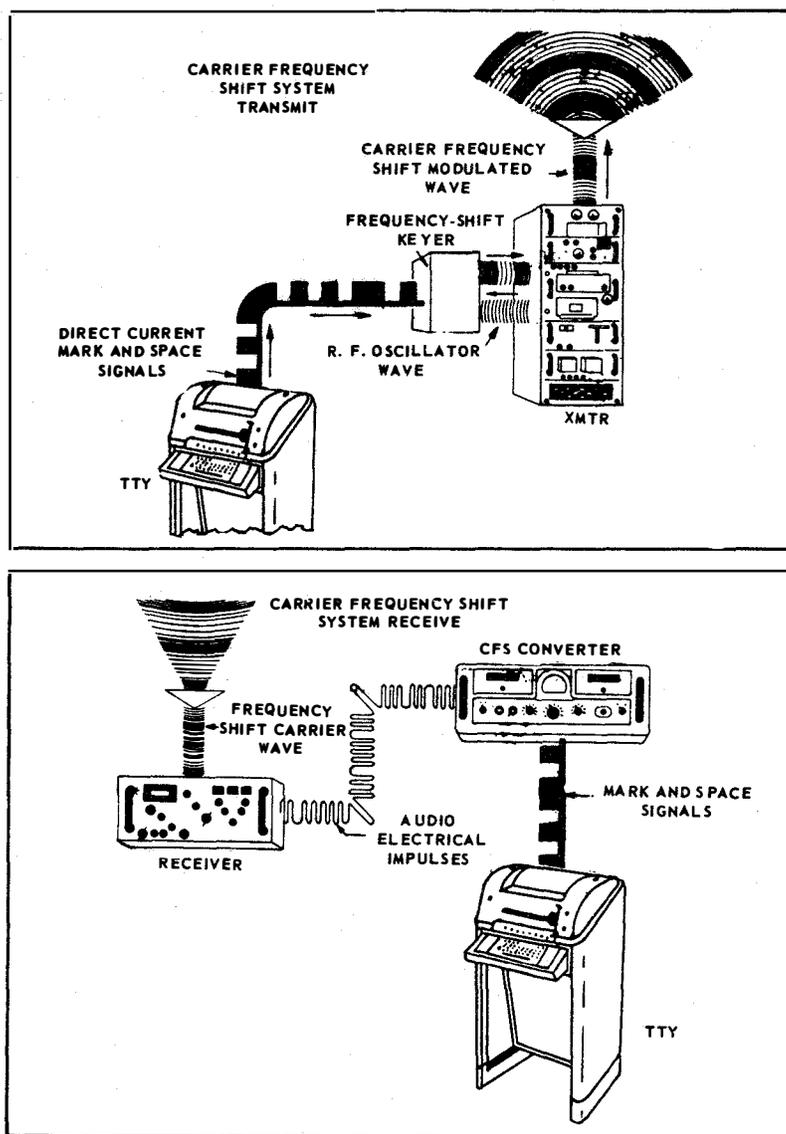
frequency and 425 Hz below. A spacing impulse will be 425 Hz above the operating frequency, and a marking impulse will appear 425 Hz below. Figure 5-21 illustrates a basic frequency shift system. In modern systems, the keyer is built into the transmitter.

In both the tone-modulated system and the carrier frequency-shift system, all teletypewriter signals pass through the teletypewriter panel that controls the looping current in all the circuits. The teletypewriter panel integrates the tone-modulated and the carrier frequency-shift systems. It provides every possible inter-

connection of available teletypewriter equipment; thus, maximum operational flexibility is achieved with the fewest number of circuits and the least amount of equipment.

SIMPLEX RFCS TELETYPE SYSTEM

Radiofrequency carrier shift teletype systems are used in the LF to HF bands for long range communications. To reduce fading and interference problems in these bands, the Navy uses two methods of DIVERSITY RECEPTION. These methods are SPACE DIVERSITY and FREQUENCY DIVERSITY.



1.228.229

Figure 5-21.—Basic carrier frequency-shift (RFCS) system.

In SPACE DIVERSITY reception, one signal is transmitted, and this signal is received by two or more receivers. The receiver antennas are separated by a distance greater than one wavelength. The outputs of the receivers are fed into frequency-shift converters which convert the audio frequency-shift signals into d.c. mark and space signals. The d.c. signals are then fed into a comparator which selects the best mark and space signals for the teletypewriter. Because of required spacing between the receiver

antennas, space diversity is mostly limited to shore stations.

In FREQUENCY DIVERSITY reception, two or more signals carrying the same intelligence are transmitted on different frequencies. The signals are received by receivers and processed in the same manner as for space diversity to operate teletype equipment from the best of the transmitted signals. This form of frequency diversity is known as RF DIVERSITY. Another form of frequency diversity called AF diversity

or tone diversity is used with multichannel broadcasts. This is discussed later in this manual.

A simplified block diagram of a simplex MF/HF RFCS teletype system is shown in figure 5-22. A SIMPLEX communication circuit consists of a single channel over which two or more stations may communicate. Each station may transmit and receive, but not simultaneously. On the transmit side (fig. 5-22), the teletypewriter (TTY) set keyboard or transmitter distributor applies the d.c. teletype signals to the communication patch panel where they are patched to the transmitter. The d.c. mark and space signals shift the frequency of the RF carrier generated by the transmitter as explained previously.

On the received side, the RF frequency-shift signal is received and demodulated by the receiver, resulting in an audio signal which shifts 850 Hz between marks and spaces. This audio frequency-shift signal is fed to a converter in the converter/comparator group where it is converted into the original d.c. mark and space signals. The d.c. mark and space signals are then patched through the communication patch panel to the TTY set.

TTY Sets

Most of the teletypewriter sets used by the Navy belong to the model 28 family of teletype-

writer equipments. The model 28 equipments feature various weights and sizes, quiet operation, and high operating speeds. They present relatively few maintenance problems, and are suited particularly for shipboard use under severe conditions of roll, vibration, and shock.

Another feature of the model 28 teletypewriters is their ability to operate at speeds of 60, 75, or 100 words per minute. Conversion from one speed to another is accomplished by changing the driving gears that are located within the equipment. The majority of the Navy's teletypewriters are presently operated at 100 words per minute.

Teletypewriters may be send/receive units or receive units only. They may be designed as floor models, table models, and rack and wall mounted sets. A representative send/receive floor model set is shown in figure 5-23.

The TTY set (fig. 5-23) receives teletype messages from the line and prints them on page size copy paper. In addition, it can receive messages and record them on tape and in printed form. With page-printed monitoring, the set transmits messages that are originated either by perforated tape or by keyboard operation. It mechanically prepares perforated and printed tape for separate transmission with or without simultaneous transmission and page-printed monitoring.

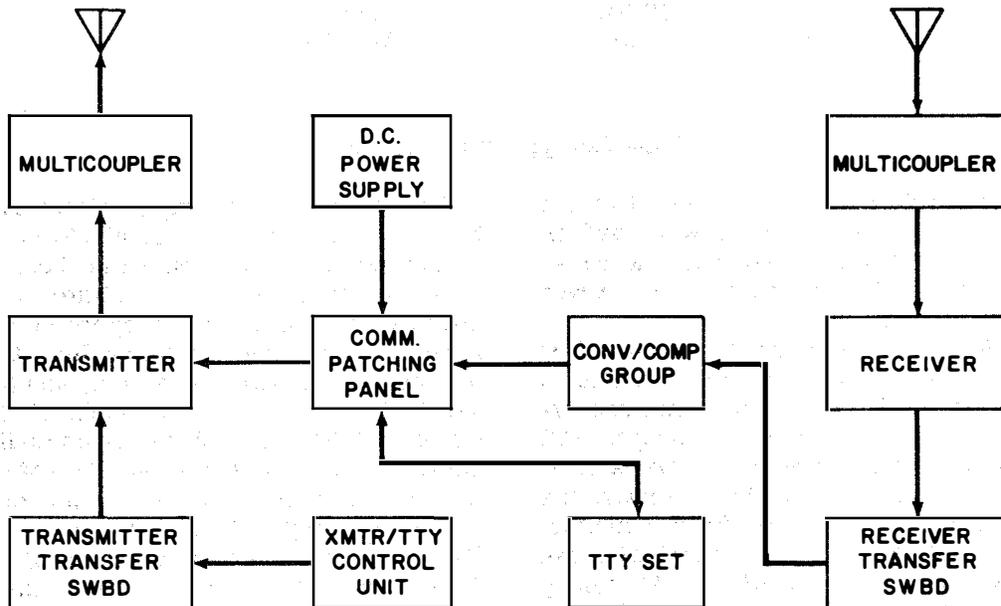


Figure 5-22.—Simplex RFCS teletype system.

162.133

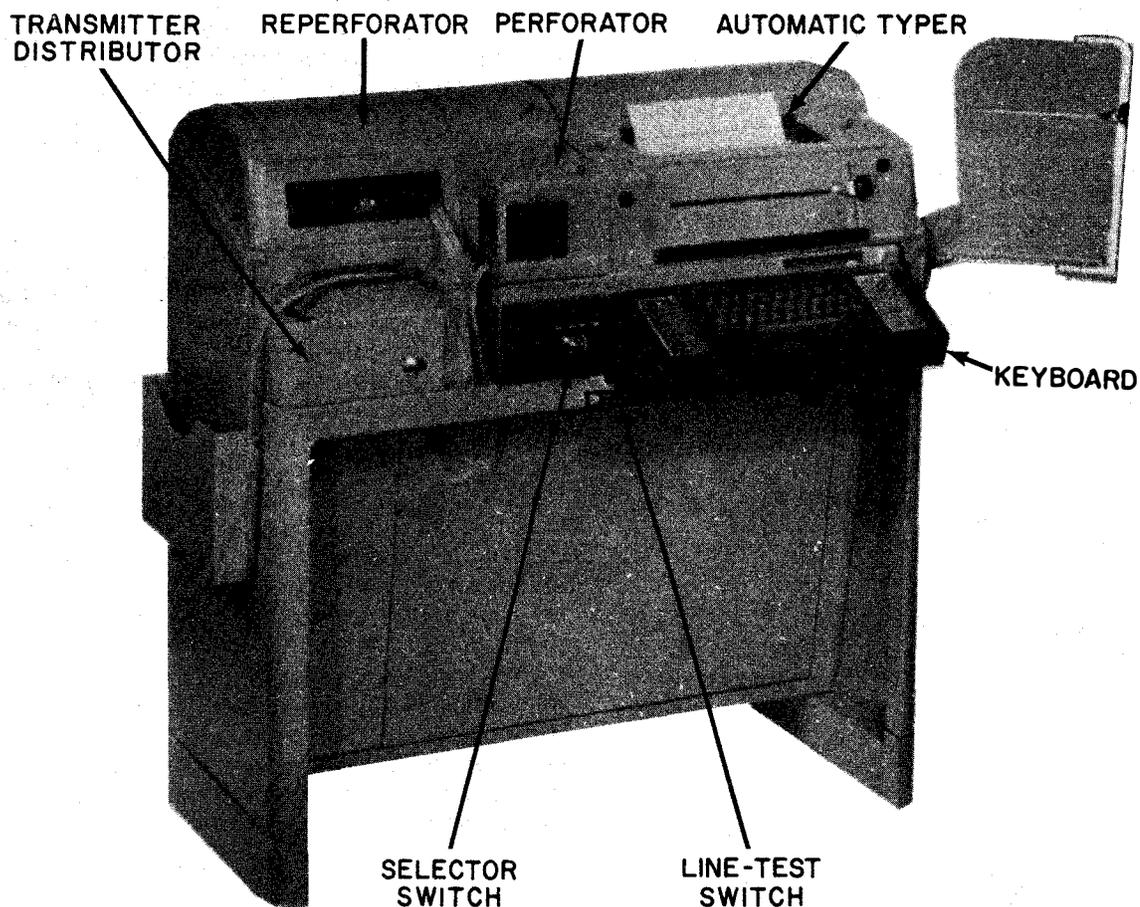


Figure 5-23.—Teletypewriter set (AN/UGC-6).

1.217(31)

The teletypewriter set is composed of the following components: a cabinet, a Keyboard, an automatic typer, a typing perforator, a transmitter distributor, a typing reperforator, power distribution panels and power supply.

In operation, the components are linked by electrical or mechanical connections to offer a wide range of possibilities for sending, receiving, or storing teletypewriter messages. All equipment components are housed in the cabinet. Transmission signals are initiated through the keyboard or through the transmitter distributor. Signals are received, or local transmission can be monitored, on the automatic typer. The typing perforator and typing reperforator are devices for preparing tapes on which locally initiated or incoming teletypewriter messages can be stored for future transmission through the transmitter distributor.

The keyboard, typing perforator, automatic typer, and transmitter distributor are operated by the motor mounted on the keyboard. Selection of these components for either individual or simultaneous operation is by the selector switch located at the front of the cabinet, to the left of the keyboard. All these components are connected in series in the signal line, but the selector switch has provisions for excluding various components from the line. The external signal line is connected to the equipment through a line-test switch. This switch is located below the selector switch on the front of the cabinet. This arrangement provides a means of disconnecting the equipment from the line for local testing of the components. The typing reperforator is operated by a separate motor and power distribution system. It also is connected to a separate external signal line.

To become a part of the Naval Tactical Data System (NTDS), the AN/UGC-6 is modified (and designated AN/UGC-13) to provide input/output communications with a selected data processing computer.

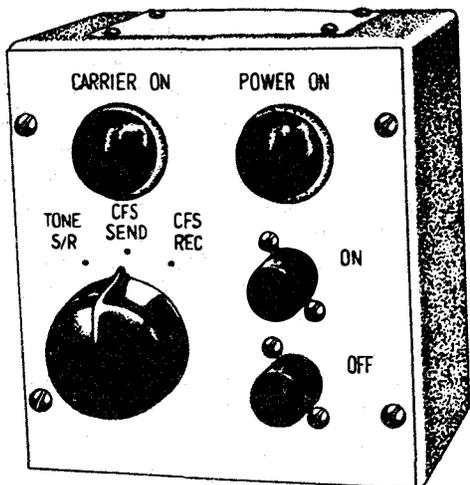
Transmitter/TTY Control

The transmitter/TTY control unit (fig. 5-24) is mounted close to the teletype keyboard, and permits remote control of the transmitter. It has a transmitter power on-off switch, a power-on indicator lamp, a carrier-on indicator lamp, and a three position rotary selector switch. For RFCS operation, the operator sets the switch to CFS SEND for transmitting and to CFS REC for receiving. The TONE S/R position is used for both transmitting and receiving AFTS signals.

Converter/Comparator Group

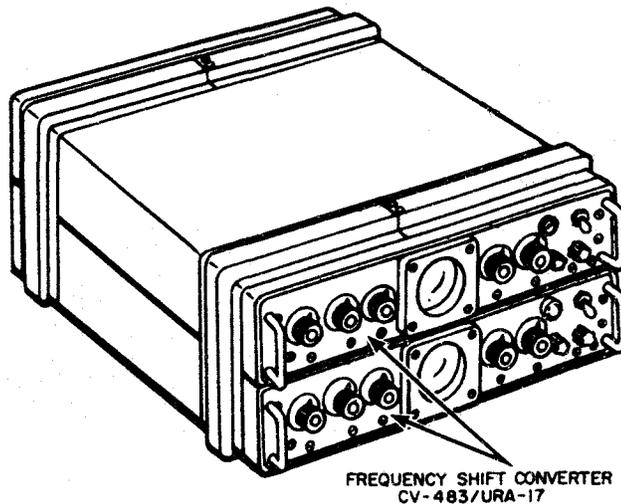
The converter/comparator group (fig. 5-22) is used with receivers in either space or frequency diversity operation. When diversity operation is not required, each converter can be used separately with a single receiver. A representative converter/comparator group is shown in figure 5-25.

Each converter (fig. 5-25) has its own comparator circuitry. This built in design feature results in a considerable reduction in size from older units where the comparator is located in a separate chassis. A further reduction in size is achieved by the use of semiconductors and printed circuit boards.



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Figure 5-24.—Transmitter/TTY control unit.



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Figure 5-25.—Converter/Comparator Group (AN/URA-17).

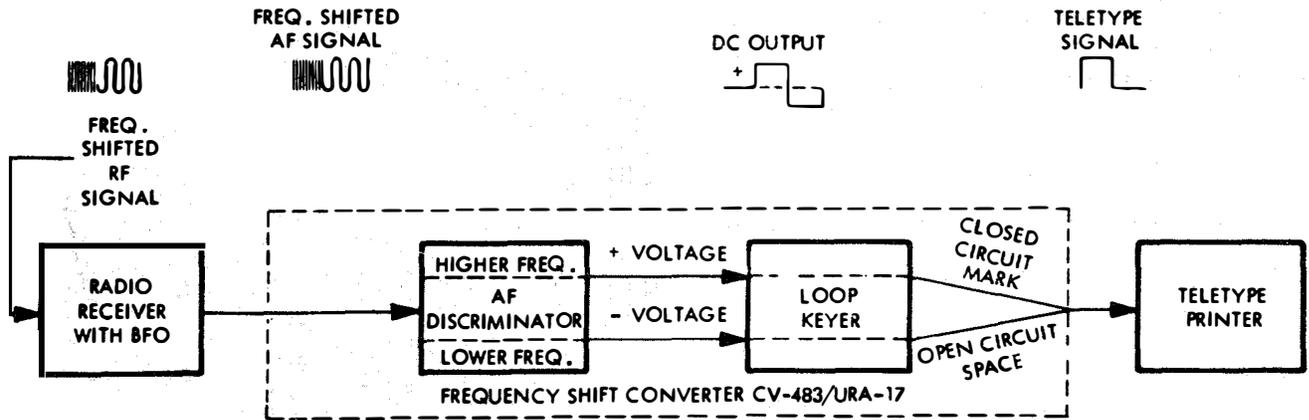
The simplified block diagram (fig. 5-26) shows the basic RF function of converting the frequency-shift RF signal into a signal for controlling the d.c. loop of the TTY. The frequency shifts of the AF output from the receiver are converted into d.c. pulses by the AF discriminator. The d.c. pulses are fed into the loop keyer which opens and closes the d.c. loop of the TTY according to the mark and space characters received.

The comparator section of the converter/comparator functions to compare the strength of the signals from the receivers in diversity operation. Signals from each converter are fed into a comparator circuit which compares the signals and allows only the stronger signal to be fed to the communication patching panel for patching to the TTY.

Communication Patching Panels

To provide flexibility in teletype systems, the wiring of all teletypewriter and associated equipments is terminated on jacks in communication patching panels usually referred to as teletype patch panels. The equipment then is connected electrically in any desired combination by means of patching cords.

The plugs on the cords are inserted into the jacks at the front of the panel. In some instances, commonly used combinations of equipment are permanently wired together within the panel



162.23

Figure 5-26.—Frequency shift receiving system simplified block diagram.

(called "normal-through"). They are wired so that individual pieces of equipment can be "lifted" from the combination, and then used alone or in other combinations.

In addition to providing flexibility, teletype panels also furnish a central point for connecting the d.c. voltage supply into the teletypewriter circuits. Thus, one source of supply can be used for all circuits passing through a particular panel.

Teletype panels SB-1203/UG and SB-1210/UGQ (fig. 5-27) are used for interconnection and transfer of teletypewriter equipment aboard ship. The SB-1203/UG is a general-purpose panel, whereas the SB-1210/UGQ is intended for use with cryptographic devices. The colors RED and BLACK are used to identify secure and nonsecure information. Red indicates that secure (classified) information is being passed through the panel, and black indicates that nonsecure (unclassified) information is being passed through the panel.

Each of the panels contains six channels, with each channel comprising a looping series circuit of looping jacks, set jacks, and a rheostat for adjusting line current. The number of looping and set jacks in each channel varies according to the panel model. Each panel includes a meter and rotary selector switch for measuring the line current in any channel. There are six miscellaneous jacks to which may be connected any teletypewriter equipment not regularly assigned to a channel.

If the desired teletype equipment is wired in the same looping channel as the radio adapter (keyer or converter) to be used (normal through

connection), no patch cords are required. But, if the desired teletypewriter (for example, in channel 1) is not wired in the same looping channel as the keyer or converter to be used (for example, channel 3), one end of the patch cord must be inserted in the set jack in channel 1, and the other end in either one of the two looping jacks in channel 3.

In any switching operation between the various plugs and jacks of a teletype panel, the cord plug must be pulled from the loopingjack before removing the other plug from the set (machine) jack. Pulling the plug from the set jack first open the circuits to the channel, causing all teletype messages in the channel to be interrupted. IT ALSO PRODUCES A DANGEROUS D.C. VOLTAGE ON THE EXPOSED PLUG.

AFTS SYSTEM

A simplified block diagram of a half-duplex (send or receive) UHF, AFTS system is shown in figure 5-28. A half-duplex communication circuit permits unidirectional communications between stations. Communications can be in either direction, but not simultaneously. The term half-duplex is qualified by adding "send only", "receive only", or "send or receive."

A FULL-DUPLEX (or DUPLEX) communication circuit permits uninterrupted exchange of information between stations by using two separate circuits. Each station may transmit and receive simultaneously.

Signal Flow

On the transmit side (fig. 5-28), d.c. signals from the TTY set are fed to the communication

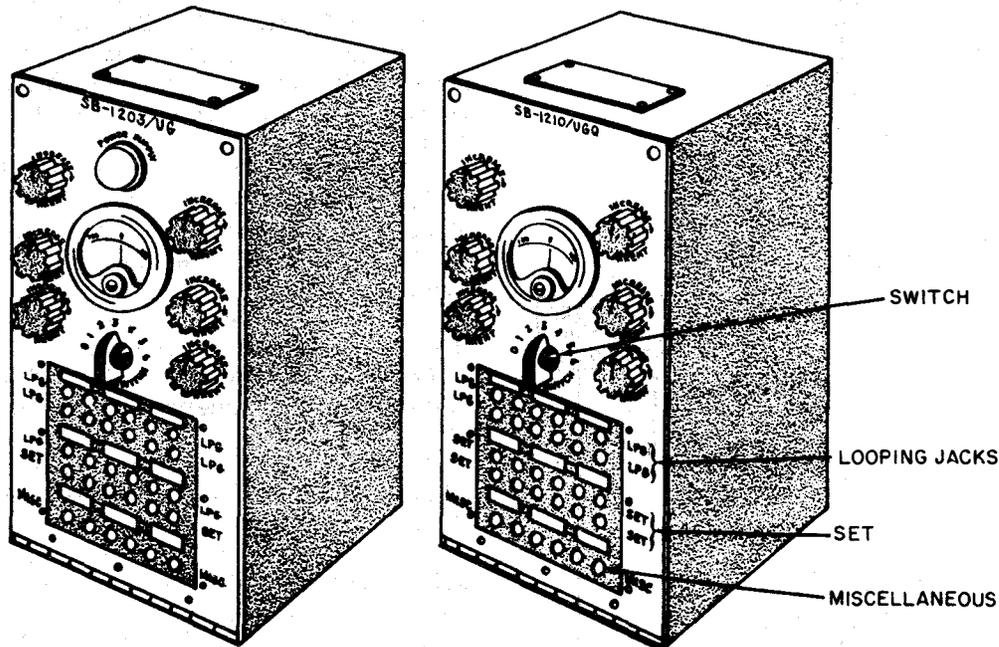


Figure 5-27.—Communication patching panels.

70.79

patching panel where they are patched to the tone terminal set. The tone terminal set converts the d.c. signals into audio tone-shift signals, which are patched to the transmitter section of the transceiver through the transmitter transfer switchboard. The audio tone-shift signals modulate the RF carrier generated by the transmitter. The RF tone-modulated signals are then radiated by the antenna.

On the receive side, the RF tone modulated signals are received at the antenna and patched via the multicoupler to the receiver section of the transceiver, where demodulation takes place. The resulting audio tone-shift signals are then patched through the receiver transfer switchboard to the tone terminal set, where they are converted back to the d.c. signals. The d.c. signals are patched through the communication patching panel to the TTY set.

Tone Terminal Set

A representative tone terminal set (tone converter) used for single-channel AFTS teletype communications is shown in figure 5-29. (The CV-2460/SGC is replacing this set in some installations.)

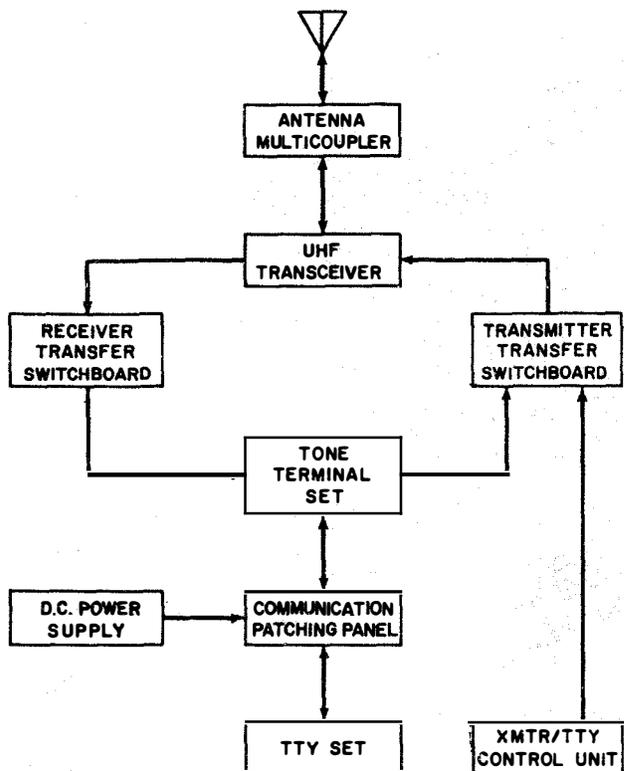
In tone modulation transmission, the teletypewriter pulses are converted into corresponding

audio tones, which amplitude modulate the RF carrier in the transmitter. Conversion to the audio tones is accomplished by an audio oscillator in the tone converter, which operates at 700 Hz when the teletype loop is in a closed-circuit condition and at 500 Hz when the loop is in an open-circuit condition.

An internal relay in the tone converter closes a control line to the radio transmitter, which places the unit on the air when the operator begins typing a message. The control line remains closed until after the message has been transmitted.

When receiving messages, the tone converter accepts the mark and space tones coming in from an associated radio receiver and converts the intelligence of the tones into signals suitable to operate a relay in the converter. The make and break contacts of the relay are connected in the local teletypewriter d.c. loop circuit. This action causes the local teletypewriter to print in unison with the mark and space signals from the distant teletypewriter.

The receive level calibrated attenuator control is located on the upper left side of the front panel of the tone converter (fig. 5-29). This control permits adjustment of the level of the incoming tone signals from the receiver. The loop current rheostat is next to the receive



162.134

Figure 5-28.—Half-duplex AFTS teletype system.

level control, and is adjusted to 60 ma. when the teletype loop is in the mark, or closed circuit condition. A zero-center meter indicator is located on the upper middle portion of the front panel. An associated switch is located directly below the meter. It has several positions to permit measurements to be taken in all the necessary portions of the circuit.

An indicator light is located on each side of the meter. One light indicates the receive condition, and the other indicates the transmit condition. Both lights are off when the tone converter is in the standby condition.

The send bias rheostat is located to the right of the meter. This control permits correction of any teletype distortion (for example, unequal length of mark and space signals) in the local teletypewriter loop when sending a teletype message.

At the far right is a jack marked, "TTY monitor." A test or monitoring teletypewriter may be patched into this jack, thereby placing it in series with all other equipments in the loop.

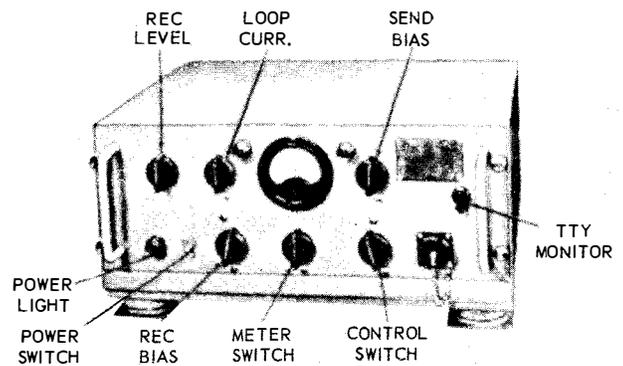
WARNING: THIS JACK PROVIDES 115 V.D.C. FOR A MONITOR TTY SET; HEADPHONES MUST NOT BE PLUGGED INTO THIS JACK.

The power indicator light is located on the lower left side of the front panel of the tone converter. The power ON-OFF switch is located next to it.

The receive bias potentiometer is located to the right of the power switch. This control enables correction of distortion (unequal length of mark and space tones) in the receiving tone circuit.

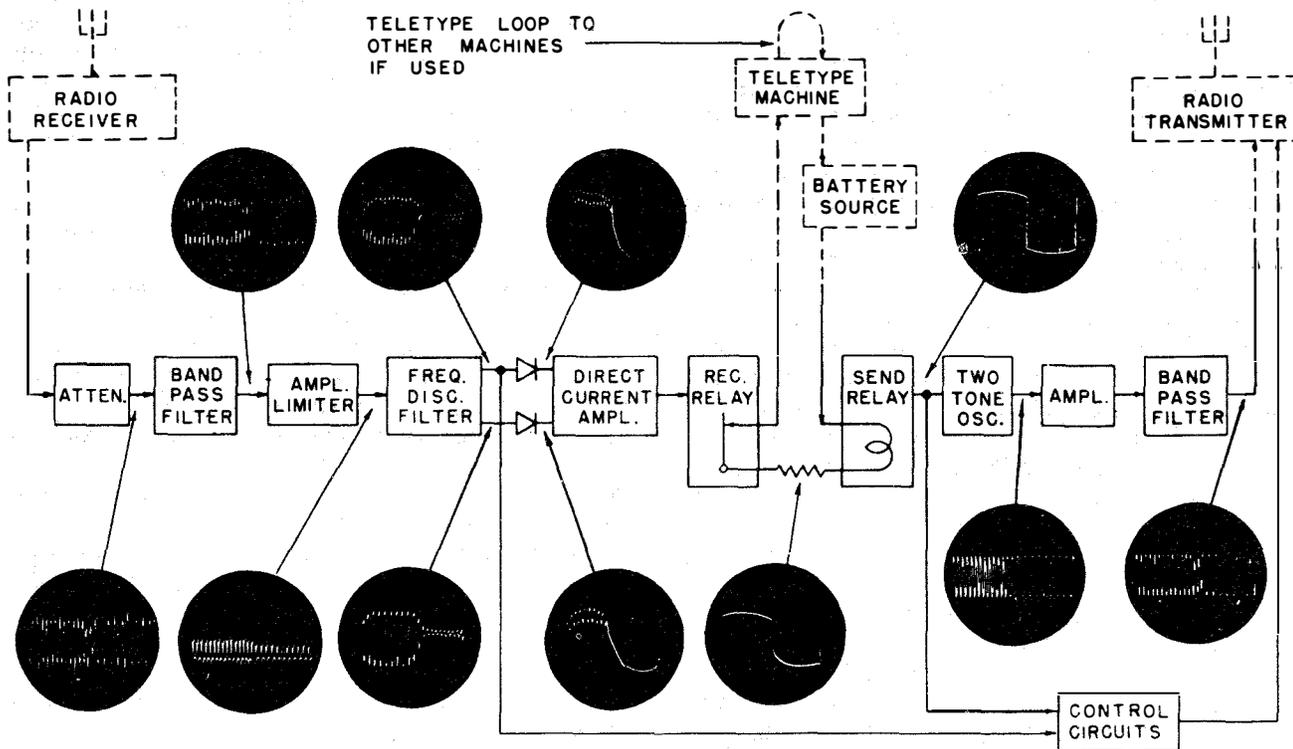
The control switch is located at the right of the meter switch. The position of the control switch determines the function of the tone converter to either receive or to transmit teletype signals.

A block diagram of the tone converter is illustrated in figure 5-30. Typical oscilloscope patterns are included. The attenuator is located at the input of the receive circuit to permit adjustment of the level of the incoming 2-tone signal. The bandpass filter passes all frequencies in the band from 400 to 800 Hz and rejects all other frequencies. The amplifier limiter stages have a constant-output level. The frequency discriminator filter selects the fundamental frequencies of 500 Hz and 700 Hz and routes them through separate germanium rectifiers to corresponding d.c. amplifiers. The amplified d.c. signals are then routed to their associated relay coils. A 700 Hz input signal to the frequency discriminator filter causes the receive relay to close the teletype d.c. loop; a 500 Hz input signal causes the relay to open the loop. Thus, corresponding mark and space signals are developed in the teletype loop circuit.



1.240

Figure 5-29.—Teletype terminal equipment (AN/SGC-1A).



1.241

Figure 5-30.—Block diagram of tone converter.

In sending, the mark and space signals in the d.c. loop cause the send relay to apply either a d.c. voltage or no d.c. voltage to the two-tone oscillator. A mark signal causes the oscillator to operate at 700 Hz; a space signal causes it to operate at 500 Hz.

The output of the oscillator passes through a level-controlling potentiometer (not shown in the diagram) to the amplifier stage. The output of the amplifier passes through a bandpass filter to the ship's radio transmitter.

The control switch is used to change from one operating condition to another or to permit the accomplishment of specific operating or maintenance functions. If it is desired to prevent the sending of a message by the teletypewriter, the control switch may be turned to REC/STDY. Thus, the equipment cannot change to the transmit condition even though the teletypewriter is operated, but it can receive messages or remain in the standby condition.

In carrying on communications, the equipment should not be operated with the control switch turned to TRS because the equipment is then locked in the transmit condition. In this

condition, it cannot receive any message until released by turning the control switch to one of the other two operating positions.

Usually, for half-duplex communication, this switch is set at the AUTO position. In auto condition, operators at two or more stations having this equipment can engage in full communication. After a station has completed sending its message, it is ready for reception of any return message after an automatic three-second time delay. When the switch is in the AUTO position, the tone converter may be in one of three conditions: receiving, transmitting, or standby. When it is in the standby condition, the reception of an incoming mark tone causes the control circuit to change to the receiving condition. Following the end of the incoming message, the internal circuits of the equipment shift back to the standby condition. When it is in this condition, the operation of the local teletypewriter causes the circuit to change from standby to the transmit condition. After the last letter of the message is sent, there is a time delay of about three seconds, and then the internal equipment circuits shift back to the standby condition. The

interlocking functions prevent the equipment from shifting directly from transmit to receive, or vice versa. Thus, an incoming signal will not interrupt an output signal, nor will keying the local teletypewriter, when receiving, cause the circuit to shift to the transmit condition. The control circuits also, when shifted to transmit condition, cause the control contacts of the transmit control relay to the radio transmitter to close, thereby placing the transmitter carrier on the air.

After a station has sent its message, it is ready for reception of any return message following an automatic three-second time delay. Because of the small time delay inherent in the operation of the control circuits of the local and distant terminals, the first character transmitted is usually lost. Therefore, the first character typed should be the "letters" key.

MULTIPLEX SYSTEMS

The number of communication circuits in operation throughout any given area is increasing constantly; as a result, the radio frequency spectrum is rapidly becoming saturated to such an extent that radio frequencies are not readily available for the establishment of new circuits. These required increases have been met in part by conversion of teletypewriter operation to 100 WPM and are being met still further by conversion to multiplex systems.

The primary purpose of a multiplex system is to increase the message-handling capacity of teletypewriter channels and the transmitters and receivers associated with them. This is accomplished by the simultaneous transmission of several messages over a common channel.

Multiplexing can be accomplished by two methods; Time-division and frequency-division. Time-division multiplexing divides the time duration of a standard start-stop signal into a number of equal intervals and allots each interval to a separate teletypewriter circuit. Frequency division multiplexing uses a number of tone channels slightly displaced in frequency. The tones are separated from each other at the receiving point by filters. Of the two methods, the Navy uses mostly frequency-division. Multiplexing equipment (the AN/UCC-1) is discussed in Chapter 7 of this manual.

SATELLITE COMMUNICATION SYSTEMS

A satellite communication system uses earth orbiting vehicles (satellites) to relay radio

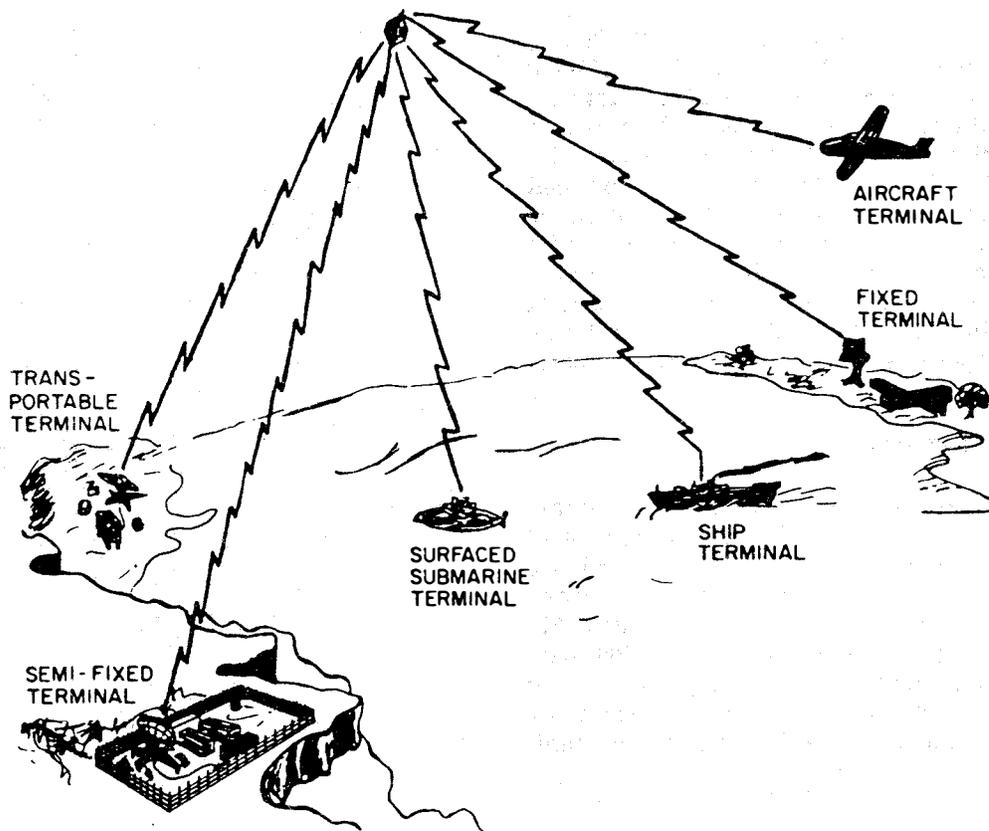
transmissions. Communication satellites are of two types—passive and active. A passive satellite merely reflects radio signals back to earth; whereas an active satellite amplifies received signals and retransmits them back to earth. This increases the signal strength at the receiving terminal compared to that available from a passive satellite. For this reason, ground transmitters need less power and smaller antennas.

The basic design of a satellite communication system depends to a large degree upon the satellite orbit. An orbit is identified by its shape and the inclination of its orbital plane in relation to the earth's equatorial plane. In general terms, an orbit is either elliptical or circular, and its inclination is classified as inclined, polar, or equatorial. A special type of orbit used in satellite communications is the synchronous orbit. A satellite in a circular orbit at a height of approximately 19,300 nautical miles above the earth is in synchronous orbit. At this altitude, the satellite's period of rotation is 24 hours (the same as the earth's); thus, the satellite orbits in synchronism with the earth's rotation. Satellites in this type of orbit appear to hover motionlessly in the sky.

A typical satellite communication system involves an active satellite with a communication transmitter and receiver installed, and two earth, shipboard, or aircraft terminals equipped to transmit signals to, and receive signals from, the satellite (fig. 5-31). One earth, shipboard, or aircraft terminal transmits to the satellite on a frequency referred to as the "up-link" frequency. The satellite receives, amplifies, and translates the signal to the "down-link" frequency and transmits it back to earth where it is received by the receiving terminal.

ADVANTAGES

Satellite communications relieve the crowded HF spectrum for long range communications. Frequencies in the UHF band or above are considered to be "line-of-sight" frequencies. However, if a satellite is substituted for the ionosphere to either reflect signals back to earth or amplify and transmit them, frequencies higher than those in the HF band may be utilized. Longer ranges are available, depending upon the height of the satellite, and greater reliability is attained as satellite communication frequencies are not dependent upon the ionosphere and are affected only slightly by atmospheric conditions.



162.58(162A)

Figure 5-31.—Satellite communications.

Destruction of an orbiting satellite is possible by rocketry; however, destruction of a single satellite would be too difficult and expensive for the tactical advantage gained. Further, it would be extremely difficult to destroy an entire multiple-satellite system, such as the 26 random orbit system in use by the Defense Satellite Communication System. A high degree of invulnerability to jamming is also afforded the satellite communication system by the highly directional antennas and wide bandwidths used.

In addition, as most satellite communications terminals are transportable, satellite communication systems are more flexible than conventional systems.

LIMITATIONS

Limitations of a satellite communications system are determined by the satellite's technical characteristics and orbital parameters. Active communication satellites are limited by satellite transmitter power and, to a lesser extent, receiver sensitivity.

The availability of a satellite to act as a relay station between two communication terminals depends upon the locations of the terminals and the orbital parameters of the satellite. All satellites, except those in synchronous orbit, will be in view of any given pair of terminals only part of the time. In addition, with the present military satellite communication system, only two terminals can use a satellite at one time; thus, satellite scheduling is necessary.

EARTH TERMINALS

Satellite communication earth terminals generally include a single large antenna, a powerful transmitter, a highly sensitive receiver, multiplex equipment, modulating-demodulating equipment, and telemetry equipment. The antennas are highly directional, high gain antennas capable of transmitting and receiving signals simultaneously.

There are three types of earth terminals currently in use in the Defense Satellite Communication System. They are the AN/FSC-9, AN/MSC-46, and AN/TSC-54. The AN/FSC-9 is a fixed terminal that uses a parabolic antenna 60 feet in diameter. The transmitter output power is variable from 10 watts to 20 kilowatts. The AN/MSC-46 is a transportable terminal using a parabolic antenna 40 feet in diameter with a transmitter output power from 100 watts to 10 kilowatts. The AN/TSC-54 is a highly transportable terminal which uses a cluster of four parabolic antennas, each 10 feet in diameter. The output power is variable from zero to 5 kilowatts.

SHIPBOARD TERMINALS

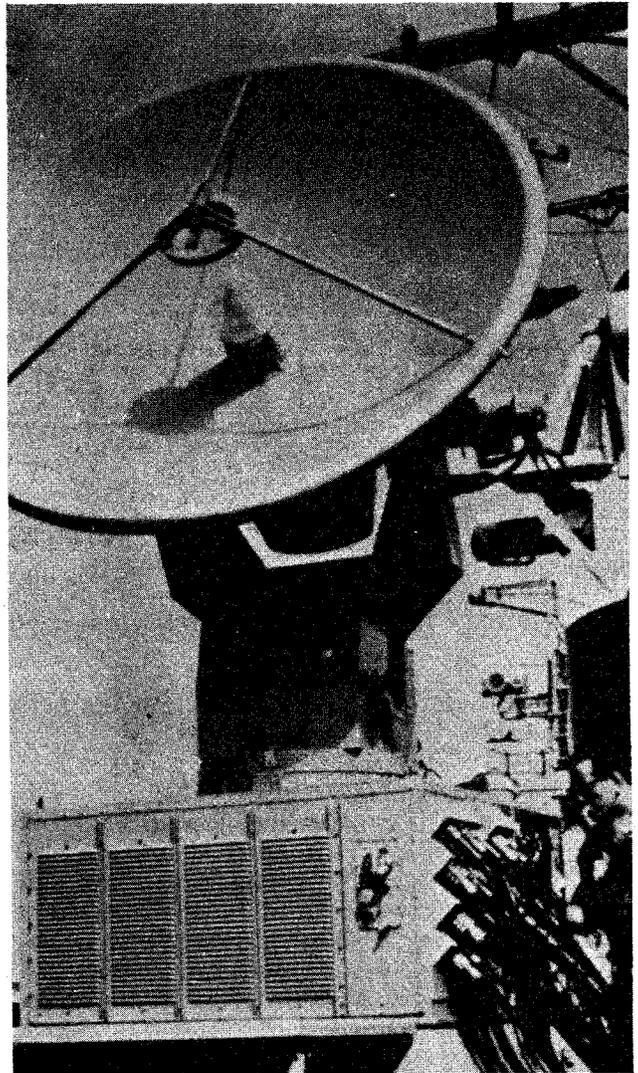
Shipboard satellite communication terminals include the AN/SSC-2, AN/SSC-3, and AN/WSC-1. The AN/SSC-2 has a 6-foot parabolic antenna and was designed for use with synchronous orbiting satellites. The AN/SSC-3 (fig. 5-32) was designed for use with the Defense Satellite Communication System. The AN/WSC-1 (the latest shipboard satellite communication terminal) is discussed later in this training manual.

FACSIMILE SYSTEMS

Facsimile (FAX) is a method for transmitting still images over an electrical communication system. The images, called pictures or copy in facsimile terminology, may be weather maps, photographs, sketches, typewritten or printed text, or handwriting. The still image serving as the facsimile copy or picture cannot be transmitted instantly in its entirety. Three distinct operations are performed. These are (1) scanning, (2) transmitting, and (3) recording or receiving.

The scanning operation consists of subdividing the picture in an orderly manner into a large number of elemental segments. This process is accomplished in the facsimile transmitter by a scanning drum and phototube arrangement.

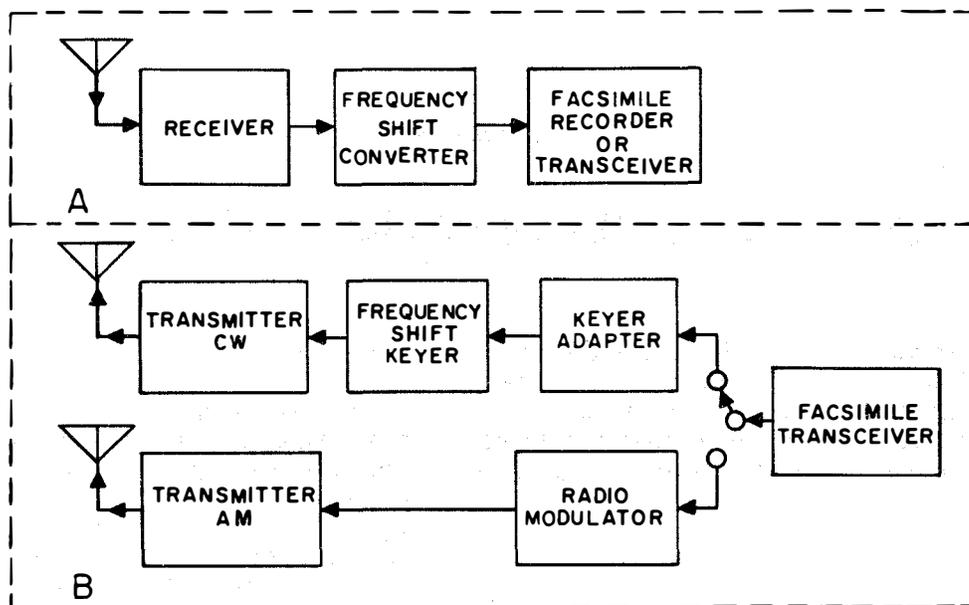
The picture to be transmitted is mounted on a cylindrical scanning drum, which rotates at a constant speed and at the same time moves longitudinally along a shaft. Light from an exciter lamp illuminates a small segment of the moving picture and is reflected by the picture through an aperture to a phototube. During the transmission of a complete picture, the light



50.185
Figure 5-32.—Shipboard Satellite Communication Terminal (AN/SSC-3).

traverses every segment of the picture as the drum slowly spirals past the fixed lighted area.

At any instant, the amount of light reflected back to the phototube is a measure of the lightness or darkness of the tiny segment of the picture that is being scanned. The phototube transforms the varying amounts of light into varying electrical signals, which, in turn, are used to amplitude modulate the constant frequency output of a local oscillator. Then, the modulated signal is amplified and sent to the radio circuits.



70.14

Figure 5-33.—Facsimile system simplified block diagram.

Electrical signals received by the facsimile receiver are amplified and serve to actuate a recording mechanism that makes a permanent recording (segment by segment) on recording paper. The paper is attached to a receiver drum similar to the one in the facsimile transmitter. The receiver drum rotates synchronously with the transmitter drum. This action continues until the original picture is reproduced in its entirety. The recording mechanism may reproduce photographically with a modulated light source shining on photographic paper or film, or it may reproduce directly by burning a white protective coating from specially prepared black recording paper.

Synchronization is obtained by driving both receiving and transmitting drums with synchronous motors operating at exactly the same speed.

Framing (orienting) the receiver drum with respect to the transmitter drum is accomplished by transmitting a series of phasing pulses just

before a picture transmission is to begin. The pulses operate a clutch mechanism that starts the scanning drum in the receiver so that it is phased properly with respect to the transmitter.

The equipment necessary for radio facsimile operation and its relationship to other units in the various receiving and transmitting systems are illustrated by the block diagram in figure 5-33. As shown in part A of the figure, the receiving system consists of a standard radio receiver, a frequency shift converter, and a facsimile recorder. Part B shows two systems for transmitting facsimile signals. One, the upper row of blocks, is for long-range, carrier frequency shift transmission and consists of a facsimile transceiver, a keyer adapter, a frequency shift keyer, and a CW transmitter. The other, the lower row of blocks, is for short-range, audio-frequency shift transmission and employs a facsimile transceiver, a radio modulator, and an AM transmitter.

CHAPTER 6

CW AND VOICE COMMUNICATION SYSTEMS

CW and voice communication systems are discussed in chapter 5 of this manual. The purpose of this chapter is to describe some of the representative antennas, multicouplers, transmitters, and receivers used with these systems.

ANTENNAS

Antenna theory and basic antennas are discussed in Basic Electronics, Vol. 1, NAVPERS 10087-C. This section describes some of the common types of antennas used with shipboard communication systems.

WIRE ANTENNAS

A wire antenna consists of a wire rope suspended either vertically or horizontally from a yardarm or the mast itself to outriggers, to another mast, or to the superstructure. A simplified diagram of a shipboard wire antenna is shown in figure 6-1.

Single wire antennas are not used aboard ship as extensively as they have been used in the past. They have, to a large extent, been replaced by whip, dipole, and other antenna assemblies. In some installations, wire antennas are used only in emergencies.

Because of the frequency range in which these antennas are used, the portion of the ship's structure used to support the wire and other nearby structures are an electrically integral part of the wire antenna. Therefore wire antennas are usually designed for a particular ship or installation.

Wire rope used for transmitting will normally be without insulation, while receiving antenna wire rope will have a Vinylite insulating jacket (as will transceiving wire antennas) to reduce interference from precipitation static.

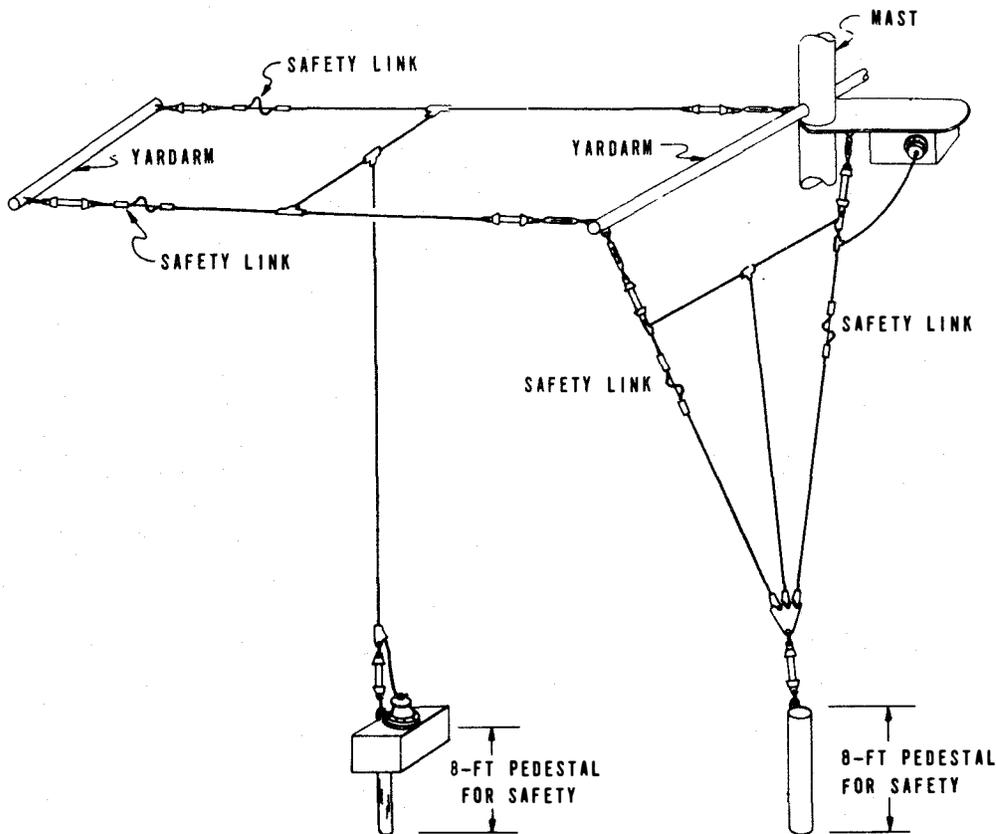
WHIP ANTENNAS

Because whip antennas are essentially self-supporting, they may be installed in many locations aboard ship where space is at a premium, and locations are unsuitable for other antenna types. They may be deck mounted or mounted on brackets on the stacks or superstructure.

Whip antennas that are to be used for receiving only are mounted as far away from the transmitting antennas as possible so that a minimum of energy from the local transmitters will be picked up.

One type of whip antenna commonly used aboard ship is constructed with 7-foot sections of aluminum rod. The lower rod is 3 inches in diameter and the whip tapers to a diameter of 1 inch at the upper section. (Fiberglass Whips are replacing the aluminum whips in some installations.) Some whips may be trussed with wire rope (which increases the frequency bandwidth) resulting in better performance (fig. 6-2). The recommended method for mounting a receiving whip antenna up to 35 feet in length is shown in figure 6-3. Whip antennas over 35 feet are mounted on a plate supported by three or four insulators (fig. 6-4) for greater strength. Small whip antennas have been mounted horizontally on yardarms or masts in some installations for use as low-frequency probe antennas. Such antennas usually come supplied with a line termination box (fig. 6-5) which normally is mounted to the ship's structure. Some applications use two whips connected as a single antenna for better electrical performance.

If the antennas are less than 25 feet apart, they are usually connected with a crossbar (fig. 6-6) which is the feedpoint at its center. If the antennas are a considerable distance apart or for some other reason a direct connection is not practical, transmission line termination is used. Referring to figure 6-7, the transmission



1.46(67C)

Figure 6-1.—Wire rope antenna.

lines (of equal length) are fed to a tee, which is the assembly feed point. Each whip is usually matched individually to the transmission line by antenna base matching networks. Wire rope is used in place of the whips in some installations.

On aircraft carriers and missile ships, a method of tilting the whip antenna (fig. 6-8) is employed for those installed along the edges of the flight deck, or in the missile firing zone.

The tilting mounts may be mechanically or hydraulically operated. Mechanically operated mounts have a counterweight at the base of the antenna heavy enough to nearly balance the antenna in any position. The antenna may be locked in either a vertical or horizontal position by positive locking devices in both the operating and stowed positions.

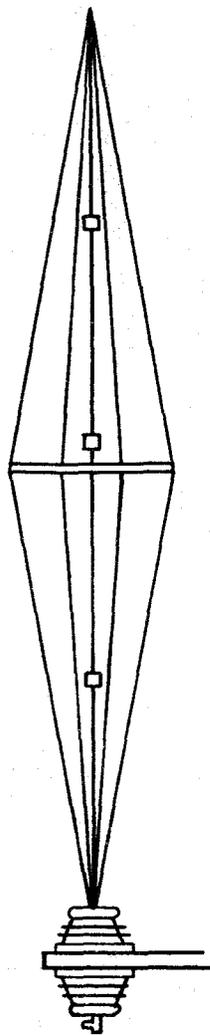
BROADBAND ANTENNAS

Broadband antennas for use in the HF and the UHF bands have been developed for use with antenna multicouplers. To be used with a multi-

coupler, the antenna must be capable of handling simultaneous transmission from several transmitters without excessive loss of power in the multicoupler equipment. The antenna must therefore function satisfactorily over a relatively wide band of frequencies.

The effectiveness of a given antenna depends largely on impedance matching. If a good impedance match exists between the transmission line and the antenna throughout the operating band of frequencies, efficiency and power transfer is improved.

One type of broadband antenna, called a fan, is shown in figure 6-9. Effectively, this is a V-shaped plane radiator. Physically, it is composed of five wires cut for one-quarter wavelength at the lowest frequency to be used. The wires are fanned 30° between adjacent wires. On small ships, the fan antenna may consist of only three or four wires. Ships may have two fan antennas, one a vertical fan and the other a horizontal fan antenna.



67.218

Figure 6-2.—Trussed whip antenna.

UHF ANTENNAS

A large variety of UHF antennas have been developed for shipboard use. Two of these antennas are shown in figure 6-10. They are used for transmitting or receiving vertically polarized waves in the 220 to 400 MHz range.

The VSWR of the left antenna (fig. 6-10A) is less than 2.1 to 1 over the desired frequency range; however, the antenna may be used over a wider frequency range with only a nominal decrease in efficiency.

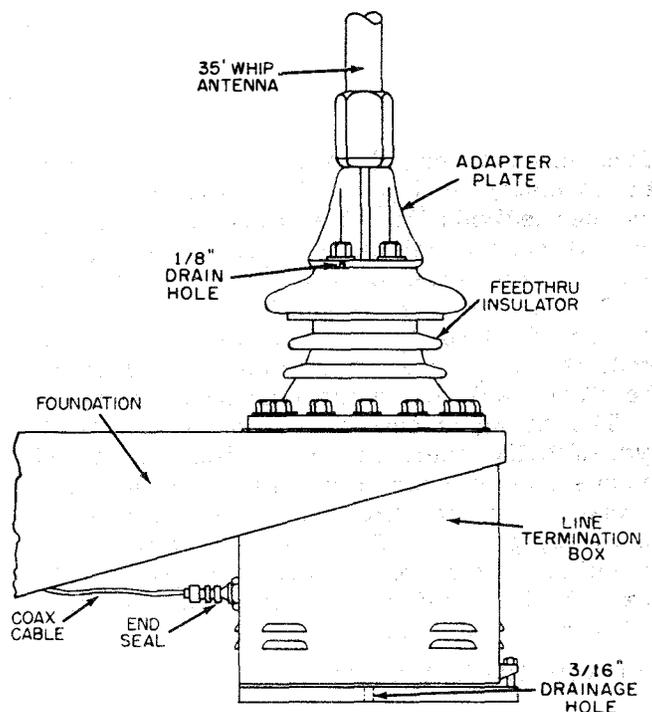
The radiation pattern is similar to that of a dipole. However, the pattern may be affected by the external supporting structure and the proximity of metallic masses. (Radiation patterns are discussed in Basic Electronics, Vol. 1,

NAVPERS 10087-C, chapter 29.) The nominal input impedance is 52 ohms; however the actual input impedance is a function of frequency.

The vertical portion of the antenna forms the radiating element and is made up essentially of an inner and outer coaxial line, the two lines being concentric. Two aluminum tubes, (A), welded to the outer antenna sections serve as both the outer conductor of the inner coaxial line and the inner conductor of the outer coaxial line. The tie rod is the inner conductor of the inner coaxial line. An insulated gap is formed in each of the outermost conductors by the spacer insulators.

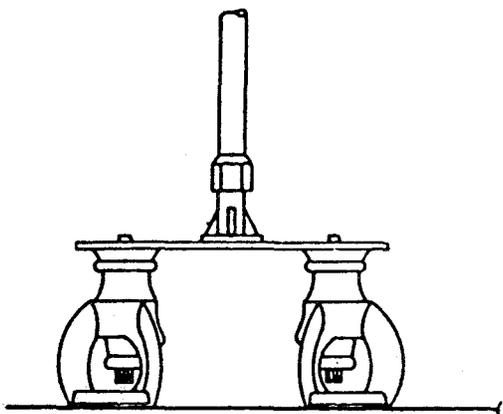
Another UHF antenna, shown in figure 6-10B has a VSWR of less than 1.9 to 1 over the designed frequency range. This antenna also may be operated over a wider frequency range with only a nominal decrease in efficiency. The radiation pattern of this antenna is similar to that of a dipole, and the nominal input impedance is 52 ohms. However, the actual input impedance is a function of frequency.

The lower antenna section acts as part of the radiating portion and also houses the coaxial feedline. The inner conductor of the feedline is connected to the tie rod, one end of which is



1.47

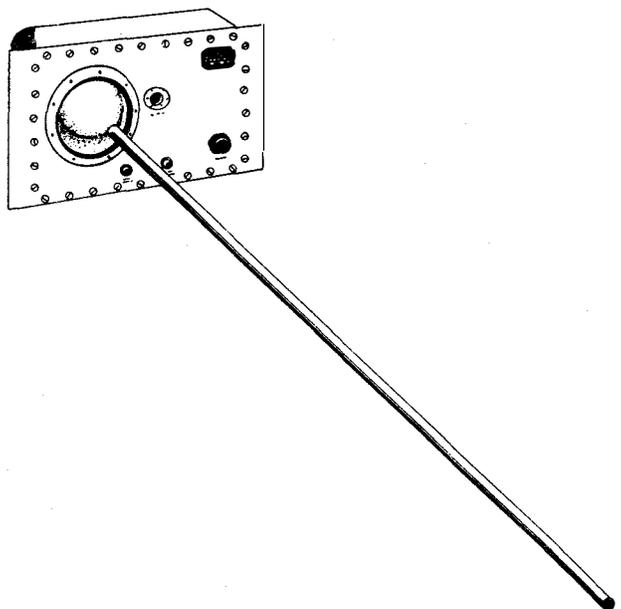
Figure 6-3.—Method of mounting whip antenna of 35 feet or less.



67.219

Figure 6-4.—Method of mounting whip antenna over 35 feet.

attached to the upper antenna section and the other of which is attached to the base of the lower antenna section. The lower portion of the tie rod is encircled by a tuning stub, which is closed and threaded at the top end and open at the bottom end, except for the supporting insulator. By rotating the stub on the threads, the input impedance of the antenna may be varied.

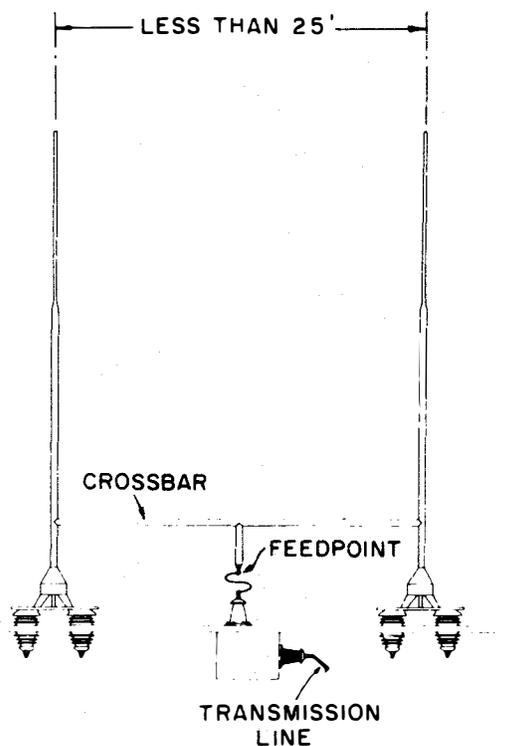


67.220

Figure 6-5.—Small whip antenna with line termination box.

Another UHF antenna is shown in figure 6-11. This type is covered with a polyester fiberglass radome which provides a rugged, weatherproof covering for both the transmission line and the antenna without interfering with radiation.

The transmission line is internal and consists of a circular inner conductor and a square outer conductor. It is designed to match the 50-ohm impedance of the external transmission line.



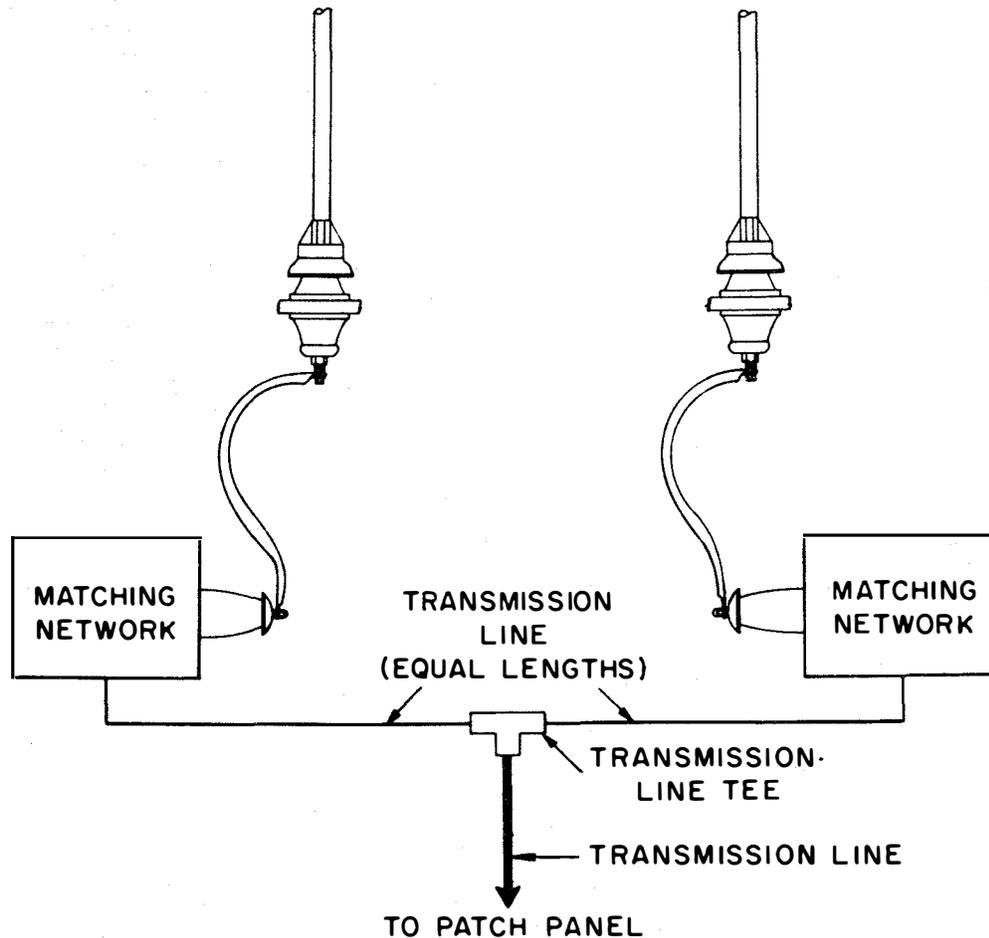
67.221

Figure 6-6.—Twin whip antennas with crossbar terminations.

The antenna is a colinear array of two cylindrical, parallel-fed, dipole elements. The non-resonant dipoles provide broadband coverage and an omni-directional horizontal radiation pattern. The lower half power point of the vertically polarized propagation falls on or below the horizon. The required pattern tilt is achieved by feeding the dipoles so that the upper dipole lags the lower dipole in phase by a few degrees.

MATCHING NETWORKS

An antenna matching network consists of one or more parts such as coils, capacitors, and



67.222

Figure 6-7.—Twin whip antennas with coaxial termination.

lengths of transmission line connected in series or parallel with the transmission line to reduce the standing wave ratio on the line. Matching networks are usually adjusted upon installation and require no further adjustment for proper operation. Figure 6-12 shows a matching network outside of the antenna feedbox with a sample matching network schematic.

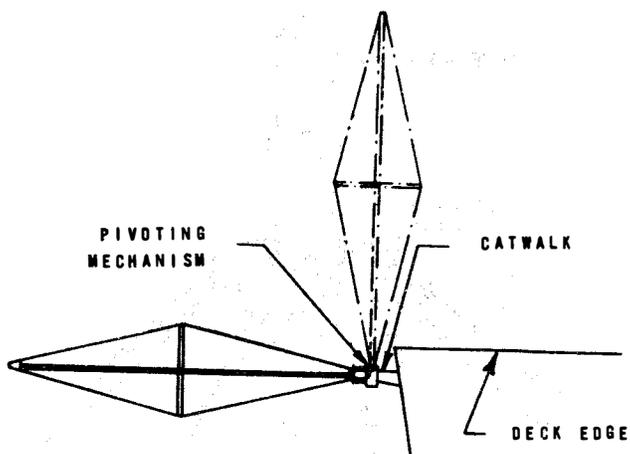
Matching networks can also be built with variable components so that they can be used for impedance matching over a band of frequencies. These networks are called antenna tuners.

Antenna tuners are usually adjusted automatically or manually each time the operating frequency is changed. Standard tuners are made with integral enclosures so that installation consists simply of mounting the tuner, assembling

the connections with the antenna and transmission line, and pressurizing if required. Access must be provided to the pressure gauge, and pressurizing and purging connections.

ANTENNA DISTRIBUTION SYSTEMS

Receiving antenna distribution systems operate at low power levels and so are readily adaptable to a standard modular construction form. A basic patch panel is shown in figure 6-13. Even the most basic distribution system would have several antenna transmission lines and several receivers. The patch panel would consist of two of the basic patch panels shown in figure 6-13 mounted in a standard 19-inch rack. One panel would terminate the antenna transmission lines and the other the lines leading



67.223

Figure 6-8.—Tilting whip antenna.

to the receivers. Thus any antenna could be patched to any receiver via patch cords.

Many distribution systems will be more complex. A complex distribution system to cover most situations is illustrated in figure 6-14. In this system, four antennas can be patched to four receivers, or one antenna can be patched to more than one receiver via the multicouplers (multicouplers are covered later in the chapter). There are also provisions for patching RF and audio from one compartment to another. A frequency standard is connected (through a distribution amplifier not shown) to the receivers.

Transmitting antenna distribution systems perform the same functions as receiving systems. However, because of the range in power levels, design and fabrication problems are more difficult. The ideal design would be to have all the transmission lines designed for the highest power level. But, because of cost and the fact that high power patch cords are large and difficult to handle, this approach is seldom followed.

In practice, a patch panel similar to the one shown for receiving systems is practical for power levels of 2 kw or less. One type of transmitter patch panel is shown in figure 6-15.

Transmitting patch panels are interlocked with the transmitter so that no open jack connection can be energized and no energized patch cord can be removed. This provides for both personnel and equipment safety.

MULTICOUPLERS

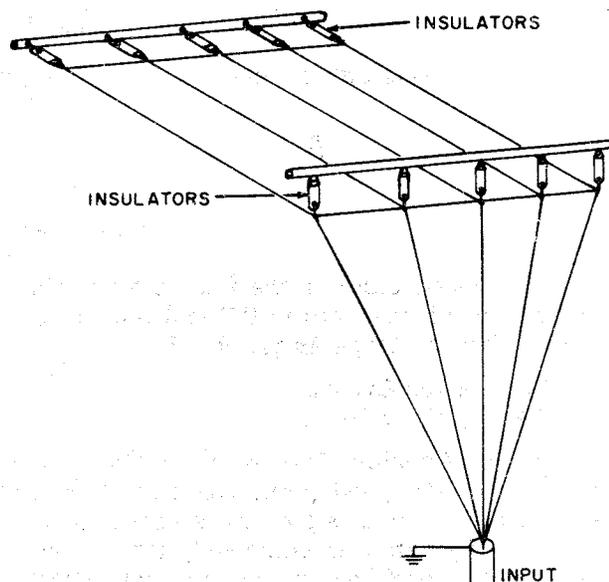
Shipboard radio communications systems have certain restraints or requirements imposed

on them because of their operational and physical environments. Principally, these are the limited space available for antennas and the simultaneous transmission on a number of channels at relatively high power levels with limited frequency separation. These conditions can result in unacceptable interchannel interference because of coupling between antennas, spurious emissions from transmitters, and limited input RF signal strength of the receivers.

Antenna couplers and multicouplers are used to improve the operational performance and function of shipboard radio communications systems. Antenna couplers and multicouplers provide an efficient coupling path between each transmitter and antenna or each transmitter and a common antenna, isolation between transmitters, filtering of harmonic and spurious transmitter output, rejection of local transmitter signals, impedance matching of the antenna to the transmitter or receiver, protection of receiver input circuits from high RF voltages, and reduction of spurious radiation from receivers.

HF MULTICOUPLERS

Most of the multicouplers for the HF range are designed for use with either transmitters or receivers, although there are some which are used with both. Because of the large size of



67.134

Figure 6-9.—Five-wire vertical fan antenna.

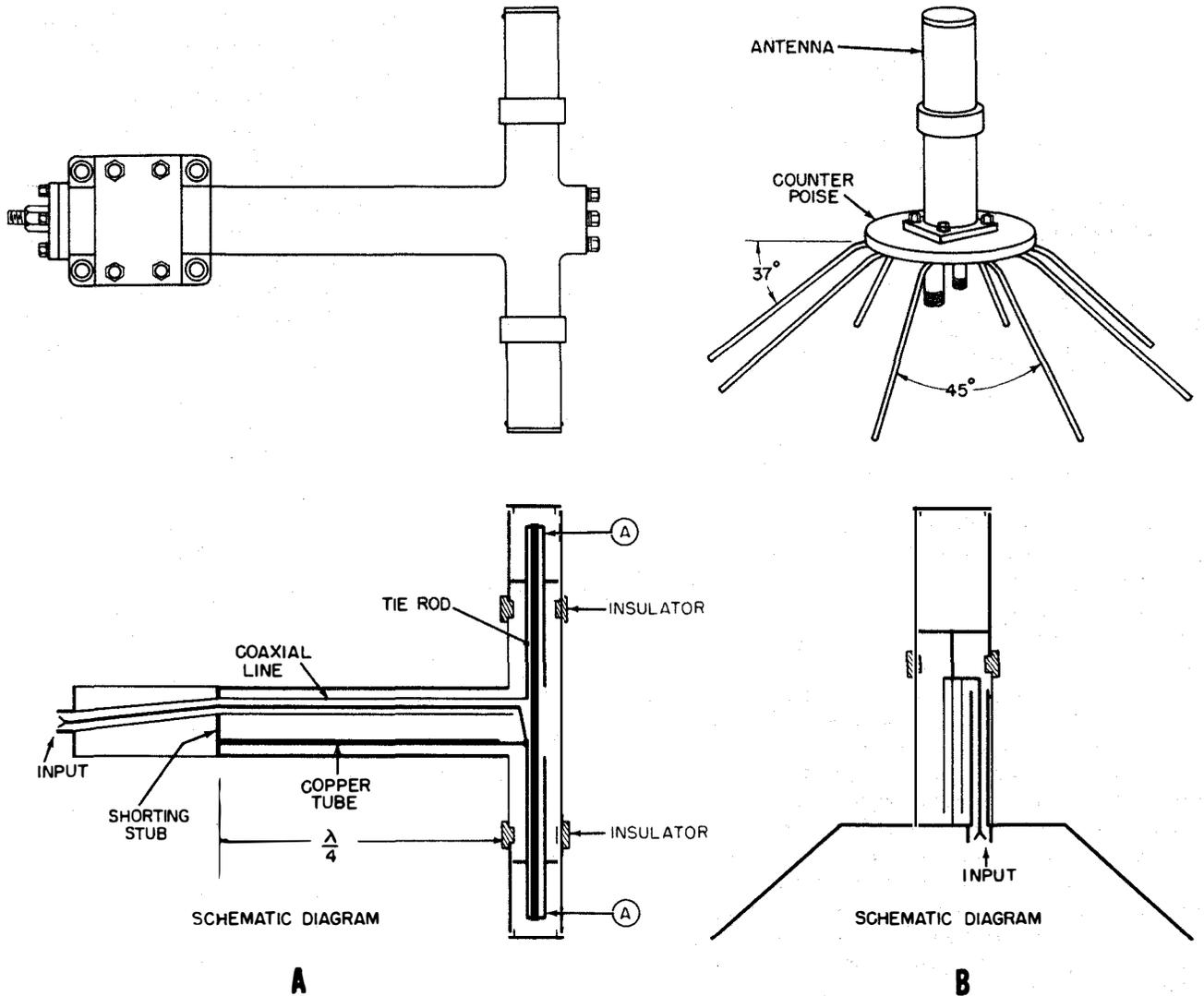


Figure 6-10.—UHF antennas.

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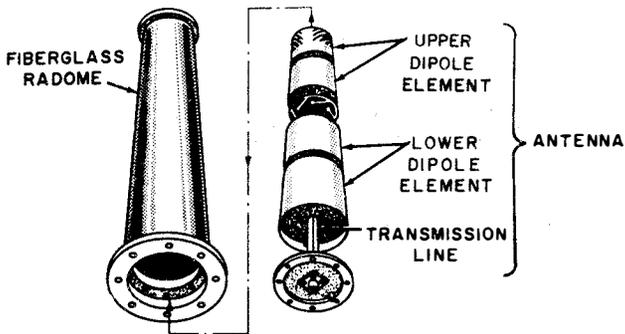
antennas (particularly in the 2 to 12 MHz range) the number of channels in HF multicouplers is usually made as large as practical.

**Antenna Coupler Groups
AN/SRA-56, 57, & 58**

Antenna Coupler Groups AN/SRA-56, -57, and -58 are designed primarily for shipboard use. Each coupler group permits several transmitters to operate simultaneously into a single, associated, broadband antenna, thus reducing the total number of antennas required in the limited space aboard ship.

These antenna coupler groups provide a coupling path of prescribed efficiency between each transmitter and the associated antenna. They also provide isolation between transmitters, tunable bandpass filters to suppress harmonic and spurious transmitter outputs, and matching networks to reduce antenna impedances.

GENERAL DESCRIPTION.—The three antenna coupler groups are similar in appearance and function. They differ in frequency ranges and the capability of providing four-channel or



109.44

Figure 6-11.—Mast covered UHF antenna.

eight-channel configurations. Antenna Coupler Group AN/SRA-56 operates in the frequency range from 2 to 6 MHz. The AN/SRA-57, operates from 4 to 12 MHz, and the AN/SRA-58, operates in the 10 to 30 MHz range. Antenna Coupler Groups AN/SRA-56 or -57 can each be operated alone in a four-channel configuration, or two of the same antenna coupler groups can be combined by means of an impedance matching network to form an eight-channel configuration. Antenna Coupler Group AN/SRA-58 can be used in a four-channel configuration only.

A single antenna coupler group consists of four antenna couplers (channels), built as drawer assemblies and installed in an electrical equipment cabinet, and a power supply installed in

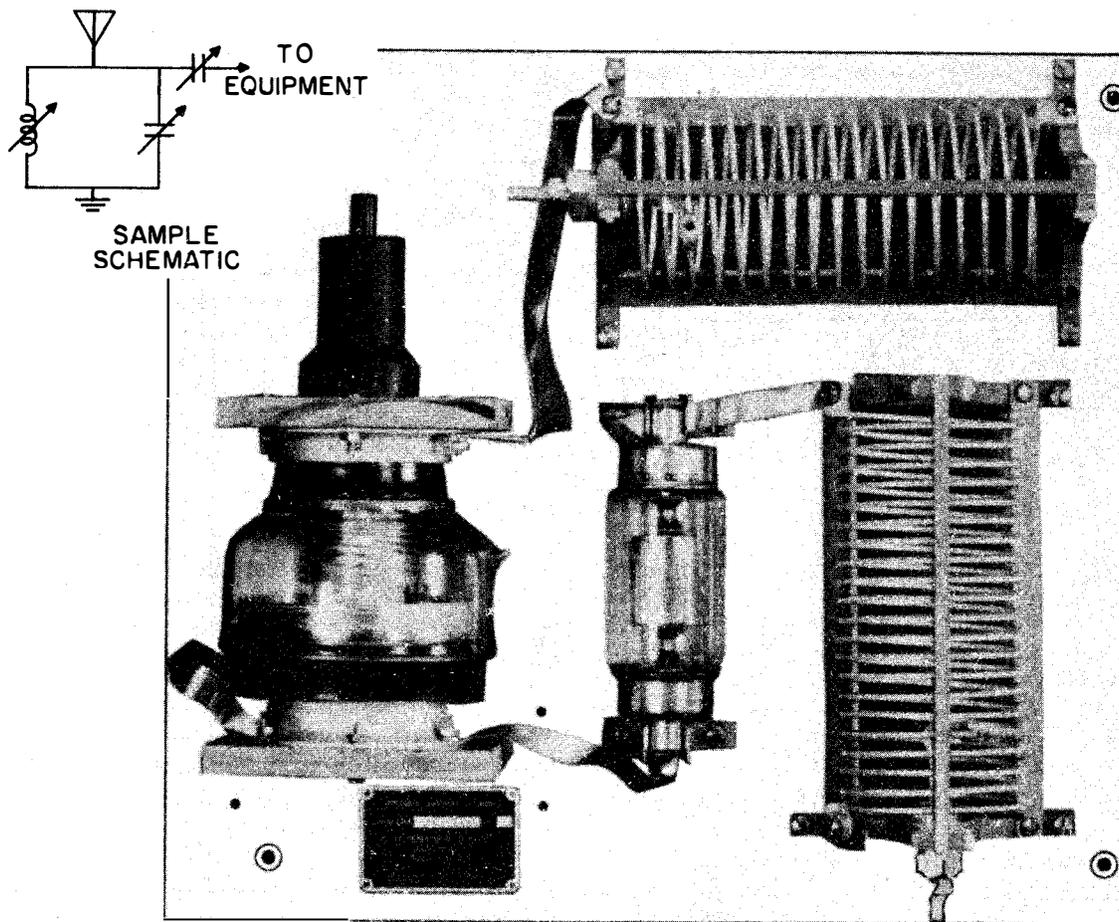


Figure 6-12.—Matching network.

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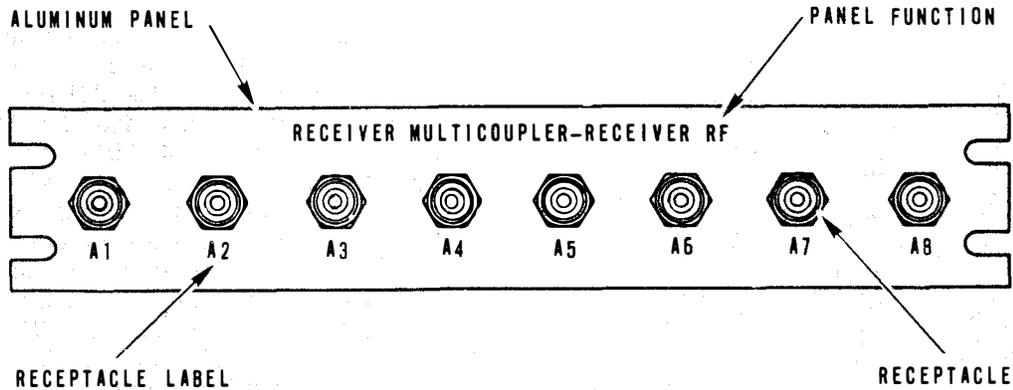


Figure 6-13.—Receiver patch panel.

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the bottom position of the cabinet (fig. 6-16). The antenna coupler groups are modular in design. All antenna coupler drawers are interchangeable within the same antenna coupler group. The power supply assemblies and many of the subassemblies and components in the equipment cabinets and in the antenna coupler drawers are interchangeable within all three coupler groups. Each antenna coupler group is a self-contained unit having all required RF circuits, operational controls, monitoring, control, and protective circuits, and power distribution and supply circuits housed within the electrical equipment cabinet.

Each antenna coupler group or eight-channel configuration operates with a separate broadband antenna having a maximum VSWR of 3-to-1 over the nominal frequency range of the associated antenna coupler group. The antenna coupler groups can operate with transmitters having power outputs as high as 1 kilowatt average and 2 kilowatts peak envelope power for each channel, and as low as 500 watts average per channel. Any individual coupler within a coupler group may be operated at any frequency within its tuning range, provided that it does not operate within 5% of the frequency occupied by another coupler within the same group.

Each antenna coupler contains monitoring, control, and protective circuits that provide and enforce sequential tuning and operation. The power supply panel in each coupler group contains a fused circuit that provides a.c. to operate the cooling air fans in each antenna coupler to remove the heat generated during tuning and operation, a power supply that provides d.c. to operate the control and protective circuits, and a sonic generator that provides an audible alarm

to warn the operator of a loss of air flow within an antenna coupler.

FUNCTIONAL DESCRIPTION.—An overall functional block diagram of Antenna Coupler Groups AN/SRA-56, -57 and -58 is shown in figure 6-17 (foldin) at the end of this chapter. Each coupler group cabinet contains four channels that enable four 1-kw (average) transmitters to operate simultaneously into a common broadband antenna. The circuits that form these four channels and the auxiliary circuits required to operate the channels are physically contained in a single equipment cabinet that houses one complete coupler group. Two AN/SRA-56 or AN/SRA-57 coupler groups can be combined into an eight-channel configuration using a separate impedance matching network.

The RF signals from an individual transmitter through a coupler group into an antenna are processed in the following manner. RF power from transmitter 1 (fig. 6-17, foldin end of chapter) enters the coupler group through operate reflectometer 1A6A2 and is fed to RF relay assembly 1A6A7. During the tuning procedure for the associated antenna coupler (1A1), vacuum relays in the RF relay assembly are activated, and the RF signal path is switched through power attenuator 1A6A1 and tune reflectometer 1A6A6. The attenuated RF is fed to RF circuitry in antenna coupler 1A1 where it is used to tune the antenna coupler before the full power is switched by the RF relays and applied directly to the antenna coupler input during regular operation. The operate and tune reflectometers sample the RF power and provide signal outputs to the monitoring and control circuits during tuning and operation of the antenna coupler.

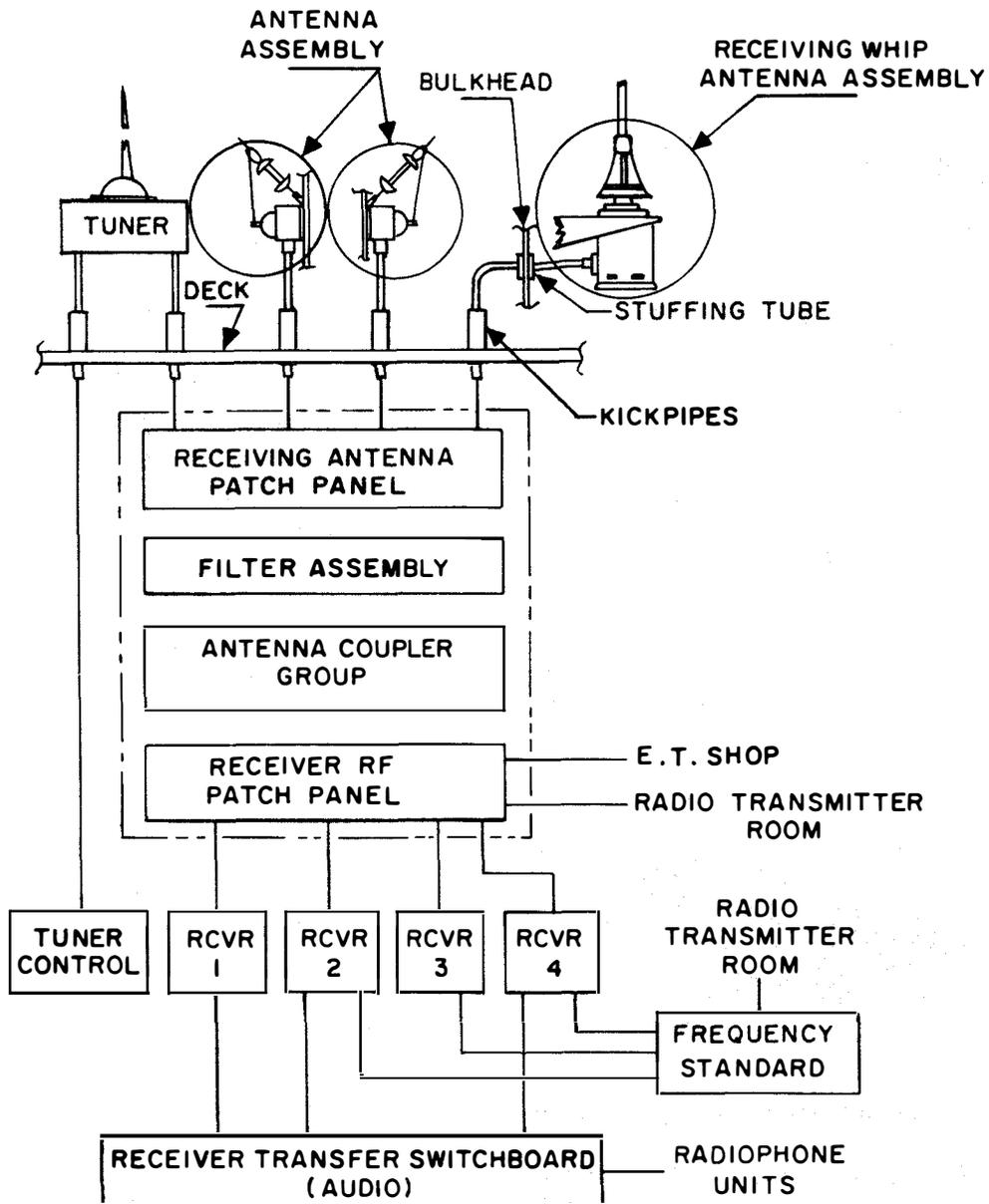


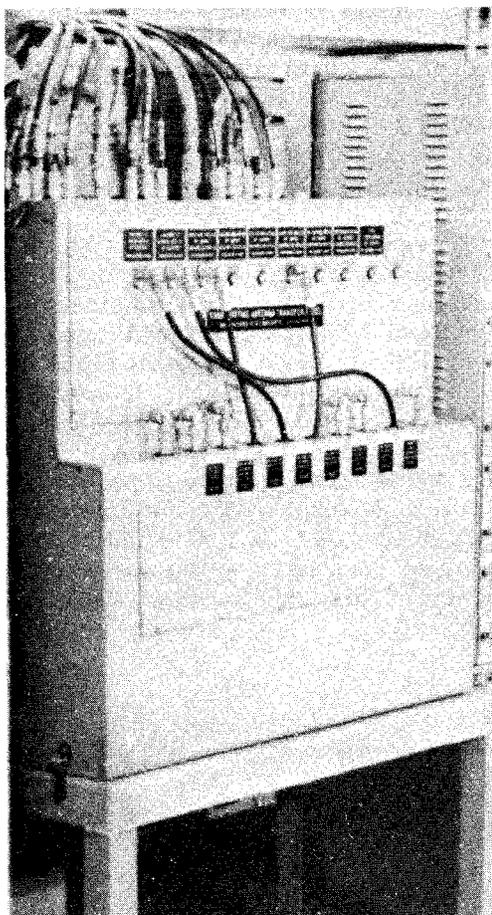
Figure 6-14.—Complex distribution system.

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From the RF relay assembly, either the attenuated RF used in tuning, or the full power RF used in regular operation, is applied to a highly selective bandpass filter in antenna coupler 1A1 through electronic Q control assembly 1A1A4. The processed RF output from the bandpass filter is inductively coupled to the combiner by means of an output coupling link 1A6L1 which is physically moved in and out of the output

resonator to load the antenna coupler during the final tuning step and operation.

The RF voltages present on the input and output resonators are sampled to provide additional signal inputs to the monitoring and control circuits of the antenna coupler during tuning and operation. The RF circuits, operational controls, monitoring, and control circuits provide a means of tuning the antenna coupler

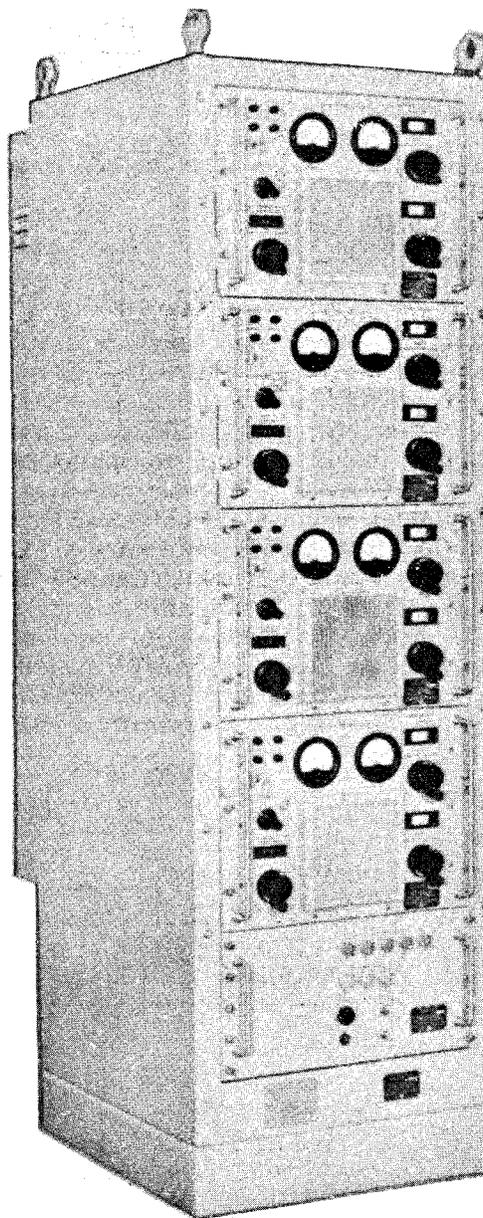


70.27

Figure 6-15.—Transmitting antenna patch panel.

in the required sequence, operating the antenna coupler in an established manner, and protecting the antenna coupler and its associated transmitter if a malfunction should occur.

In the combiner, the RF output from channel 1 is matched and combined with the RF outputs from the other three channels in the coupler group cabinet. The RF output of the combiner is fed via coaxial transmission line to the antenna, or directly to an impedance matching network when two coupler group cabinets are used in an eight-channel configuration (AN/SRA-56 and AN/SRA-57 only). The impedance matching network operates in a manner similar



120.11-56-58

Figure 6-16.—Antenna coupler group AN/SRA-56, AN/SRA-57, or AN/SRA-58.

to the combiner to match and combine the RF outputs from the two coupler groups. The RF output from the impedance matching network is then delivered to the antenna via coaxial transmission line.

The power distribution and supply circuits located on the power supply panel 1A5 provide

to each antenna coupler (1) a.c. to operate the cooling fans which remove the heat generated during operation and (2) d.c. to operate the control and protective circuits. The power supply panel also contains an audible alarm to warn the operator of a loss-of-air flow within any of the antenna couplers.

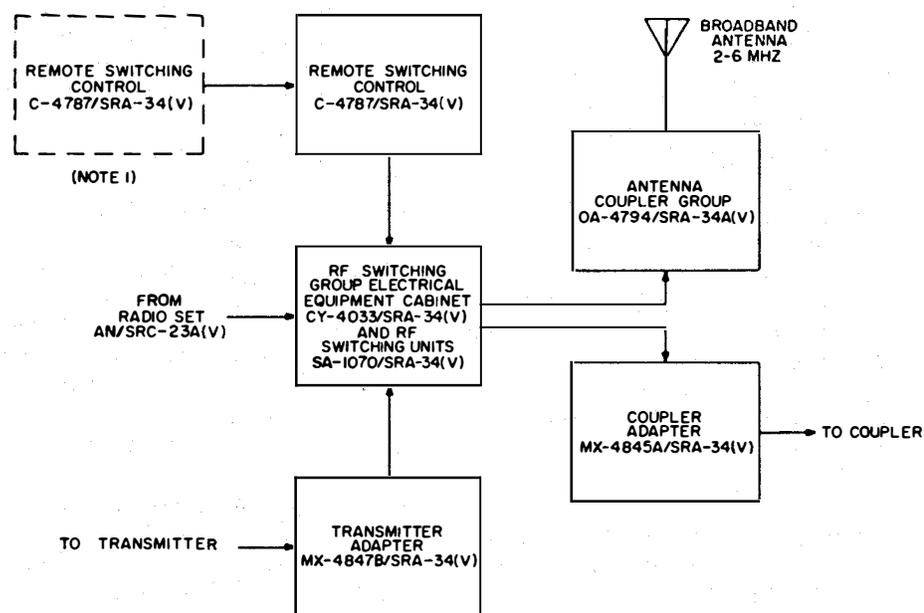
Antenna Coupler Group AN/SRA-34A (V)

Antenna Coupler Group AN/SRA-34A (V) is a variable group of antenna couplers, associated adapters, and switching units. The major units of the group are antenna coupler group OA-4794A, coupler adapter MX-4845A, transmitter adapter MX-4847B, remote switching control C-4787, and RF switching group including electrical equipment cabinet CY-4033 and RF switching units SA-1070 as shown in figure 6-18. Each of these major units is shown in figure 6-18 as a functional section of the AN/SRA-34A (V); however, the quantity of each major unit supplied for a particular AN/SRA-34A(V) system will vary depending upon individual installation requirements. For example, a specific installation

may require several MX-4845A equipments and may not include an MX-4847B unit.

The AN/SRA-34A (V) units have one primary feature in common. All are intended for use in a duplex system of antenna coupler control. (A duplex system permits two RF signals to operate on the same transmission line simultaneously.)

FUNCTION OF MAJOR UNITS.—Antenna Coupler Group OA-4794A/SRA-34 (V) provides antenna coupling between HF receivers and/or transmitters utilizing duplex control, and ship-board antennas that cover the 2,000- to 5,999-MHz frequency range. The OA-4794A/SRA-34 (V) consists of Electrical Equipment Cabinet CY-4032A/SRA-34 (V) and four Antenna Coupler CU-1169/SRC-16 units. The OA-4794A/SRA-34 (V) is capable of accepting up to four RF input channels. Channel spacing is dependent on the particular receiver and/or transmitter in use. The RF power handling capability of each channel is 5 kw peak envelope power, and 2.5 kw average. The CY-4032A/SRA-34 (V) contains a water-cooled heat exchanger which permits internal closed-cycle air cooling for the CU-1169/SRC-16 units.



NOTE 1. ADDITIONAL REMOTE SWITCHING CONTROLS (MAX OF 4) MAY BE INTERCONNECTED; ONE FOR EACH RF SWITCHING UNIT SA-1070/SRA-34(V).

120.11-34

Figure 6-18.—Antenna coupler group AN/SRA-34A(V) functional block diagram.

Coupler Adapter MX-4845A/SRA-34 (V) adapts the control circuits of various antenna couplers to the diplex antenna coupler control system. Compatibility with the AN/SRA-13 through AN/SRA-16, AN/SRA-22, AN/SRA-56 through AN/SRA-58, and AN/URA-38 may be achieved by use of one of the jumper plug assemblies supplied with the MX-4845A/SRA-34(V). The only connection required between the MX-4845A/SRA-34 (V) and the RF switching group is the RF transmission line.

Transmitter Adapter MX-4847B/SRA-34 (V) adapts the control circuits of various radio transmitters to the diplex antenna coupler control system. Compatibility with the AN/WRT-2, AN/URC-32, AN/SRT-15, or the AN/URT-23 is achieved by use of one of the jumper plug assemblies supplied with the MX-4847B/SRA-34 (V). The only connection required between MX-4847B/SRA-34 (V) and the RF switching group is the RF transmission line.

The RF switching group functions as an RF switching matrix between radio transmitters, and/or receivers and antenna couplers employing diplex control. Electrical Equipment Cabinet CY-4033/SRA-34 (V) contains provisions for one to four RF Switching Units SA-1070/SRA-34 (V). A maximum of 20 RF sources may be connected to a maximum of 25 loads on a 1-for-1 basis. One RF switching unit is required for every five RF sources. The RF switching group may be controlled locally (manually) or remotely. Remote control requires the use of one or more Remote Switching Control C-4787/SRA-34 (V) units. The CY-4033/SRA-34 (V) contains a water-cooled heat exchanger which permits internal closed-cycle air cooling.

The remote switching control C-4787/SRA-34(V) is a remote control unit for the RF switching group. It may be located up to 900 feet from the CY-4033/SRA-34 (V). One SA-1070/SRA-34 (V) is controlled by each remote switching control unit. Each SA-1070/SRA-34 (V) requires a C-4787/SRA-34 (V) for remote control operation.

ANTENNA COUPLER GROUP OA-4794A.— Antenna coupler group OA-4794 consists of four antenna couplers CU-1169/SRC-16 mounted in electrical equipment cabinet CY-4032A as stated previously. This coupler group (fig. 6-19) may be used with an automatic receiver-transmitter such as Radio Set AN/SRC-23A (V), or with manual equipment and the appropriate adapter. Each of the antenna couplers mounted in

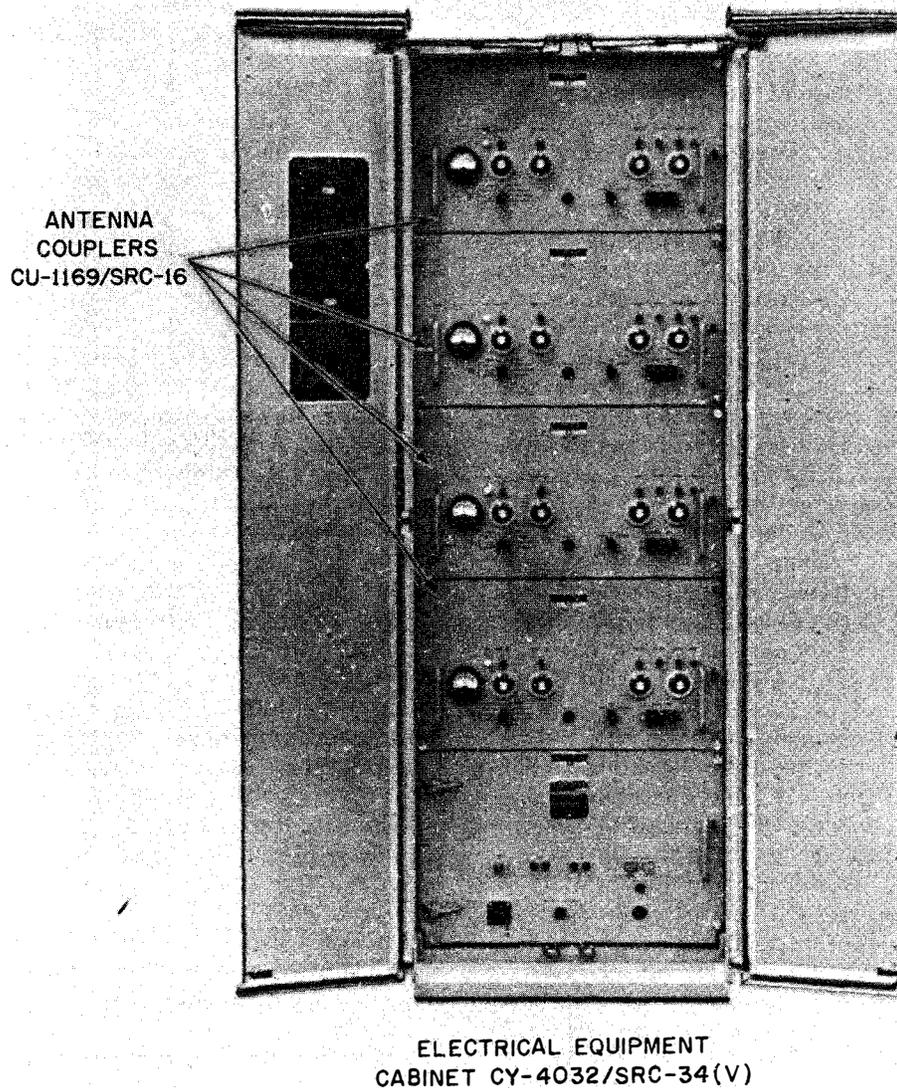
Electrical Equipment Cabinet CY-4032A/SRA-34 (V) has its own RF input, but all four are connected to a common antenna. The antenna coupler bandpass permits RF output from any one, or up to eight, of the antenna couplers to a common antenna. (Outputs from two adjacent antenna coupler groups operating in the same frequency band may be connected together.) If more than one transmitter is transmitting at the same time, the frequencies must differ by at least 5 percent.

The necessary control information is transferred between the transmitter-receiver and the antenna coupler by a sequence of low-power pulses diplexed on the RF line. Since there are four antenna couplers involved, each requires its own control circuits. Each antenna coupler, therefore, has its own diplex subassemblies that consist of a low-pass filter assembly, a coupler electronic gate, and an electronic digital counter. In addition to the diplex subassemblies, a pair of antenna couplers shares a sequential timer card and a power supply module. The four antenna couplers share a common thermal alarm control.

The circuits of Electrical Equipment Cabinet and the four antenna couplers are cooled by an internal closed-cycle cooling system employing a water-cooled heat exchanger. In the event of excessive temperatures, alarm signals are generated that light the alarm indicators on the lower panel of the electrical equipment cabinet (fig. 6-19).

Each of the four antenna couplers requires its own diplex circuits for operation. These circuits include a low-pass filter, an electronic digital counter, a coupler electronic gate, one circuit of a sequential timer, and an input to the thermal alarm control as shown by the functional block diagram in figure 6-20.

Control information is transferred by a sequence of low-power pulses diplexed on the RF line. This sequence of pulses is repeated continuously as long as the equipment is energized. The first pulse is a synchronization pulse and is twice the duration of the remaining pulses. This pulse is detected in the coupler electronic gate, and the information is used to reset flip-flops in the electronic digital counter. Each of seven control pulses is preceded by a clock pulse. The clock pulse is detected in the coupler electronic gate, and this information steps flip-flops in the electronic digital counter to provide the proper enable pulses. The control pulses carry binary information; that is, they are each either on or off, indicating, for example, operate or standby.



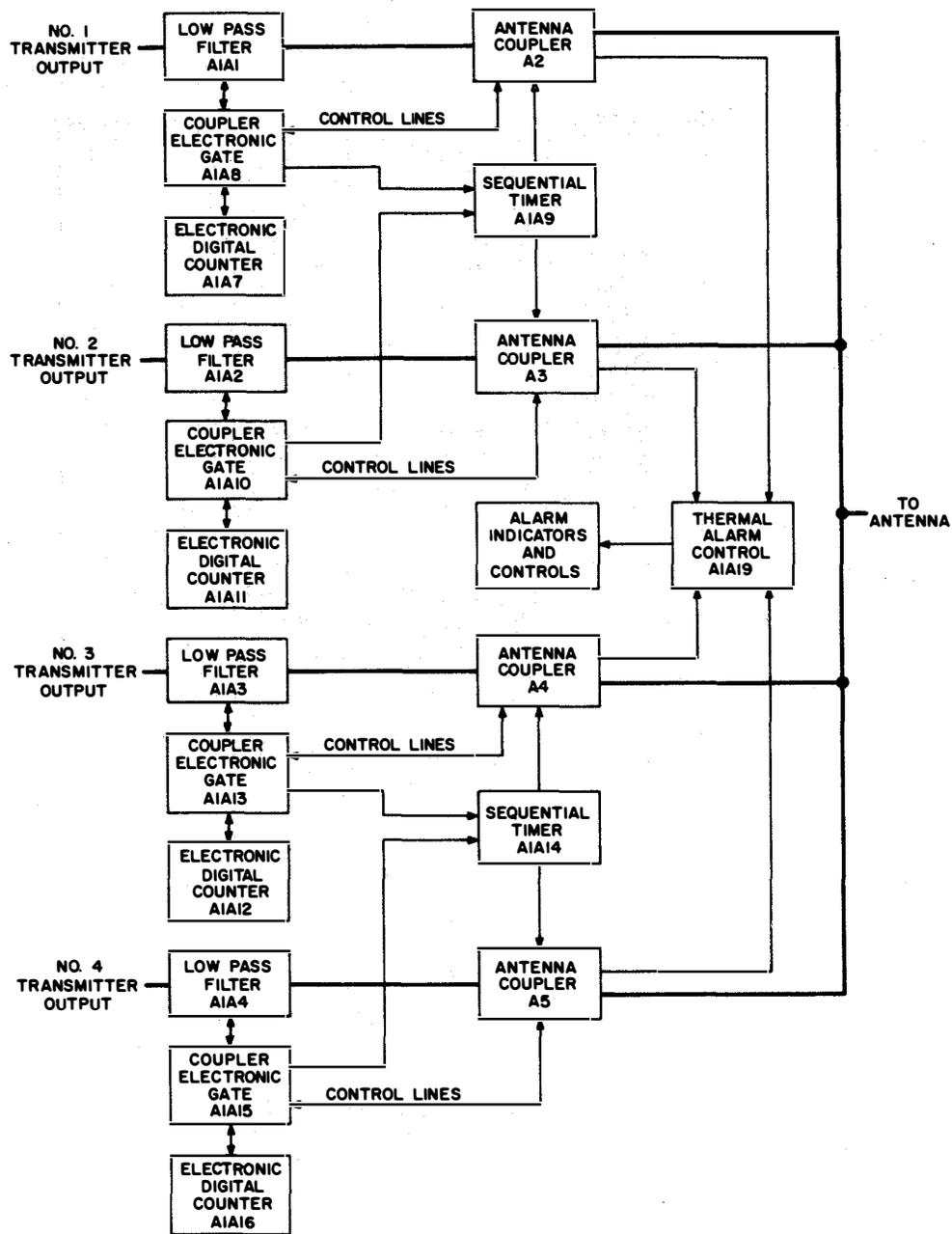
67.228(162A)

Figure 6-19.—Antenna coupler group OA-4794A/SRA-34(V).

The coupler electronic gate has circuits for detecting and generating the various control pulses. The synchronizing pulse is detected, and the sync output is sent to the electronic digital counter to reset the flip-flops. The clock pulses are detected and sent to the electronic digital counter to trigger the flip-flops. The control pulses from the transmitter-receiver are detected and ANDed with enable pulses to control

the antenna coupler. The control signals from the antenna couplers are ANDed with the enable pulses from the electronic digital counter and then applied to the RF line to control the transmitter-receiver.

The sequential timer card contains two identical circuits. Each antenna coupler uses one circuit; therefore, two antennas couplers share the same card. If a coupler is receiver



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Figure 6-20.—Antenna coupler group OA-4794A/SRA-34(V) functional block diagram.

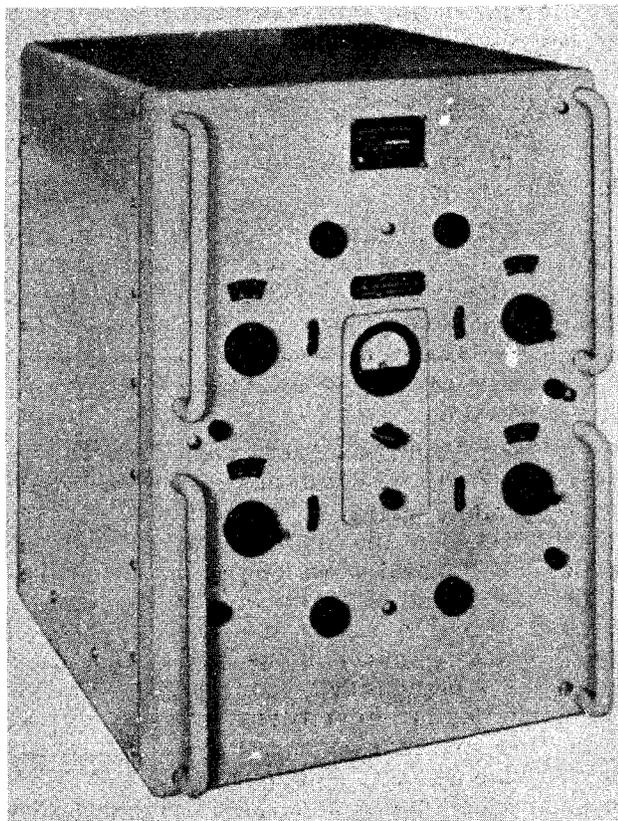
tuned, the circuit provides a continuous operate signal (ground) to the antenna coupler for 30 seconds after the receiver tune and operate signals are removed by the transmitter-receiver. This 30-second extension of the operate signal is provided to permit switching the RF line (and diplexed control information) from the transmitter to the receiver.

The thermal alarm control receives a warning temperature ground from a thermal switch at the rear of the cabinet and alarm signals from all four antenna couplers. The warning signal energizes warning indicators, sounds a horn, and enables the UNSAFE temperature alarm gate for alarm signals coming from the antenna couplers. An alarm signal from any

antenna coupler accompanied by the warning temperature ground will light the UNSAFE temperature indicator and cause an alarm signal to be sent to the transmitter-receiver feeding that antenna coupler. The transmitter is placed in standby, and the antenna coupler alarm indicator is lit. In the thermal alarm control, there is a horn disable circuit operated by the HORN CANCEL button on the front panel and an emergency operation circuit called battle short enable. This circuit can be operated by the BATTLE SHORT button on the front panel.

The low-pass filters (fig. 6-20) provide access to the RF transmission lines for the acceptance or application of the pulse train. They also provide low-frequency isolation so that the pulse train signals will not be loaded excessively by the antenna coupler inputs. A radio frequency line filter (not shown) suppresses RF interference in the cabinet primary power input. A separate filter is provided within the subassembly for each primary power lead.

The power supplies (not shown) provide regulated 29 volts to the coupler electronic gates, electronic digital counters, and sequential timers. They also provide unregulated 28 volts to the thermal alarm control.



UHF MULTICOUPLERS

UHF multicouplers are usually used for transceiving. This and the close channel spacing desired during operation require multiple-resonator filters to achieve the necessary isolation between channels. In all cases, coaxial cavity resonators are used. UHF multicouplers are designed for use with antennas whose VSWR is 2:1 or less throughout the operating frequency range of the multicouplers. Two UHF multicouplers largely used in the fleet are the CU-691/U and the AN/SRA-33.

Antenna Coupler CU-691/U

Antenna Coupler CU-691/U (fig. 6-21) provides isolation between four transmitter and/or receiver combinations operating simultaneously into a common antenna. Isolation is achieved with four highly selective tandem filters and a combining network. The high selectivity reduces intermodulation interference, cross modulation interference, and spurious responses. Harmonic radiation from the transmitter(s) is also attenuated.

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Figure 6-21.—Antenna coupler CU-691/U.

GENERAL DESCRIPTION.—Inside the coupler are eight silver-plated aluminum tunable cavities. When properly tuned, each cavity is a $1/4$ -wavelength shorted coaxial element. The cavities are aperture coupled in groups of two, forming four dual-cavity tunable tandem filters. Adjustable tuning slugs in the cavity side walls permit compensation for minor irregularities in the cavity resonance curve. The outputs of the four filters are coupled to a common junction at the input of a combining network. The output of the combining network is the output connector for the antenna transmission line. The coupler is capable of accepting RF energy on all input channels simultaneously, each channel having a carrier power level of 200 watts.

A monitor coupler assembly is inserted in each input transmission line between the input type N coaxial connector and the input to the tandem filter. The coupler assembly develops d.c. voltages proportional to the forward and reflected wave components existing on each line. The d.c. voltages are supplied to the meter

circuit via the function selector switch. Calibrating resistors, selected by the switch, derive meter readings from the developed d.c. voltages which show forward power and standing-wave ratio. The meter readings are useful for tuning the filters and for monitoring line conditions during operation.

FUNCTIONAL DESCRIPTION.—Antenna Coupler CU-691/U is shown in block diagram form in figure 6-22. To simplify the operation, the coupler is considered as being composed of four subdivisions; the tandem cavities, the combining network, the monitor circuits, and the tuning system.

Tandem Cavities.—Each tandem cavity is a two-section filter consisting of two cavities. Corresponding pairs of cavities are tracked together across the tuning range (225 to 400 MHz) by a manually-positioned, spring-loaded gear train which rotates precision lead screws connected to the cavity movable conductors. Small tracking slugs in the cavity side walls (eight slugs in each cavity) compensate for minor irregularities in the cavity resonance curve, thus permitting extremely accurate tracking throughout the tuning range. The input and output transmission lines are loop coupled to the input and output cavities, respectively. Cavity pairs are coupled through an aperture in the cavity side walls.

Combining Network.—The output loop of each of the four tandem cavities is connected to a short section of transmission line. The four lines join in a common junction at the input to the combining network. The output of the combining network is the output connector for the antenna transmission line. The combining network consists of two short, equal lengths of transmission line in series. The two sections differ in characteristic impedance because of a difference in the size of the inner conductors. The outer conductors of each section are identical. The impedance of the two sections of the combining network together with the impedance of the four sections of line from the tandem cavities, are such that the impedance looking into the output terminal is nominally the same as the impedance looking into the input terminal of a resonant tandem cavity. Both impedances have a nominal value of 50 ohms. The impedance looking into either the input or output coupling loop of any nonresonant cavity is essentially an open circuit.

Monitor Circuits.—The monitor circuits consist of four coupler units connected to a common indicator circuit through a function switch. Each coupler unit is inserted in the short section of transmission line between the input jack and the corresponding tandem cavity input. With this arrangement, each input line is monitored separately before entering the associated tandem cavity. The coupler units derive d.c. voltages proportional to the forward and reflected wave components existing on the input transmission lines. The derived d.c. voltage proportional to the forward wave components (voltage and current) is used as the basis for the POWER meter reading and as the source of the full-scale level set by the SWR CAL control when the meter function switch is in the SWR CAL position. The derived d.c. voltage proportional to the reflected wave components is used as the basis for the SWR meter readings.

Tuning System.—The movable conductors in each pair of cavities are mechanically tracked through a gear train to a coarse tuning control, a fine tuning control, and a set of index plates. Mechanical loading eliminates backlash in the gear trains and in the precision lead screw assemblies.

Antenna Coupler Group AN/SRA-33

Antenna Coupler Group AN/SRA-33 provides isolation between as many as four transmitter and/or receiver combinations operating simultaneously into a common UHF antenna. Any number of transmitter and/or receiver combinations up to the maximum of four can be used without degrading operation. The AN/SRA-33 is designed for operation with shipboard Radio Set AN/SRC-20, Radio Set AN/SRC-21, and Radio Set AN/GRC-27. The AN/SRA-33 consists of four antenna couplers (CU-1131/SRA-33 through CU-1134/SRA-33), a Control-Power Supply C-4586/SRA-33, and Electronic Equipment Cabinet CY-3852/SRA-33, and a set of special purpose cables (fig. 6-23).

GENERAL DESCRIPTION.—Except for the physical arrangement of components the four-antenna couplers (CU-1131/SRA-33 through CU-1134/SRA-33) are identical. The components of each antenna coupler are arranged so that the RF output connectors will be in close proximity and allow for optimum design of the combiner network (part of Electronic Equipment Cabinet

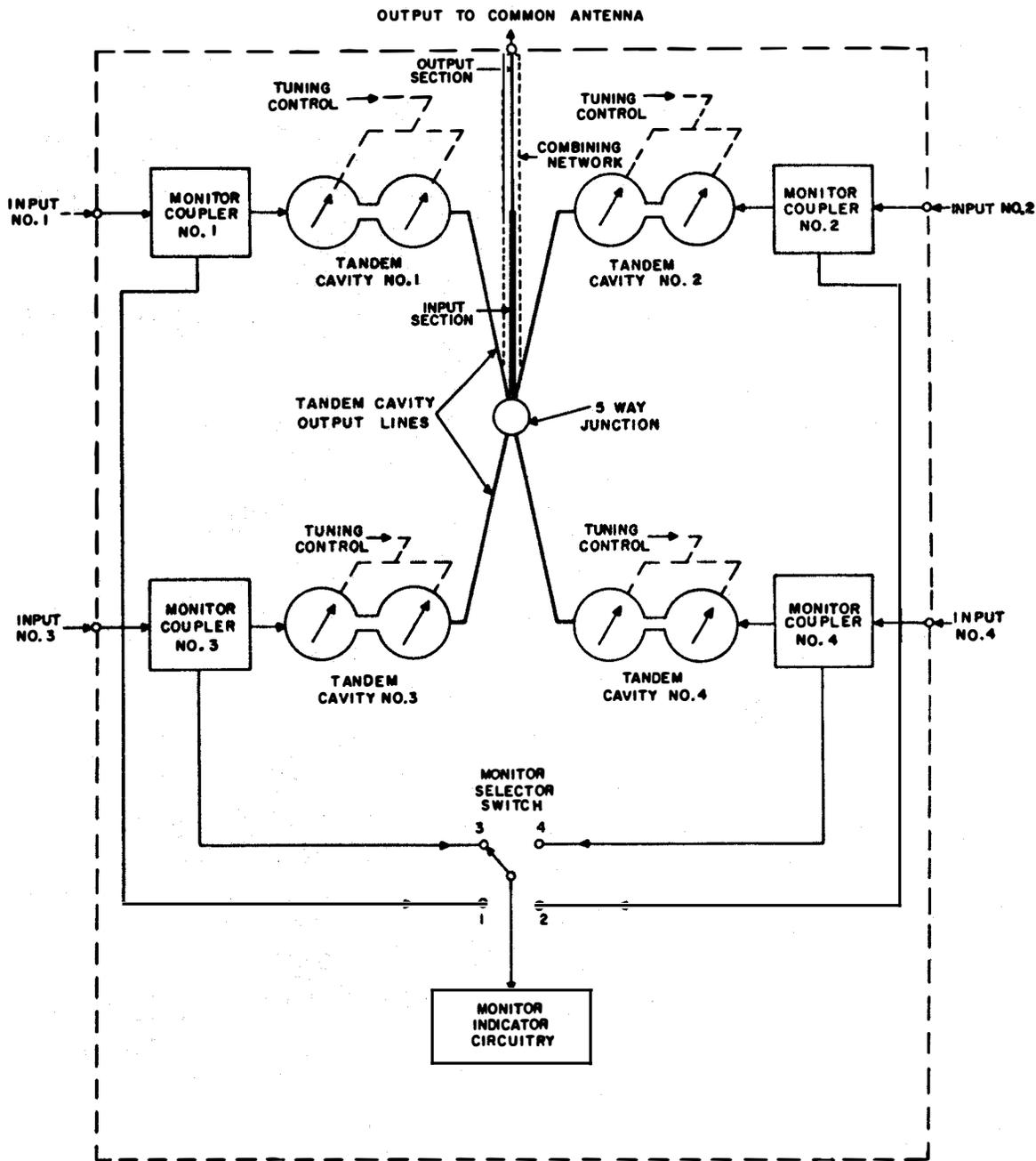


Figure 6-22.—Antenna coupler CU-691/U block diagram.

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CY-3852/SRA-33). Each antenna coupler contains a tuned dual-cavity resonator. The RF input connector (located on the front of the unit) is loop coupled to the input cavity. The input and output cavities are aperture coupled and the

output cavity is loop coupled to the RF output connector.

The cavity resonator is servo tuned in 0.05 MHz steps from 225.00 MHz to 399.95 MHz. Frequency selection may be performed either

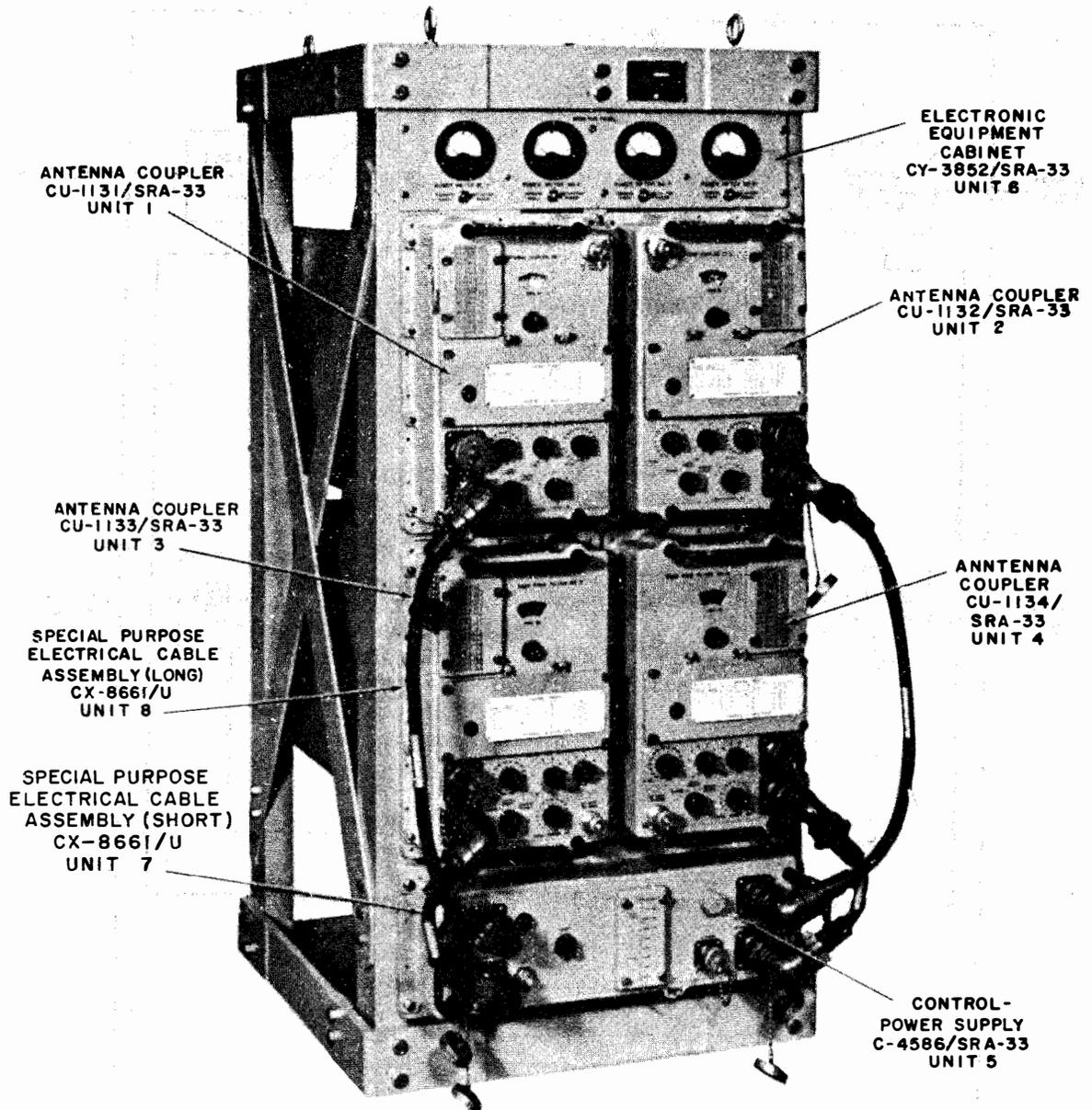


Figure 6-23.—Antenna coupler group AN/SRA-33.

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locally or remotely. In remote operation, 19 preset frequency channels are available. Remote channel selection operates on either the 5-wire, 19-channel code used in the AN/SRC-20 and

AN/SRC-21 or the 4-wire, 10-channel code used in the AN/GRC-27. Local operation has the option of preset channel selection or manual frequency selection. The antenna coupler also

incorporates interlock circuits which prevent application of RF power during tuning cycles.

The control power supply unit C-4586 contains d.c. power supplies, a lockout control circuit, and an RF power meter circuit. The power supply circuit operates from a 115- or 230-volt, 60-Hz, single-phase source and supplies all operating voltages for the AN/SRA-33 units. Conversion to 115-volt or 230-volt operation is accomplished by operating an internal switch and changing one front panel fuse.

The lockout circuit disables the associated transmitter and disconnects the coupler from the antenna when (1) the antenna coupler is tuning (2) when the coupler is tuned below 225 MHz (low frequency lockout) or (3) another antenna coupler-transmitter combination is set to the same channel and keyed to transmit. This third feature prevents operating two couplers on the same channel, if one of them is used for transmitting, and provides priority to the transmitting coupler. Transmit disable control consists of a pair of relay contacts which are opened for disable and closed for enable.

The RF power meter circuit consists of voltage-divider calibration adjustments for the four antenna coupler RF power meters.

The electronic equipment cabinet CY-3852 provides mounting space for the other units of the AN/SRA-33 and in addition contains the output RF combiner network and four RF power meters. The combiner network couples the 50-ohm RF outputs of the four antenna couplers to a common antenna RF jack at the rear of the cabinet. The combiner network provides impedance matching between the four antenna coupler RF outputs (50 ohms nominal) and the common antenna transmission line (50 ohms nominal) jack at the rear of the cabinet. The combiner network also contains an interlock circuit which enables the remaining couplers to be operated when one or more couplers are removed from the cabinet.

FUNCTIONAL DESCRIPTION.—A functional block diagram of the AN/SRA-33 is shown in figure 6-24 (foldin end of chapter). Except for the common output combiner network, the RF circuit of each antenna coupler operates independently. The RF input to the antenna coupler is fed through a directional coupler, a servo tuned dual-cavity resonator, and a coaxial switch to the combiner network. The directional coupler provides samples of forward and reflected RF power for the metering circuits. The dual-cavity

resonator provides the required antenna coupler selectivity and is mechanically tuned by a servo tuning system. The coaxial disable switch (part of the combining network) opens the RF line when (1) the antenna coupler is removed from the equipment rack, (2) when the antenna coupler is tuning, (3) when another antenna coupler is tuned to the same preset channel and keyed to transmit or (4) when a preset or manual frequency is below 225 MHz. The 50-ohm RF outputs of the four antenna couplers are coupled to the 50-ohm antenna output by the combiner network.

The four antenna couplers each have an independent tuning system which consists of a frequency selector circuit and a servo tuning circuit. The frequency selector circuit converts channel or frequency input information into an analog d.c. voltage which is fed to the servo tuning circuit. The frequency selector operates in a manual or preset mode. In the manual mode the frequency is selected by the manual frequency selector on the front panel of the antenna coupler. In the preset mode the frequency is selected by the preset memory drum. Nineteen preset frequencies can be preset on this memory drum. These 19 channels can then be selected either locally or remotely. Local channel selection is performed by a front panel control. Remote channel selection is by a 5-wire, 19-channel information input (compatible with AN/SRC-20 or AN/SRC-21) or a 4-wire, 10-channel information input (compatible with AN/GRC-27). The frequency selector circuit also provides 5-wire channel information to the lockout control circuit.

The lockout control circuit performs two basic protective functions: (1) it opens the transmitter disable line to prevent application of RF power to the antenna coupler, and (2) it opens the coaxial disable switch in the combiner network RF input line thereby enabling the remaining antenna couplers to be operational. Except when used with AN/GRC-27, an antenna coupler lockout occurs whenever (1) the antenna coupler is servo tuning, (2) another antenna coupler is set to the same preset channel and keyed to transmit, or (3) when a preset or remote channel is tuned to 224.95 MHz (low frequency lockout). When the antenna coupler is servo tuning, the lockout circuit receives a +28-volt servo run disable control from the servo tuning circuit. Channel lockout input controls consist of (1) a 5-wire, 19-channel control line from each antenna coupler and (2)

a +26.5-volt transmit key line from each associated transmitter.

RADIO TRANSMITTING SET AN/WRT-2

Radio transmitting set AN/WRT-2 and receiving set AN/WRR-2 are representative equipments used in HF voice and CW systems. Other transmitting and receiving sets used in these systems are discussed later in this manual in connection with teletype systems.

Radio Transmitting Set AN/WRT-2, is capable of delivering an average power output of 500 watts and a peak envelope power (PEP) of 1000 watts in 1-kHz steps (or continuously) over a frequency range of 2.0 to 30.0 MHz. The set provides for emission of machine or hand-keyed telegraphy, radio frequency carrier shift (RFCS) also called frequency-shift keyed (FSK) teletype, compatible amplitude-modulated speech, single sideband suppressed carrier, independent sideband, and facsimile by using appropriate terminal equipment. The AN/WRT-2 may be installed aboard ships, submarines, and at shore stations. The major components of the set (fig. 6-25) are the transmitter group, (radio-frequency amplifier, radio-frequency oscillator, electrical frequency control, amplifier power supply, and power supply) and the radio frequency tuner.

The radio transmitter group contains all of the equipment required for transmission by machine or break-in CW, independent sideband, single sideband, AM phone, and/or RFCS keying, except such accessories as the key (machine or hand), antenna, and remote operating components. Facsimile transmission requires additional terminal equipment.

The transmitter may be operated from a three-phase, 60 Hz ship's supply of 115, 220, or 440 volts. The transmitter group is coupled to an antenna (not shown) through a radio-frequency tuner and associated antenna control circuits.

Provision is made for a total of six audio inputs. Front panel handset jacks are furnished for local phone operation of the equipment with a handset. Remote phone- and/or hand-key operation is also possible.

Provision is made for interconnections to teletype and telegraphy equipment and to a remote transmitter standby control. An internal dummy load is provided for transmitter tuneup.

The AN/WRT-2 consists of the following functional sections: RF generating, power

amplifier, modulating, primary power, and low-voltage power supply, as shown in figure 6-26.

The RF generating section produces the RF signal in conventional master oscillator-frequency multiplier circuits and applies it to the power amplifier. The master oscillator is slaved to the assigned operating frequency by a unique frequency control circuit discussed later in this chapter.

The power amplifier section raises the RF signal input power from the RF generating section to the desired operating power level. The output of the power amplifier is fed to the antenna via the RF tuner circuits.

The modulating section accepts audio signals or d. c. keying signals (for CW or RFCS operation) and suitably transforms these signals to modulate or control the RF energy generated by the RF generating section. The output of the modulating section is applied to the input mixer in the power amplifier section.

The low voltage section contains all the circuits which supply low d.c. voltages to the transmitting set. The high voltage supply is a separate section and supplies the plate voltage for the power amplifier tubes.

The primary power section supplies all a.c. voltages for the transmitting set. The transformers in the primary power section have taps for input voltages of 115, 220, and 440 volts at 60 Hz.

RF GENERATING SECTION

The complete frequency coverage of Transmitting Set AN/WRT-2 is accomplished in 12 bands. The master oscillator, V301 (fig. 6-27), which is located in the radio-frequency oscillator chassis, generates RF signals from 1.5 MHz to 7.5 MHz. These signals are amplified by V302. For bands 1 through 6, the fundamental frequencies (1.5 to 7.5 MHz) of the master oscillator are fed directly to the power amplifier section through S302. For bands 7 through 9, the fundamental frequencies of bands 4 through 6 (3.75 to 6.75 MHz) are doubled by the first doubler, V303, and fed through S302 to the power amplifier section. For bands 10 through 12, the fundamental frequencies of bands 4 through 6 are multiplied four times by the action of the first and second doublers, V303 and V304, before being applied to the power amplifier section.

In addition to supplying the power amplifier section input, the S302 output is also fed to the

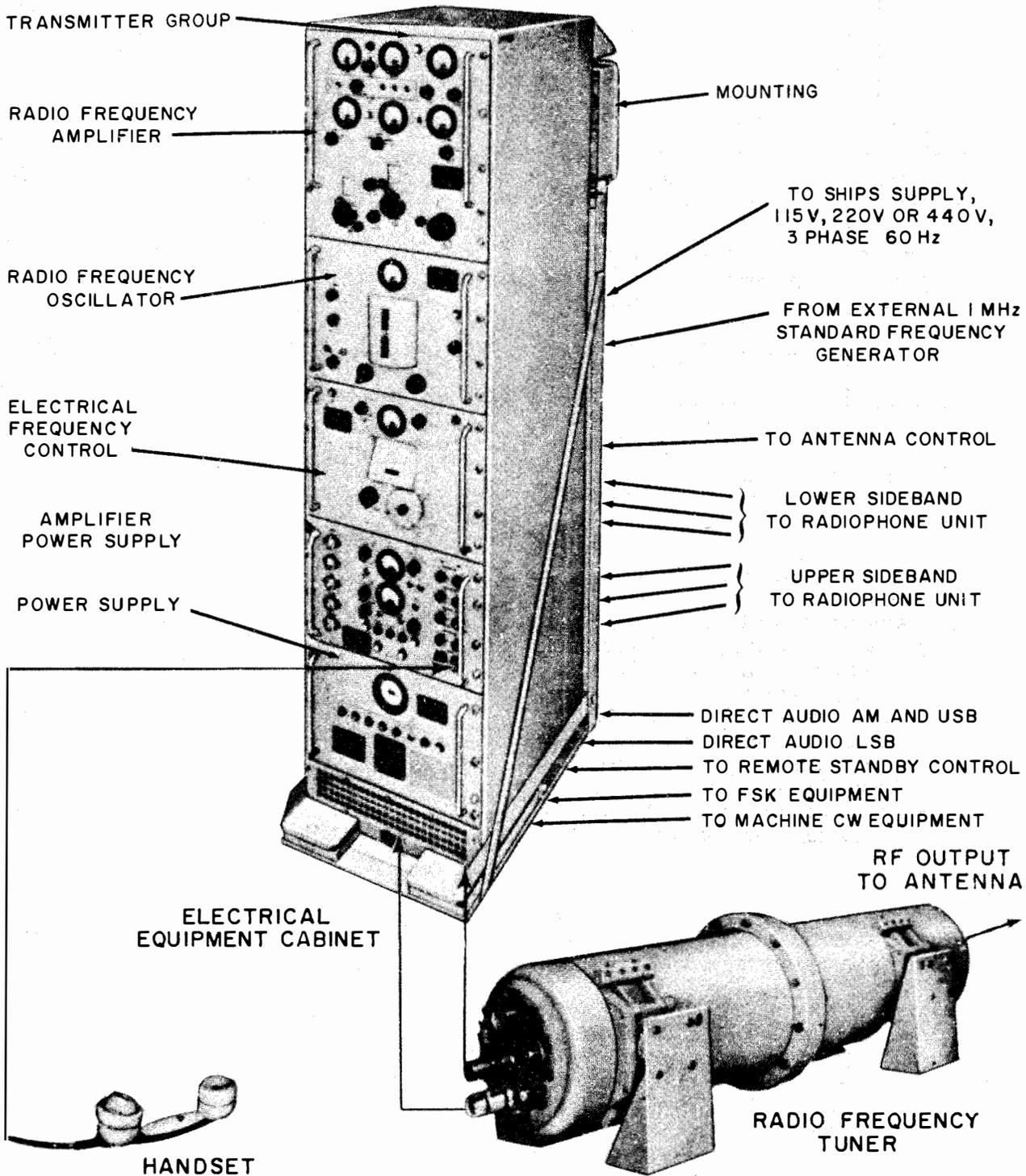
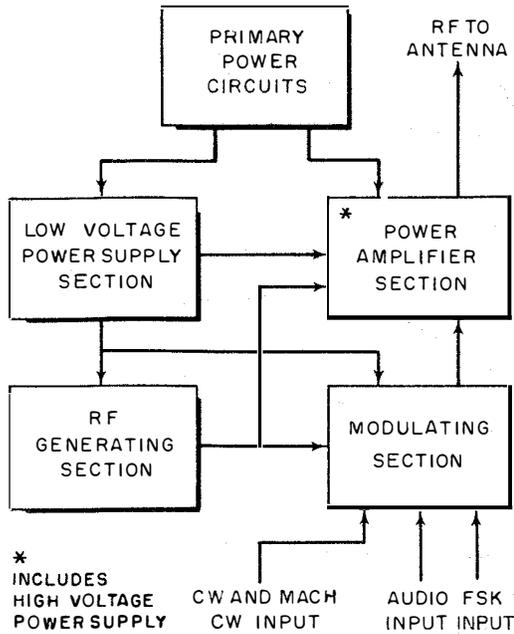


Figure 6-25.—Radio transmitting set AN/WRT-2.

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Figure 6-26.—Overall block diagram.

electrical frequency control circuit (fig. 6-28). This circuit supplies a frequency-correction voltage to the master oscillator, V301, which keeps the oscillator operating at the selected frequency with the stability of 1 part in 10^8 Hz.

The control of the master oscillator frequency is accomplished by two independent operations. First, the output frequency of the master oscillator (via amplifier V302 and the frequency doublers) is compared with that of an

interpolation oscillator in a master oscillator phase detector. Any difference between these two frequencies causes a correction voltage to be applied to the master oscillator (MO), and thereby forces the oscillator to return to the proper operating frequency.

Second, when operating in 1 kHz steps, the interpolation oscillator is frequency stabilized in order to provide improved accuracy in correcting the master oscillator frequency. The control of the interpolation oscillator (IO) involves the locking-in of this circuit to multiples of 1 kHz. This action is accomplished by comparing the output of the interpolation oscillator with a 1 kHz crystal stabilized reference signal to develop an interpolation oscillator correction voltage. The correction voltage is applied to the interpolation oscillator and holds it at the required frequency. Thus, the controlled stability of the IO results in an added stability of the MO.

The front panel of the radiofrequency oscillator and electrical frequency control chassis showing the indicators and controls is shown in figure 6-29.

MODULATING SECTION

The modulating section accepts audio signals or d.c. keying signals and suitably transforms them to modulate or control the RF energy generated by the RF generating section. The circuits of the modulating section are contained in two units of the transmitter: the radio frequency oscillator and the amplifier-power supply.

The filter method of generating single sidebands is used in the modulator. With this

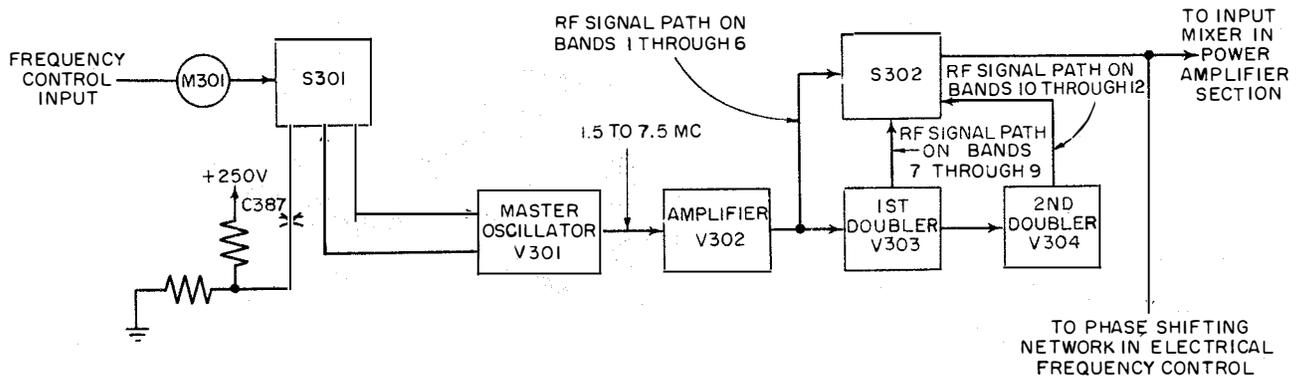
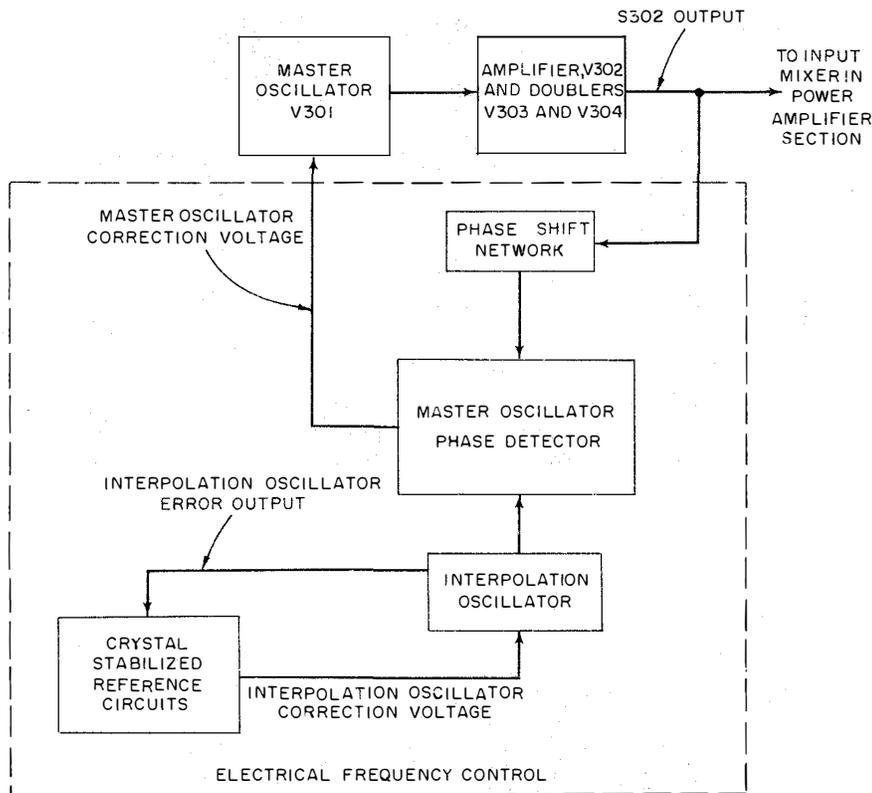


Figure 6-27.—Radiofrequency oscillator.

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Figure 6-28.—Electrical frequency control circuit simplified block diagram.

method, sideband operation must be accomplished at a low frequency level since accurate filter design is difficult to achieve at high frequencies. After generation, the sidebands may be heterodyned to the desired transmitter operating frequency. In the transmitter group, a 2.0-MHz carrier is applied to balanced modulators for sideband generation. The sidebands are then mixed with the MO signal to obtain sum frequencies at the desired frequency level of operation.

A block diagram of the modulation section is shown in figure 6-30. Three types of emission are available with audio input signals: single sideband, independent sideband, or compatible amplitude modulation (USB and carrier).

Audio Stage

The audio input from the microphone is fed via T1407 or T1408 and filter FL1401 to either

of two identical speech amplifier channels, (fig. 6-30). The channels are the upper sideband (USB) and lower sideband (LSB) channels, respectively. Because the channels are the same, only those blocks in the USB channel are shown.

For amplitude modulation operation, only the upper sideband speech amplifier circuits are used and only one sideband plus the carrier (compatible AM) is transmitted. For single sideband (SSB) operation either the upper sideband or lower sideband speech amplifier circuits may be used. For independent sideband (ISB) operation, two independent audio signals may be applied simultaneously to the two separate speech amplifier circuits. The desired type of operation is selected through EMISSION SELECTOR switch S508.

Speech signals generated by the USB telephone handset are coupled through T1407 to band-pass filter FL1401. The filtered signal is then applied to the USB speech amplifier and the USB-AGC control.

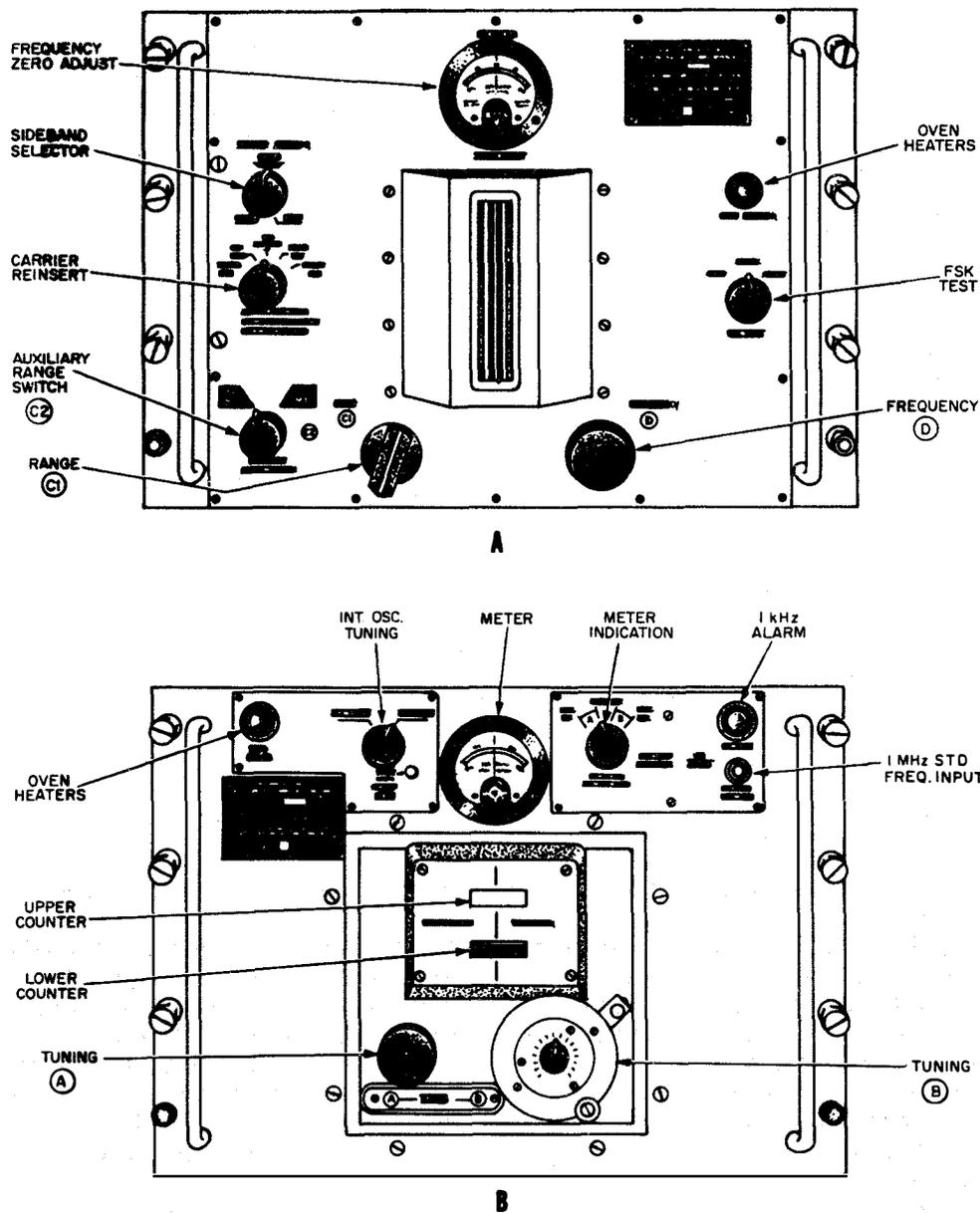


Figure 6-29.—AN/WRT-2 front panels; (A) Radiofrequency oscillator (B) Electrical frequency control.

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A portion of the audio signal output of the second USB speech amplifier is diverted to the USB sidetone amplifier. This signal is fed back to the phone handset for monitoring purposes. TEST TONE switch S511 substitutes the output of the 425-cycle test oscillator, Q1411 and Q1412, for that of the audio when a single-tone

test signal is desired. Meter amplifier Q501 and Mod level meter M502 provide a visual indication of the speech amplifier output levels. Meter M502 is connected in the output circuit by MOD LEVEL switch S512.

The output of the USB speech amplifier is applied through switch S508 to the grids of USB

modulator V1201. The modulator contains a twin-triode tube with its control grids driven 180° out of phase by an audio signal, while the common cathodes receive a 2.0-MHz carrier signal.

The 2.0-MHz signal which is applied to both the carrier reinsert cathode followers and the sideband modulators is derived from the 1-MHz crystal-stabilized reference oscillator in the RF generating section. The oscillator output is applied to the 10:1 frequency divider circuit. The 500-kHz output from binary No. 1 is applied to 500-kHz amplifier stage V1207A (fig. 6-30). The output of V1207A is coupled to two half-wave diode rectifier circuits (not shown) for harmonic generation. Tuned tanks at the control grids of the 2.0-MHz selector V1208 and 1500-kHz selector V1209 select the 2.0-MHz and 1500-kHz harmonics, respectively, from the rectifier outputs. Stages V1208 and V1209 amplify their respective harmonic. The purpose of the 1500-kHz selector is described later.

As stated previously, the 2.0-MHz input is applied to the common cathodes of the twin-triode USB balanced modulator V1201 while the audio speech amplifier output is applied to the twin-triode control grids 180° out of phase. The plates of the modulator are connected in push-pull. The action of a balanced modulator cancels the carrier (2.0 MHz) input. The signal appearing at the input USB filter, FL1201, consists of sum and difference frequencies and a carrier frequency signal of negligible magnitude if the push-pull balanced modulator stage is properly balanced.

USB filter FL1201 allows only upper sideband frequency components to pass (without severe attenuation) to the grid of sideband combiner V1203. The bandpass of FL1201 is from 2,000,300 to 2,008,000 Hz.

The sideband combiner consists of a twin triode tube. The 2,000,300- to 2,008,000-Hz output from FL1201 is applied to the control grid of the A section of V1203, while a similar range of frequencies below the 2.0-MHz carrier signal is applied to the V1203B grid from the LSB filter FL1202 (not shown). The plates of V1203A and V1203B have separate plate loads in the carrier reject filter FL1203. The filter (filter components not shown) rejects the 2.0 MHz carrier at the V1203 output. The common secondary coil connected between terminals 2 and 4 of FL1203 receive both the USB and LSB signal components as separate signals. These outputs are fed to either the 2.0-MHz amplifier, V1206, or to the 500-kHz modulator V1204, depending on the

transmitter operating frequency, and the position of auxiliary range switch section S1202A.

The 2.0-MHz carrier signal from V1208 is also applied to carrier reinsert cathode follower V1207B. The cathode circuit of V1207B contains a voltage divider network from which various voltage levels of the 2.0-MHz carrier signal can be selected by CARRIER REINSERT switch S1201. Varying degrees of carrier reinsertion are required to facilitate signal recovery at the receiver. A higher level of carrier reinsertion is possible during CW operation because the peaks of the speech signals limit the amount of drive that can be applied to the power amplifier stages. Attenuation settings of $-\infty$, -20, -10, 0, and +3db are provided. For AM, MACH CW, and CW operation it is necessary to transmit a carrier signal.

Keying Circuits

Three classes of d.c. keying signals are accepted by the modulating section: frequency-shift neutral keying from a teletype or multiplex unit, machine or CW keying signals from an automatic coder, or hand-keyed CW signals.

In FSK operation, the S508C and S508D contacts (fig. 6-30) are closed. Switch section S508B is open and S508A is in the FSK position. The FSK or MACH CW input signals are applied through S508C to a keying multivibrator, Q1401 and Q1402. The output of the 425-Hz test oscillator Q1411 and Q1412 is applied through S508D to the FSK switch. This circuit comprises CR1402 through CR1409 and is a symmetrical electronic switch which is driven by keying multivibrator Q1401 and Q1402.

When a space signal is on the line, the keying multivibrator causes the FSK switch to route the 425-Hz signal to the LSB modulator. When a mark signal is on the line, the keying multivibrator changes state and the FSK switch transfers the 425-Hz signal to the USB modulator. Thus, the mark signal is 425-Hz above the carrier frequency and the space signal is 425-Hz below the carrier frequency.

During CW operation, the CW keys actuates a bias keying stage, Q502, the output of which is applied through S508A to the grid of the 2.0-MHz amplifier, V1206, to the grid of the 500-kHz amplifier, V1205, and to the grids of the mixer and driver stages of the radio frequency amplifier (shown later). This action cuts off the transmitter carrier when the key is open.

As stated earlier, the master oscillator in the RFO operates from 1.5 to 7.5 MHz. The use

of the fundamental MO frequencies for band 1 through 6 (2.0 to 8.0 MHz) necessitates the inclusion of the 1500-kHz selector, V1209 and the 500-kHz modulator, V1204. On the lowest transmitter range, the MO frequency is 1.5 MHz. Because of the action of S302 the master oscillator output on the lowest range bypasses the frequency multiplier stages and is fed directly to an input mixer. A 500-kHz signal must also be introduced into the input mixer if the transmitter output frequency is to be 2 MHz, which is the lowest frequency that can be transmitted.

When the transmitter output is to be in the 2.0- to 8.0-MHz range, auxiliary range switch sections S1202A and S1202C apply the sideband combiner output (via FL1203) and the output of 1500-kHz selector V1209 to the 500-kHz modulator V1204. The 500-kHz modulator is identical in operation to the USB modulator described earlier. The push-pull output of V1204 suppresses the 1500-kHz signal and a tuned tank in the grid circuit of the 500-kHz amplifier V1205 selects only the difference-frequency components generated by the modulator, plus or minus

the modulation (intelligence) contained in the original 2.0-MHz signal. The 500-kHz signal then passes through auxiliary range switch S1202B to the mixer in the PA section and serves as the injection frequency to the PA mixer throughout the frequency coverage of bands 1 through 6.

POWER AMPLIFIER AND ANTENNA SECTION

A block diagram of the power amplifier and antenna sections is shown in figure 6-31. These sections include driver and power amplifier stages, tuning and coupling circuits, and the RF monitor.

After mixing in the input mixer stage of the modulating section, the RF signal contains the modulation component and is in the frequency range from 2.0 to 30.0 MHz as selected by the operator. The output of the mixer is amplified in the first and second driver stages, V801 and V802, in the power amplifier section. The amplified RF is then applied to the power amplifier stages, V804 through V807.

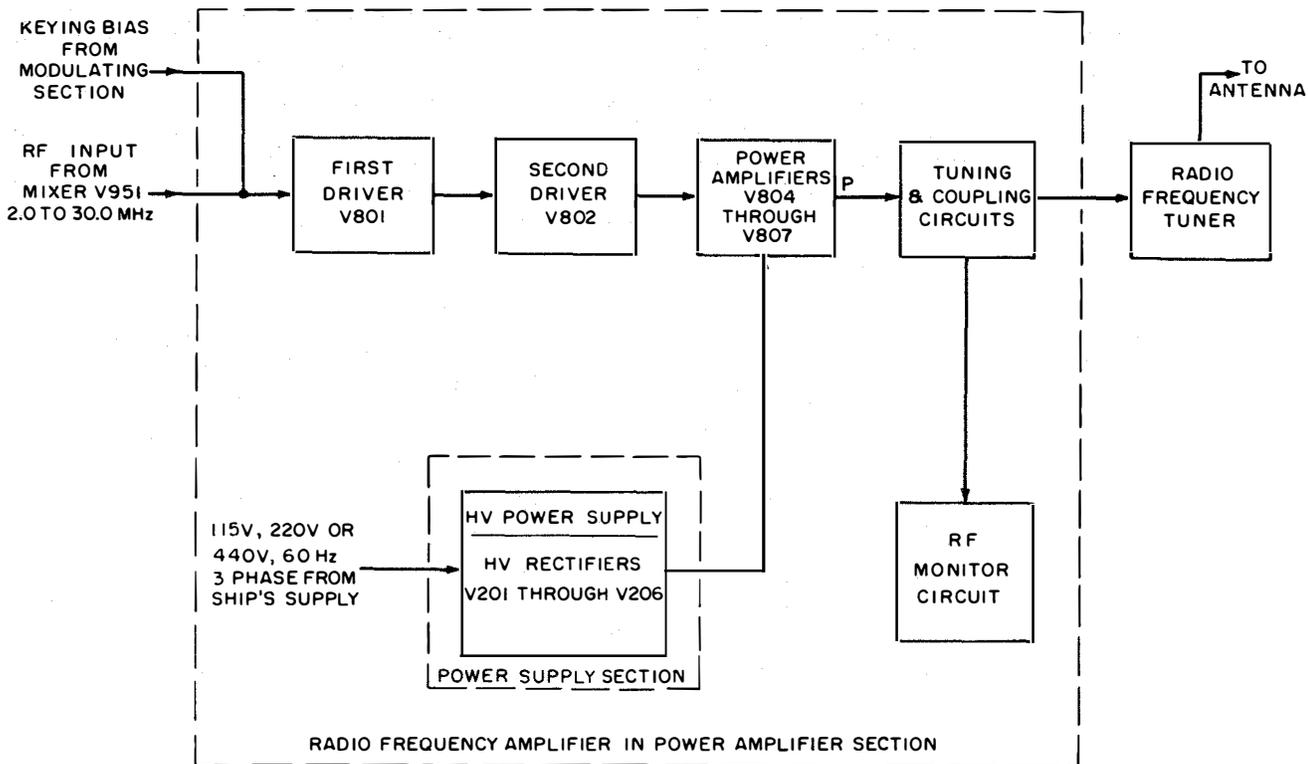


Figure 6-31.—Power amplifier section block diagram.

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The power amplifier stages consist of four 4CX300 tetrode tubes connected in parallel (not shown). Plate voltage for these tubes is supplied by high voltage rectifiers V201 through V206. The power amplifier output is fed through the tuning and coupling circuits and the radio frequency tuner to the antenna.

A portion of the output from the tuning circuit is fed to the RF monitor circuit, which consists of a modulation monitor for measuring the modulation percentage, and a reflectometer for measuring the output power level and voltage standing wave ratio on the line which feeds the antenna.

Tuning and Coupling Circuits

The antenna tuning and coupling circuits used in the AN/WRT-2 are not conventional and are therefore treated with the aid of a simplified schematic diagram.

The plate output of the power amplifier tubes is fed into the tuning and coupling circuits by C827 (fig. 6-32). The resonant frequency of tuning components L803 through L805 and C836 and C837 is adjusted by a PA TUNING (G) control and PA COUPLING (H) control located on the radio frequency amplifier front panel. These components form a pi network low-pass filter at the operating frequency. The PA tuning control adjusts all five tuning components simultaneously while the (H) control adjust only C837 and L805.

As stated previously, the RF monitoring circuit contains a modulation monitor circuit which indicates percentage of modulation, and a reflectometer circuit which measures the transmitter power output and the VSWR on the line of the antenna.

Antenna Tuner

The radio frequency tuner increases or decreases the effective physical length of the antenna by removing or inserting inductance in series with the antenna. As shown in figure 6-33, drive motor B3301 and 2-speed drive MP-3301 drive a sliding short up and down the main coil L3302 which can be switched in series with the antenna via antenna transfer switch S3301. The arm of R3301 is geared to the mechanical drive mechanism and electrical contact is made to the POSITION INDICATOR meter M806, on the front panel of the radio frequency amplifier (RFA). The meter indicates the relative position of the sliding short on the main coil.

Fixed capacitance may also be inserted in series or in parallel with the antenna for tuning purposes.

Switch S806 provides 115 volts a.c. for the actuator L3303 (fig. 6-33) when placed in the DIRECT, A, or B position. These positions correspond to positions 1, 2, and 3 on S3301. A tuner control switch on the front panel applies 115 volts a.c. to the actuator when the bypass function is desired. In this position (as shown) relay K3302A is energized. When the tuner

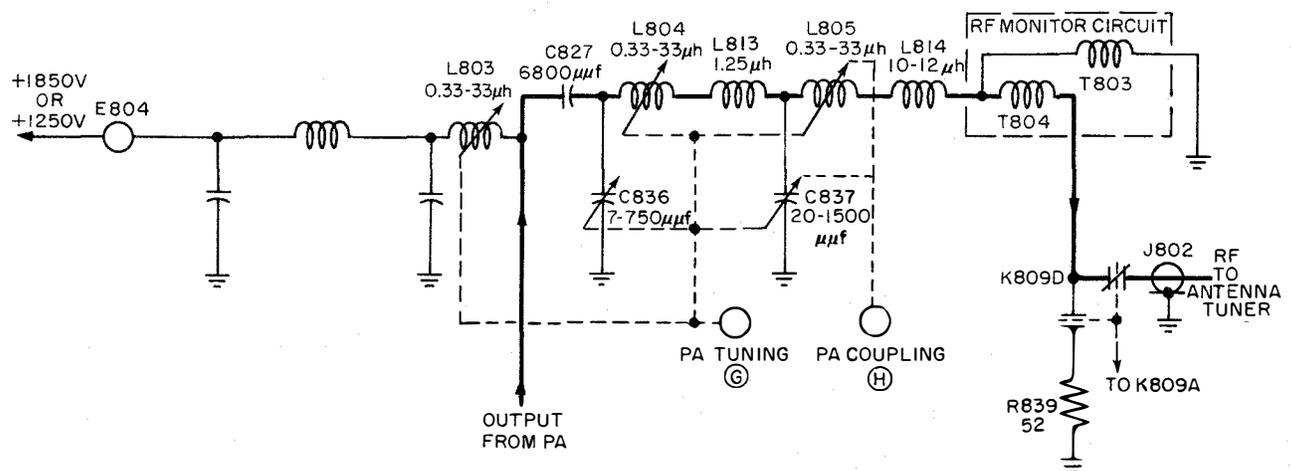
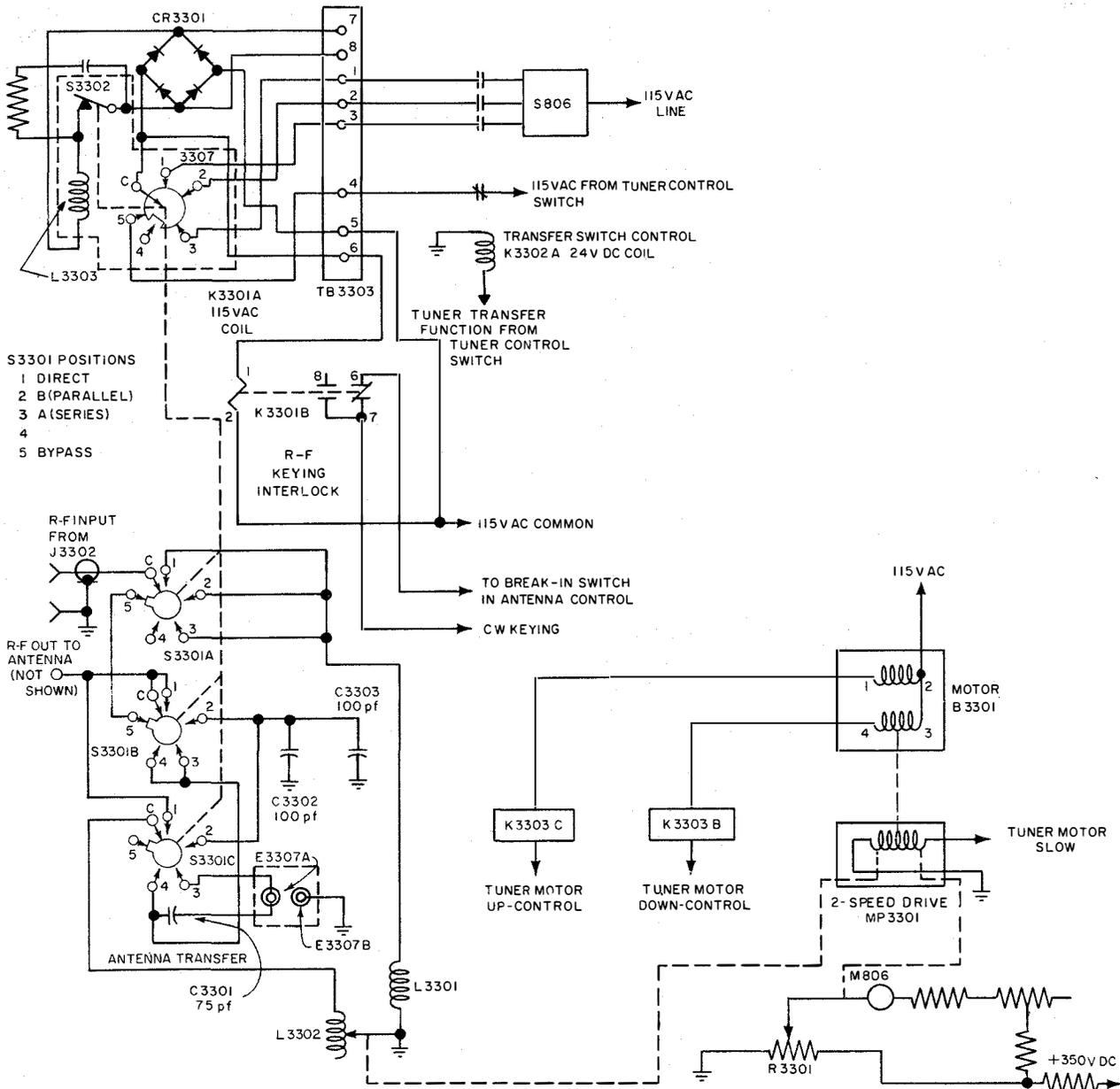


Figure 6-32.—Tuning and coupling circuits.



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Figure 6-33.—Radiofrequency tuner schematic diagram.

components are to be used, the tuner control switch is placed in the TUNER-IN position, and K3302A deenergizes. This again permits the desired tuning components to be selected by S806.

Switches S3307 and S3301, driven by actuator L3303, place C3302 and C3303 in parallel with

the antenna when switch S806 is in the B position. When S806 is in the A position, C3301 is placed in series with the antenna, and when in the DIRECT position, only L3302 is in series with the antenna. The setting of COUPLER (J) switch S806 depends on the operating frequency of the transmitter. If the transfer switch control relay,

K3302, is energized, switches S3307 and S3301 automatically return to position 5 and the tuner is bypassed.

Antenna tuner up, down, and slow controls on the RFA front panel enable the operator to select the desired movement of the L3302 arm (sliding short) and also to control the speed of tuning. Limit switches (not shown) limit the upper and lower travel of the shorting arm.

POWER SUPPLY SECTION

A block diagram of the power section is shown in figure 6-34. The high voltage rectifiers supply d.c. voltage to the PA tubes. The low voltage power supply supplies the remaining d.c. voltages needed for proper operation, such as the +350-volts -350 volts, -24 volts, +12-volts, -12-volts, 250-volts regulated, +24 volts regulated, and a -6 volt regulated supply.

The primary power input of 115 volts, 220 volts, or 440 volts, depending upon the ship's supply, is applied to the T501, T201, T202, and T203 primary windings. Tapped terminals on T501 provide an output of 220 and 115 volts. The output of T501 is applied to the circuits of the low voltage power supply section through FILAMENT POWER switch S502. The 220 volts is applied to the primaries of T502 and T503 while the 115 volts is applied to T617 in the electrical frequency control and to T204 in the PA circuits.

The output of T502 is rectified by the plus and minus 350-volt rectifiers, and applied to the circuits of the RFA. Part of the output of the 350-volt rectifier is also applied to the 250-volt regulator. The 250-volt regulator consists of series regulators V321 and V322, regulator amplifier V323, and voltage reference tube V324. The regulated output is applied to stages in the electrical frequency control circuit and RF oscillator.

The output of T503 is rectified by the -24-volt rectifiers, and fed to the various circuits throughout the transmitter which require this potential. A second output of T503 is applied to the 12-volt rectifier. The negative output of the 12-volt power supply is fed to the speech amplifier and control circuits. The positive output is fed only to control circuits in the amplifier-power supply and mike circuits.

The output of T617 is rectified by the 24-volt and 6 volt regulators, respectively. The 24-volt output is regulated and fed to the circuit of the RF generating and modulating sections. The 6-volt

regulated supply is used by circuits of the 1-MHz oscillator.

In the high voltage power supply, bridge connected rectifiers V201 through V206 get their filament voltage from T204 and their plate voltage from delta-wye connected transformers T201, T202, and T203. The secondaries of the high voltage transformers are tapped so that a lower voltage is applied in TUNE and 100-watt operation than for 500-watt operation. The output from the high voltage rectifiers (1250 volts d.c. in tune and 100-watt operation, or 1850 volts d.c. in 500-watt operation) is applied to the plates of the power amplifier tubes in the power amplifier section.

RADIO RECEIVING SET AN/WRR-2

The AN/WRR-2 is a triple conversion super-hetrodyne receiver designed to operate in the frequency range of 2 to 32 MHz. The receiver three detector-amplifiers provide for the reception of CW, MCW, AM, SSB, FSK, and facsimile (FAX). Simultaneous use of both upper and lower SSB channels for receiving two different types of intelligence is possible if both signals are of the SSB type.

The receiver consists of Electronic Frequency converter CV-290/WRR-2 (converter drawer) and Intermediate-Frequency-Audio Frequency amplifier AM-2477/WRR-2 (demodulator drawer) in individual joined cabinets as shown in figure 6-35.

FUNCTIONAL OPERATION

Figure 6-36 is a block diagram showing the converter and demodulator as separate major units. The main signal path through the various assemblies is indicated by a heavy line.

Converter

An RF signal (2 to 32 MHz) from the antenna is applied to the antenna coupler, which provides an adjustable amount of signal attenuation for optimum performance under strong signal conditions. The output of the antenna coupler is fed to the preselector where it is amplified and applied to a mixer. Here it is combined with a locally generated RF signal from the high frequency oscillator (3.725 to 33.725 MHz) to produce the first IF signal at a frequency between 1625 and 1725 kHz. This frequency is selected by the tunable IF filter and applied to the injection

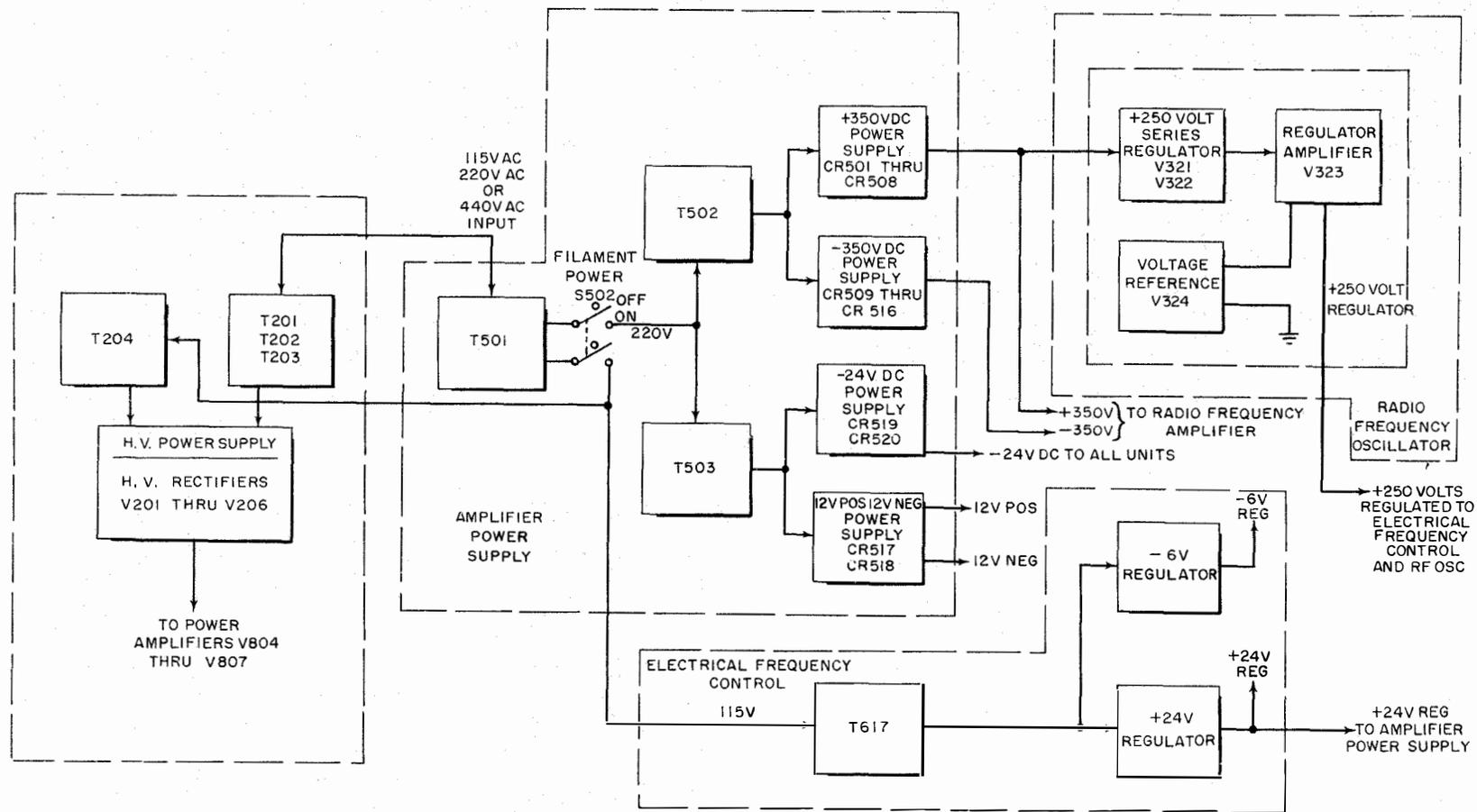
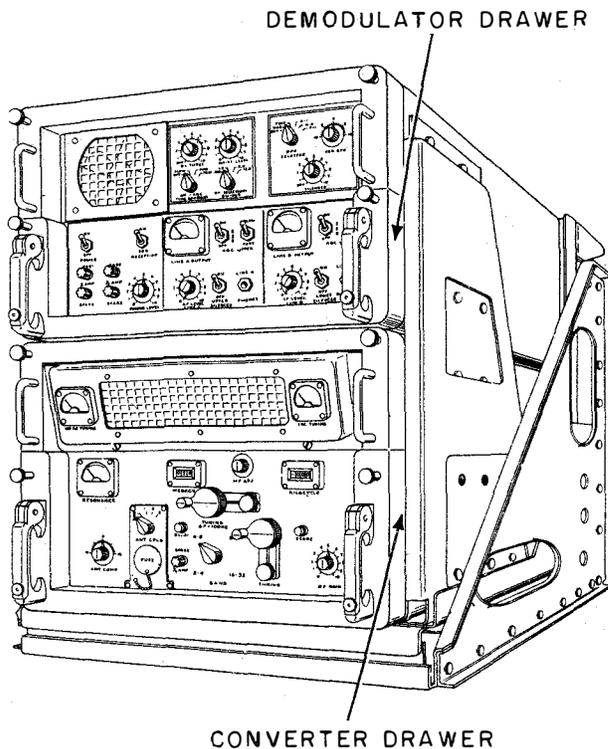


Figure 6-34.-Power supply section block diagram.

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Figure 6-35.—Radio receiving set AN/WRR-2.

IF amplifier, which in turn produces the 80 kHz (third IF) signal to be applied to the demodulator. The injection IF amplifier performs IF amplification and two frequency conversions, the first from 1625-1725 kHz to 220 kHz, and the second from 220 kHz to 80 kHz.

Demodulator

In the demodulator the 80 kHz filter receives the signal and distributes it to the AM and USB detector-amplifiers. The USB detector-amplifier supplies the 80 kHz signal to the LSB detector-amplifier. In the AM detector-amplifier the 80 kHz signal is amplified and detected. Several stages of audio amplification follow the detector. A beat-frequency oscillator (BFO) is also included for reception of CW signals. Audio limiting, silencing, and automatic gain control (AGC) are also included. In the USB detector-amplifier the 80 kHz signal is amplified and applied to a ring-type demodulator where it is mixed with an 80 kHz carrier signal to produce an audio output.

A two-stage audio amplifier, silencer circuit, and an AGC circuit follow the demodulator. In the LSB detector amplifier the 80 kHz signal is amplified and also applied to a ring type demodulator similar to that in the USB section.

TUNING SYSTEM

Incremental tuning is provided in steps of 1 kHz over the entire operating range of the receiver (2 to 32 MHz). Continuous tuning is also available in this range at a slightly lower frequency stability.

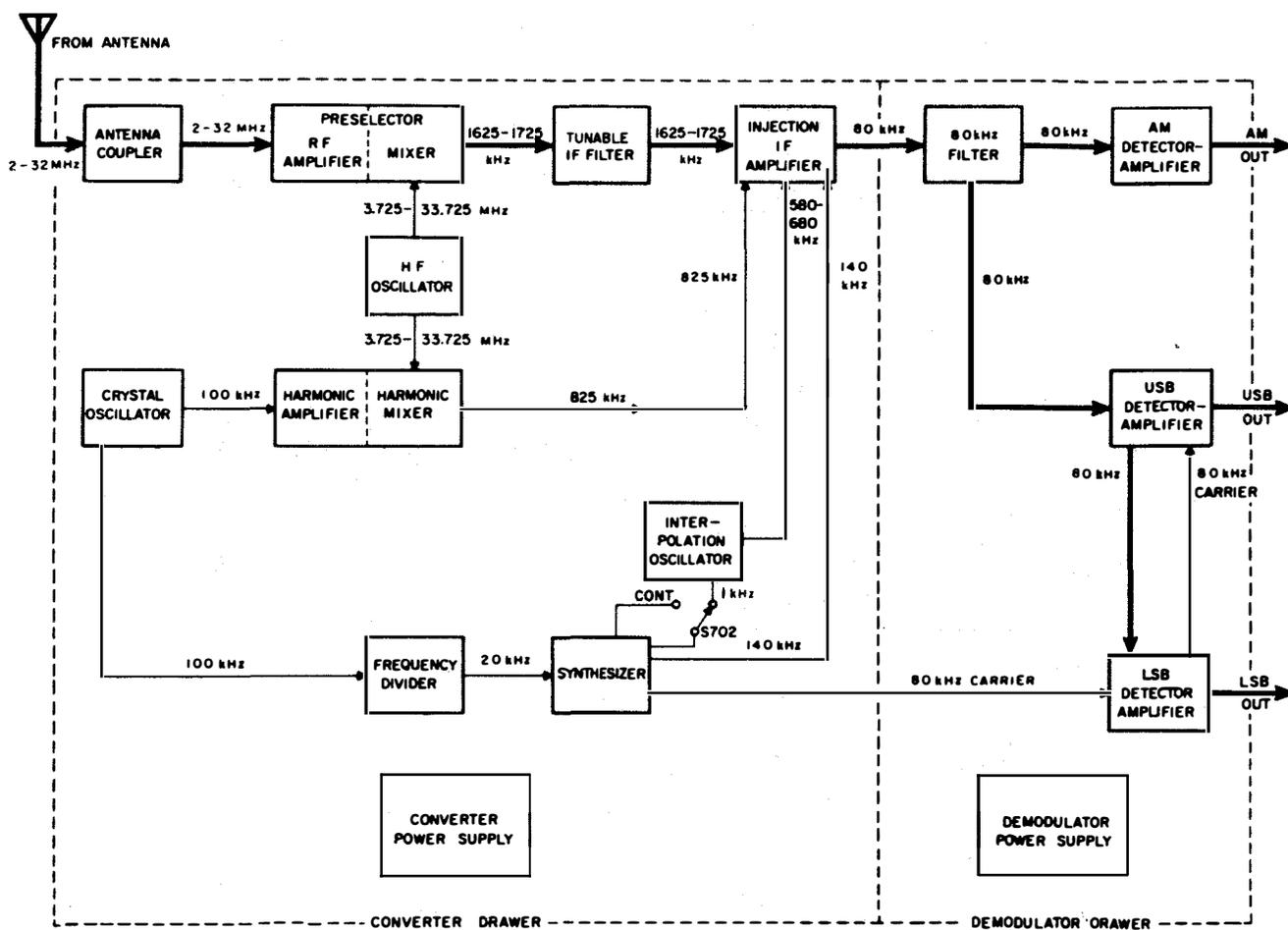
Incremental Tuning

Figure 6-37 is a basic tuning diagram of the receiver in the incremental mode, tuned, as an example to 2,105 MHz. In this example, the tuning $\Delta F = 100\text{KC}$ panel control is set to cause the MEGACYCLE counter to read 02.1. This tunes the preselector to receive all signals in the 100 kHz range from 2.1 to 2.2 MHz, as shown in detail A of the diagram. The relative position of 2.105 MHz is also shown. Other RF signals in this range will also be present at this stage.

The tuning capacitor of the HF oscillator is ganged with that of the preselector; therefore setting the MEGACYCLE counter to 02.1 also tunes the HF oscillator (V301) to 3.825 MHz, providing the first injection frequency. This signal beats with the selected 2.105 MHz in the preselector mixer (V151) to produce a first IF signal of 1720 kHz. The 3.825 MHz signal will also mix with any other signals present in the 2.1 to 2.2 MHz range.

The TUNING (KILOCYCLE) control is set to cause the KILOCYCLE counter to read 05.0. This tunes the tunable IF filter to 1720 kHz. The filter rejects all other signals present in the 2.1 to 2.2 MHz range (see detail B).

When the HF oscillator supplies its 3.825 MHz signal to the first mixer it also supplies an identical signal to the harmonic mixer (V251). Here the signal is combined with a 3.0 MHz pip selected by the tunable harmonic amplifier (V201-V202) from the 100 kHz frequency spectrum developed by the frequency divider and the harmonic amplifier. The TUNING $\Delta F = 100\text{ KC}$ control tunes the harmonic amplifier, selecting the pip. Combining the 3.825 MHz signal from the HF oscillator with the 3.0 MHz pip produces an 825 kHz difference frequency which is applied to the first injection amplifier. After amplification the 825 kHz is applied to the first injection



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Figure 6-36.—Radio receiving set AN/WRR-2 block diagram.

mixer (V506), where it is combined with a 675 kHz signal from the interpolation oscillator (V401).

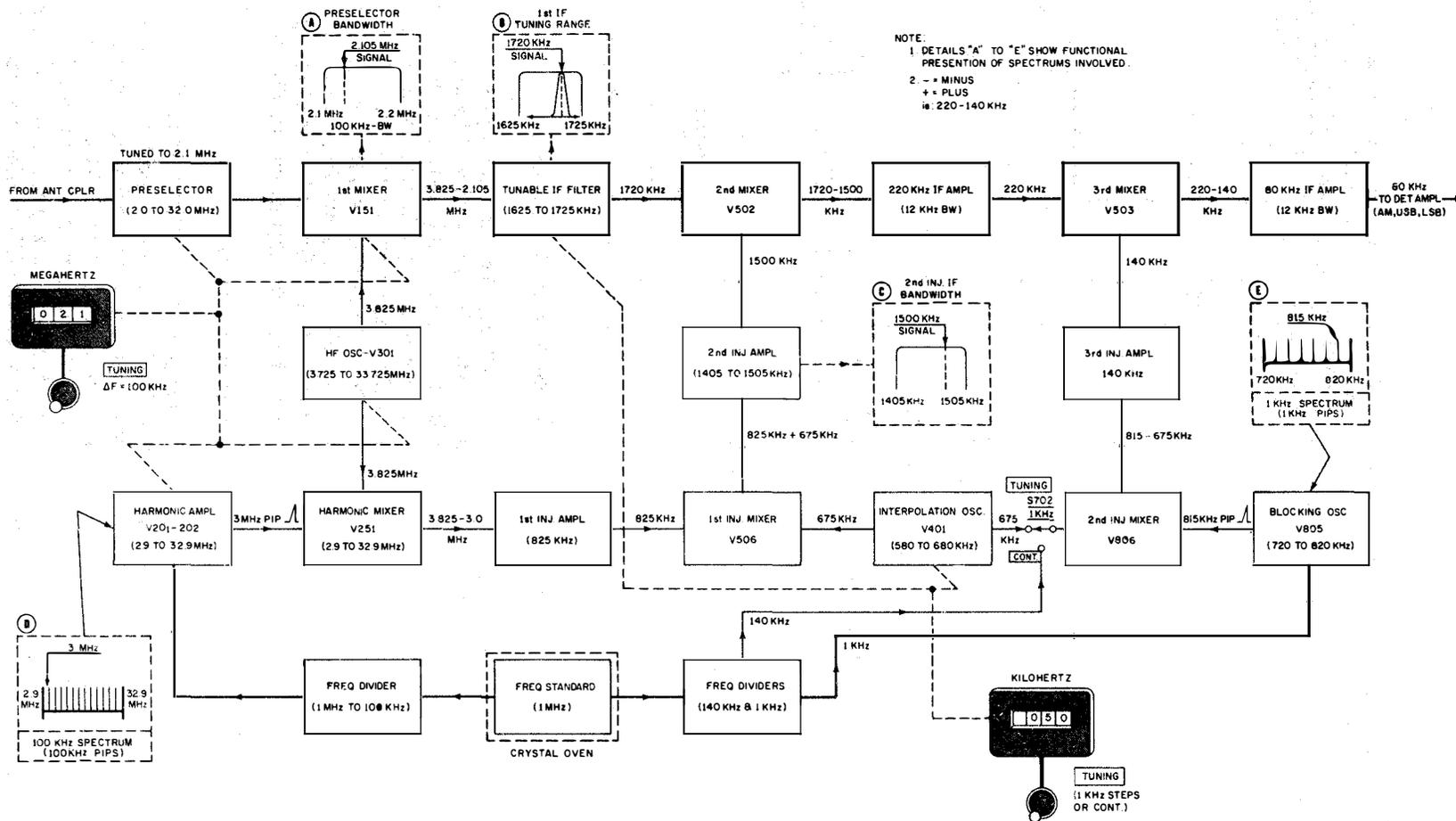
The interpolation oscillator is tuned, simultaneously with the tunable IF filter, by the TUNING (KILOCYCLE) control. When the KILOCYCLE counter reads 05.0, the interpolation oscillator provides a 675 kHz signal. Combining this signal with the 825 kHz provides a 1500 kHz signal which is applied to the second injection amplifier and then to the second conversion mixer (V502). Here the 1500 kHz is combined with the 1720 kHz signal from the tunable IF filter, and the difference frequency of 220 kHz is applied to the 220 kHz amplifier.

When the interpolation oscillator sends its 625 kHz signal to the first injection mixer, it sends an identical signal to the second injection mixer (V806) through the TUNING 1 KC/CONT.

switch (S702). The second injection mixer combines the 675 kHz with an 815 kHz pip from the 1 kHz spectrum (see detail E) to produce a 140 kHz signal for application to the third injection amplifier and then to the third mixer (V503). The 140 kHz combines with the 220 kHz from the second mixer and amplifier to produce the third IF signal of 80 kHz. This signal is applied to the three detector-amplifiers in the demodulator.

Continuous Tuning

Placing the TUNING 1KC/CONT. switch in the CONT. position supplies a 140 kHz signal from the harmonic generator to the second injection mixer. The 1 kHz blocking oscillator does not function in this mode. The interpolation oscillator now provides continuous tuning within each 100 kHz segment established by the



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Figure 6-37.—Radio receiving set AN/WRR-2 basic tuning diagram.

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receiver front end. The output of the interpolation oscillator is not frequency-drift-canceled during continuous tuning, and receiver stability in this mode is subject to interpolation oscillator frequency drift.

Frequency-Drift Cancellation

The receiver has two frequency-drift canceling circuits, one for the output of the HF oscillator, and the other, used only in incremental tuning, for the output of the interpolation oscillator.

HF OSCILLATOR.—This drift canceling circuit stabilizes the 220 kHz output of the second mixer (V502) by compensating for changes in the HF oscillator frequency. The second mixer receives two input signals, one (1720 kHz) from the tunable IF filter, the other (1500 kHz) from the second injection amplifier. Both signals are obtained from the output of the HF oscillator. A change in the HF oscillator output frequency will affect, by the same amount but in different directions, both inputs to the second mixer, causing the error to cancel.

INTERPOLATION OSCILLATOR.—The second drift canceling circuit stabilizes the 80 kHz output of the third mixer (503) by compensating for changes in the output of the interpolation oscillator. As with the first circuit, the third mixer receives two input frequencies, 220 kHz from the 220 kHz IF amplifier and 140 kHz from the third injection amplifier, both obtained from the output of the interpolation oscillator. Any variation in the output frequency of the interpolation oscillator affects both inputs at V503 in equal amounts but in opposite directions, canceling the error.

POWER SUPPLIES

The receiver has two power supplies, converter and demodulator (fig. 6-36). The converter power supply serves all circuits except those of the three detector amplifiers, upper and lower sideband, and AM. Voltage and current-stabilizing circuits are incorporated in the converter power supply to ensure steady inputs for voltage sensitive components in accordance with stability requirements. A fullwave bridge rectifier comprising silicon diodes provides the necessary high voltage output.

Operation of the demodulator power supply is similar to that of the unregulated portion of the

converter power supply. The demodulator power supply is a conventional bridge type rectifier connected to a choke input filter. Functional sections of the demodulator get their filament voltages from a 6.3 volts a.c. winding of the power supply transformer.

RADIO TRANSMITTING SET AN/WRT-1A

Radio Transmitting Set AN/WRT-1A is a shipboard transmitter designed for operation in the frequency range of 300 to 1500 kHz. The transmitter is continuously tunable through the frequency range and is capable of supplying a nominal peak power output of at least 500 watts into a 50 ohm resistive load with a voltage standing wave ratio of less than 4 to 1. The set can transmit CW, FSK, and AM voice. It has no SSB capability.

Because of operating in the medium frequencies with a substantial power output, the AN/WRT-1A lends itself well for communicating over long distances during the hours of darkness. Its range is reduced to medium distances during daylight hours. The transmitting set consists of the transmitter group, radiofrequency tuner, and antenna coupler as shown in figure 6-38.

TRANSMITTER GROUP

Transmitter Group OA-2321A/WRT-1 (fig. 6-38) consists of Electrical Equipment Cabinet CY-2607/WRT-1 which houses the Radiofrequency Amplifier AM-2197/WRT-1, Radiofrequency Oscillator O-621/WRT-1, Electrical Frequency Control C-2861/WRT-1, Amplifier-Power Supply AM-2198-A/WRT-1, and Power Supply PP-2222/WRT.

Radiofrequency Amplifier

The Radiofrequency Amplifier AM-2197/WRT-1 contains the intermediate, driver, and power amplifiers necessary to raise the RF output of Radiofrequency Oscillator O-621/WRT-1 to a peak power level of 500 watts when connected to a 50 ohm resistive load. A modulating amplifier, preceding the intermediate amplifiers, provides amplitude modulation in radiophone operation. The tuning and coupling controls of the power amplifier as well as the controls and indicators for remote operation of Radiofrequency Tuner TN-345/WRT-1 and Antenna Coupler CU-760/WRT-1 are mounted on

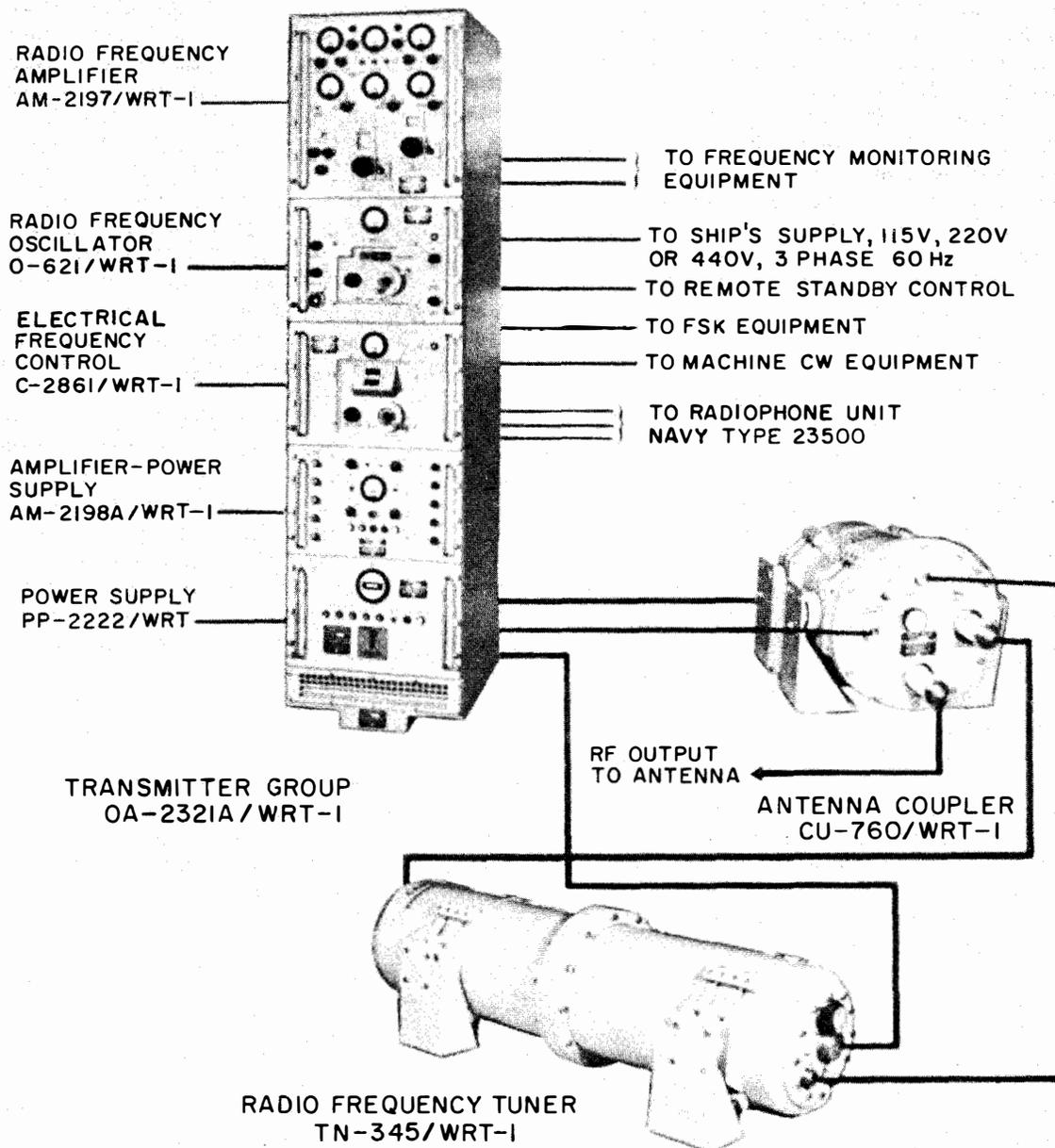


Figure 6-38.—Radio transmitting set AN/WRT-1A.

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the front panel of Radiofrequency Amplifier AM-2197/WRT-1. Radiofrequency Amplifier AM-2197/WRT-1 also contains a dummy load with the necessary switching relays, a reflectometer, a modulation monitor, and indicators for monitoring supply voltages, operating currents, RF output, and standing wave ratio. The power amplifiers are maintained at a safe oper-

ating temperature by a blower mounted in this drawer. Tuning of Radiofrequency Amplifier AM-2197/WRT-1 is accomplished through a tuning and coupling mechanism gear train.

Radiofrequency Oscillator

Radiofrequency Oscillator O-621/WRT-1 contains an oven and three sub-chassis; the

master oscillator, the keying circuits and the 250-volt d.c. regulator. The master oscillator is continuously tunable from 300 to 1500 kHz through 12 bands of 100 kHz each. The operating frequency of Radio Transmitting Set AN/WRT-1A is set by means of controls located on the front panel of the radiofrequency oscillator, and is indicated directly by a counter also located on the front panel. The carrier frequency is stabilized by control circuits located in Electrical Frequency Control C-2861/WRT-1. A jack located on the front panel permits checking the carrier frequency with frequency monitoring equipment. The keying circuits contain a CW (on-off) keying amplifier, a frequency shift keyer and wave shaping circuits. The frequency shift keying and CW keyer circuits may be adjusted by means of controls located on the front panel of this unit. The 250-volt regulator provides a regulated plate supply voltage to the other units of the transmitter.

Electrical Frequency Control

Electrical Frequency Control C-2861/WRT-1, (fig. 6-38) contains a frequency comparator chassis, an oven for maintaining the frequency-determining components at the proper operating temperature, a feedback amplifier chassis, and a 100 kHz amplifier chassis. The circuits of the electrical frequency control impart overall accuracy and stability to the master oscillator by comparing its output with the output of a stable low-frequency interpolation oscillator.

Amplifier-Power Supply

Amplifier-Power Supply AM-2198A/WRT-1 contains the low voltage power supplies, the transmitter control circuitry, the speech amplifier and a 1000 Hz tone generator. With the exception of the high voltage for the power amplifiers all of the d.c. voltages are developed in the amplifier-power supply. Protective relays are provided to disable the low voltage rectifiers in case an overload occurs. Branch circuit fuses are provided at the front panel for the power supply circuits. The front panel of the amplifier-power supply contains the controls for selecting the type of emission, tune or adjust condition, power level, local or remote operation, as well as the controls for energizing the filament and plate power circuits. The speech amplifier chassis provides for the amplification

and clipping of the audio input during phone operation. Front panel controls are also provided for modulation level, clipping, sidetone level, and input level. A front panel jack is provided for a local phone connection.

Power Supply

Power Supply PP-2222/WRT contains the high voltage transformers, the high voltage rectifiers, and the high voltage control relays. Plate voltage for Radiofrequency Amplifier AM-2197/WRT-1 is supplied from the rectifiers in the power supply. Movable links are provided to connect the primary windings of each transformer for 115, 220 or 440-volt three-phase primary input power. An elapsed time meter is mounted on the front panel of the power supply to indicate operating hours. An emergency stop switch is also provided on the front panel to disconnect all power to the circuits of the transmitter in case of an emergency. Overload control circuits disable the high voltage power supply automatically in case of an overload.

RADIOFREQUENCY TUNER

Radiofrequency Tuner TN-345/WRT-1 (fig. 6-38) enables Transmitter Group OA-2321A/WRT-1 to deliver the maximum power, to a fixed antenna, at a minimum standing wave ratio, for any frequency within the range of 300 kHz to 1500 kHz. Maximum power at a minimum standing wave ratio, is delivered when the antenna appears as a purely resistive load. Since the antenna dimensions are fixed, the impedance presented to the transmitter will vary with frequency.

The radiofrequency tuner effectively changes the antenna impedance by inserting or removing inductance in series with the antenna. The tuner is contained in a shock mounted, pressurized cylinder which houses the electrical and mechanical parts of the unit. One connector for control circuits and one RF input connector together with a pressure gauge, relief valve, and a valve for pressurizing the equipment are mounted at one end of the cylinder. The RF output connection is mounted at the other end.

ANTENNA COUPLER

The Antenna Coupler CU-760/WRT-1 (fig. 6-38) provides an additional inductance that may

be inserted in the antenna circuit. Thus, the coupler extends the range of impedances that can be matched by Radiofrequency Tuner TN-345/WRT-1. Antenna Coupler CU-760/WRT-1 is housed in a shock mounted, pressurized cylinder. All RF connections together with a pressure gauge, relief valve, and valve for attaching the pressurizing equipment are located at one end of the cylinder.

RADIO SET AN/URC-9A

Radio Set AN/URC-9A is designed for ship-board or fixed station operation. It provides amplitude modulation or tone modulation on any of 3500 channels spaced 0.05 MHz apart in the 225 to 399.95 MHz frequency range. Nineteen of the 3500 channels can be preset. Complete control,

including selection of preset channels, can be exercised from a remote control point. In addition, circuits are incorporated which permit the connection of two sets for two-way automatic retransmission and broadband transmit and receive operation.

To provide complete control from a fixed remote control station, Radio Set Control C-2383/URC is required. To provide transmit-receive control from up to 5 remote control stations, through the standard 12 wire system, Control Adaptor MX-8430/URC-9, and Radio Set Control C-1138/UR or C-1207/UR are required.

GENERAL DESCRIPTION

Radio Set AN/URC-9A, (fig. 6-39) functions as a triple-conversion, superhetrodyne receiver

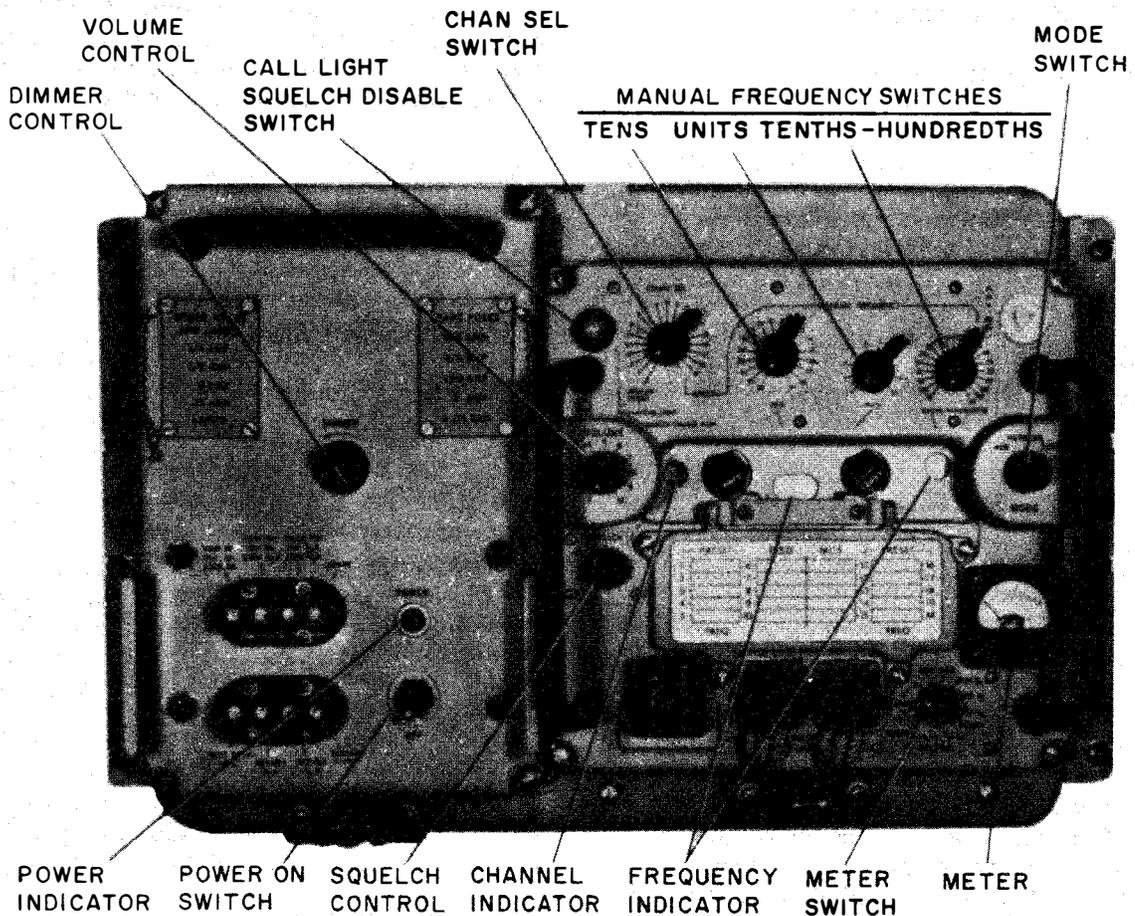


Figure 6-39.—Radio set AN/URC-9A.

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during non-transmitting conditions. When the microphone push-to-talk switch is activated, a series of T/R (transmit-receive) relays convert the unit to a transmitter. Three crystal-controlled oscillators provide stable RF and IF frequencies on both transmit and receive.

The AN/URC-9A operates in the frequency range from 225 to 399.95 MHz, which is covered in 0.05 MHz steps by 3500 crystal-controlled channels. Frequency selection is determined by the position of the CHAN SEL switch, which has 19 preset channel positions, a MANUAL position, and a REMOTE PRESET position. The 19 preset channel frequencies can be set to any one of the 3500 available channels on a memory drum, accessible through a door in the front panel. When the CHAN SEL switch is in the MANUAL position, any one of the 3500 channels can be selected using the MANUAL FREQUENCY TENS, UNITS, and TENTHS-HUNDREDTHS control on the front panel (fig. 6-39). The squelch level is controlled from the front panel and the transmit-receive function can be controlled from Radio Set Control C-1138/UR or C-1207/UR.

When the CHANSEL switch is in the REMOTE PRESET position, control of channel selection and squelch level is transferred to Radio Set Control C-2383/URC. When used with the AN/URC-9A, the audio connectors of the AN/URC-9A and C-2383/URC are paralleled and either unit may be used for transmitting and receiving regardless of the CHAN SEL switch position. Radio Set Control C-2383/URC is not used with sets that have been modified for homing beacon operation. Controls for Radio Set AN/URC-9A are described in table 6-1.

FUNCTIONAL DESCRIPTION

All of the functional blocks shown in figure 6-40 (foldin end of chapter) are contained in Receiver-transmitter RT-581A/URC-9. Power Supply PP-2702/URC-9 is a separate assembly. Both the receiver-transmitter and the power supply are housed in Receiver-Transmitter Case CY-2959/URC. During normal receive, the signal passes from the directional coupler to the RF and power amplifier assembly. The received signal is mixed with a signal from the crystal-controlled frequency multiplier oscillator, and the 20 to 29.95 MHz difference frequency is routed to the first IF amplifier. A crystal-controlled oscillator, in the first IF amplifier, provides a 17 to 26 MHz signal for mixing. The 20 to 29.95 MHz signal (incoming

and the 17 to 26 MHz oscillator signals are mixed to provide a 3.0 to 3.95 MHz difference signal. The 3.0 to 3.95 MHz signal is passed to the second IF amplifier. A crystal oscillator in the second IF amplifier provides the third mixing signal. (If the incoming signal is in the range of 3.0 to 3.4 MHz, the output of the crystal oscillator is in the 3.5 to 3.95 MHz range; if the incoming signal is in the 3.5 to 3.95 MHz range, the oscillator output is 3.0 to 3.4 MHz.) The 500 kHz difference signal is routed through a 500 kHz filter to the third IF amplifier. In the third IF amplifier, the signal is demodulated, passed through a noise limiter, amplified, and applied to the audio amplifier and modulator assembly. The audio signal is amplified and routed to the local and remote headsets. All tuning elements are controlled automatically by the frequency selector.

During normal transmit, the push-to-talk switch on the microphone operates relays which convert the RT-581A/URC-9 to a transmitter. The transmit signal is generated by the 3.0 to 3.95 MHz oscillator in the second IF amplifier. Relay circuitry disables the 500kHz IF amplifier and selects a crystal that is 500kHz different in frequency than the receive crystal. The 3.0 to 3.95 MHz signal is mixed with the signal from the 17 to 26 MHz crystal oscillator, producing a sum frequency in the 20 to 29.95 MHz range. The sum signal is amplified and passed to the RF and power amplifier assembly where it is mixed with a signal from the frequency multiplier oscillator. The output of the oscillator is 200 to 370 MHz. The resultant output is applied to the power amplifier. The power output is modulated by an audio signal from the audio amplifier and modulator assembly. The amplitude-modulated RF signal then is routed through the directional coupler and the antenna coupler to the antenna.

Operation in the retransmission mode requires that two sets be interconnected, because a transceiver cannot send and receive concurrently. When two sets are connected in this manner, the reception of a signal of the proper level causes the alternate set to operate as a transmitter. This is done by connecting the squelch circuitry (in the audio amplifier and modulator assembly) to the audio detection circuits. When a signal is received on one set, it is used to modulate the transmitter output of the alternate set. The audio signal appears at the headsets of the transmitting set.

Chapter 6—CW AND VOICE COMMUNICATION SYSTEMS

Table 6-1.—Controls for radio set AN/URC-9A

| CONTROL NAME | FUNCTION |
|---------------------------|--|
| POWER Switch | Controls primary input to the AN/URC-9A. |
| POWER Indicator | Indicates that primary power has been applied to the AN/URC-9A. |
| DIMMER Control | Controls intensity of panel lights. |
| CHAN SEL Switch | <p>A 21-position switch with positions as follows:</p> <p>REMOTE Transfers control to a remote channel selector.</p> <p>PRESET</p> <p>Positions Selects preset channels 1 through 19</p> <p>MANUAL Transfers frequency selection to MANUAL FREQUENCY switches.</p> |
| MANUAL FREQUENCY Switches | <p>Select operating frequency when CHAN SEL switch is in MANUAL position as follows:</p> <p>TENS Selects first and second digits.</p> <p>switch</p> <p>UNITS Selects third digit</p> <p>switch</p> <p>TENTHS- Selects fourth and fifth digits.</p> <p>HUNDREDTHS switch</p> |
| Channel Indicator | Indicates preset channel (or manual, M) in use. |
| Frequency Indicators | Indicates frequency in use. |
| SQUELCH Control | <p>Controls the ability to receive weak signals. Setting of SQUELCH control establishes the minimum strength of signal required to operate receiver. When SQUELCH control is in OFF position, squelch circuit is disabled and receiver sensitivity is maximum. When SQUELCH control is at maximum a 100-microvolt signal is required to operate the squelch circuit. The SQUELCH control is inoperative when CHAN SEL switch is in REMOTE PRESET position.</p> |

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Table 6-1.—Controls for radio set AN/URC-9A.—Continued.

| CONTROL NAME | FUNCTION |
|-------------------------------|---|
| SQUELCH DISABLE - PUSH switch | Disables squelch circuit when pressed. Switch is inoperative when CHAN SEL switch is in REMOTE PRESET position. |
| CALL LIGHT | Lights when squelch is disabled or signal strong enough to operate the squelch is received. |
| VOLUME Control | Adjusts audio level to local speaker or headset. |
| MODE Switch | <p>Selects following modes of operation:</p> <p>NOR Normal operation</p> <p>RETRANS Automatic relaying operation</p> <p>TONE Modulates carrier with 1000 Hz tone.</p> |
| Meter and METER switch | <p>The meter monitors any one of 11 functions selected by the METER switch as follows:</p> <p>OFF Meter disconnected.</p> <p>S METER Indicates strength of received signal.</p> <p>SWR Indicates reflected RF power.</p> <p>PWR Indicates RF power output.</p> <p>DVRI_b Indicates plate current of transmit driver V105.</p> <p>PAI_g Indicates control grid current of transmit power amplifier V106.</p> <p>PAI_b Indicates plate current of transmit power amplifier V106.</p> <p>% MOD Indicates modulator output.</p> |

Table 6-1.—Controls for radio set AN/URC-9A.—Continued.

| CONTROL NAME | FUNCTION | |
|----------------------------------|----------|--|
| Meter and METER switch (cont) | BIAS | Indicates voltage from -11-volt dc supply. |
| | +26.5V | Indicates voltage from +26.5-volt dc supply. |
| | +125V | Indicates voltage from +125-volt dc supply. |
| | +325V | Indicates voltage from +325-volt dc supply. |

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The third and final position of the MODE switch, TONE, causes a 1000 Hertz tone to be applied to the audio amplifier and modulator assembly. This 1000 Hertz signal is used to modulate the RF carrier and is transmitted as a "homing beam".

Setting the controls for broadband operation causes the received audio signal to be routed to the input of the broadband equipment. The output of the broadband equipment is applied to the headsets. During transmit, the microphone signal is applied to broadband equipment. The output of the broadband equipment is connected to the audio amplifier and modulator assembly. The resultant signal then is transmitted in the normal manner.

RADIO SETS AN/SRC-20 & 21

Radio Sets AN/SRC-20 and AN/SRC-21 (figs. 6-41 & 6-42) are shipboard or fixedstation UHF transceivers capable of simplex transmission and reception of amplitude-modulated radiotelephone and tone modulated signals. They represent the types of transceivers used in the secure voice systems discussed in Chapter 5. The radio sets operate in the 225 to 399.9 MHz (UHF) range; (using receiver-transmitter RT-581/URC-9). This range is covered in 0.1 MHz steps over 1750 crystal-controlled channels. Nineteen of the 1750 channels can be preset for automatic selection. Complete control of the radio sets, including automatic selection of the preset

channels, can be exercised from up to four remote points. Provisions also are included to (1) operate in conjunction with another set for automatic retransmission, (2) modulate the carrier with a 1000 Hertz signal which is used as a homing beacon, (3) operate the radio set in conjunction with equipment requiring broad bandwidth characteristics, and (4) operate the radio set in conjunction with Antenna Coupler Group AN/SRA-33.

The only difference between Radio Sets AN/SRC-20 and AN/SRC-21 is the use of a linear, 100 watt, RF amplifier in the AN/SRC-20. Radio Set AN/SRC-20 is composed of Radio Frequency Amplifier AM-1565/URC, Radio Set AN/URC-9, and Radio Set Control C-3866/SRC. Radio Set AN/SRC-21 is composed of Radio Set AN/URC-9, and Radio Set Control C-3866/SRC as shown by figure 6-43.

The minimum carrier output of Radio Set AN/SRC-20 is 100 watts with modulation capability of 80 percent; for Radio Set AN/SRC-21, the minimum carrier output is 16 watts with an 80 percent modulation capability.

**RADIOFREQUENCY AMPLIFIER
(AM-1565/URC)**

The AM-1565/URC is an automatically tuned, fixed-station, linear, UHF power amplifier which operates class AB₁. The amplifier provides a minimum carrier level of 100 watts over a frequency range of 225 to 399.9 MHz and is

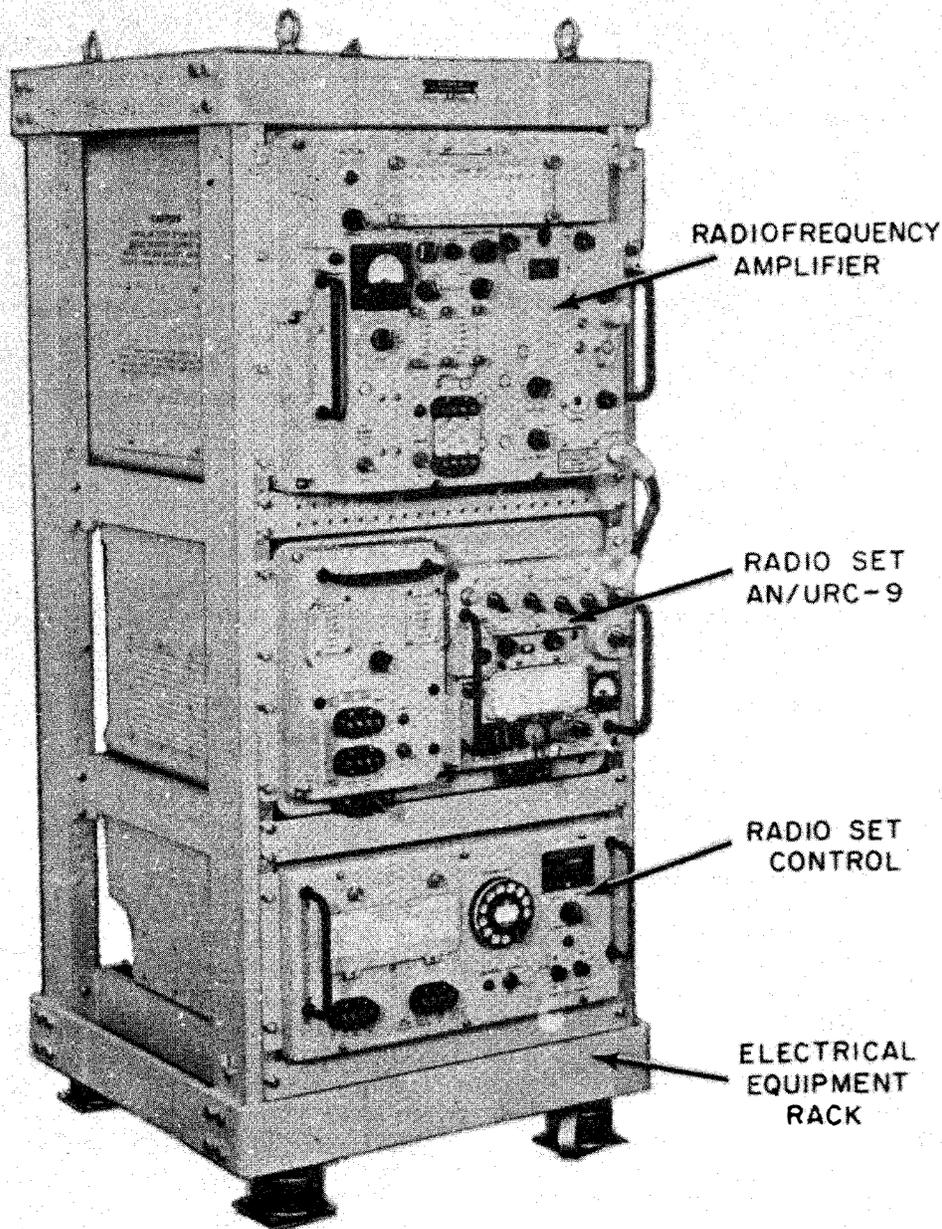


Figure 6-41.—Radio set AN/SRC-20.

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continuously tunable over the entire range. A dial calibrated in frequency and a logarithmically calibrated dial are provided to allow presetting of channels. The cathode and plate-tuned circuits of the RF amplifier are high-Q, coaxial cavities and are servo tuned to the desired frequency.

Radiofrequency excitation is controlled automatically by a ferrite attenuator which compensates for variation in the exciter output. The linearity of this RF amplifier minimizes interference due to transmitter intermodulation. An internal power supply operates from a 115 or

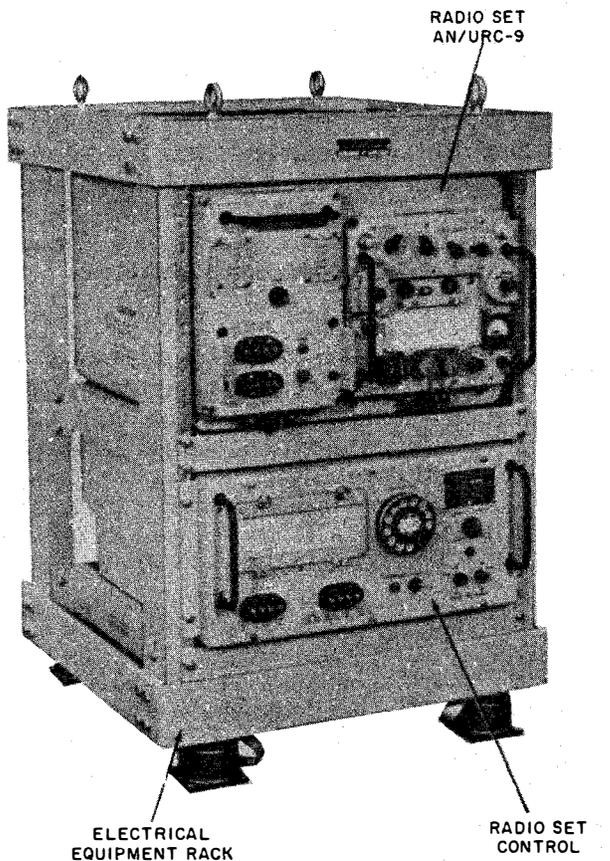


Figure 6-42.—Radio set AN/SRC-21.

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230 VAC, 50 to 60 Hertz source. The RF amplifier and integral power supply are installed in the equipment case on a tilting slide mechanism; allowing the unit to be withdrawn from the case for servicing. Major subassemblies, such as the power amplifier and servo amplifier, can be removed from the chassis. Internal blowers provide forced-air cooling. Connections are provided on the rear of the case for an antenna coupler, exciter, a.c. power, and remote control.

Channel selection is accomplished by Auto-positioners. The RF amplifier is continuously tunable over the entire frequency range, with provisions for presetting 19 channels for remote or local selection. One additional channel allows manual tuning. All channel information of the power amplifier is made available to the associated exciter. The power amplifier can be controlled by a remote unit.

RADIO SET AN/URC-9

The AN/URC-9 functions as a triple-conversion, superheterodyne receiver during

standby operation. When the microphone push-to-talk switch is closed, the T/R (transmit-receive) relays convert the unit to a transmitter. Many of the IF, RF, and audio circuits are used on both transmit and receive. Three crystal-controlled oscillators provide stable RF and IF frequencies on both transmit and receive. Receiver-Transmitter RT-581/URC-9 is automatically tuned by standard Auto-positioners which can be controlled locally from the front panel or by remote control. Any one of the 19 preset channels can be selected from the front panel or by remote control, and any of the 1750 channels within the frequency range of the radio can be selected by use of the manual frequency control on the front panel.

Receiver-Transmitter Case CY-2959/URC-9 contains two compartments, one for Power Supply PP-2702/URC-9 and one for Receiver-Transmitter RT-581/URC-9. A centrifugal fan unit, mounted in the top of the power supply compartment, circulates cooling air around the heat exchanger case and through the power supply compartment. The louvered ports on the sides of the case are covered to make the equipment immersion proof during transit. During operation, the plates are removed and relocated above the louvered ports to make the equipment splashproof. A centrifugal-axial fan

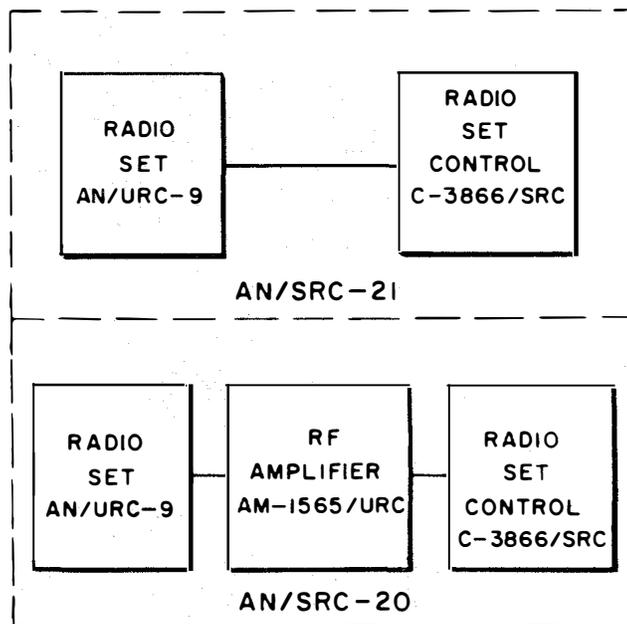


Figure 6-43.—AN/SRC-20 & 21 major units.

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unit is mounted on the main chassis of the RT-581/URC-9 and supplies cooling air to the receiver-transmitter units; in particular, the power amplifier and the modulator output tubes.

Power Supply PP-2702/URC-9 provides all operating voltages required by the receiver-transmitter. The supply operates on 115 or 230 VAC, single phase, 50 to 60 Hertz.

RADIO SET CONTROL C-3866/SRC

The C-3866/SRC (fig. 6-44) is a control unit which permits local or remote operation of the radio set and provides automatic (dial) selection of any one of the 19 preset channels. When the correct combination of remote dialing and audio equipment is used, C-3866/SRC makes possible remote control from up to four remote stations.

The unit contains a pushbutton start-stop circuit which controls primary power for either the AN/SRC-20 or AN/SRC-21. All primary power is routed through this unit. A telephone-type dial is used to select any one of the 19 preset channels. Programming relays and a stepping relay are used to generate a 5-wire binary code to deliver channel information to the Autopositioners in the radio set and the antenna coupler. The stepping relay also provides d.c. voltages for positioning the remote

channel indicators (synchros), such as Indicator Control C-3868/SRC (fig. 6-45). When the set is controlled from a remote location by Radio Set Control C-1138/UR (discussed in Chapter 5), the C-3866/SRC provides matching for the audio lines. Nineteen squelch level potentiometers are available in the C-3866/SRC for setting the squelch level of each preset channel. The unit also contains three relay power supplies.

MODES OF OPERATION

Radio Sets AN/SRC-20, 21 have three modes of operation--normal, retransmit, and tone. They can also operate with equipment requiring broad bandwidth capabilities. The mode of operation of the radio sets is determined by the MODE and PLAIN-BROADBAND switches on Receiver-Transmitter RT-581/URC-9.

Normal Mode

In the normal mode, the RT-581/URC-9 operates as a standard transceiver, with audio and receive-transmit control available at either the front panel of the unit or at a remote controlling station. When the CHANNEL SEL switch is in MANUAL, or one of the 10 preset channel positions, squelch control is exercised at the

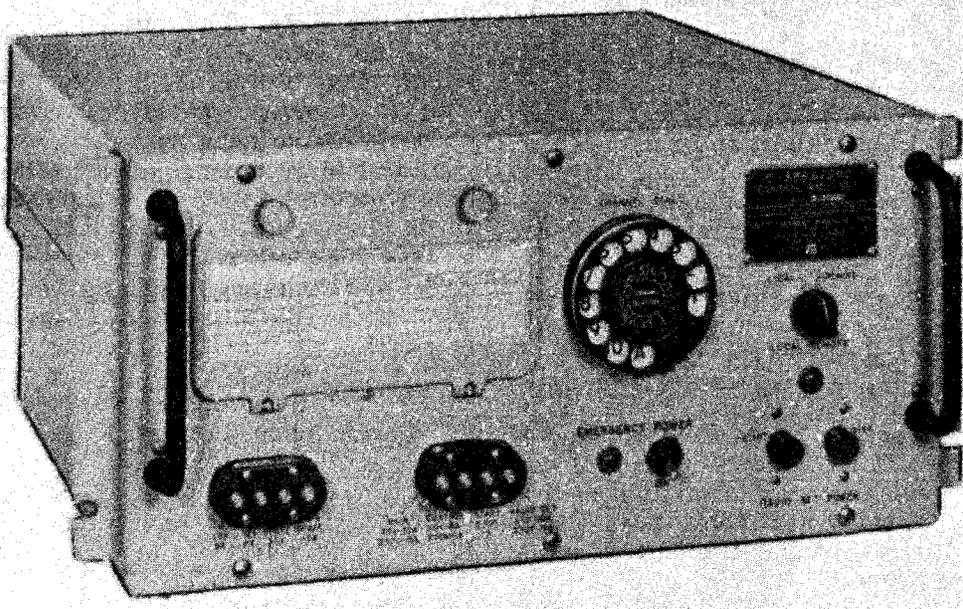
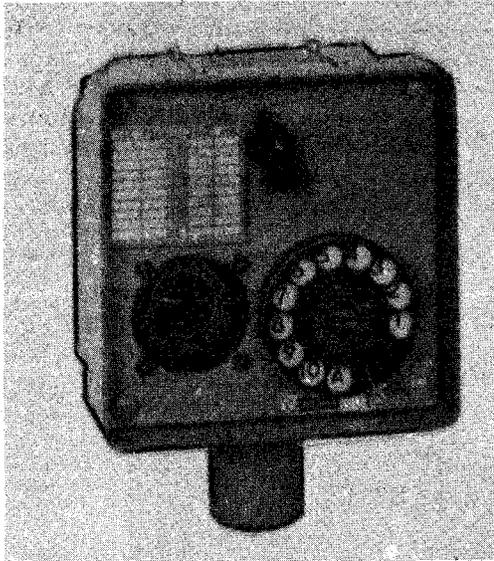


Figure 6-44.—Radio set control C-3866/SRC.

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Figure 6-45.—Indicator control C-3866/SRC.

front panel. When the CHANNEL SEL switch is in REMOTE PRESET, the squelch level is determined by Radio Set Control C-3866/SRC. There are 19 squelch level controls on C-3866/SRC. This allows individual squelch control for each of the 19 preset channels. The squelch circuitry is controlled by the carrier; the receiver audio output is squelched whenever the carrier drops below a predetermined level. Local audio output level is controlled by a front panel VOLUME control. Remote audio level is controlled by a VOLUME control on the remote equipment. During the normal mode, the system is in standby unless the push-to-talk switch is closed. While in standby, the system functions as a receiver. When the push-to-talk switch is closed, the transmit-receive (T/R) relays convert the system to the transmit condition. When using the normal mode with the PLAIN-BROADBAND switch in the BROADBAND position, the following changes occur:

1. The audio signals are rerouted through the broadband equipment.
2. The demodulated signal is routed to a cathode follower driver and not squelched in the AN/URC-9.
3. Normal sidetone is replaced by broadband sidetone.

Retransmit Mode

In the retransmit mode, the AN/SRC-20, 21 can be operated with similar equipment for automatic message relaying. During standby, both sets operate as receivers using carrier-controlled squelch. The receiver-transmit controls of both sets are controlled by the carrier-controlled squelch relays. When one set receives a signal, the carrier-controlled squelch relay keys the other set to the transmit condition. The audio output of the receiving set is applied to the audio input of the transmitting set. The retransmit audio can be monitored at either the local or remote stations. When the push-to-talk switch is closed, both transmitters are keyed to transmit. The local or remote microphone signal is fed to both transmitters for simultaneous transmission. The transmitter carriers should be separated by 5 MHz for proper operation.

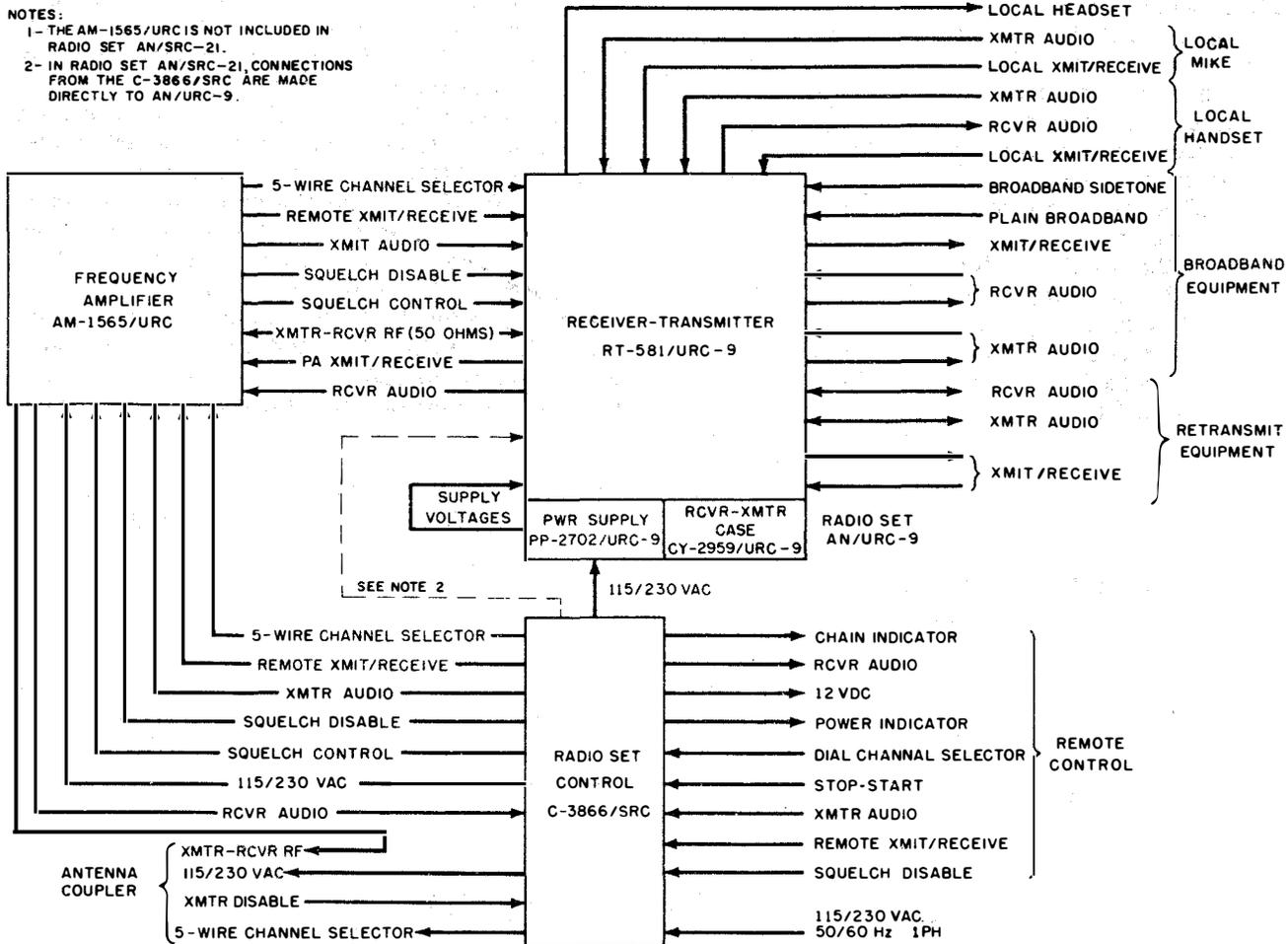
Tone Mode

In the tone mode, a 1000 Hertz tone is generated in the RT-581/URC-9 and used to modulate the carrier. This signal is used as a sounding or homing beam for aircraft and ships within reception distance.

FUNCTIONAL BLOCK DIAGRAMS

Figure 6-46 is an over-all block diagram of Radio Sets AN/SRC-20, 21 showing the relationship of the basic units to each other, and to external equipment. Assume that 19 channels have been preset, the equipment is operating in the normal mode, and the CHANNEL SEL switch is in the REMOTE PRESET position. Under these conditions, typical operation of the system is as follows:

Channel selection is initiated by Radio Set Control C-3866/SRC or one of the remote control stations. Transmit-receive control is initiated by Radio Set AN/URC-9 or one of the remote control stations. The desired channel is selected by use of a telephone-type dial. The 5-wire channel information is routed to the antenna coupler and to Radio-Frequency Amplifier AM-1565/URC where the Autopositioner is driven to select the desired frequency. The channel information is relayed from the AM-1565/URC to Radio Set AN/URC-9 where the frequency selection process is repeated. The transmit-receive control circuits are disabled, and the system is held in the receive condition



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Figure 6-46.—Radio sets AN/SRC-20 and 21 functional block diagram.

until frequency selection is completed in both the AN/URC-9 and the AN/SRA-33.

After frequency selection is completed, the push-to-talk switch may be energized to convert the system to the transmit condition. During remote transmit operation, audio is routed through the C-3866/SRC and through the AM-1565/URC to Radio Set AN/URC-9. In the AN/URC-9, the audio signal is amplified and used to modulate the RF carrier. The output of the AN/URC-9 is a 16 to 24-watt UHF signal in the 225 to 399.9 MHz range. The UHF signal is routed to the AM-1565/URC where it is amplified to a 100-watt minimum carrier level and routed through the directional coupler and the antenna coupler to the antenna.

An audio sidetone signal is generated during transmit and allows monitoring of the

transmitted signal at all local and remote stations. Channel indication also is supplied to all local and remote stations. If the PLAIN-BROADBAND switch is in the BROADBAND position, the audio signal from local or remote microphone is coupled through the AN/URC-9 to the broadband equipment. The output of the broadband equipment is routed back to the AN/URC-9 and used to modulate the RF carrier. The output from the AN/URC-9 is routed to the AM-1565/URC. The operation of the AM-1565/URC in broadband is the same as in normal.

During normal receive, the received signal is routed through the AM-1565/URC to the AN/URC-9. In the AN/URC-9 the UHF signal is shifted down in frequency and detected to remove the audio intelligence. The audio signal is routed through the C-3866/SRC to the remote

units. When the PLAIN-BROADBAND switch is in the BROADBAND position during normal receive operation, the received audio is routed through a broadband cathode follower in the AN/URC-9 to the broadband equipment. The audio from the broadband equipment is then routed to the audio amplifier circuits in the AN/URC-9 and can be monitored at all local and remote stations.

When the MODE switch (AN/URC-9) is in the RETRANS position, the AN/SRC-20, 21, is operated with a similar equipment to provide automatic retransmission facilities. During this mode of operation, the squelch circuits of the AN/SRC-20, 21, are carrier controlled, and the

transmit-receive circuits of each set are controlled by the squelch circuits of the other set. The audio output of each set is routed to the audio input of the companion set.

The received signal at the antenna is routed through the antenna coupler and the AM-1565/URC to the AN/URC-9. The receive circuits of the AN/URC-9 operate the same as in normal. When the carrier is detected, the squelch relays energize. These relays connect the audio output of the AN/URC-9 to the audio input of the companion set and place the companion set in the transmit condition. The audio then is automatically retransmitted. When the companion set receives a signal, the sequence is reversed;

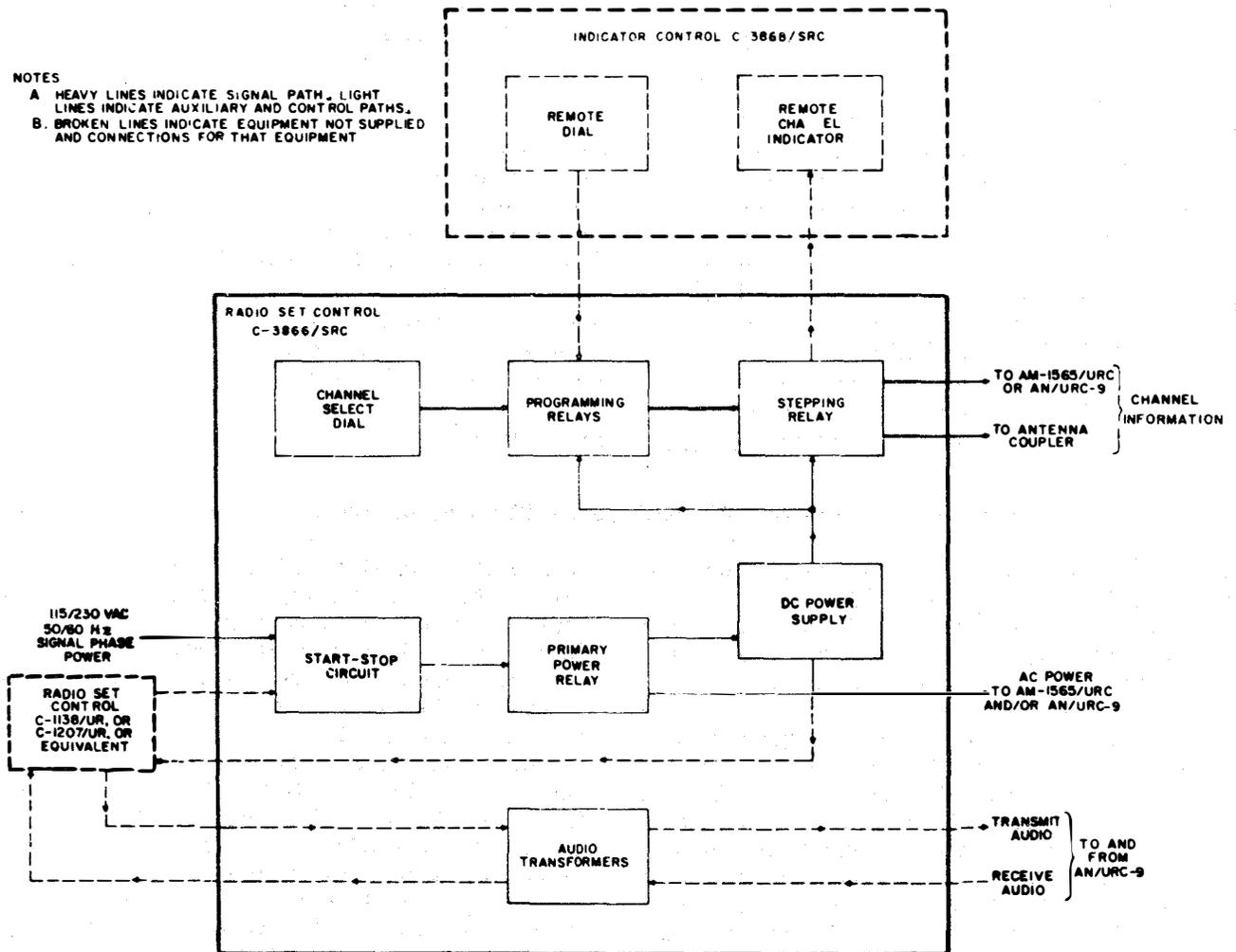


Figure 6-47.—Radio set control C-3866/SRC functional block diagram.

that is, the squelch circuits of that set places the AN/SRC-20, 21, in the transmit condition and routes an audio signal to the audio input circuits.

The retransmit audio can be monitored at the local and remote stations, and if the push-to-talk switch is energized, both radio sets are placed in the transmit condition.

During tone operation of the AN/SRC-20, 21, a 1000 Hertz signal is generated by a tone oscillator in the AN/URC-9 and transmitted as a "homing beacon". All transmit circuits operate as in normal with the exception of the audio input.

Radio Set Control C-3866/SRC

A functional block diagram of the C-3866/SRC is shown in figure 6-47. The pushbutton start-stop circuit controls all primary power delivered to the AN/SRC-20, 21. All primary power is fused through this unit.

A telephone-type dial is used to select 19 preset channels. The dial controls programming relays which, in turn, control a stepping relay used to generate a five-wire binary code. This code is used as channel information for the Auto-positioner in the AM-1565/URC (in the AN/SRC-20), the AN/URC-9, and the antenna coupler. The stepping relay also provides d.c. voltages for positioning remote channel indicators, such as Indicator Control C-3868/SRC.

When the set is controlled from a remote location (C-1138/UR), the dial on the C-3866/SRC is replaced by a dial on the remote unit, and the C-3866/SRC provides audio-matching facilities between the remote unit and the AN/URC-9. The C-3866/SRC also provides a five-wire binary code for the antenna coupler.

Three d.c. power supplies are included in the C-3866/SRC. These power supplies provide the necessary relay voltages.

Radio Frequency Amplifier AM-1565/URC

A functional block diagram of the AM-1565/URC is shown in figure 6-48 (foldin end of chapter). When the set is keyed to transmit, the signal from Radio Set AN/URC-9 passes through a variable attenuator to the RF amplifiers. After amplification, the signal passes through a directional coupler and a low-pass filter (used to minimize harmonic radiation), to the antenna coupler, and then to the antenna. During receive, the signal passes from the antenna coupler to the input of Radio Set AN/URC-9 via the coaxial relays.

The drive regulator circuits, in conjunction with the ferrite attenuator and front panel controls, compensate for variations in exciter output and drive requirement over the frequency range. This is done by either using a part of the output of the RF amplifier or a manual control to change the RF conducting properties of the variable attenuator.

Automatic tuning of the RF amplifier is performed by a servo system together with the Auto-positioner and preset channel potentiometers.

The Auto-positioner, operated by front panel controls (or by Radio Set C-3866/SRC in remote operation), forms an unbalanced a.c. bridge between the potentiometer of the desired channel frequency and the servo circuits. As the servo system seeks the new null position, the servo motor drives ganged plates in the resonant cavities of the RF amplifiers until proper cavity length is obtained. The servo system uses a rate generator feedback system to prevent hunting and oscillation.

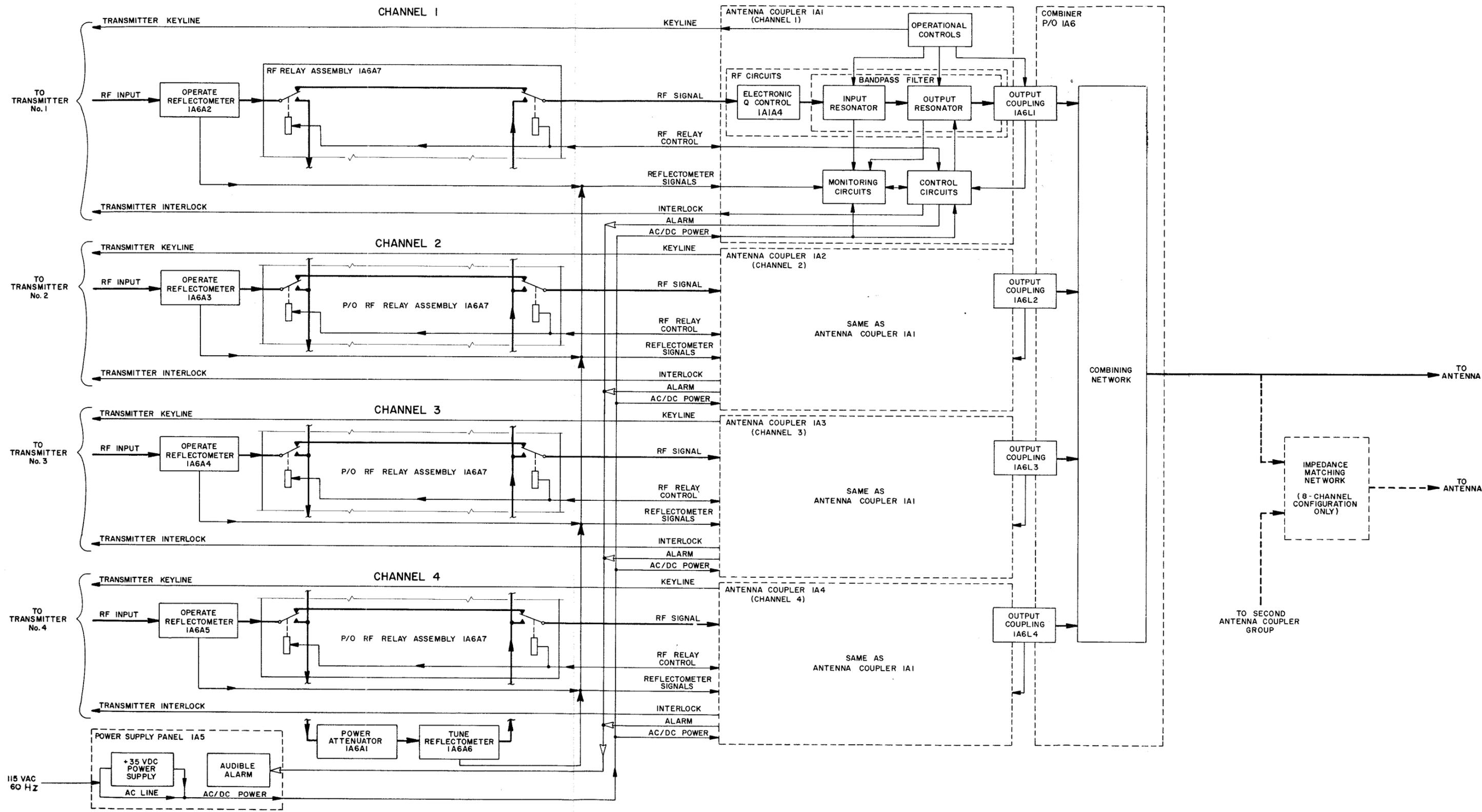


Figure 6-17.—Functional block diagram (AN/SRA-56, 57, or 58).

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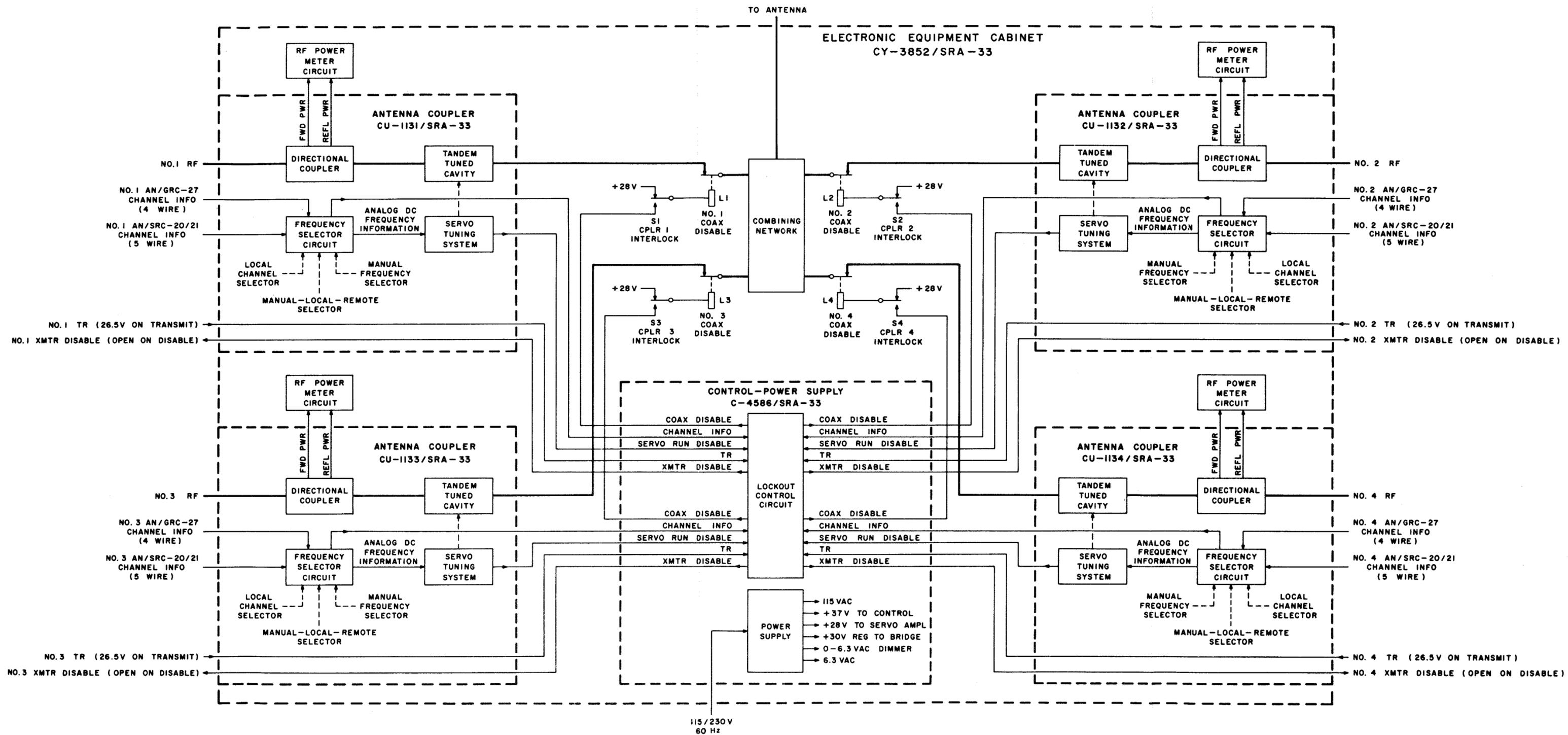


Figure 6-24.—Antenna coupler group AN/SRA-33 functional block diagram.

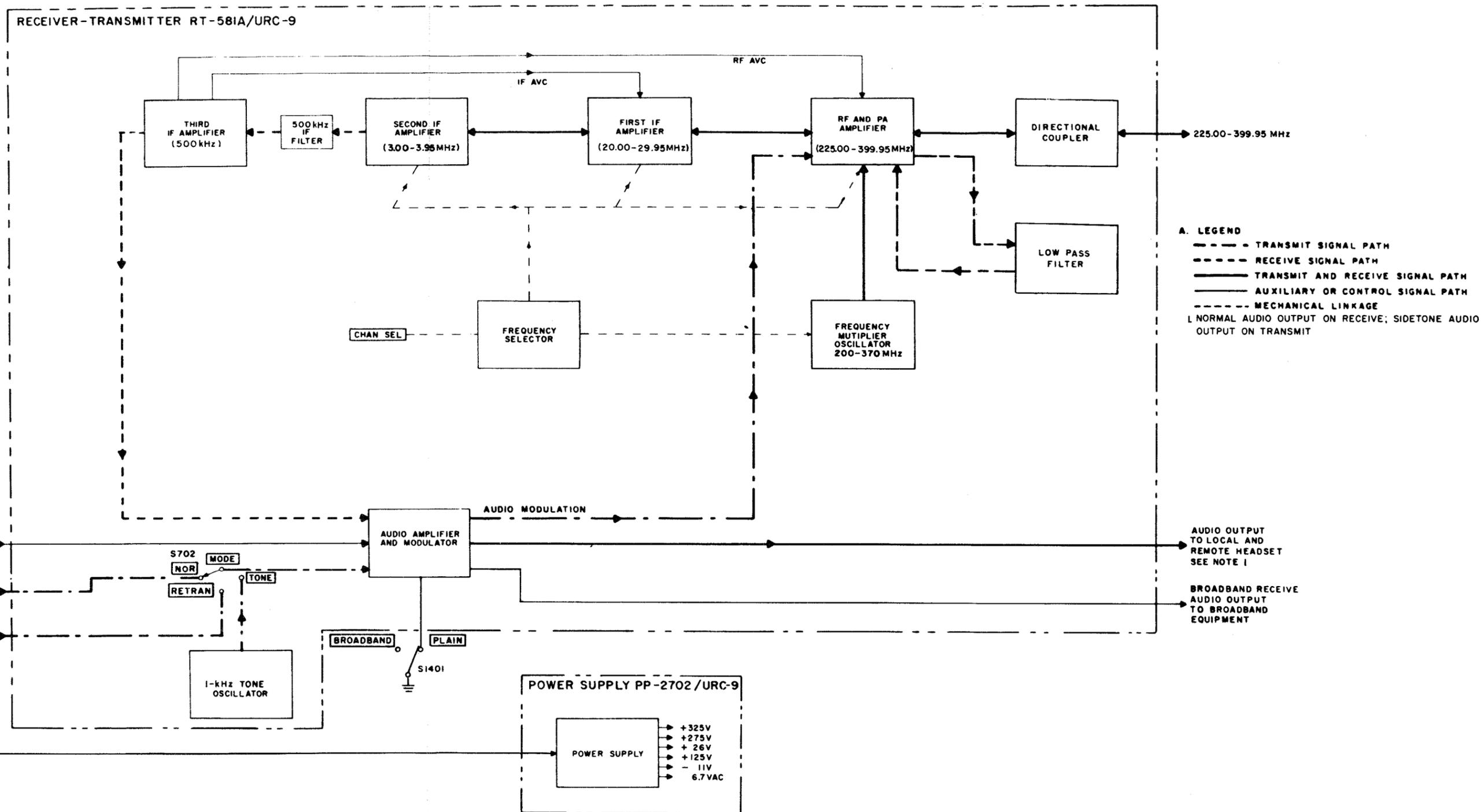


Figure 6-40.—Radio set AN/URC-9A functional block diagram.

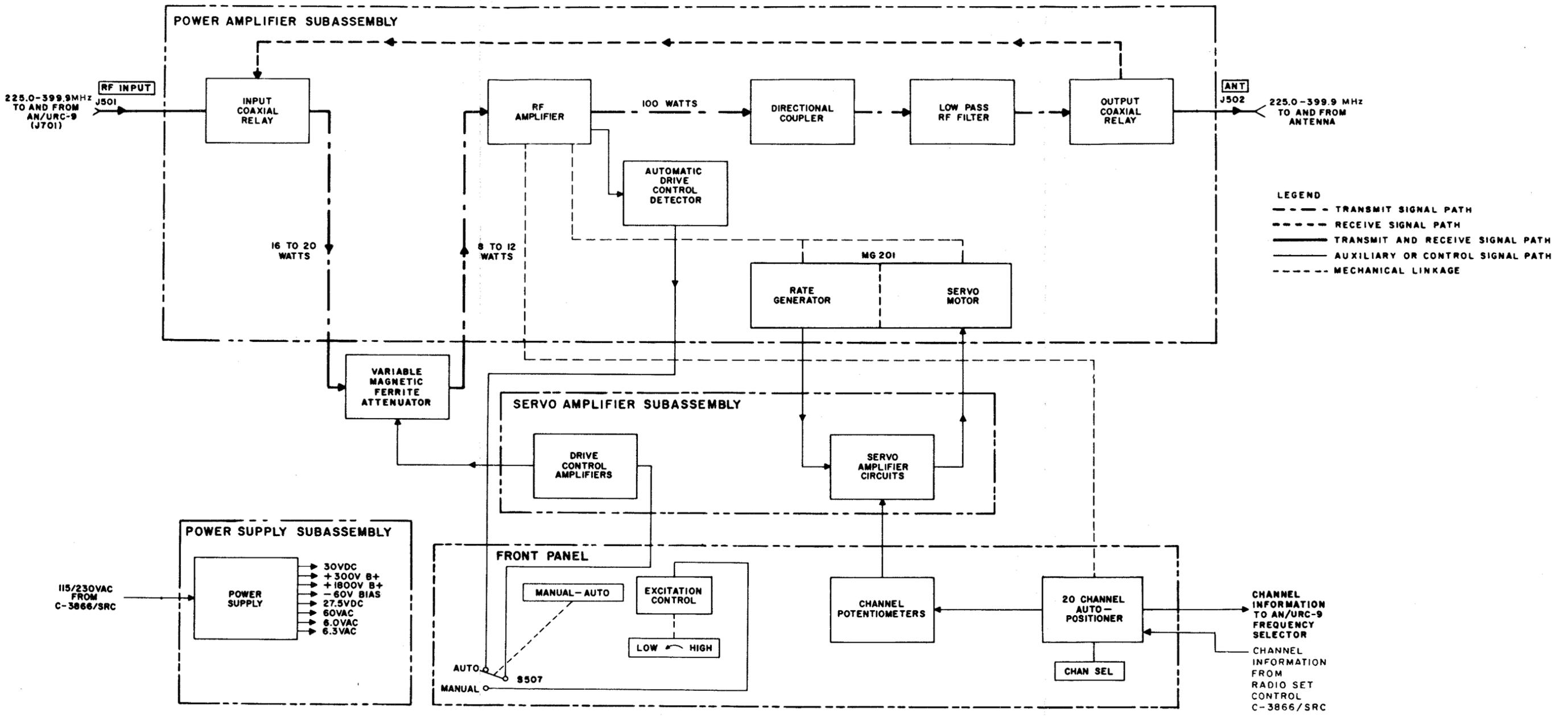


Figure 6-48.—Radiofrequency amplifier AM-1565/URC functional block diagram.

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CHAPTER 7

TELETYPE COMMUNICATION SYSTEMS

This chapter builds upon the material relating to teletype systems presented in chapter 5 of this manual. Functional block diagrams of shipboard systems are shown, and a representative transmitter, receiver, and telegraph terminal are described.

SHIPBOARD TELETYPE SYSTEMS

As discussed in chapter 5, the Navy uses audiofrequency tone-shift (AFTS) and radiofrequency carrier-shift (RFCS) teletype systems. The equipment used in these systems is configured in various ways, depending upon the type of ship and communications concerned.

AUDIOFREQUENCY TONE-SHIFT SYSTEM

Audiofrequency tone-shift teletype systems are normally used in the UHF band for short range shipboard communications. These systems consist of the antennas and associated couplers or multicouplers, transmitters and receivers, and/or transceivers patched through their respective transfer switchboards to tone terminal equipment. The tone terminal equipment is patched through nonsecure communication patching panels, through security equipment, then through secure communication patching panels to secure TTY equipment. For nonsecure operation, the TTY equipment is patched to the tone terminal equipment via the nonsecure communication patching panels. A representative audiofrequency tone-shift UHF system using a transceiver is shown in figure 7-1.

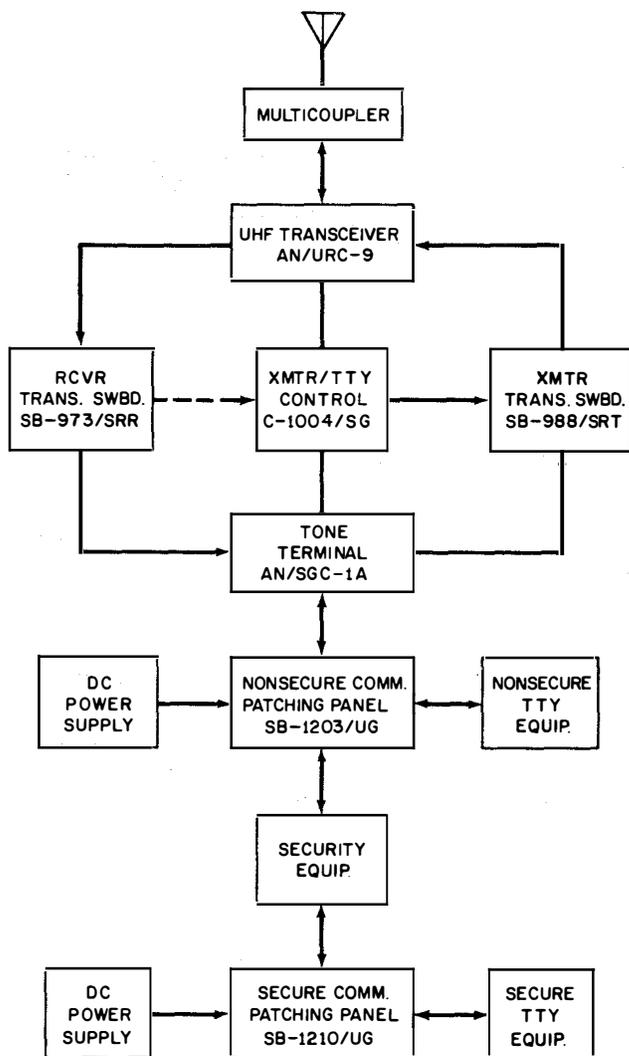
On the transmit side (fig. 7-1) d. c. signals from the secure TTY send equipment are patched through the secure communication patching panels to the TTY security equipment where encryption takes place. The encrypted d. c. signals are then patched through the nonsecure communication patching panel to the tone ter-

minal set. The tone terminal set converts the encrypted d. c. signals into audio tone-shift signals as described in chapter 5. The encrypted audio tone-shift signals are then patched via the transmitter transfer switchboard to the transmitter section of the transceiver. The audio tone-shift signal modulates the RF carrier generated by the transmitter, resulting in encrypted tone-modulated RF signals being radiated by the antenna.

On the receive side (fig. 7-1), encrypted tone modulated RF signals are received at the antenna and patched via the multicoupler to the receiver section of the transceiver, where demodulation takes place. The resulting audio tone-shifted signals are then patched via the receiver transfer switchboard to the tone terminal set. The tone terminal set converts the audio tones back into encrypted d. c. signals, which are patched through the nonsecure communication patching panel to the security equipment. The decrypted d. c. signals from the security equipment are then patched to the secure receive TTY equipment via the secure communication patching panel.

RADIOFREQUENCY CARRIER-SHIFT SYSTEM

On the transmit side (fig. 7-2) d. c. signals from the secure send TTY equipment are patched through the secure communication patching panel to the security equipment. The encrypted d. c. signals are then patched via the nonsecure communication patching panel either directly or through an FSK switchboard to the HF transmitter. The encrypted d. c. signals shift the frequency of the RF carrier generated by the transmitter. A shift of 425 Hz above the assigned frequency results when the d. c. loop is on a space, and a shift of 425 Hz below the assigned frequency results when the d. c. loop is on a



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Figure 7-1.—AFTS teletype system.

mark. The resulting output from the transmitter is a carrier frequency-shift signal which shifts a total of 850 Hz between marks and spaces. The transmitter can be controlled from a remote operating position by the XMTR/TTY Control Unit patched to the transmitter transfer switchboard.

On the receive side (fig. 7-2) the carrier frequency-shift signals are received and demodulated by the receiver, resulting in audio signals which shift 850 Hz between marks and spaces. The audio signals are patched to the converter/comparator via the receiver transfer switchboard. The converter/comparator converts the audio-shift signals back to encrypted d.c. pulses,

which are patched via the nonsecure communication patching panel to the security equipment. The decrypted d. c. pulses are then fed from the security equipment through the secure communication patching panel to secure receive TTY equipment.

MULTICHANNEL TELETYPE SYSTEMS

Secure multichannel (multiplex) teletype systems are the primary means of shore to ship communications. Ships having multichannel capabilities also use these systems to communicate with shore stations and other ships similarly equipped.

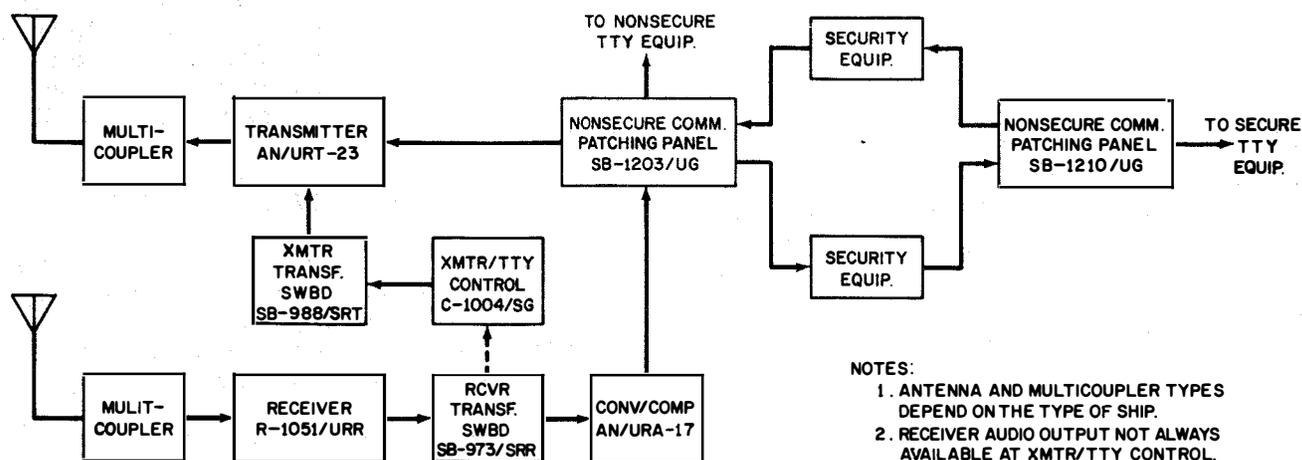
Direct current signals from the secure TTY send equipment (fig. 7-3) are patched via the secure communication patching panel to the security equipment. The encrypted d. c. signals are then patched through the nonsecure communication patching panel to the send channels of the Telegraph Terminal AN/UCC-ID(V). (A functional description of the AN/UCC-ID(V) appears later in this chapter.) The encrypted d. c. signals are applied to frequency-shift keys in the telegraph terminal which converts the d. c. signals to audio tones. The resulting output from the send side of the telegraph terminal is an encrypted composite audio signal, consisting of as many tones as are required for the number of channels used.

The encrypted composite audio signal from the telegraph terminal is fed via an audio line to the transmitter transfer switchboard. (The tones do not interfere with one another as they are separated in frequency.) The composite audio signal (which occupies approximately a 3 kHz bandwidth) is then patched via the transmitter transfer switchboard to the HF transmitters which are set up for SSB operation. The outputs from the transmitters consist of one sideband which contains the encrypted composite tones. The RF carrier and the other sideband are filtered out in the transmitter, resulting in all transmitter power being used for transmitting the tones.

On the receive side (fig. 7-3) the encrypted composite tones are received and demodulated by the receivers. (Two receivers are used to provide for diversity reception.) The outputs of the receivers are audio signals which are identical to those from the send side of the telegraph terminal.

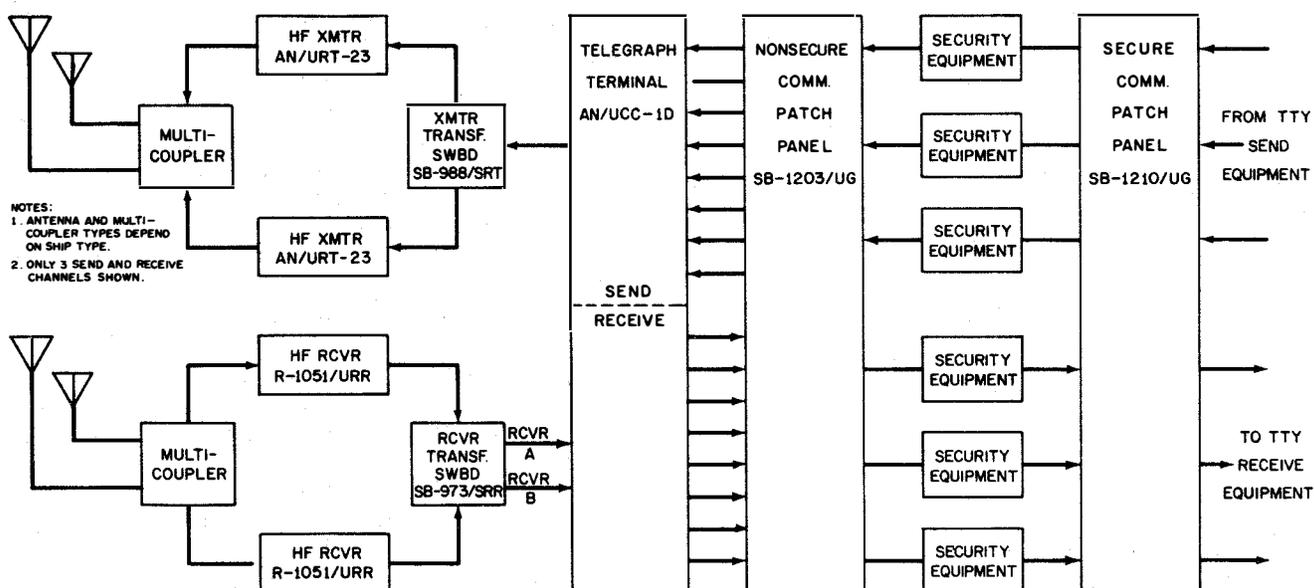
The encrypted composite audio signals from the receivers are patched via the receiver

Chapter 7—TELETYPE COMMUNICATION SYSTEMS



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Figure 7-2.—Full duplex RFCS teletype system.



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Figure 7-3.—Multichannel teletype system.

transfer switchboard into the receiver A and receiver B inputs of the telegraph terminal. Frequency-shift converters in the telegraph terminal convert the encrypted composite audio signals back to encrypted d. c. signals, which are fed to the nonsecure communication patching panel. Each telegraph channel appears on a separate loop on the nonsecure communication patching panel. The encrypted d. c. signals from

each channel are fed to the security equipment, where they are decrypted. Decrypted d. c. signals are then patched via the secure communication patching panel to the secure receive TTY equipment.

RADIO TRANSMITTING SET AN/URT-23 (V)

Radio Transmitting Set AN/URT-23(V) is a 1 kw. single sideband radio transmitting set that

can be supplied in any one of four possible configurations. The normal configuration includes Radio Transmitter T-827/URT, and is capable of general purpose voice, continuous wave, and radio teletypewriter transmissions in the 2 to 30 MHz frequency range. The exact spacing and number of channels available, modes of operation, and frequency range are dependent on the model of the T-827/URT supplied. Stack or rack mounting may be used to install the units of the AN/URT-23(V) in a ship or shore fixed installation with other ancillary equipment to form a complete communications system. Any one of three-phase primary power sources can be used to provide operating power to the set: 115 volts 400 Hz; or 208 or 440 volts 60 Hz.

GENERAL DESCRIPTION

The major units used to make up the AN/URT-23(V) are: Radio Transmitter T-827/URT, Radio Frequency Amplifier AM-3924(P)/URT, Power Supply PP-3916/UR or (optionally) Power Supply PP-3917/UR, and Electrical Equipment Shock Mount Base MT-3399/U, as shown in figure 7-4. In both ship and shore installations, Antenna Coupler Group AN/URA-38A (consisting of Antenna Coupler CU-938A/URA-38 and Antenna Coupler Control C-3698A/URA-38) is normally used to automatically match the impedance of the system to the 50 ohm transmission line. Provisions are included, however, which allow operation with any 50 ohm antenna coupling system.

The T-827/URT is a low level transmitter (exciter) which provides a Upper Side Band (USB), Lower Side Band (LSB), Independent Side Band (ISB), CW, FSK, or compatible AM signal of sufficient power to drive the AM-3924(P)/URT. Digital tuning is used to cover the 2 to 30 MHz frequency range. (Model T-827/URT tunes from 2.0 to 29.9995 MHz in 500 Hz increments; Model T-827 A/URT and later models tune from 2.0 to 29.9999 MHz in 100 Hz increments.) A five-wire coded output from the T-827/URT is also applied to the AM-3924(P)/URT to automatically tune it to the correct frequency band. The T-827/URT is discussed in more detail later.

Radio Frequency Amplifier AM-3924(P)/URT

The AM-3924(P)/URT (fig. 7-4) is a two stage linear power amplifier, which produces an output of 1 kw. with a nominal input of 100 mw. Nineteen frequency bands are used to cover the 2 to 30 MHz operating frequency range. The operating band is automatically selected by a five-wire

code generated by the T-827/URT or internally generated if the T-827/URT is not used. The code controls two motor-driven bandswitch assemblies on which are mounted broadband transformers used as interstage and output tuned circuits for the two amplifier stages. Automatic control circuits compensate for variations in system gain, mode of operation, or loading to protect the unit against overload. The AM-3924(P)/URT can be modified to allow operation with an exciter other than the T-827/URT. Plugged mounting holes are provided in the front panel and rear of the case to allow the installation of the circuitry.

The AM-3924(P)/URT operates from a three-phase primary power source of 115 volts 400 Hz or 208 or 440 volts 60 Hz. All low voltages required for operation (except two of the relay control voltages) are internally produced. The high voltages required for powering the electron tubes used in the amplifier stages are produced by the associated Power Supply PP-3916/UR (when using 60 Hz primary power) or the optional internally mounted Power Supply PP-3917/UR (when using 400 Hz primary power).

All operating controls and indicators are located on the front panel (fig. 7-5). Those controls used only for initial setup are protected by a hinged access cover. All connections are made at the rear of the case. The four electron tubes and the associated interstage broadband transformer assemblies are cooled by forced ventilation. Cooling air is drawn through a filter on the front panel and exhausted through a port on the rear of the case.

Power Supplies

Power Supply PP-3916/UR (fig. 7-4) produces operating voltages for the AM-3924(P)/URT when operating from the 60 Hz power sources, as stated previously. All components of the PP-3916/UR, except the power transformers, are mounted on a chassis and panel assembly, which is hinge-mounted to a metal case. Loosening the front panel screws allows the chassis and panel assembly to be dropped 90 degrees to a horizontal position for servicing and troubleshooting. The power transformers are constructed as an integral part of the case. Two self-indicating fuse holders and a POWER ON indicator are located on the front panel of the PP-3916/UR. There are no operating controls.

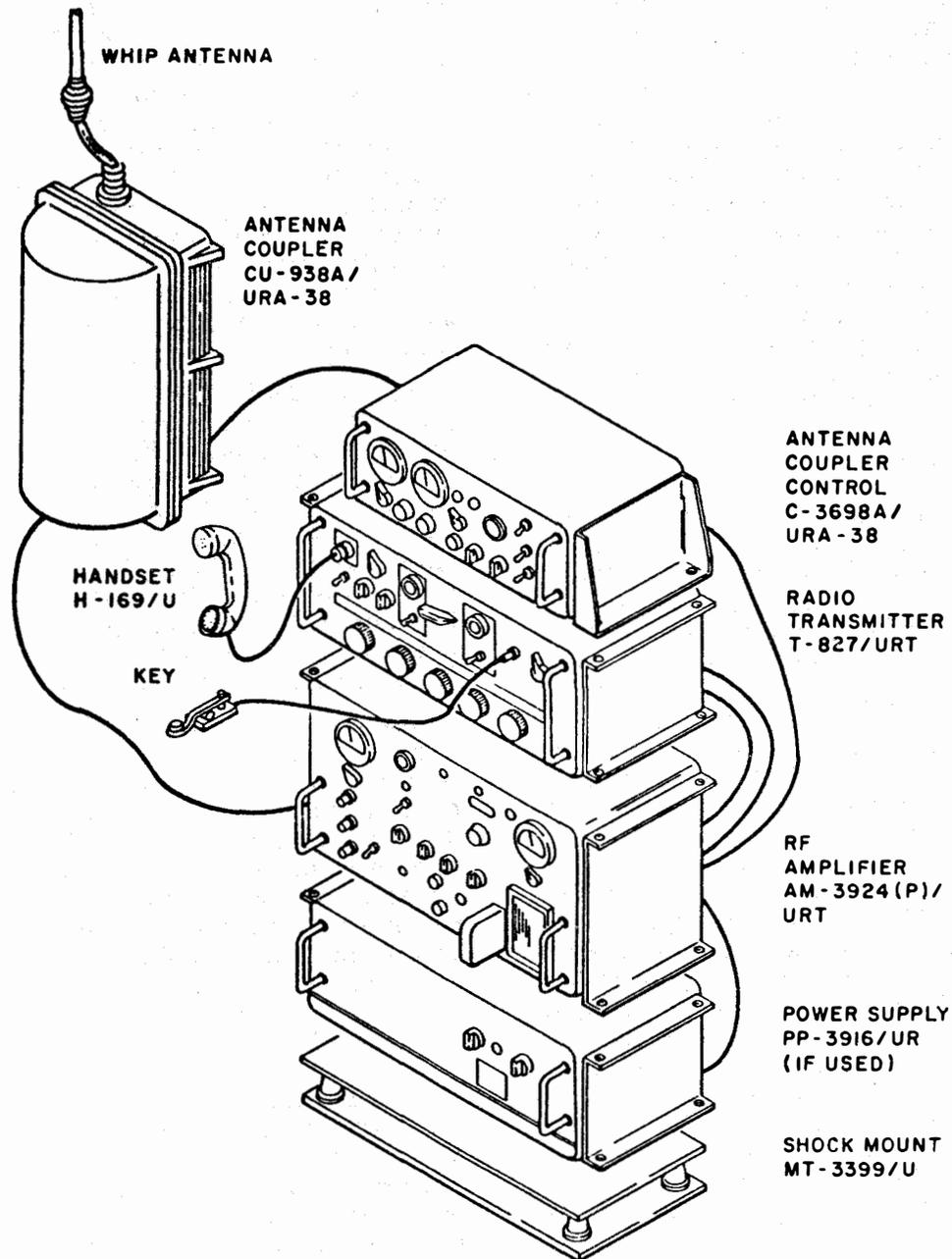


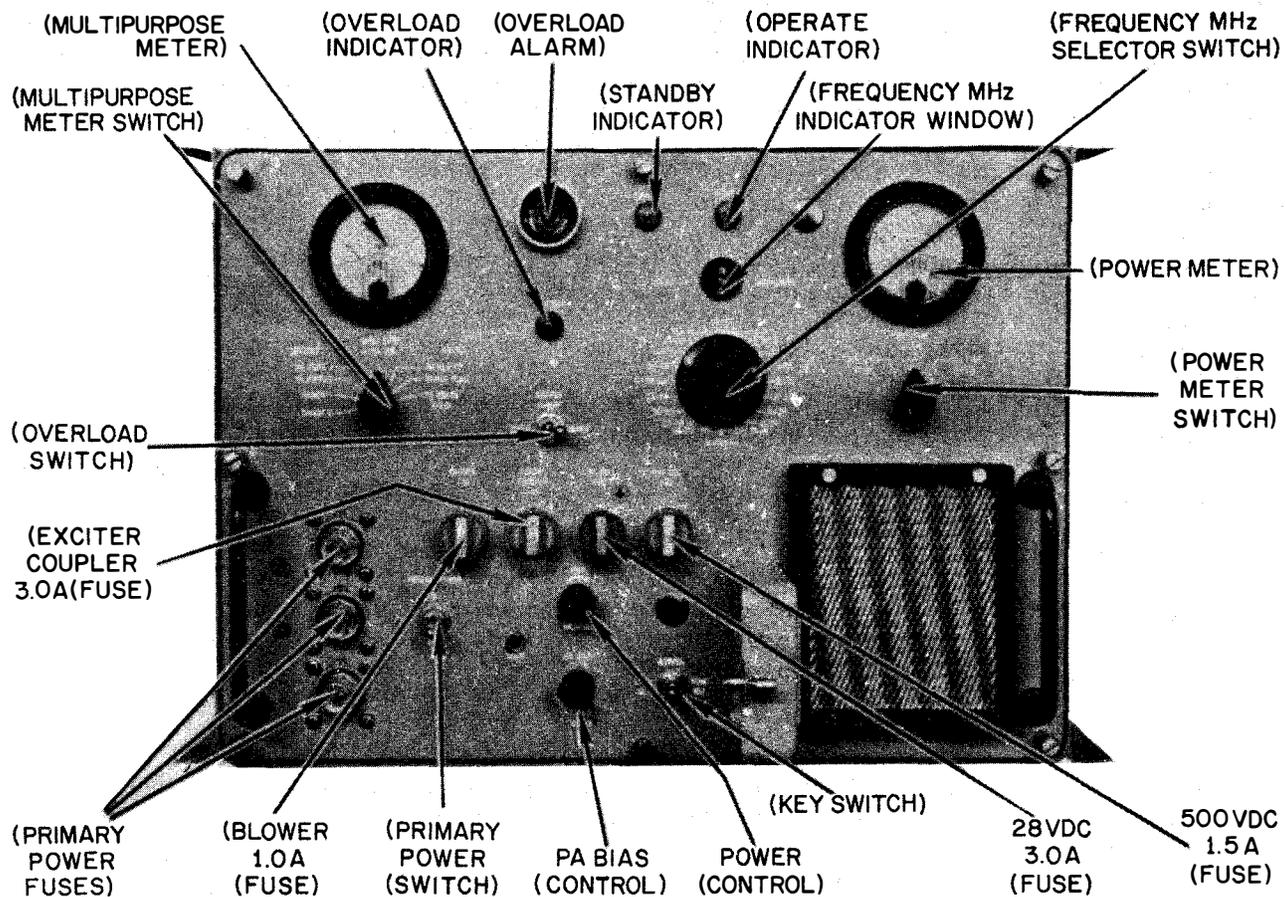
Figure 7-4.—Radio Transmitting Set AN/URT-23 (V).

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The PP-3917/UR produces operating voltages for the AM-3924(P)/URT when operating from a 400 Hz, three-phase, 115 volt primary power source. When used, the PP-3917/UR is mounted as an internal subassembly of the AM-3924(P)/URT.

Antenna Coupler Group AN/URA-38A

Antenna Coupler Group AN/URA-38A is an automatic antenna tuning system intended primarily for use with the AN/URT-23(V). However, the equipment design includes provisions for



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Figure 7-5.—Radiofrequency Amplifier AM-3924(P)/URT.

manual and semiautomatic tuning, thus making the system readily adaptable for use with other radio transmitters. In addition, the manual tuning capability is useful when a failure occurs in the automatic tuning circuitry. Also, tuning can be accomplished without the use of RF power (silent tuning). This method is useful in installations where radio silence must be maintained except for brief transmission periods.

Antenna Coupler CU-938A/URA-38 (fig. 7-4) matches the impedance of a 15, 25, 28, or 35 foot whip antenna to a 50-ohm transmission line, at any frequency in the 2 to 30 MHz range. When operating with the AN/URT-23(V), control signals from the associated antenna coupler control unit automatically tune the CU-938A/URA-38 Matching Network in less than five seconds. During manual and silent operation, tuning is accomplished by the operator with the controls mounted

on the antenna coupler control unit. A low power (not to exceed 150 watts) CW signal is required for tuning. Once tuned, the CU-938A/URA-38 is capable of handling 1 kw. of PEP and average power.

The CU-938A/URA-38 is enclosed in an aluminum, airtight, pressurized case. Access is gained to the chassis by removing the dome-shaped cover from the case. Fins on the bottom of the case carry heat from the unit. Six mounting feet enable the unit to be attached to the mast of a ship at the base of a whip antenna. The CU-938A/URA-38 is pressurized with dry nitrogen to aid internal heat transfer and prevent corona and arcing. All components of the CU-938A/URA-38 are secured to a chassis, which is mounted to the case so that an air duct exists between the chassis plate and the case. An internal fan circulates the nitrogen over and through

the heat producing elements and then through the air duct. While passing through the air duct, the nitrogen loses its heat to the bottom of the case. This heat is then transferred by convection through the fins on the case and by conduction through the mounting feet.

Antenna Coupler Control C-3698A/URA-38 (fig. 7-6) provides power and control signals required to tune the CU-938A/URA-38. The control signals are either automatically produced by the C-3698A/URA-38 when a tune cycle is initiated or manually produced with the front panel controls. All d. c. operating voltages are produced from a 115 volt, 48 to 63 or 350 to 450 Hz, single phase primary power source. Metering and protection circuits are provided to enable complete control of the CU-938A/URA-38 from the remotely positioned C-3698A/URA-38.

RADIO TRANSMITTER T-827/URT

Radio Transmitter T-827/URT accepts audio or coded intelligence and converts it to one of 56,000 possible operating radio frequencies in the 2.0 to 29.9995 MHz frequency range. It is capable of operating in any of LSB, USB, ISB, CW, FSK and compatible AM modes of operation. Tuning is accomplished digitally by means of five control knobs (MCS and KCS) and a switch

(CPS) located on the front panel (fig. 7-7). The T-827/URT has a minimum output level of at least 0.25 watt, and is designed to be used with an associated RF power amplifier such as the AM-3007/URT or the AM-3924/URT.

In AM and SSB transmit modes of operation, the output from a microphone is applied to the T-827/URT. The voice signals are amplified and used to modulate a 500 kHz local carrier, providing a 500 kHz IF. The resulting double sideband signal is filtered according to the mode of operation, amplified, and converted by a triple-conversion process to the desired RF operating frequency. The RF signal is power amplified to a nominal 0.1-watt level. In CW operation, the 500 kHz local carrier is inserted directly into the IF amplifiers at a coded rate. The signal is further processed in the same manner as the voice signals in the AM or SSB modes of operation. In FSK operation, the coded application of loop current is converted to audio frequencies representing marks and spaces. These audio signals are applied to the audio circuits of the T-827/URT. Thereafter, these signals are processed in the same manner as the voice signals in AM or SSB modes of operation.

As shown by the functional block diagram (fig. 7-8 foldin end of chapter), the T-827/URT

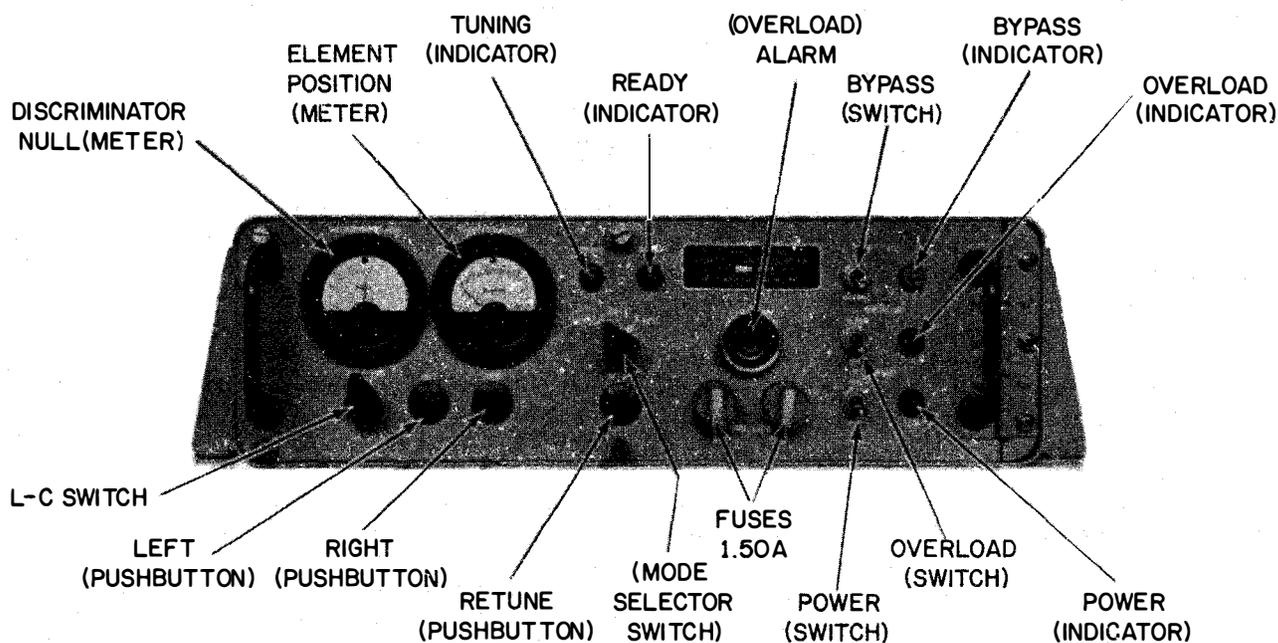
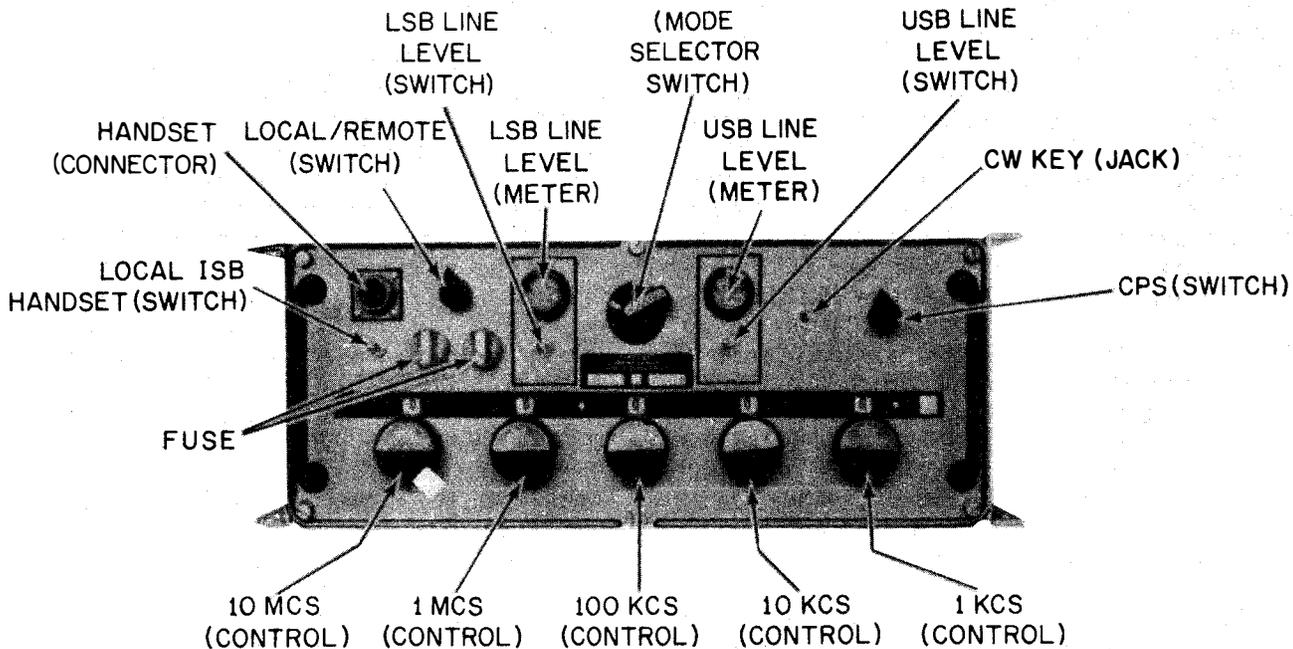


Figure 7-6.—Antenna Coupler Control C-3698/URA-38.



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Figure 7-7.—Radio Transmitting Set T-827/URT operating controls and indicators.

consists of nine plug-in electronic assemblies and a power supply. Assembly A2A6 consists of six subassemblies.

Main Signal Flow

The main signal flow in the T-827/URT originates in the 5 MHz frequency standard in assembly A2A5 (fig. 7-8). This circuit is housed in an oven assembly maintained at a nearly constant temperature of 85° C by the oven control circuit. The 5 MHz frequency standard produces an accurate, stable reference frequency, upon which all frequencies used in the T-827/URT are based. The accurate output from the 5 MHz frequency standard is applied to a switching and compare circuit. An external 5 MHz frequency may also be applied to this circuit. The switching and compare circuit routes the internal or external 5 MHz signal to the multiplier-divider circuits or to the compare circuit. The compare circuit compares the internal 5 MHz frequency with the external 5 MHz frequency for an indication of the internal frequency accuracy. The 5 MHz output from the switching and compare circuit is applied to the multiplier-divider circuit, where it is converted to frequencies of 500 kHz, 1 MHz, and 10 MHz. All three frequencies

are used in the mixing processes required to produce the injection frequencies used in the RF conversion process. The 500 kHz frequency output from the multiplier-divider circuit also serves as the local carrier for the T-827/URT.

The 500 kHz local carrier output from the multiplier-divider circuit is applied to the 500 kHz IF amplifiers in assembly A2A1. These circuits amplify the 500 kHz local carrier to a level suitable for use in the balanced modulators. There are two balanced modulators, identical except for output filtering. The balanced modulator used is selected according to the mode of operation. One balanced modulator is used in the USB, FSK, AM, and ISB modes of operation. The other balanced modulator is used during the LSB and ISB modes of operation. Neither balanced modulator is used during the CW mode of operation. Audio intelligence from the audio amplifier is applied to the appropriate balanced modulator to modulate the 500 kHz local carrier, resulting in a double sideband signal without a carrier. The double sideband signal is filtered according to the mode of operation to remove either the LSB or USB portion of the signal.

The other portion of A2A1 Assembly is the control gates sidetone oscillator circuit (described later).

The 500 kHz output from the balanced modulators is applied to the IF amplifiers (assembly A2A12). The IF amplifiers provide a 500 kHz IF output at a level suitable for use in the low and midfrequency mixers circuit. The level of the 500 kHz IF output from the IF amplifiers is prevented from exceeding a predetermined peak and average power level by application of the average power control (APC) and the peak power control (PPC) signals produced in the associated RF power amplifier. The 500 kHz local carrier is reinserted into the 500 kHz IF signal during the AM mode of operation in the IF amplifier circuit. The unmodulated 500 kHz IF signal for CW mode of operation is also produced by this circuit. The 500 kHz carrier required in both the AM and CW modes of operation is applied to the IF amplifiers circuit by the control gates sidetone oscillator circuit contained in Assembly A2A1 (fig. 7-8).

The output from the IF amplifier circuit is applied to the low and midfrequency mixers. These two mixer circuits, which comprise a part of Subassembly A2A6A6, in conjunction with the high frequency mixer circuit portion of Assembly A2A4, convert the 500 kHz IF signal to the desired RF frequency by a triple conversion process. The 500 kHz IF signal is mixed with the 1- and 10-kHz injection frequency by the low frequency mixer to produce a second IF frequency between 2.8 and 2.9 MHz. This frequency is filtered and applied to the midfrequency mixer. The second IF is mixed with the 100 kHz injection frequency by the midfrequency mixer to produce a third IF between 19.5 and 20.5 MHz or between 29.5 and 30.5 MHz. The third IF used is determined by the hi/lo band control signal.

The output from the midfrequency mixer is filtered and applied to the high frequency mixer in Assembly A2A4. The third IF is mixed with the MHz injection frequency by the high frequency mixer to produce the desired RF output frequency. The MHz injection frequency is determined by the position at which the MHz frequency generator is set by the code from the code generator. The output from the high frequency mixer is applied to the RF amplifiers, which amplify the RF frequency to a level suitable to drive the associated RF power amplifier. The input and output circuits of the RF Amplifiers are automatically tuned by the tuning code produced by the code generator, according to the frequency of the desired operating channel.

Audio Signal Flow

The intelligence applied to the T-827/URT is either the coded keying for CW, the coded keying for FSK, or the audio for all other modes of operation. The coded CW keying turns a gating circuit on and off in the control gates sidetone oscillator circuit. Each time the key is pressed, the gate is turned on, allowing the 500 kHz local carrier to pass from the 500 kHz amplifiers to the IF amplifiers. Also, each time the CW key is pressed, the output of a sidetone oscillator is gated through to the sidetone line. This sidetone signal is applied to the associated receiver (such as R-1051/URR), enabling the operator to monitor the CW keying. The audio output from the microphone is applied to the audio amplifiers in Audio Amplifier Assemblies A2A2 and A2A3 (fig. 7-8).

When operating in the USB, ISB, AM, or FSK modes of operation, the audio input is amplified by Assembly A2A2 and is applied to the appropriate balanced modulator. When operating in the LSB and ISB modes of operation, the audio is amplified by Assembly A2A3 and is applied to the appropriate balanced modulator. A gate for each assembly is turned on in the control gates sidetone oscillator (Assembly A2A1) when the corresponding assembly is turned on. This gate allows the audio to pass as a side tone signal to the associated receiver, enabling the operator to monitor the respective transmission.

When operating in the FSK mode of operation, the coded TTU input is applied to the TTY generator in Assembly A2A9. The TTY generator produces the required mark and space frequencies and applies them to Audio Amplifier Assembly A2A2. The gate for reinserting the 500 kHz carrier into the IF signal during AM operation is also contained in the control gates sidetone oscillator circuit. This circuit also has a gating network for reinserting a pilot local carrier into the IF signals during LSB, USB, or ISB operation.

Frequency Generation

The injection frequencies used in the first frequency conversion in the mixers circuit are generated within the 1 and 10 kHz Synthesizer Subassembly A2A6A3. This circuit consists of two crystal oscillators, each of which has ten possible output frequencies. The output from the 1 kHz oscillator (1.850 MHz to 1.859 MHz, in 1 kHz steps) is determined by the setting of the

front panel 1 kHz (KCS) control (fig. 7-7), and the output from the 10 kHz oscillator (5.25 MHz to 5.16 MHz, in 10 kHz steps) is determined by the setting of the front panel 10 kHz (KCS) control. The outputs from the two oscillators are subtractively mixed to produce one of 100 possible frequencies spaced at the 1 kHz intervals between 3.301 and 3.400 MHz. The output is applied to the low frequency mixer.

The injection frequencies used in the second frequency conversion in the mixers circuit are generated within Subassembly A2A6A2 (fig. 7-8). This circuit consists of a crystal oscillator, the output of which is one of ten frequencies spaced at 100 kHz intervals between 4.553 and 5.453 MHz. The output frequency is determined by the setting of the front panel 100 kHz (KCS) control. If a lo-band injection frequency is required, the 17.847 MHz output from the 17.847 MHz mixer is additively mixed in the lo-band mixer with the output from the 100 kHz oscillator (4.553 MHz to 5.453 MHz, in 100-kHz steps) to provide a frequency in the 22.4 to 23.3 MHz range. If a hi-band injection is required, the 27.847-MHz output from the 27.847-MHz mixer is additively mixed in the hi-band mixer with the output from the 100-kHz oscillator (4.553 MHz to 5.453 MHz, in 100-kHz steps) to provide a frequency in the 32.4 to 33.3 MHz range. In either case, the resultant frequency is applied to the midfrequency mixer.

The injection frequencies used in the third frequency conversion in the mixer circuit are generated within Subassembly A2A6A1. This circuit consists of a phase-locked crystal oscillator that is automatically tuned to produce one of seventeen frequencies between 2.5 MHz and 23.5 MHz. The output frequency is determined by the setting of the front panel MCS controls (fig. 7-7).

Error Cancellation

A combination of error cancelling loops and phase-locked loops is used in the frequency synthesizer circuits of the T-827/URT to ensure that the injection frequencies applied to the mixers are correct. Subassembly A2A6A1 (fig. 7-8) employs a phase-locked loop to ensure the accuracy of the MHz injection frequencies. The 1-MHz output from the multiplier-divider in Assembly A2A5 is applied to the spectrum generator to produce a spectrum of frequencies spaced at 1-MHz intervals between 1 MHz and 25 MHz. The output from the spectrum generator and the output from the MHz oscillator are mixed. Any

error in output from the MHz oscillator is detected, and an error voltage is produced. This error signal is applied to the MHz oscillator to lock it to the correct frequency. The accuracy of the oscillator output is the same as that of the 5-MHz frequency standard.

Subassembly A2A6A2 employs an error cancelling loop to ensure the accuracy of the 100-kHz injection frequencies. The 500-kHz output from the multiplier-divider is applied to the 100-kHz spectrum generator to produce a spectrum of frequencies spaced at 100-kHz intervals between 15.3 MHz and 16.2 MHz. The output from the 100-kHz oscillator (4.553 MHz to 5.453 MHz, in 100-kHz steps) is applied to the 10.747-MHz mixer, where it is mixed with that spectrum point of the 100-kHz spectrum which will result in an output of 10.747-MHz. The 10.747-MHz signal is additively mixed with the 7.1 MHz output from the 7.1-MHz mixer to produce the 17.847-MHz signal, which is used in one of two mixing processes. It is mixed with the 100-MHz oscillator output to cancel any oscillator frequency error and produce the lo-band injection frequencies, or it is mixed with the 10-MHz output from the multiplier-divider. This mixing produces a 27.847-MHz signal, which is mixed with the 100-MHz oscillator output to cancel any oscillator frequency error and produce the hi-band injection frequencies. The hi or lo-band of injection frequencies is determined by the voltage level on the hi/lo band control line output from the code generator. If an error were present in the 100-kHz oscillator output, it would be cancelled in this mixing scheme.

Any error existing in the 1 and 10 kHz oscillator (Subassembly A2A6A3) is cancelled in the following manner. The 100-kHz pulses from the 100-kHz spectrum generator are applied to the 10-kHz spectrum generator, producing an output from 3.82 to 3.91 MHz in 10-kHz increments. The 10-kHz spectrum generator also produces 10-kHz pulses, which are applied to the 1-kHz spectrum generator to produce a spectrum of frequencies spaced at 1 kHz intervals between 0.122 MHz and 0.131 MHz. The output from the 10-kHz oscillator (5.25 MHz to 5.16 MHz, in 10-kHz steps) is additively mixed with whichever spectrum point of the 10-kHz spectrum will result in a frequency of 9.07 MHz.

The output from the 1-kHz oscillator (1.850 MHz to 1.859 MHz, in 1 kHz steps) is additively mixed with whichever spectrum point of the 1-kHz spectrum will result in a frequency of 1.981 MHz. The 1.981-MHz and the 9.07-MHz signals

are then subtractively mixed, producing the 7.089-MHz signal, which contains the errors of both oscillators. The 1-kHz spectrum generator also produces 5-kHz pulses, which are applied to the 5-kHz spectrum generator to produce an output consisting of two spectrum points, 110 kHz and 115 kHz. These spectrum points are used to lock the output frequency of the 500-Hz phase-locked oscillator to 110 kHz or 115 kHz, when desired. With the front panel CPS switch in the 000 position, the output from the phase-locked oscillator is 110 kHz and is locked to that exact frequency by the 100-kHz spectrum point applied to the phase detector. This 100-kHz signal is divided by ten and applied to the 7.1 MHz mixer, where it is additively mixed with the 7.089-MHz output from the 7.089-MHz mixer. The resulting 7.1-MHz signal is then applied to the error loop of Subassembly A2A6A2. Therefore, if an error exists in the 1 or 10 kHz oscillators, the same error will exist in the 100-kHz injection frequencies. This error is then cancelled in the low and midfrequency mixers of the mixers circuit.

Power Supply

The operating voltages for all circuits in the T-827/URT are produced by Power Supply Assembly A2A8 (fig. 7-8). The 105 to 125 v.a.c. primary power is converted to d.c. voltages of 110 v.d.c. (RF amplifier tubes plate and screen supply), -30 v.d.c. (RF amplifier tubes bias), and 28-v.d.c. (general use). The 28 v.d.c. is also regulated to 20 v.d.c. The 20 v.d.c. is used for operating voltage in the semiconductor circuits of the T-827/URT.

FUNCTIONAL BLOCK DIAGRAM

A functional block diagram of the AN/URT-23(V) is shown in figure 7-9 (fold in end of chapter). The RF Power Amplifier AM-3924 (P)/URT is driven by a low-level (nominal 100 mw.) RF output from the T-827/URT. Two stages of amplification (a driver amplifier and a final amplifier, fig. 7-9) are used to linearly amplify this input to a level of 1 kw. Each stage consists of two parallel connected electron tubes and operates into one of nineteen pretuned transformer assemblies. The transformer assemblies for each stage are automatically switched into the circuit according to the operating frequency. The 1 kw. output from the final amplifier is applied through the VSWR bridge and the antenna trans-

fer relay to the antenna coupler system. The VSWR bridge samples both reflected and forward power for application to the front panel power meter for measurement and monitoring. In addition, the VSWR bridge supplies the necessary signals for the APC and PPC circuits to develop their respective control voltages. The antenna transfer relay connects the antenna to an auxiliary receiver when the system is not keyed.

A five-wire coding scheme is used to automatically bandswitch the correct transformer assemblies into the driver and final amplifier circuits. The code is generated either by an encoder within the T-827/URT, or internally by an encoder within the AM-3924 (P)/URT when the T-827/URT is not used. In either case, the code consists of a pattern of opens and grounds, which establishes a ground path to one side of a relay coil through a decoder switch in the AM-3924(P)/URT bandswitching system. This ground path energizes the relay and, in turn, a motor, which rotates the decoder and bandswitch assemblies until the ground path is broken. While a new channel is being selected, an inhibit signal is applied to the keying circuit to prevent the system from being keyed before the switches have stopped in the correct position.

The VSWR bridge supplies a signal to the APC-PPC circuit, which is, in essence, the envelope of the RF output from the system. This signal is used to develop one control voltage which is proportional to the peak power output from the system and another which is proportional to the average power. Both control voltages are applied to the T-827/URT, where they are used to maintain the power output from the system at a constant 1kw. PEP. This closed loop circuit ensures that the RF power output is maintained at the rated level as well as preventing it from exceeding a safe limit. In addition, the PPC voltage is applied to the AM-3924 (P)/URT Bias Circuits as a protective measure in the event that the control circuits in the T-827/URT fail or that the system is being operated with an exciter that does not have power control capabilities. In this condition, as the peak power output increases beyond its rated level, the bias voltage to the driver amplifier is increased to reduce the RF output.

The APC-PPC circuit can also be commanded to reduce the power output from the system to a lower value required for tuning the antenna coupler. This is accomplished either manually with the front panel TUNE KEY switch or automatically by the AN/URA-38. At the same

time, a carrier insert signal is supplied to the T-827/URT, causing that unit to provide the single tone carrier output required for tuning. If desired, a resistor in the PPC circuit can be changed in value to enable the tune power level to be set to other values required to tune antenna couplers other than the AN/URA-38. When operating in the CW or FSK mode, the CW/FSK ground from the T-827/URT is used to de-energize the APC detector and switch the PPC output to the T-827/URT APC input. Also, a class B drive signal is produced and applied to the bias power supply when the CW/FSK ground is present.

An overload detector is used to continually monitor the plate currents of the two final amplifier tubes, the RF output voltage, and the temperature of the PP-3916/UR. If a dangerous condition occurs in any of these areas, the overload circuit trips and provides an inhibit signal to the keying circuit, preventing further keying of the circuit until the overload has been cleared. When the overload circuit trips, an indicator lamp and an alarm are energized to provide both visual and audible indication that an overload condition has occurred. A front panel switch enables the audible overload alarm to be disabled. The overload circuit can be reset through the front panel RESET switch. However, if the overload was not of a momentary nature, the overload circuit will again immediately trip to prevent keying. In addition, the keying circuit remains inhibited whenever the overload switch is held in the reset position, thus preventing an operator from forcing operation in an overload condition. When the time elapsed meter has recorded 1,000 hours of filament-on time for the electron tubes, it trips and energizes the overload indicator and alarm to provide an indication that the tubes should be checked for possible replacement and the time elapsed meter set to zero. However, in this condition, the operate bias for the final amplifier is not prevented from being keyed.

The AM-3924(P)/URT is keyed on and off through the bias levels applied to the four electron tubes in the final and driver amplifiers. Keying is accomplished by grounding the system keyline at any of the other units or by setting the AM-3924(P)/URT front panel KEY switch at TUNE KEY or LOCAL KEY. In any case, the keying circuit switches the bias voltage for the driver and final amplifier electron tubes from cutoff to operate levels. The keying circuit is inhibited (bias maintained beyond cutoff)

whenever the tuning motor is energized, an overload occurs, the RESET switch is depressed, or the ground key interlock signal is supplied by the AN/URA-38. Also, when the tuning motor is energized or the ground key interlock signal is supplied by the AN/URA-38, the T-827/URT is unkeyed by cutting off the 28 v.d.c. interlock signal that the AM-3924(P)/URT normally supplies to energize the T/R relays in the T-827/URT.

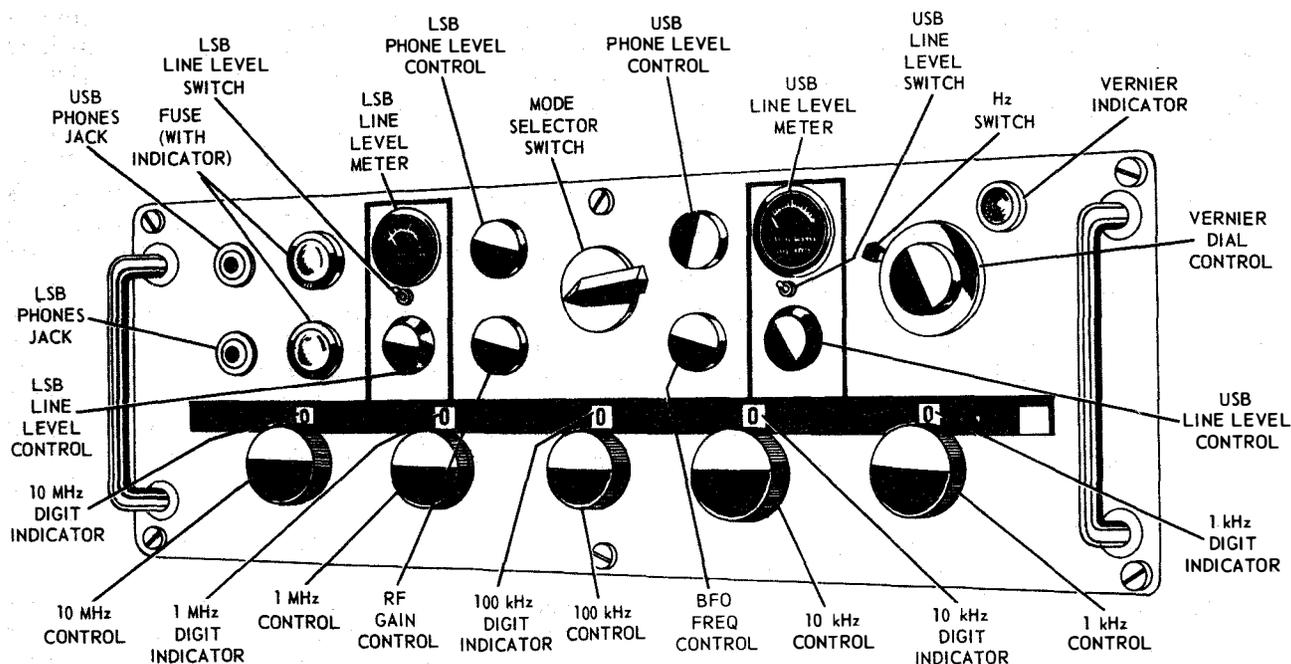
A metering circuit allows any one of eight parameters of the amplifier tubes to be connected to a meter for measurement or monitoring. These parameters consist of the cathode current of each of the four electron tubes, the input RF power to the driver amplifier, the plate supply voltages, and the screen supply voltage.

RADIO RECEIVER R-1051/URR

Radio Receiver R-1051/URR is a triple-conversion superheterodyne receiver, tunable over the high frequency range from 2 to 30-MHz. Tuning of the R-1051/URR is accomplished digitally by five controls (MCS and KCS) and a switch (CPS) located on the front panel (fig. 7-10). A display window directly above each control provides a digital readout of the digits to which the controls are set. The displayed frequency can be changed in 1 kHz increments. The front panel switch allows the operating frequency to be changed in 500 Hz increments, or 100 Hz increments depending on the model. This tuning provides 56,000 discrete frequencies in which the receiver is locked to a very accurate frequency standard. Each 1-kHz increment can be continuously tuned through by selecting the VERNIER position of the CPS switch. When using the vernier, the full accuracy of the frequency standard is sacrificed. The R-1051/URR demodulates and provides audio outputs for the following types of received signals: LSB, USB, ISB, CW, FSK, and AM. A functional block diagram of the receiver is shown in figure 7-11 (foldin end of chapter.)

MAIN SIGNAL FLOW

A received signal from the antenna passes through closed relay contacts in the antenna overload circuit to the RF amplifiers (fig. 7-11). If a signal in excess of 15 volts appears at the receiver input, the antenna overload circuit will open the relay contacts. The excessive voltage is thereby prevented from being applied to the



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Figure 7-10.—Radio Receiver R-1051/URR operating controls and indicators.

RF amplifiers, which form a part of Assembly A2A4. Within the RF amplifiers, the signal passes through a double-tuned input circuit, two RF amplifier stages, a single-tuned interstage circuit, and output circuits. All of the resonant tuned circuits are tuned by the MCS, 100 kHz (KCS), and 10 kHz (KCS) frequency controls on the front panel (fig. 7-10). The MCS controls operate a code generator, which activates a motor-driven turret containing 28 strips. Each strip contains a tuned transformer and a portion of the capacitance required by each of the four tuned circuits. For each megahertz increment, a different tuned transformer and capacitor are switched into the four tuned circuits by the 100 kHz (KCS) and 10 kHz (KCS) controls on the front panel (fig. 7-10).

The output from the RF amplifiers is applied to the mixers, which form a part of Subassembly A2A6A6 (fig. 7-11). The mixers consist of three transistor mixer stages, with inter stage coupling provided by selective filters. The first mixer receives the injection frequencies from Subassembly A2A6A1. The injection frequency is determined by the megahertz band selected by the MCS controls on the front panel. The desired output frequency from the first mixer always falls within two frequency bands, either 19.5 to 20.5

MHz or 29.5 to 30.5 MHz. The high or low band is also determined by the megahertz band to which the R-1051/URR is tuned. The output from the first mixer is gated through the appropriate 20 or 30-MHz filter. This signal is mixed in the second mixer stage with the injection frequencies supplied from 100 kHz Synthesizer Electronic Subassembly A2A6A2. The desired frequency band from the second mixer is 2.8 to 2.9 MHz. This signal is coupled through a 2.85 MHz filter to the third mixer. The injection frequencies for the third mixer are supplied by Subassembly A2A6A3. The output from the third mixer is a 500-kHz IF signal.

The 500-kHz IF output from the third mixer is applied to the mode gates. Three parallel paths are presented to the signal. The path that passes through the LSB mechanical filter (also used in ISB) is not gated since it has an independent output from the mode selector electronic assembly. Because the outputs from the USB mechanical filter (also used in FSK and ISB) and the AM mechanical filter (also used in CW) are paralleled for a common output, the input paths to these two filters must be gated so that only one path is open at any given time. Application of the correct gating potentials is determined by the mode of operation selected at the front panel.

The output from the LSB filter is applied to the IF amplifiers in Assembly A2A3. The common output of the USB and AM filters is also applied to the IF amplifiers in Assembly A2A2. The operating d.c. voltage is applied to the proper electronic assembly according to the mode of operation selected at the front panel. In the ISB mode of operation, a d.c. operating voltage is applied to both IF amplifiers. AGC voltage from the step AGC circuit controls the overall gain of the IF amplifiers by varying the attenuation of the input and the gain of the second IF amplifier stage. The input to the step AGC circuit is derived from the output of the second IF amplifier stage.

The output of the IF amplifiers is applied to the detector circuits, consisting of a product detector and an AM detector. Depending on the mode of operation selected at the front panel, either the balanced product detector or the AM detector is powered by d.c. operating voltage. The product detector demodulates the USB, LSB, FSK, and ISB signals. In these modes of operation, a 500-kHz injection frequency originating at a multiplier-divider in Assembly A2A5 is applied to the product detector for carrier reinsertion. This 500-kHz injection passes through the 500 kHz gate in Assembly A2A1 with little attenuation in these modes of operation. In AM and CW modes, this gate presents a high attenuation, since no carrier reinsertion is required by the AM detector. In the CW mode of operation, the BFO assembly in Assembly A2A1 is turned on, and a variable 500-kHz output is applied to the input of the AM detector in assembly A2A2. The output frequency from the BFO circuit is controlled by the BFO FREQ control on the front panel.

The audio derived from the detector circuits in Assembly A2A2 is applied to the USB LINE LEVEL control on the front panel, which controls the audio level prior to its application to the audio amplifiers. The LSB LINE LEVEL control sets the audio level from the product detector in Assembly A2A3. Assemblies A2A2 and A2A3 each have two outputs. One is a 600-ohm remote output, which is applied to a connector at the rear of the case. The second output is to the PHONES jacks on the front panel. The PHONES output passes through a PHONE LEVEL control on the front panel, which adjusts the phone signal amplitude without altering the level of the remote output. Each remote output is monitored at the front panel by a LINE LEVEL

meter, which has two scale ranges controlled by the LINE LEVEL switch on the front panel.

STEP AGC SIGNAL FLOW

The step AGC circuit, which forms a part of Assemblies A2A2 and A2A3, controls the gain of the RF amplifiers and IF amplifiers according to the received RF signal strength. The output from the IF amplifiers is applied to the step AGC circuits, where it is converted to a d. c. voltage that is applied to both the RF and IF amplifiers. The gain of the RF and IF amplifiers may be manually controlled by applying a d. c. voltage on the AGC lines with the RF GAIN control. This manual action overrides the normal AGC voltages.

FREQUENCY STANDARD

The 5-MHz frequency standard (Assembly A2A5, fig. 7-11) produces an accurate, stable reference frequency upon which all frequencies used in the R-1051/URR are based. The circuit is housed in an oven assembly maintained at a nearly constant temperature of 85 °C by the oven control circuit. The accurate output from the 5 MHz frequency standard is applied to a switching and compare circuit. An external 5-MHz frequency may also be applied to this circuit. The switching and compare circuit routes the internal or external 5-MHz signal to the multiplier-divider circuits or to the compare circuit. The compare circuit compares the internal 5-MHz frequency with the external 5-MHz frequency for an indication of the accuracy of the internal frequency standard.

The 5-MHz output from the switching and compare circuit is applied to the multiplier-divider circuit, where it is converted to frequencies of 500-kHz, 1 MHz, and 10 MHz. These three outputs are used in the mixing processes required to produce the injection frequencies used in the RF conversion process. The 500-kHz output is also applied to the 500-kHz gate circuit for insertion into the product detector for demodulation.

FREQUENCY GENERATION

The injection frequencies used in the first frequency conversion in the mixers circuit are generated within Subassembly A2A6A1. This circuit consists of a phase-locked crystal oscillator that is automatically tuned to produce one

of seventeen frequencies between 2.5 MHz and 23.5 MHz. The output is applied to the high frequency mixer. The output frequency depends on the setting of the front panel MCS controls.

The injection frequencies used in the second frequency conversion in the mixers circuit are generated within Subassembly A2A6A2. This circuit consists of a crystal oscillator, the output of which is one of ten frequencies spaced at 100 kHz intervals between 4.553 and 5.453 MHz. The output frequency is determined by the setting of the front panel 100 kHz (KCS) control. If a lo-band injection frequency is required, the 17.847 MHz output from the 17.847 MHz mixer is additively mixed in the lo-band mixer with the output from the 100 kHz oscillator (4.553 MHz to 5.453 MHz, in 100 kHz steps) to provide a frequency in the 22.4 to 23.3 MHz range. If a hi-band injection frequency is required, the 27.847 MHz output from the 27.847 MHz mixer is additively mixed in the hi-band mixer with the output from the 100 kHz oscillator (4.553 MHz to 5.453 MHz, in 100 kHz steps) to provide a frequency in the 32.4 to 33.3 MHz range. In either case, the resultant frequency is applied to the mid-frequency mixers.

The injection frequencies used in the third frequency conversion in the mixers circuit are generated within Subassembly A2A6A3. This circuit consists of two crystal oscillators, each of which has ten possible output frequencies. The output from the 1 kHz oscillator (1.850 MHz to 1.859 MHz, in 1 kHz steps) is determined by the setting of the front panel 1 kHz (KCS) control, and the output from the 10 kHz oscillator (5.25 MHz to 5.16 MHz, in 10 kHz steps) is determined by the setting of the front panel 10 kHz (KCS) control. The outputs from the two oscillators are subtractively mixed to provide one of 100 possible output frequencies spaced at 1 kHz intervals between 3.301 MHz and 3.400 MHz. The output is applied to the low frequency mixer.

A combination of error cancelling loops and phase-locked loops (similar to those described for the T-827/URT) is used in the frequency synthesizer circuits of the R-1051/URR to ensure that the injection frequencies applied to the mixers are correct.

POWER SUPPLIES

The operating voltages for all circuits in the R-1051/URR are produced by the Power Supply Assembly A2A8 (fig. 7-11). The 105 to 125-v.a.c. primary power is converted to d. c.

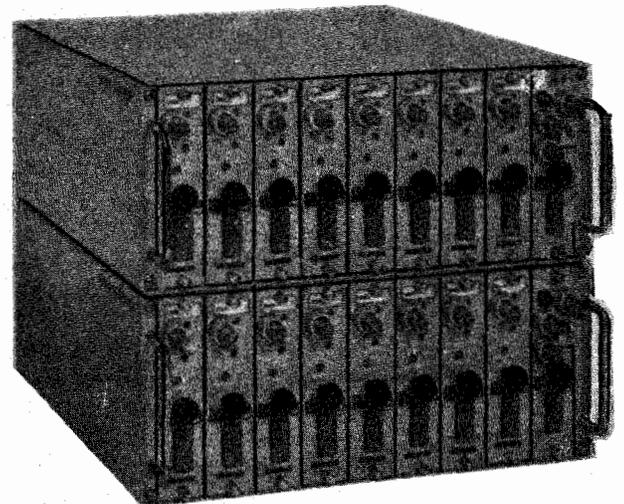
voltages of 110 volts (RF amplifier tubes plate and screen supply), -30 volts (RF amplifier tubes bias), and 28 volts (general use). The 28 v.d.c. is also regulated to 20 v.d.c. for use in all semiconductor circuits of the R-1051/URR.

TELEGRAPH TERMINAL AN/UCC-1D(V)

Telegraph Terminal AN/UCC-1D(V) is a frequency division multiplex carrier-telegraph terminal equipment for use with SSB or DSB radio circuits, audiofrequency wire lines, or microwave circuits. Each Electrical Equipment Cabinet CY-4639A houses one Control Attenuator C-6554A (right side fig. 7-12) and up to a maximum of eight Frequency Shift Keyers KY-588A (P) for transmission, or eight Frequency Shift Converters CV-1920A(P) for receiving, or any combination of both. The terminal also includes a special test set (TS-2232A) as a separate piece of equipment for aligning the keyer and converter circuits.

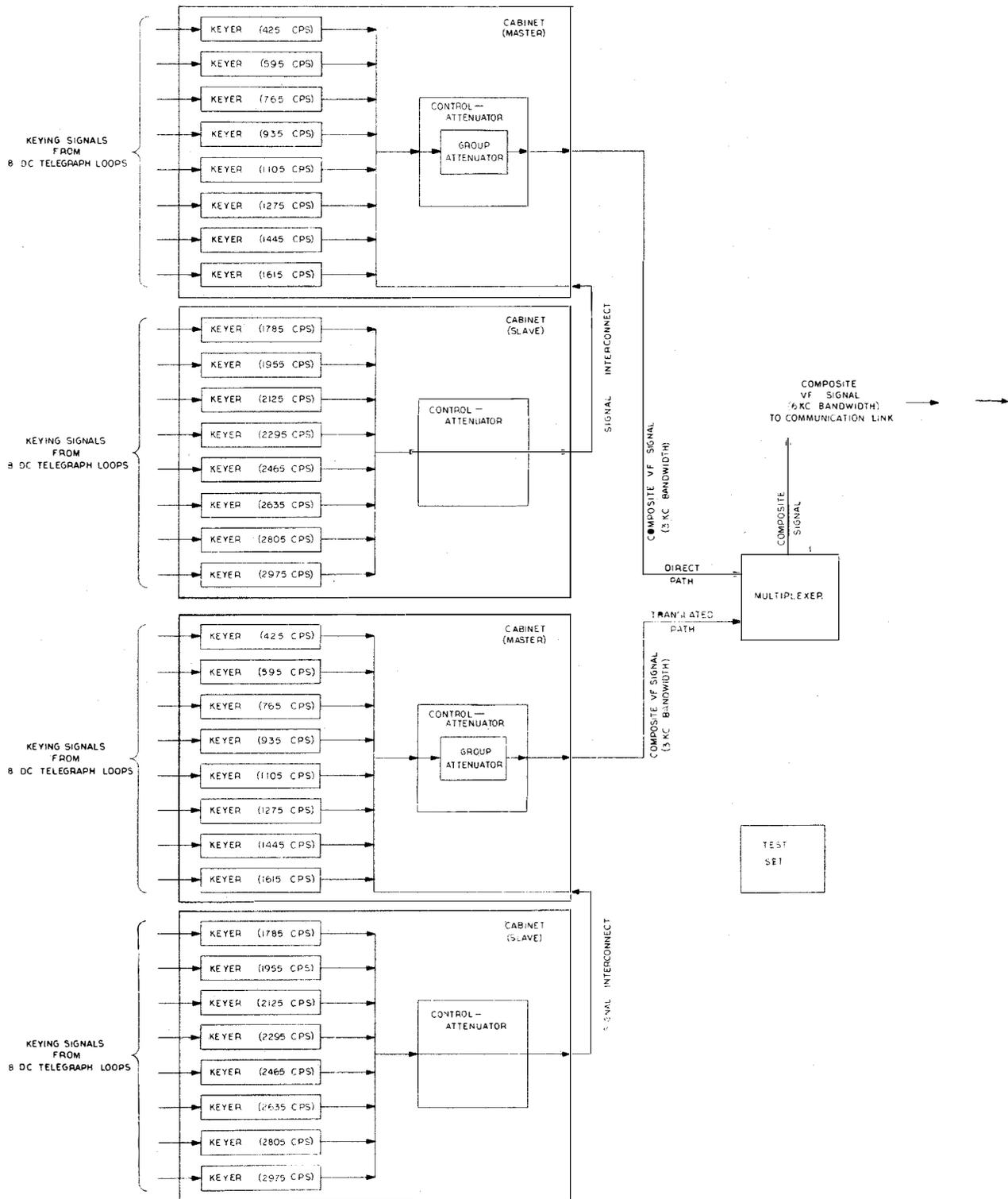
GENERAL DESCRIPTION

The control attenuator, keyers and converters are solid state, integrated circuit plug-in modules; thus, the number of channels may be varied by increasing or decreasing the total number of modules. Depending upon the number of modules and the configuration used, the terminal



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Figure 7-12.—Telegraph Terminal AN/UCC-1D(V).

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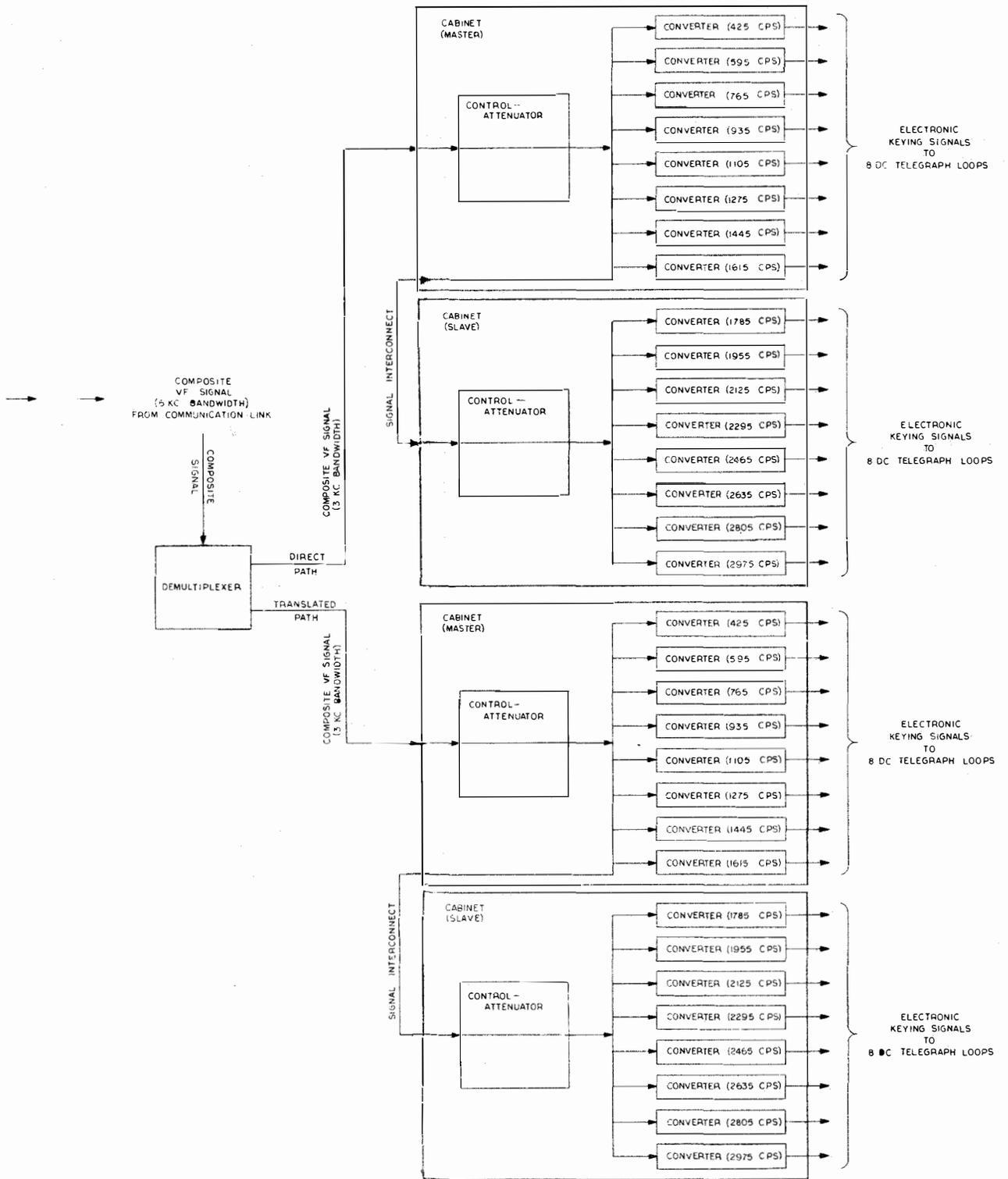


Figure 7-13.—Telegraph Terminal AN/UCC-1D(V) functional block diagram.

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can provide up to 16 narrow-band channels within a 382 to 3017 Hz bandwidth. The terminal can operate as non-diversity, in-band (AF) diversity, space diversity, or RF diversity.

Each frequency-shift keyer provides one channel that accepts d. c. telegraph signals from an external loop, and supplies the appropriate audiofrequency mark/space frequency-shift output signal. The keyer provides polar or neutral loop operation without any change in switch settings. All active keyer components are contained on a plug-in printed circuit card that is interchangeable with cards of other keyers. Each keyer has its own power supply.

Each frequency-shift converter provides one channel that accepts a particular frequency-shift audiofrequency signal, and produces an electronic keying signal for operation of a d. c. telegraph loop. The converter is capable of keying either neutral or low level polar loops. Switch settings allow the voice-frequency input to be obtained from either the composite line or an individual line, and allow connection of either two or four converters to form diversity combinations. All active converter components are contained on a plug-in printed-circuit card that is interchangeable with cards of other converters. Each converter has its own power supply.

Each control attenuator has switches that permit selection of the cabinet's mode of operation (master or slave) and connection of the composite voice-frequency lines to the connectors at the rear of the cabinet. Each unit also incorporates a constant level amplifier that maintains the composite output power at a constant level when up to sixteen tones having a combined peak power within the range of -24 to +18 dbm are combined. A control on the module panel allows adjustment of the composite output power level.

The portable test set used for alignment and test of the other telegraph terminal units provides facilities for the following:

1. tone-level measurement
2. loop-current measurement
3. reversals generation (75 or 150 baud)
4. converter phase-distortion alignment
5. audible signal tracing (with speaker)
6. mark and space tone generation for 16 narrow-band and four wide-band channels

FUNCTIONAL DESCRIPTION

The functions that can be performed by the AN/UCC-1D(V) are shown in figure 7-13. The

terminal provides up to 16 different narrow-band audiofrequency tone channels, each passing a different band of frequencies. Associated with each channel are two oscillators and a gate circuit. One oscillator constantly generates the mark frequency; the other constantly generates the space frequency. The gate circuit is keyed by a telegraph loop causing one frequency or the other to pass (frequency-shift keying). The two frequencies are symmetrically disposed with respect to the center of the channel pass-band. The output from any set of different channels can be combined on a single line for transmission over a single 3-kHz communication link.

Two 3-kHz bandwidth audiofrequency signals can be accommodated by the telegraph terminal for transmission over a single 6-kHz communication link. The two 3-kHz signals may contain 16 telegraph tone channels in each 3-kHz band or 16 telegraph tone channels in one 3-kHz signal and speech in the other 3-kHz signal. Diversity combination switching is provided in the telegraph terminal at both the transmitting and receiving stations; thus, one telegraph signal can be used to key two different tone channels (keyers) at the transmitting station. In this case, the corresponding tone channels (converters) at the receiving station both develop keying signals. However, the best signal of the diversity pair operates the receiving telegraph loop, thereby preserving the telegraph signals when fading occurs in one of the two channels in the frequency-diversity pair.

Diversity switching at the receiving station also permits space-diversity or RF diversity operation, in which tone signals obtained from two different radio receivers are used to operate two identical sets of tone channels. For this type of operation, each pair of identical tone channels (converters) provides a single keying signal. Frequency-diversity operation can be combined with either space-diversity or RF diversity operation. In this case, one set of four tone channels produces a single keying signal.

In place of 16 narrow-band channels, the telegraph terminal can provide eight narrow-band and four wide-band channels. The wide-band channels use the band portion of the upper eight narrow-band channels plus the band extending from 3025 to 3815 Hz. However, extension of the wide-band channels above 3625 Hz prevents the use of the multiplexing function.

Frequency-Shift Keyer

The d. c. telegraph loop is connected to the Schmitt trigger circuit Q4-Q5 through the input switch circuit and the adjustable trigger-level bias control circuit (fig. 7-14). The adjustable bias sets the trigger level of the Schmitt Trigger Circuit.

In neutral operation, input transistor Q3 is turned on (conducting) when loop current flows and is turned off (not conducting) in the absence of loop current. In polar operation, Q3 is turned on during positive loop current and is turned off during negative loop current. With a mark input, the Schmitt trigger circuit will turn gate control transistor Q6 on, and Q7 off. The conduction state of Q6 and Q7 will be reversed with a space input.

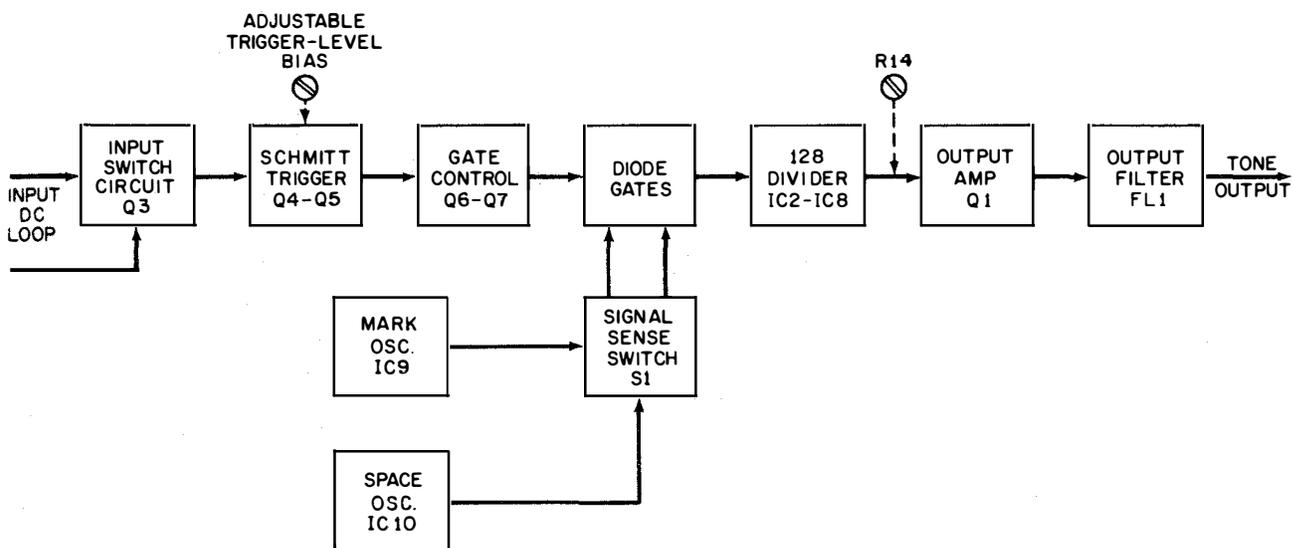
The output signal of the gate control circuit and the output frequencies of the mark and space crystal-controlled oscillators (IC 9 and IC 10) are used to drive the diode gates. When the SIGNAL SENSE switch S1 is in the NORMAL position, a loop current (mark input) causes the gate circuits to pass the output of the mark (higher frequency) oscillator. When the switch is in the REVERSE position, a loop current causes the gate circuits to pass the output of the space (lower frequency) oscillator.

The mark and space oscillators operate at frequencies which are 128 times the mark and space frequencies of the channel. They are controlled by crystals to maintain the frequency

within a close tolerance. Both oscillators operate at all times, but the output of each is passed through its gate only when the gate is enabled by the gate control circuit. The oscillator frequency passed through the gate is divided by 128 in the divider circuit IC 2 through IC 8. The output of the divider circuit (channel mark or space frequency) is applied through the output amplifier Q1 to the output bandpass filter. The input level to Q1 from IC 8 is adjusted by R14 (TONE).

The cabinet is wired in such a way that the keyers in specific cabinet stations can be connected in frequency-diversity pairs. These pairs of cabinet stations are A1 and A2, A3 and A4, A5 and A6, and A7 and A8. The cabinet also is wired in such a way that the keyers in specific cabinet stations can be connected to obtain four-channel diversity operation. These groups of four cabinet stations are A1 through A4, and A5 through A8.

With the DIVERSITY switches of the keyers in the ONE position, each keyer is connected to a separate input telegraph loop. Turning the DIVERSITY switches of two keyers in the stations which are wired to form a diversity pair to the TWO position connects them to the same input telegraph loop. Both channels process the same input telegraph signals. Turning the DIVERSITY switches of the four keyers in cabinet stations A1 through A4 or in A5 through A8 to FOUR connects the four keyers to the same input telegraph loop.



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Figure 7-14.—Frequency-shift keyer simplified functional block diagram.

The modules plugged into the two or four stations are selected to form a standard frequency diversity combination. The signals from the output bandpass filter are applied to the TONE OUTPUT switch. When the switch is set to PARALLEL, it applies the channel output through the control attenuator to the composite tone output line. When the switch is set to INDIV, it applies the channel output directly to the individual tone contacts of the cabinet connector for individual tone output.

Frequency-Shift Converter

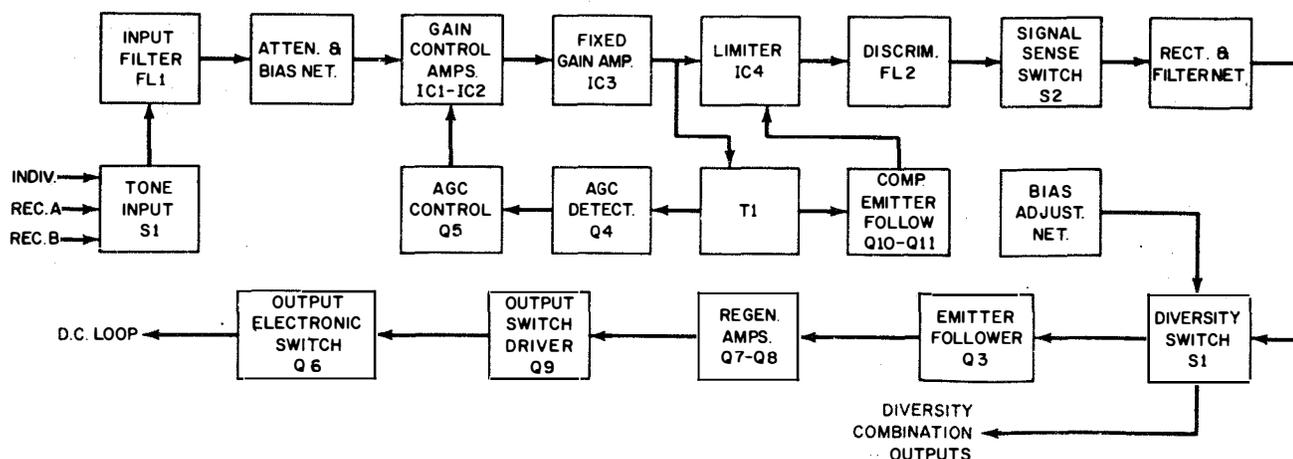
Either a composite tone signal or an individual tone signal is fed to the input bandpass filter FL1 (fig. 7-15), which blocks all channel frequencies except those of the converter's channel. The filter also contains the adjustable delay network that provides the means for equalizing delays for diversity operation. The output of FL1 is applied to the attenuator and bias network. This network provides the AGC attenuation and also biases the input gain-controlled amplifier ICI. The output of ICI is applied to the input of the second gain-controlled amplifier IC2.

The output of the second gain-controlled amplifier is applied to the input of fixed gain amplifier IC3. The output of IC3 is applied to the limiter stage IC4, which clips the signal, removing any amplitude-modulated components from the waveform applied to discriminator FL2.

Transformer T1 couples the output of IC3 to the gain and level control circuits. One output of

T1 is rectified and applied to the AGC detector transistor Q4. This voltage establishes the conduction level of Q4. The amplified output of Q4 is applied to the AGC control amplifier Q5, which provides the power gain necessary to drive the gain-controlled stages IC1 and IC2. Another output taken from T1 is rectified, filtered, and applied to compound emitter follower circuit Q10-Q11. The output of Q11 is a d.c. voltage proportional to the AGC output level. It is used to limit the amplitude of the drive voltage to the discriminator FL2. In diversity operation, when the gain of the receiver is reduced, the discriminator drive waveform is reduced, assuring that a linear combination of detected signals results in the mark-space detection.

The amplitude-limited output of IC4 is applied to the discriminator FL2, which generates a d.c. signal of one polarity when the tone signal is at the mark frequency and of the opposite polarity when the tone signal is at the space frequency. The output of the discriminator is added to the bias level supplied by the bias level network and fed through emitter follower Q3 to the output level detector Q7-Q8, a regenerative amplifier. The polarity of the discriminator output connection is determined by the SIGNAL SENSE switch S2. When the SIGNAL SENSE switch S2 is set to NORMAL, the polarity of the connection is such that the discriminator supplies a positive level when the tone signal is at the mark frequency. With S2 set to REVERSE, the discriminator supplies a negative level to the emitter follower for a mark frequency tone and supplies a positive level to the emitter follower for a space frequency tone.



31.35(162A)B

Figure 7-15.—Frequency-shift converter simplified functional block diagram.

The regenerative amplifier Q7-Q8 provides a stable reference for the detection threshold. (Threshold, in the electronics field, is defined as the least value of a current, voltage, or other quantity that produces the minimum detectable response.) A negative input cuts off Q8, holding the output switch driver Q9 in conduction. When a positive input is applied to Q8, Q9 is held cut off. The regenerative action of Q7 and Q8 ensures that the output switch driver Q9 is always in either a nonconducting or full conducting state. The output switch driver Q9 controls electronic output switch Q6, which determines loop current flow.

The two factors which determine converter diversity connections are switch settings on the individual converters and cabinet positions (stations) occupied by the converters. Because cabinet wiring for stations A1 through A4 is identical to that for stations A4 through A8, figure 7-16 illustrates only one four-station group.

Referring to figure 7-16, each channel, regardless of the station into which it is plugged, can be connected to an associated individual input transformer within the input filter FL1, or to either of two composite input transformers (designated as RCVR A and RCVR B) within the input filter. The two composite input lines are used in the frequency-diversity/space-diversity system shown in figure 7-16. In this system, two converter modules are assigned to each channel. One group of four converters (for the eight channels) processes signals from radio receiver A, which appear on the RCVR A input line; the other group of four converters processes signals from radio receiver B, which are furnished on the RCVR B input line.

With the TONE INPUT switches set as shown, the converters in stations A1 and A3 are connected to receiver A and the converters in stations A2 and A4 are connected to receiver B. The converters in stations A1 and A3 function as a frequency-diversity pair, and those in stations A2 and A4 function as a frequency-diversity pair; those in A1 and A2 function as a space-diversity pair, and those in A3 and A4 function as a space diversity pair. For example (table 7-1), the converters in the first two stations might be 425-Hz channels; those in A3 and A4 would be 1785-Hz channels, thereby forming a narrow-band, frequency-diversity/space-diversity combination. In this combination, outputs of the four channel discriminators are added in series and applied between the bias network and the emitter-follower input to the regenerative amplifier of the

converter in station A1. This can be verified by tracing the path through the DIVERSITY switches on figure 7-16, which are shown in the FOUR position. In order to combine the outputs of all four channels, the circuit grounds of the four channels must be tied together. This function is performed through one bank of the DIVERSITY switch and cabinet wiring.

To use the converters in stations A1 through A4 as two separate frequency-diversity pairs, the DIVERSITY switch on each converter must be set to TWO, and the converters must be rearranged. For example, the converters used in stations A1 through A4, respectively, might be 425-Hz, 1785-Hz, 595-Hz, and 1955-Hz channels, the first two and the last two functioning as narrow-band frequency-diversity pairs.

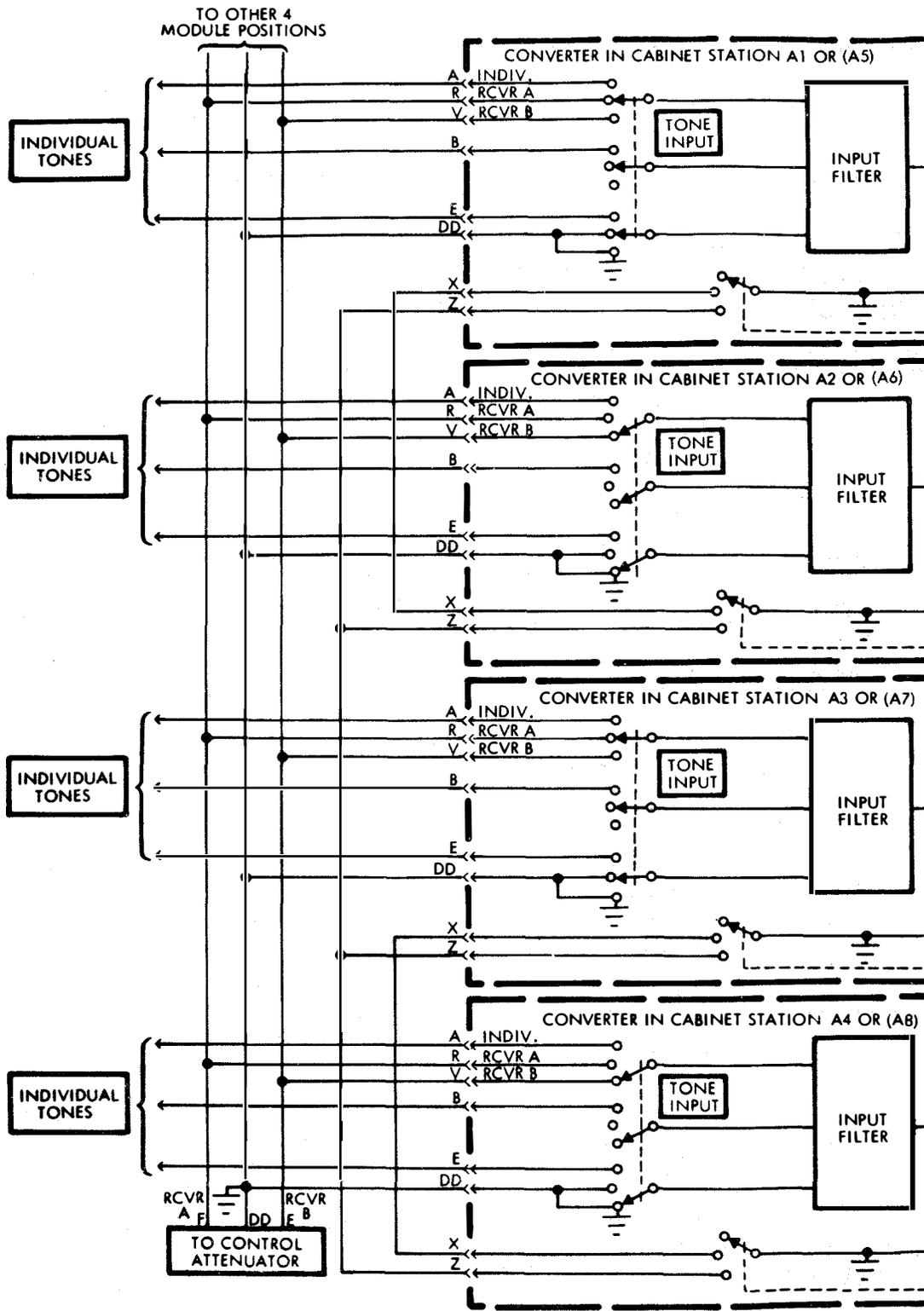
With the DIVERSITY switches of the four converters set to TWO:

1. Discriminator outputs of the modules in stations A1 and A2 are placed in series between the bias network and the input to the regenerative amplifier of the converter in station A1.
2. Discriminator outputs of the modules in stations A3 and A4 are placed in series between the bias network and the input to the regenerative amplifier of the converter in station A3.
3. The grounds of the converters in stations A1 and A2 are tied together as are the grounds of the converters in stations A3 and A4.

Since no space-diversity pairs are involved, all four of the TONE INPUT switches are set to the same position so that all four converters are connected to the same composite tone line.

The composite input lines are connected to the composite tone lines in the cabinet through the MODE switches on the control-attenuator, and the composite-tone lines are connected to the INTERCONNECT A and INTERCONNECT B connectors. The composite-tone lines are connected to the corresponding lines in other cabinets when more than one cabinet is used; in this case, the MODE switch is set to MASTER in one of the cabinets and to SLAVE in each of the other cabinets. The tone inputs are then received through the input transformers in the cabinet which has the MODE switch set to MASTER. For example, in the system shown in figure 7-16, which employs four cabinets containing converters, the input lines of the top cabinet and of the third cabinet from the top are used.

Each converter can be set to operate individually as a receiving channel by turning the



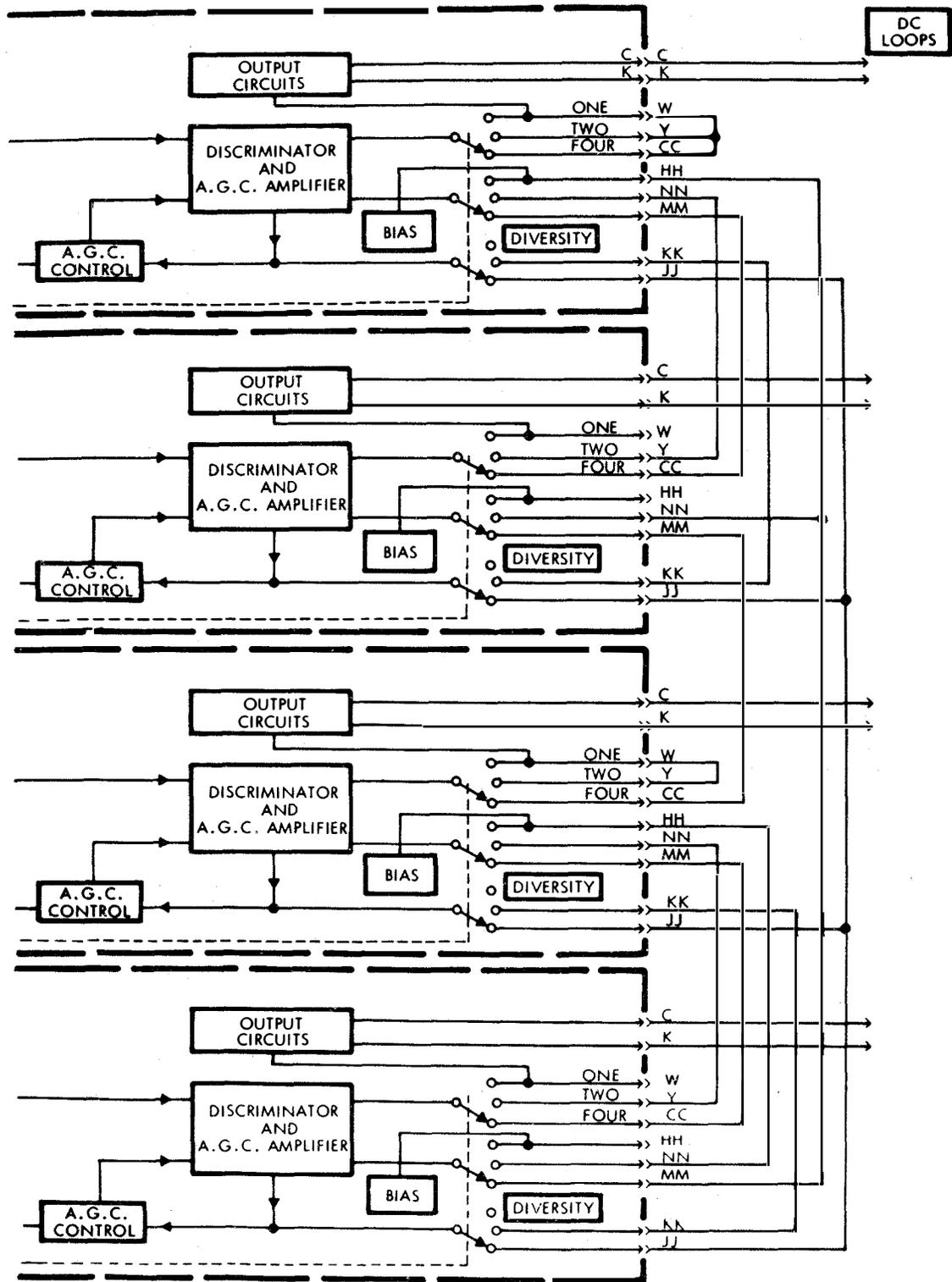


Figure 7-16.—Frequency-shift converter diversity combination block diagram,

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Table 7-1.—Frequency diversity combinations

| NARROW-BAND (Hz) | | NARROW-WIDE BAND (Hz) |
|---------------------|---------------------------------|-------------------------|
| NORMAL COMBINATIONS | NORMAL AND REVERSE COMBINATIONS | |
| 425-1785 | 425-1785 | 425-1105 |
| 595-1955 | 595-1955 | 595-1275 |
| 765-2125 | 765-2125 | 765-1445 |
| 935-2295 | 935-2295 | 935-1615 |
| 1105-2465 | 1105-2465 | |
| 1275-2635 | 1275-2635 | |
| 1445-2805 | 1445-2805 | |
| 1615-2975 | 1615-2975 | |

Notes:

1. These combinations are recommended so that a system utilizing a Telegraph Terminal AN/UCC-1D(V) at one station is compatible with a different telegraph terminal at another station in the system.
2. To use the NORMAL/REVERSE Diversity Combinations, the SIGNAL SENSE switch on channels 425 Hz thru 2975 must be set to the REVERSE position.

DIVERSITY switch on the module to ONE. Each converter can be connected to an individual input line by setting the TONE INPUT switch on the module to INDIV.

Figure 7-16 illustrates the intermediate AGC circuit connections for diversity operation. Notice that these connections are made through another bank of the DIVERSITY switch.

When a group of converters is used in a diversity combination, the inputs to the AGC control amplifiers of all modules in the group are connected together. This common connection is at the collector of the AGC detector of each module. The converter receiving the strongest input signal produces the most negative output from the AGC detector. This signal overrides those of the other converters and drives all AGC control amplifiers in the group. The AGC control amplifiers of all converters in the group are driven by the AGC signal of the converter receiving the strongest input signal. This causes the discriminator drive signals of all converters except the one with the strongest input signal to be attenuated with respect to the discriminator drive signal of the converter receiving the strongest input signal. Thus, only the strongest

input signal produces sufficient discriminator output to drive the regenerative amplifier (output level detector) and the output switch.

Control Attenuator

When the frequency-shift keyer TONE OUTPUT switches are in the PARALLEL position, the signals are combined and applied to the input transformer, T1 (fig. 7-17), of the control attenuator through the MODE switch. The output signal from T1 is applied to the input attenuation and bias network. The attenuation of this network is sufficient to provide the operating range for the amplifiers. The network also biases the input gain-controlled amplifier IC1.

The output of IC1 is RC coupled to the input of the fixed-gain amplifier IC2. The output of IC2 is transformer coupled by A1T1 to the output amplifier Q2. It is also coupled, through A1T1, rectified by CR1 and CR2, and applied to the base of the AGC detector transistor Q1A. Because the voltage required to cause this transistor to conduct is essentially constant, it serves as a reference to determine (detect) the level of the output signal from the fixed-gain amplifier IC2. The

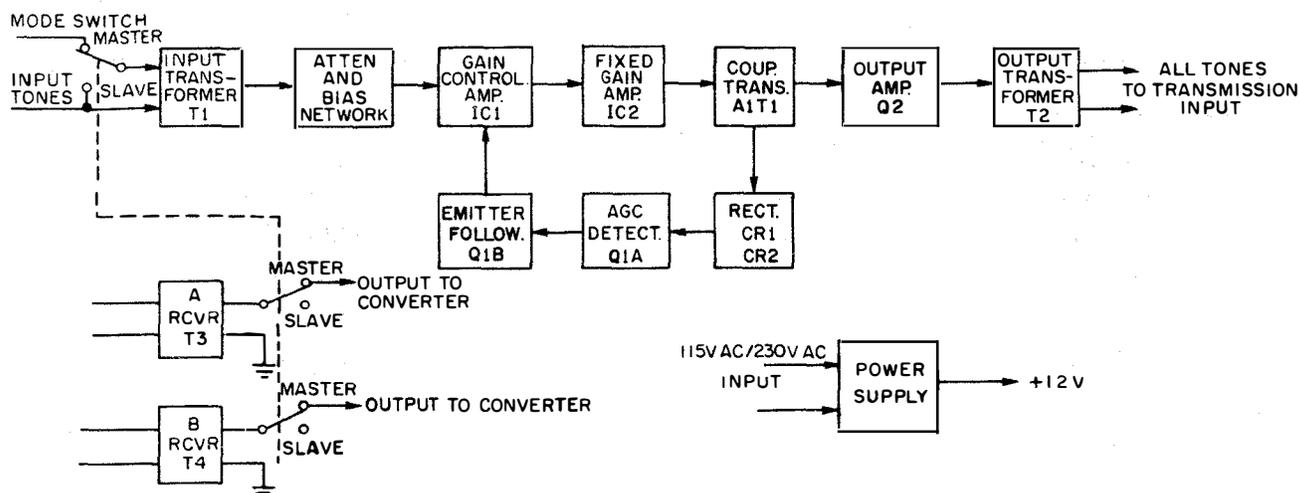


Figure 7-17.—Control attenuator simplified functional block diagram.

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amplified output of Q1A is applied to the base of emitter follower Q1B, which functions as a power amplifier with sufficient gain to control the output of the gain-controlled amplifier IC1.

The output of A1T1 is also applied to the base of the output amplifier Q2. The LEVEL control (not shown) varies the output level by adjusting the level of the signal applied to the base of Q2. The signals from the output amplifier are coupled out of the control attenuator by output transformer T2, which is located in the rear chassis assembly. Transformers T3 and T4 are the RCVR A and RCVR B isolation transformers. When signals are applied to their inputs, and when the MODE switch is in the MASTER position, the input signals are applied to the RCVR A and RCVR B lines for application to the converter inputs.

The 115 v.a.c./230 v.a.c. switch on the front panel of the control attenuator controls the application of power to the other modules in the cabinet. When the switch is in the 115 v.a.c. position, the input voltage is applied across the 115-volt input terminals of all power transformers; when the switch is in the 230 v.a.c. position, the input voltage is applied across the full primary windings of all power transformers.

Multiplexer-Demultiplexer

At the transmission end of the link (fig. 7-13), the two composite 3 kHz signals are applied on separate lines to the multiplexer, which trans-

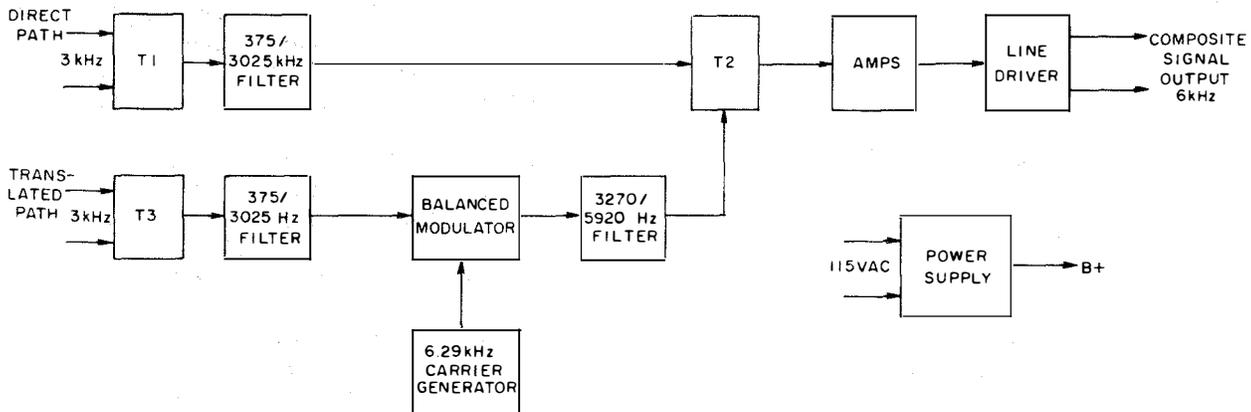
lates one of them to the 3265-5915-Hz band signals to form the 6 kHz signal. The 6 kHz signal is applied to the communication link on the single line.

At the receiving end of the communication link (fig. 7-13), the telegraph terminal reverses the process performed at the transmission end; voice-frequency signals from the 6 kHz bandwidth communication link are applied to the demultiplexer, which reverses the multiplexer frequency-translation action. The resultant two 3 kHz bandwidth tone signals are then applied on separate lines to two sets of receiving tone channels having the same bandpass characteristics as the channels used at the transmission end. Each channel accepts one voice-frequency signal, which it converts into an electronic keying signal for a receiving telegraph loop.

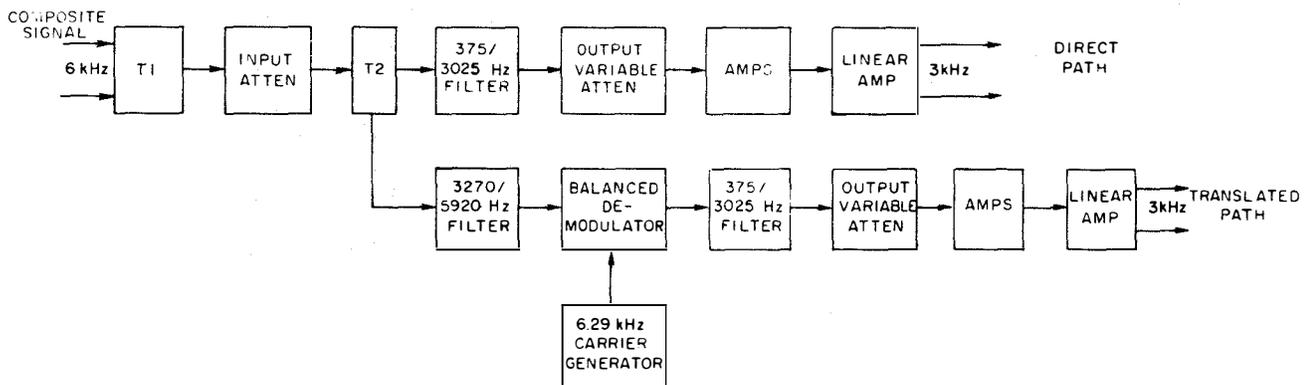
MULTIPLEXER FUNCTION.—When the multiplexer function (fig. 7-18) is performed, one of the two composite-tone input signals to be multiplexed is applied to the DIRECT PATH jack, and the other to the TRANSLATED PATCH jack (Mux-Demux inputs).

The DIRECT PATH input passes through an input transformer, which isolates the floating input circuit from the Mux-Demux ground. The output is applied to a bandpass filter, which passes the 375-3025-Hz band of frequencies for summing with the translated path output signal.

The TRANSLATED PATH input is applied to an input transformer, which isolates the floating



A MULTIPLEXING FUNCTION



B DE-MULTIPLEXING FUNCTION

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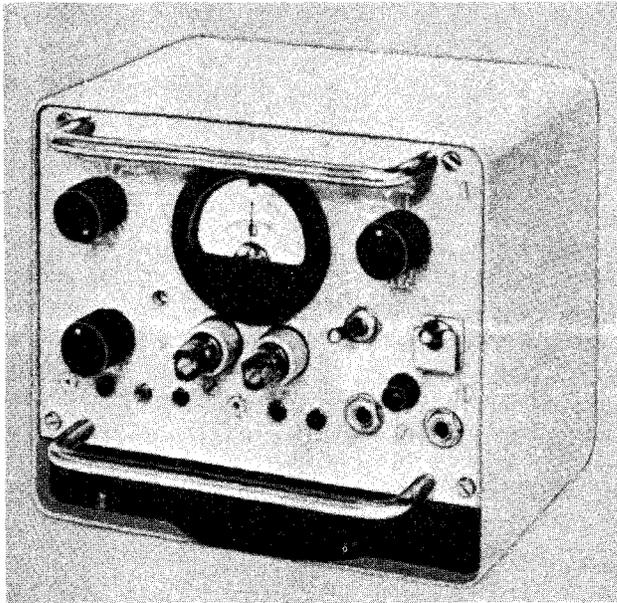
Figure 7-18.-- Multiplexer-demultiplexer block diagram.

input from the Mux-Demux ground and matches the low impedance of the input circuit to the higher input impedance of the bandpass filter. A filter removes signals that are outside the 375-3025-Hz passband. The output is fed to the modulator-demodulator section, which also receives a 6.29 kHz carrier supplied by the carrier-generator assembly. The modulator-demodulator, a balanced lattice type modulator, suppresses both the input and the carrier frequencies, and passes the upper and lower sidebands. Of the modulator-demodulator output fed to the bandpass filter, only the lower sideband of the modulated signal is passed (the upper sideband falling outside the 3270-5920-Hz passband). The translated path signal is summed with the direct path signal in T2 to form a composite signal with a passband of 375-5920 Hz. The composite signal is then amplified to the desired level and applied to a transmission input.

DEMULTIPLEXER FUNCTION.—Demultiplexer operation is essentially the reverse of the multiplexer operation described above. Because two separate outputs are furnished in the demultiplexing function, two variable attenuators and linear amplifiers are used; a third variable attenuator establishes the proper composite input signal level for application to the filters at the inputs of the two paths.

TEST SET

Telegraph Test Set TS-2232A/UCC-1C(V) (fig. 7-19) consists of a reversals generator, an audio amplifier and loudspeaker, a tone generator, a meter, switches to control operation, and a power supply circuit. THE FUNCTION SELECTOR switch is the primary control of test set operation. It determines the connection and routing of input and output signals. Because, in



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Figure 7-19.—Telegraph Test Set TS-2232A/
UCC-1C(V).

various positions, it functions with the various circuits in the test set, these positions will be discussed with the circuits they affect.

The reversals generator (fig. 7-20) consists of a free running multivibrator driving a transistor switch output circuit. The MODE SELECTOR switch S1 determines the mode of operation of the reversals generator, controlling the timing circuitry and providing loop closure to pins A (output) and P (ground) of the test connector P1. The positions of S1 and the functions of the reversals generator are as follows:

1. 75 BAUDS, the reversals generator runs at 75 bauds as determined by R2.
2. 150 BAUDS, the reversals generator runs at 150 bauds as determined by R1.
3. MARK, S1 closes the loop through R16
4. SPACE, S1 opens the loop.

The reversals output is available at the test connector only when the FUNCTION SELECTOR switch (S2) is in the REV OUT position.

The tone generator consists of a crystal-controlled oscillator, 12 frequency control crystals, eight integrated circuit flip flops and a feedback circuit consisting of a pulse amplifier.

Seven of the eight integrated circuit flip flops make up a variable seven-stage counter (count-down or frequency divider) circuit. The function

of the eighth stage is slightly different from the others; it functions as a frequency divider with a symmetrical output. The frequency division is changed by the TONE SELECTOR switch (S4) as required to obtain the correct frequency for the channel selected.

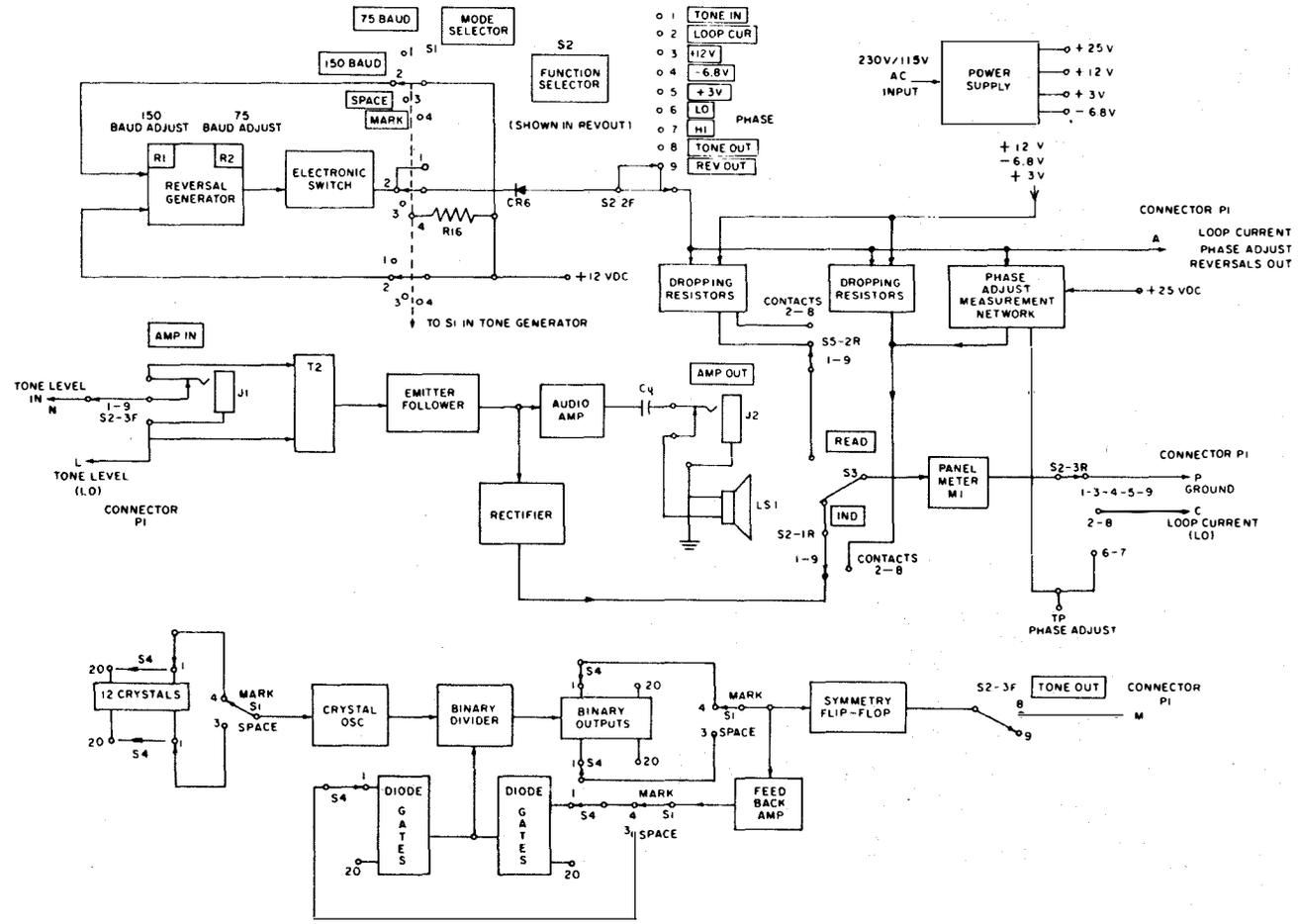
The TONE SELECTOR switch S4 connects two crystals (one for the space frequency, the other for the mark frequency) into the tone generator circuit. Twenty channel frequencies from 425 Hz to 3230 Hz are available upon command of the TONE SELECTOR switch. Since each channel has both a mark frequency and a space frequency, a total of 40 frequencies must be derived from the 12 crystals. The TONE SELECTOR switch also alters the configuration of the network of feedback diodes to cause the flip-flop counter to produce the required mark and space frequencies. A number of the frequencies (tones) generated by the test set differ slightly from the actual mark and space frequencies. This difference is the result of using frequency division to generate more than one tone from one crystal oscillator frequency. For example, the frequency of 2Y2 (91,840 kHz) can be divided by 144 to obtain a frequency of 637.8 Hz or by 80 to obtain a frequency of 1148 Hz. Although the output tones of the test set are not at the exact frequencies of channel marks and spaces, they are within the tolerances necessary to align the AN/UCC-1.

The MODE SELECTOR switch (in MARK or SPACE position) connects one of the two crystals, selected by the TONE SELECTOR switch, into the oscillator circuit, at one time. If the MODE SELECTOR switch is in either 75 BAUDS or 150 BAUDS position, both mark and space crystals are removed from the oscillator circuit.

The tone outputs are connected to pins M and P of the test connector P1 when the FUNCTION SELECTOR switch is in the TONE OUT position.

Audio Amplifier and Loudspeaker

Tone signals applied across pins N and L of the test connector are connected to input transformer T2 when the FUNCTION SELECTOR switch is in the TONE IN or REV OUT position. The input transformer drives the audio amplifier through the emitter follower. The output of the audio amplifier is capacitively coupled by a capacitor to the loudspeaker and also to AMPLIFIER OUT jack J2. This arrangement provides an audible indication of the presence and keying of signals through the loudspeaker or earphones. Tone signals also may be applied to the AMPLIFIER IN jack J1. In this case, the audible signals



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Figure 7-20. — Telegraph Test Set TS-2232A/UCC-1(V) functional block diagram.

are available at the speaker or earphones connected to J2 with the FUNCTION SELECTOR switch in any position.

Meter Circuits

The meter and associated circuits perform a variety of functions as selected by the FUNCTION SELECTOR switch. The mode of operation of the meter M1 is determined by the READ/IND. switch S3. When S3 is in the READ position, the parameters selected by the FUNCTION SELECTOR switch are measured in terms of volts, milliamperes, and dbm. When S3 is in the IND. position, the meter provides a go/no-go indication with a passing range as indicated by a reading in the green band.

Tone Level Measurement

The tone input to the audio-amplifier from the emitter follower is also applied to a rectifier. When the FUNCTION SELECTOR switch is set to TONE IN, the rectified signal is applied to the meter. The TONE IN measurement is used for equalizing the output tone levels of the individual channels.

Voltage Measurements

The d.c. supply voltages in the modules may be measured by turning the function selector switch to the +12v., -6.8v., and +3v. positions. S3 connects the meter M1 to the test connector

through dropping resistors. When the READ/IND switch is in IND position, a go/no-go indication is obtained; when it is in READ position, the meter indicates the actual value in volts.

Loop Current Measurement

When the FUNCTION SELECTOR switch is turned to the LOOP CUR position, the meter indicates loop current. Each module contains a resistor in series with the d.c. loop. The voltage, which is proportional to loop current, is applied to pins A and C of the TEST connector of the module. This voltage is coupled through the test connector of the test set, dropping resistor, and the LOOP CUR contacts of the FUNCTION SELECTOR switch, to the meter.

Delay Adjustment

The phase angles of the channel signals applied to pin A of the test connector and to the PHASE ADJ test point are compared by a delay comparison network. The d.c. component of the output of this network is proportional to the difference in phase of the input signals and dependent in polarity upon which channel has the greater delay. The output of the delay comparison network is applied to meter M1 through the FUNCTION SELECTOR switch when it is set to PHASE LO or PHASE HI. The delays of the two channels may be equalized by adjusting the modules, to obtain a zero indication on the meter.

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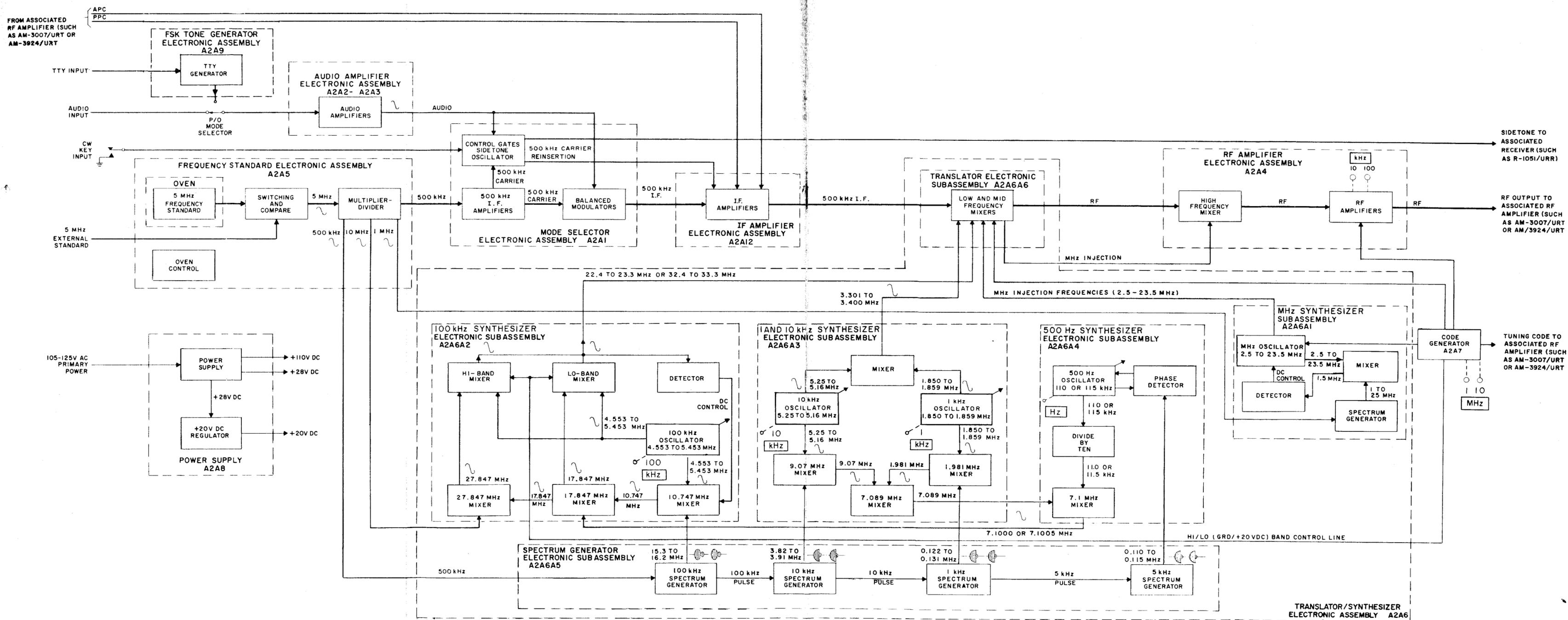


Figure 7-8.—Radio Transmitting Set T-827/URT functional block diagram.

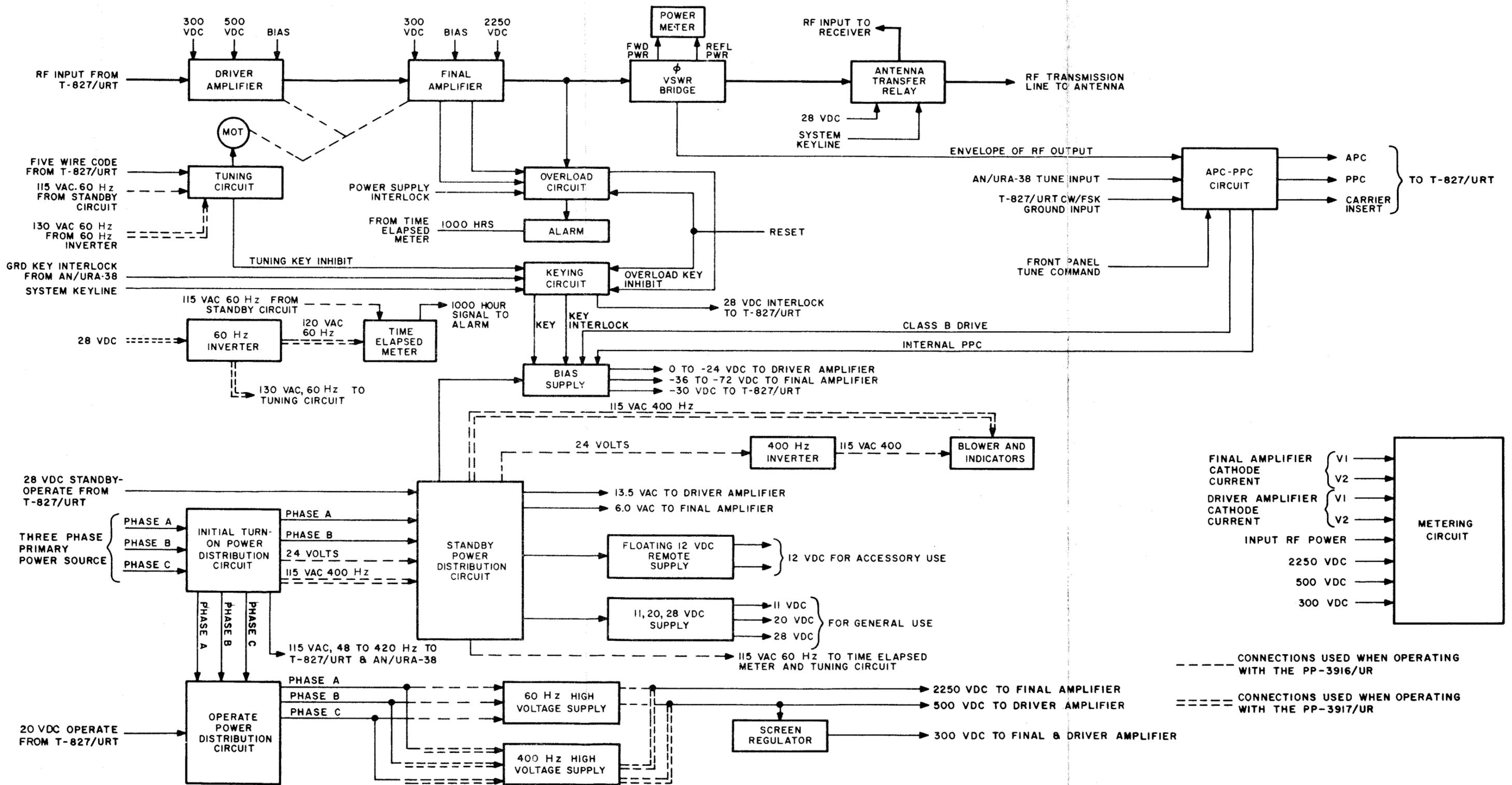


Figure 7-9.—Radio Transmitting Set AN/URT-23(V) functional block diagram.

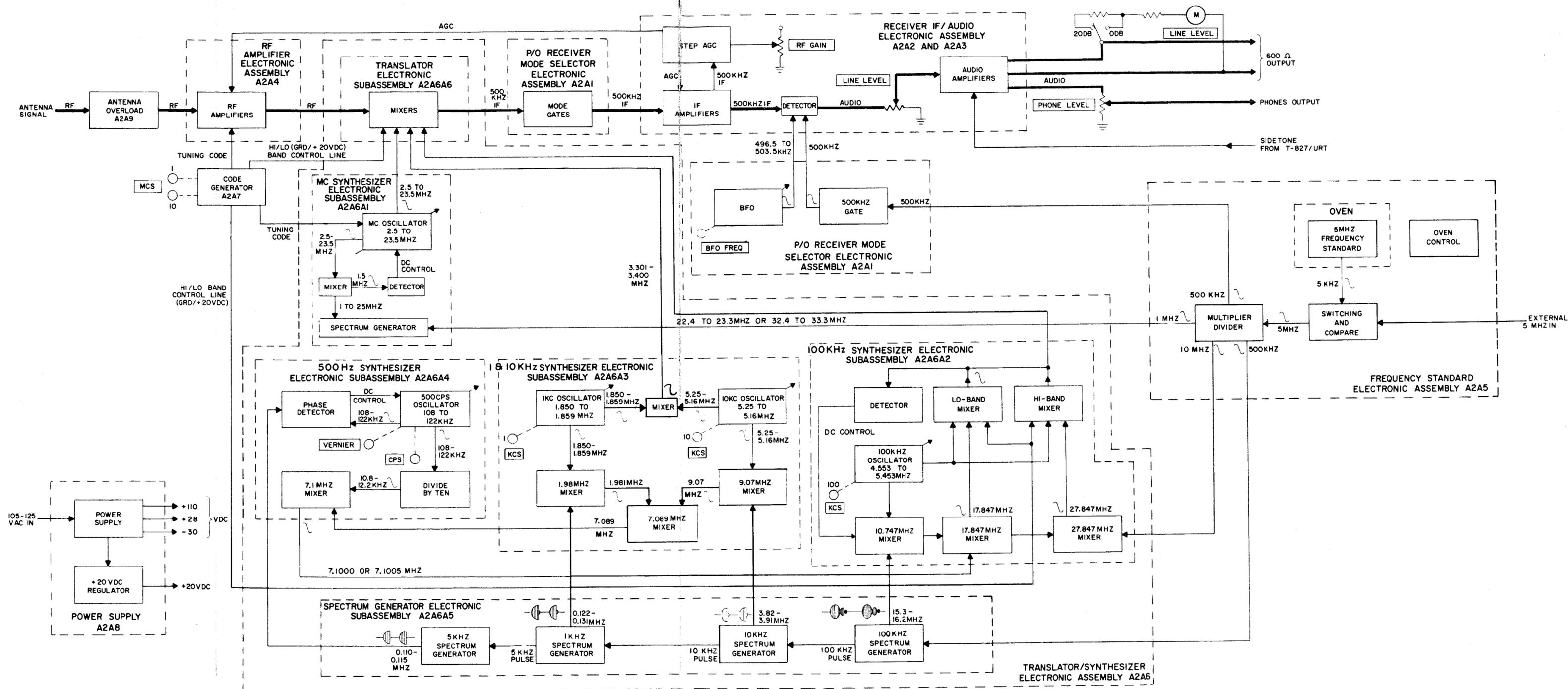


Figure 7-11.—Radio Receiver R-1051/URR functional block diagram.

CHAPTER 8

FLEET MULTICHANNEL BROADCAST SYSTEM

The Fleet Multichannel Broadcast (MULCAST) System is the primary method of delivering shore-to-ship teletype communications. The MULCAST system consists of area-oriented networks of communication stations configured so as to furnish, to the greatest extent possible, communication coverage to all ocean areas of the world. To provide worldwide coverage, the ocean areas are divided into eight Naval Communication Areas (NAVCOMMAREA). Each NAVCOMMAREA has a Naval Communication Area Master Station (NAVCAMS) which is responsible for the coordination of fleet broadcasts as well as ship-to-shore, air-to-ground and other communication circuits within the area. In addition to the NAVCAMS, each NAVCOMMAREA has one or more Naval Communication Area Local Stations (NAVCALS) dispersed throughout the NAVCOMMAREA to improve area coverage. One of the functions of the NAVCALs is to retransmit the area broadcast/or transmit a local area broadcast. During emergency conditions one of the NAVCALs may be designated to assume control of the area broadcast. During emergency conditions one of the NAVCALs may be designated to assume control of the area broadcast. Several transmission frequencies are used by both the NAVCAMS and NAVCALs to provide adequate coverage for all propagation

MULCAST equipment at the shore station consists of transmitting and monitoring equipment. Transmitting equipment includes: (1) tape readers which convert the alphanumeric characters of the paper tape into a series of d.c. pulses, (2) security equipment, which converts the plain text d.c. pulses produced by the tape reader into a series of encrypted d.c. keying signals, (3) multiplex units which accept the d.c. keying signals from several security equipments and combine (multiplex) them into a single composite signals, and (4) transmitters,

which, having been modulated by the composite signal, transmit the resulting signal on several frequencies to the fleet.

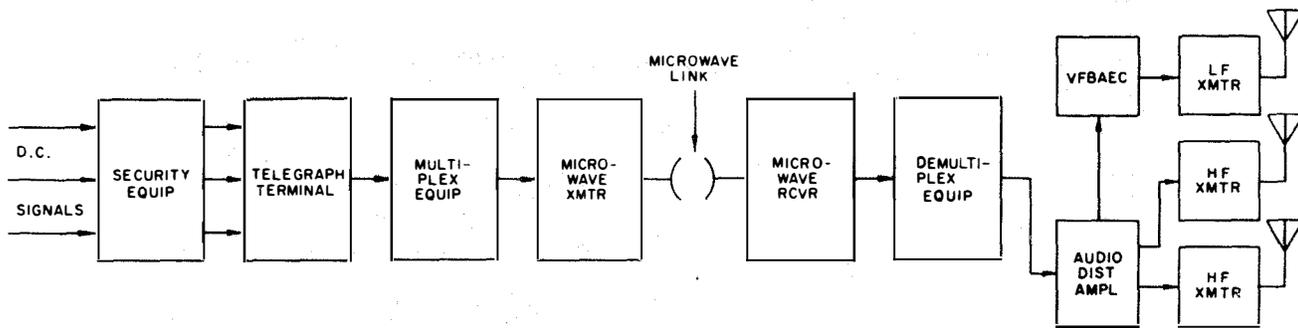
The monitoring equipment consists of: (1) receivers, which are tuned to the transmitter frequencies so that the MULCAST signal can be monitored, (2) demultiplex equipment, which breaks the composite signal into its d.c. components, and (3) security equipment, which translates the d.c. keying signal into its plain text equivalent. Each plaintext d.c. signal is then analyzed by the monitor equipment.

The MULCAST receive equipment aboard ship is similar to the monitoring equipment at the shore station.

TRANSMIT SUBSYSTEM

The shore-based portion of the MULCAST system performs the basic functions of signal processing, signal transmission and quality control monitoring. A typical communication station (COMMSTA) is made up of a transmitter site, a receiver site and a communication center. To avoid RF interference, the transmitter and receiver sites may be located five to 50 miles from the communication center. In addition, the receiver and transmitter sites are separated from each other by several miles. Landlines (telephone wires), and/or microwave links are used for routing communications between the communication center and the transmitter and receiver sites. The message processing and circuit quality monitoring functions are performed at the communication center.

As shown in figure 8-1, the plain text direct current signals produced by a tape reader are passed through security equipment where the d.c. signal is encrypted. (Punched tape provides much faster transmission speeds than direct keyboard transmission.) The encrypted d.c. keying signals from several security devices are then applied to telegraph terminal equipment



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Figure 8-1.—Fleet multichannel broadcast, transmit subsystem.

similar to the AN/UCC-1. The telegraph terminal equipment is also referred to as voice frequency carrier terminal (VFCT) equipment. The telegraph terminal equipment converts each incoming d.c. keying signal to an audio frequency tone-shift (AFTS) signal. The AFTS signal consists of a carrier which is shifted 42.5 Hz above or below a center frequency in accordance with the incoming d.c. keying signal. The center frequencies, or midpoints between the channel MARK and SPACE signal frequencies of each AFTS channel, although never actually present, are commonly used as a reference to identify the AFTS channel.

The telegraph terminal equipment also functions to multiplex each of the individual AFTS signals to form a single composite signal. The resulting composite signal has a bandwidth equivalent to a single-voice channel or approximately 3 kHz. The composite signal is then multiplexed with other COMMSTA circuits and sent to the transmitter site via microwave or landlines.

At the transmitter site the multiplexed signal package is demultiplexed. The MULCAST composite signal is patched to an audio distribution amplifier, the outputs of which are used to key an LF transmitter and several HF transmitters. A Voice Frequency Bandpass Amplitude Equalizer Coupler (VFBAEC fig. 8-1), breaks out eight channels for low-frequency from the 16 channel tone package, and provides for individual channel amplitude adjustment.

The MULCAST system uses the SSB suppressed carrier mode for transmission in the LF, MF, and HF bands. Conventional AM is used for MULCAST transmissions in the UHF band. However, the UHF band is used only at certain

locations. MULCAST transmissions in the MF, HF, and UHF bands are capable of supporting up to 16 100 wpm information channels transmitted as 16 tone channels. Present procedures require pairing of two tone channels (referred to as AF frequency diversity, in-band frequency diversity, tone diversity, and twinning) which effectively provides eight information channels. Transmissions in the LF band are capable of supporting only eight 100 wpm tone channels. Twinning operation is not used in the LF band; thus, the eight information channels are transmitted as eight tone channels.

HF TRANSMITTERS

Radio transmitters AN/FRT-39 and AN/FRT-40 are representative of the HF transmitters used in the MULCAST system.

The Radio Transmitter Set AN/FRT-39 (fig. 8-2) is capable of providing 10,000 watts peak envelope power (PEP) output throughout a frequency range of 2 MHz to 28 MHz. The principle function of the equipment is to provide long range communications from shore-to-shore point-to-point by the single-sideband type operation. The equipment may also be used for the following types of transmission:

- (1) CW (keyed carrier)
- (2) Frequency-shift carrier
- (3) Single-sideband suppressed carrier
- (4) Double-sideband suppressed carrier
- (5) Independent sideband (separate intelligence)
- (6) Single-or-double-sideband (with carrier)

The AN/FRT-39 is constructed in two basic sections, the main frame and the auxiliary frame. The main frame is located to the right

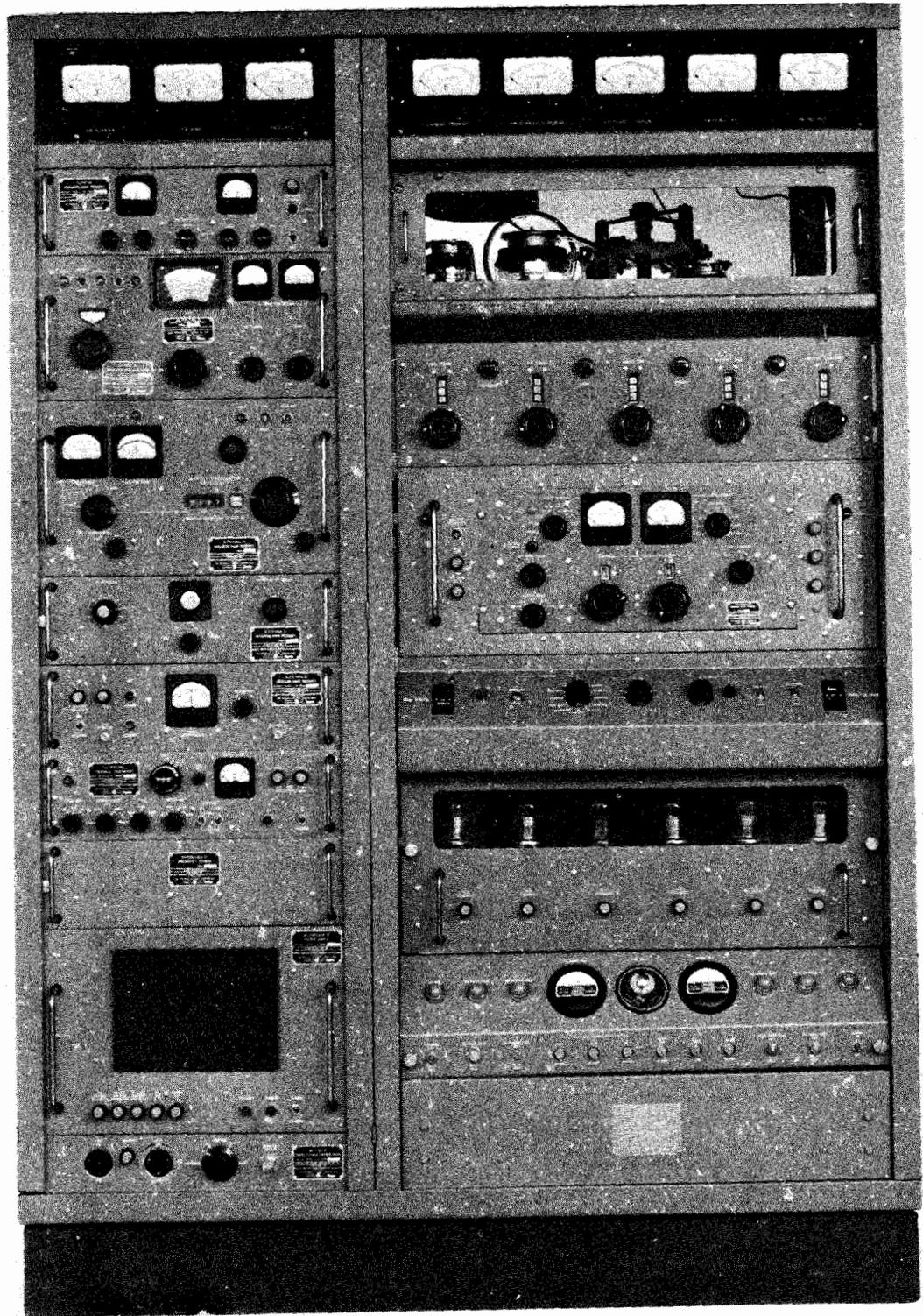


Figure 8-2.—Radio Transmitting Set AN/FRT-39.

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of the auxiliary frame and houses the power amplifier (PA), the intermediate power amplifiers (IPA), the main power supply and high voltage section, the PA loading and tuning controls, the relay and indicator control panels and the meter panel. The auxiliary frame is located to the left of the main frame and houses all of the sideband exciter equipment, exciter power supply equipment, and other control equipment for the various modes of operation.

Auxiliary Frame Components

The block diagram of the AN/FRT-39 (fig. 8-3) illustrates the auxiliary frame components to the left of the dotted line in the figure.

The sideband exciter (CBE), will accept two channels of intelligence each having a bandwidth of 7.5 kHz and process them for modulation of an intermediate sideband carrier (250 kHz) by means of two balanced modulators. The 250 kHz carrier is generated in the regenerative divider

network, which is part of the radio-frequency amplifier (CHG). The two 7.5 kHz intelligence channels are used to modulate the upper sideband (channel 1) and the lower sideband (channel 2).

The power supply (CPP-1) is mounted behind the auxiliary frame and supplies 200 volts unregulated and 150 volts regulated d.c. outputs.

The radio frequency amplifier (CHG) is provided with two signal inputs; the sideband exciter, and the controlled master oscillator. The sideband exciter frequency is $250 \text{ kHz} \pm 7.5 \text{ kHz}$, and the controlled master oscillator frequency is from 2 MHz to 4 MHz. The input frequencies are modulated by a balanced modulator with the 2 MHz to 4 MHz input and sideband exciter frequency, and subsequently, heterodyned by additional precise high frequencies in order to bring the final RF output into the 1.75 MHz to 33.75 MHz range.

The additional precise high frequencies are generated, by a crystal oscillator using different

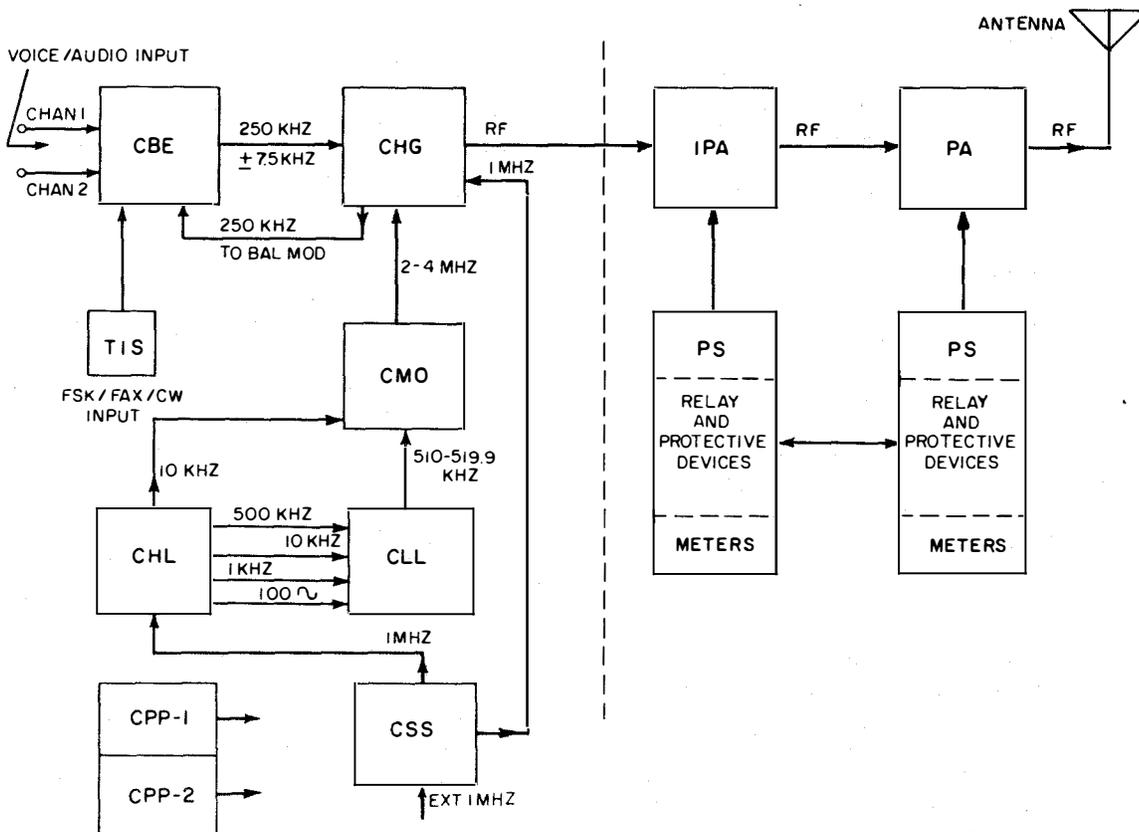


Figure 8-3.—Radio Transmitting Set AN/FRT-39 block diagram.

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crystals (8 to 15 MHz) for various bands, within the RF amplifier unit and are synthesized by the accurate 1 MHz standard.

The controlled master oscillator (CMO) supplies precise frequencies to the RF amplifier in the 2 MHz to 4 MHz range. The accuracy of the output frequency is derived from the precise 1 MHz standard.

The controlled oscillator (CLL) provides the low frequencies in 100 Hz steps for stabilizing the controlled master oscillator. These frequencies are in the range of 510 kHz to 519.9 kHz and are fed to the master oscillator's phase detector to frequency stabilize the master oscillator's 2 MHz to 4 MHz output in the 100 Hz and 1000 Hz steps.

The primary standard (CSS) is a precision oscillator within a temperature controlled oven. The oscillator has a frequency stabilization of one part in 10^8 per day. The frequency output of the primary standard is 1 MHz and is used to regulate all of the frequency generating oscillators.

The divider chain (CHL) is used to count down the primary standard 1 MHz output by using one flip-flop multivibrator and four phantastron dividers. The output frequencies available from the divider chain are: 500 kHz, 10 kHz, 1 kHz, and 100 Hz.

The power supply (CPP-2) provides:

- (1) +380 volts unregulated
- (2) -400 volts unregulated
- (3) +160 volts regulated
- (4) +75 volts regulated
- (5) -6 volts regulated
- (6) 6.3 volts a. c. regulated

The tone intelligence unit (TIS) accepts three types of d.c. signals (FSK, CW, FAX) and converts them into audiofrequency output signals for sideband transmission via the sideband generator unit.

Main Frame Components

The block diagram of the AN/FRT-39 (fig. 8-3) illustrates the main frame components to the right of the dotted line in the figure.

The RF amplifier, which consists of a first amplifier stage (class A), a second amplifier stage (class A), and an intermediate power amplifier (class AB1), is commonly called the IPA. The input to the first amplifier stage is supplied by the radiofrequency amplifier (CHG) as explained earlier. The IPA is manually tune loaded

and includes a multimeter with switching capabilities for direct reading of d.c. and RF voltages or currents. A second meter is mounted on the front panel for the purpose of reading the IPA plate current.

The IPA is rated at 1 kw RF output and can be fed to the PA or independently to an antenna by bypassing the PA when it is desirable to operate the transmitter at a maximum power output of 1 kw.

The power amplifier (PA) consists of one vacuum tube, rated at 10 kw, operating class AB1 in a grounded grid configuration. Tuning and loading of the PA output network are accomplished with the PA TUNE capacitor, PA LOAD capacitor, tapped inductance coils, OUTPUT balance capacitor, and the output loading inductors, which are tuned by ferrite slugs. PA switching is accomplished by a band switch which progressively shorts out sections of the tuning inductance. Either balanced or unbalanced output is available by the use of jumpers on the OUTPUT LOADING inductors.

The RF amplifier power supply consists of a high voltage rectifier and a bias rectifier. The high voltage rectifier is a full-wave rectifier and supplies unregulated plate voltage to both the first and second RF amplifiers. It also supplies unregulated screen voltage for the IPA, first, and second RF amplifiers. The bias rectifier is a half-wave rectifier and supplies -300 volts for the PA grid and PA bias relay. The relay provides protection for the PA in the event of bias failure. The bias rectifier also supplies -150 volts bias for the first, second, and intermediate power amplifiers. The power supply also supplies filament voltage for the IPA's.

The PA high voltage power supply circuits consist of high voltage rectifier tubes, circuit breakers, control equipment, 50 and 60 Hz power transformers, filament transformer, choke coils, high voltage capacitors, blower motors and other miscellaneous components. The power supply provides 7.5 kv PA plate voltage, 1.2-kv PA screen voltage, PA filament voltage, and 3-kv IPA plate voltage.

The relay and indicator control panels are equipped with control circuits for the purpose of disabling the transmitter when abnormal conditions (such as open interlock switches, excessive voltage, abnormal IPA grid bias, and excessive IPA plate current or screen voltage) prevail. The relays are also used to apply voltage to the various circuits in proper sequence.

With the addition of two cabinets, power amplifier, and power supply, the AN/FRT-39 becomes an AN/FRT-40 (fig. 8-4). The PA stage and antenna tuning controls of the AN/FRT-39 are slightly modified and become the IPA stage of the AN/FRT-40. The final PA section of the AN/FRT-40 consists of a power amplifier, class AB, capable of 40,000 watts (PEP).

LF TRANSMITTER

Radio Transmitting Set AN/FRT-72 is a representative LF transmitter used in the MULTICAST system. The AN/FRT-72 consists of two independently operated power amplifiers, each capable of generating 50 kw peak envelope power (25 kw average power) over a frequency range

of 30 kHz to 150 kHz. RF excitation for the two power amplifiers is supplied by one of the two exciters provided with the unit. The PAs may operated singly or combined.

In combined operation, the transmitter generates 100 kw peak envelope power (50 kw average). The complete set consists of six units housed in six cabinets as shown in figure 8-5.

General Description

The CONTROL - MODULATOR - SYNTHESIZER (unit 1, fig. 8-5) provides the control and monitoring circuits for PA-1, and houses the RF synthesizer (oscillator), the tone intelligence unit, modulator, and modulator power supply common to both PA-1 and PA-2. Front panel

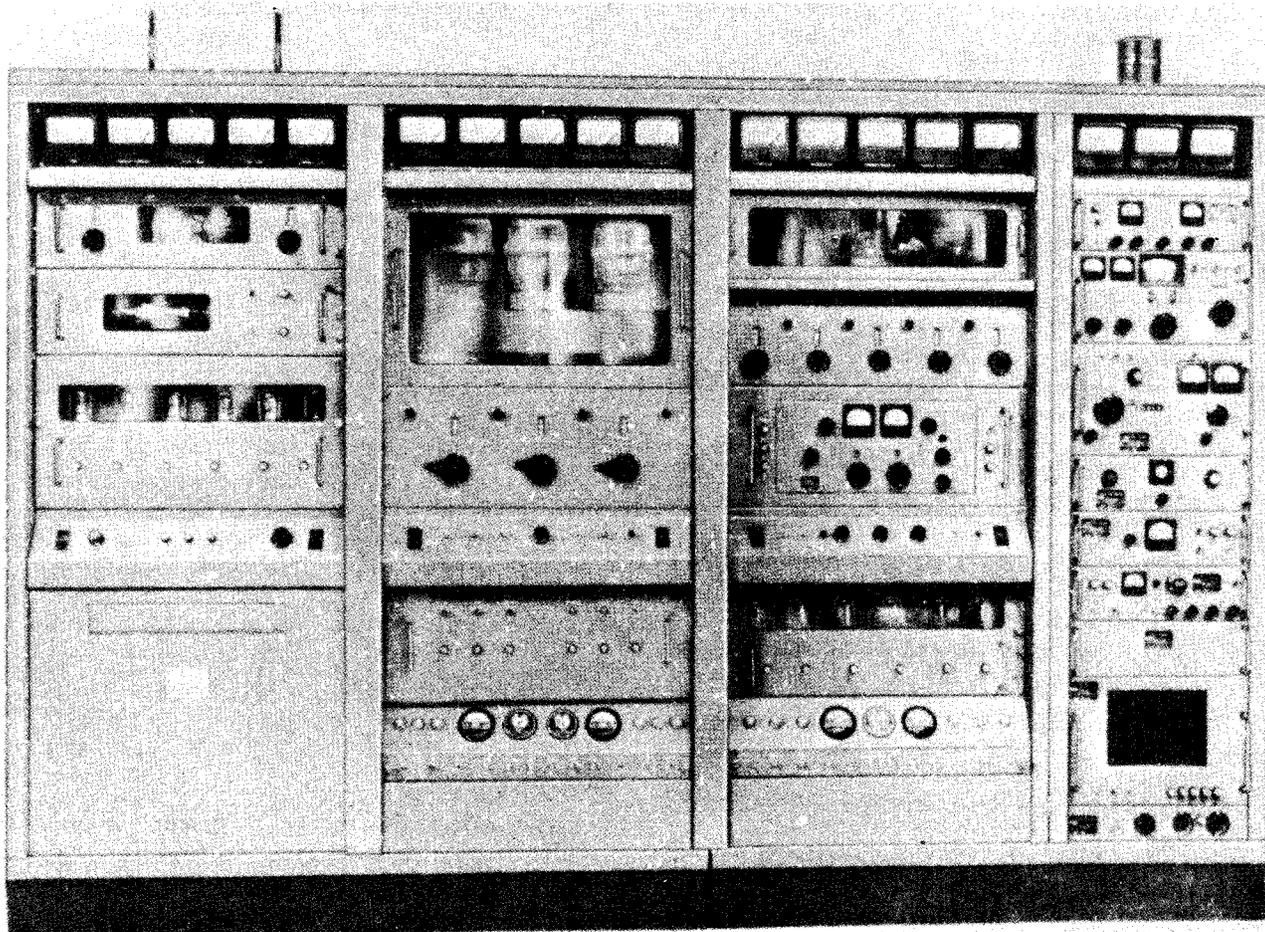


Figure 8-4.—Radio Transmitting Set AN/FRT-40.

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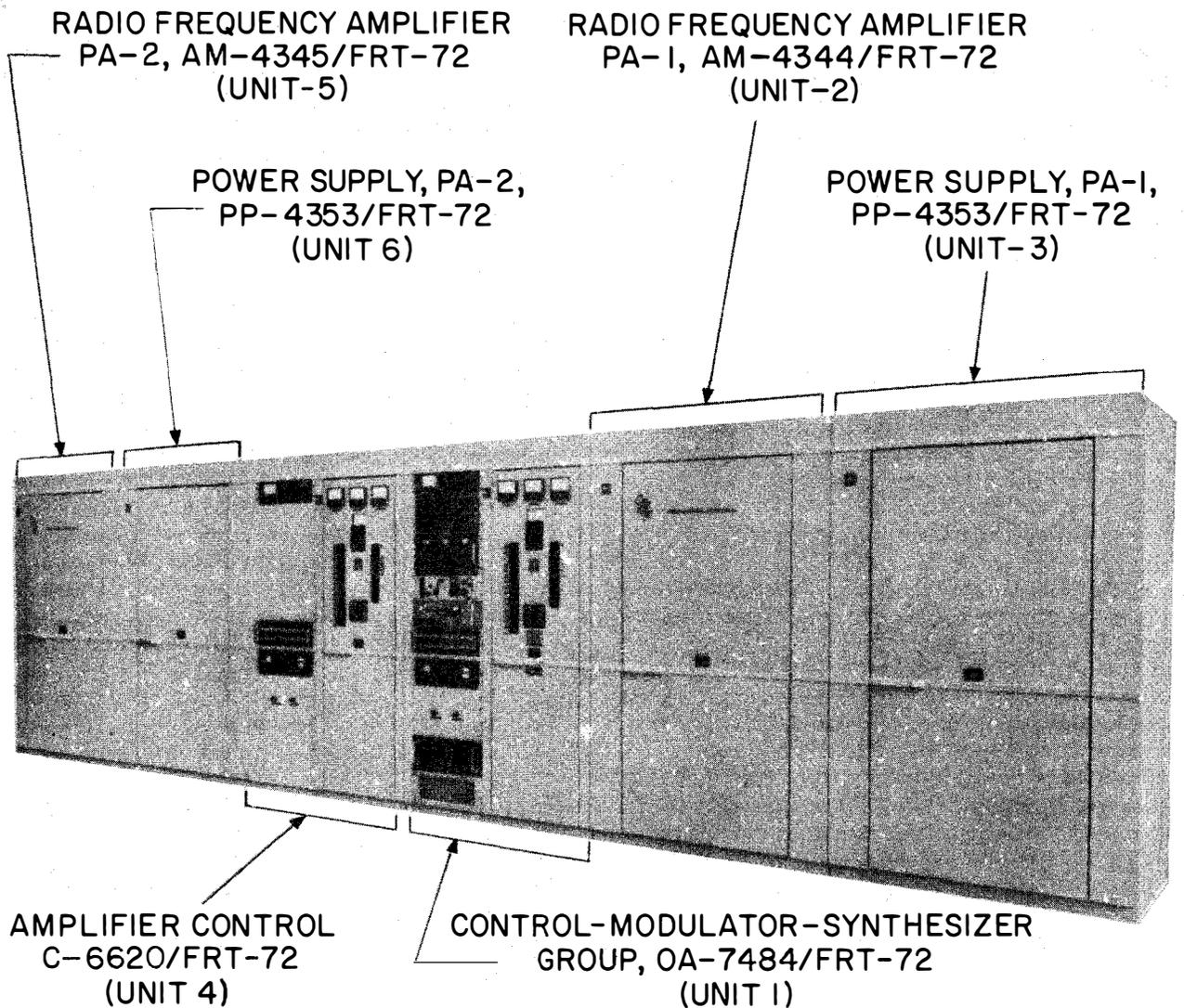


Figure 8-5.—Radio Transmitting Set AN/FRT-72.

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meters (right side, unit 1, fig. 8-5) are provided for monitoring and checking the power amplifier tubes and the high voltage power supply output. Indicator lamps indicate the condition of 16 individual interlock circuits and PA overload circuits.

Overload, recycle, and lockout circuits protect the PA-1 tubes, and an alarm horn provides indication of high voltage lockout. AN EMERGENCY OFF switch on PA-1 and PA-2 provides for removal of high voltage from each PA, and may be used to rapidly remove transmitter high voltage. **WARNING: THIS EMERGENCY OFF**

SWITCH DOES NOT REMOVE ALL POWER FROM THE TRANSMITTER. INCOMING POWER REMAINS PRESENT IN THE POWER SUPPLY PP-4353 CABINETS.

The left side of the cabinet provides mounting for the subassemblies. The subassemblies include the tone intelligence subassembly, RF synthesizer (oscillator), modulator, modulator power supply, transmitter control panel, two bias power supplies, a fuse panel, and a cooling fan panel.

The RF AMPLIFIERS PA-1 AND PA-2 (units 2 and 5 fig. 8-5) provide three-stage

amplification of the exciter output up to 50 kw average power. A combiner switch provides for series combining the two power amplifier outputs.

The POWER SUPPLIES (units 3 and 6 fig. 8-5) supply high voltage d.c. power to all three stages of the power amplifiers. An identical power supply is provided for each power amplifier. The power supply inputs are 460 volts 3-phase a.c. 50/60 Hz, fused at 110 amperes. A 3-phase bridge rectifier circuit provides the high voltage d.c. for the power amplifiers.

The AMPLIFIER CONTROL (unit 4, fig. 8-5) provides the control circuitry for PA-2. The PA control circuits in this unit are identical to those in unit 1, however, the exciter and transmitter control subassemblies are common to both PA-1 and PA-2 and are located only in unit 1.

Functional Description

A functional block diagram of the AN/FRT-72 is shown in figure 8-6. The tone intelligence subassembly 1A3 (fig. 8-6 fold in end of chapter) is an audio-shift keyer which operates in conjunction with the modulator 1A1. The tone intelligence subassembly generates separate audio tone frequencies for all modes of operation except voice. A keyed tone is supplied for CW operation, and a frequency-shifted tone is provided for FSK operation. This method of modulation eliminates direct amplitude modulation and frequency shifting of the exciter's carrier frequency, thus providing greater carrier stability. Another tone provides suitable facsimile operation. The appropriate tone frequency for the selected mode of operation is applied to the two audio channels (upper and lower sideband) of modulator 1A1.

Four discrete audio outputs are provided from the tone intelligence subassembly:

1. 1000 Hz for CW operation
2. An audio tone centered around 1900 Hz - for facsimile (FAX) transmission
3. An audio tone centered around 2000 Hz - for either FAX or FSK transmission
4. An audio tone centered around 2550 Hz - generally used for FSK transmission, when associated transmitter is operated in the independent sideband (ISB) mode

The sideband frequencies for transmission are produced in the modulator by proper mixing and filtering of the radio frequencies from the RF synthesizer (oscillator) 1A2 and the audio tone frequencies, supplied by subassembly 1A3.

The RF synthesizer (oscillator) 1A2 is a precision frequency generator. Three RF signals are generated and applied to the modulator to produce the upper and lower sidebands and the RF carrier. The synthesizer provides a fixed 100 kHz, a fixed 1 MHz, and a variable frequency of 2.030 to 2.150 MHz to obtain the transmitter frequency range of 30 to 150 kHz.

The resultant output from the modulator, containing the intelligence in the sidebands, is routed through transmitter control 1A4 to the RF amplifier sections. The transmitter control 1A4 has an operating switch which selects either of the two RF amplifiers for single PA operation or both RF amplifiers for dual PA operation.

Both RF amplifiers (PA-1 and PA-2) contain three untuned push-pull amplifier stages (pre-amplifier, driver amplifier, and power amplifier). The preamplifier tubes are type 7551 and the drivers are type 8122. Each is class A operated. The power amplifiers are type 8281 air cooled tubes, operated class AB1. The power amplifier outputs are coupled via output transformers 2T5 and 5T5 to RF switches 2A3 and 5A3.

RF switch 2A3 connects single or combined PA output to the directional coupler. RF switch 5A3 connects the PA-2 output transformer 5T5 single or combined operation tap to RF switch 2A3. Thus the output from either or both power amplifiers may be routed through directional coupler coils 2A3DC1 and 2A3DC2 to the antenna.

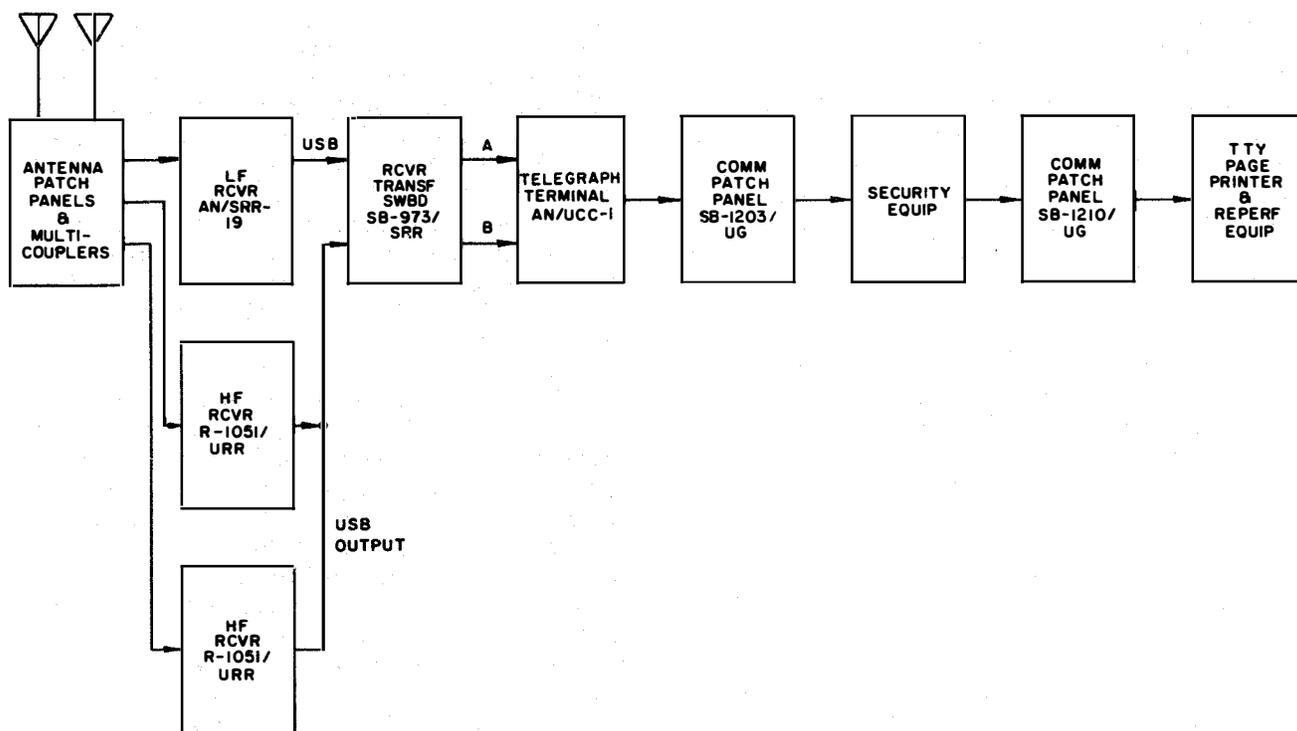
Forward and reverse power signals from the directional coupler coils are fed to the indicator-protector 1A7 to provide VSWR indication. An automatic load control circuit in the indicator-protector functions to protect the transmitter from damage due to transients or any excessive increase in the input signal level.

RECEIVE SUBSYSTEM

The shipboard receive portion of the MULTICAST system performs the basic functions of signal reception and signal processing. The most widely used frequencies for MULTICAST reception are those in the HF band. Normally two receivers are used for frequency diversity reception. Standard equipment used in a typical receive subsystem is shown in the functional block diagram (fig. 8-7).

SIGNAL FLOW

The encrypted composite multiplex tones are transmitted by the HF transmitters (fig. 8-1) in



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Figure 8-7.—Fleet multichannel broadcast, receive subsystem.

the USB mode with a fully suppressed carrier. These SSB signals are received and demodulated by the HF receivers (fig. 8-7). One receiver has its output patched via the receiver transfer switchboard to the "A" input of the telegraph terminal. The other receiver output is patched to the "B" input of the telegraph terminal.

The telegraph terminal separates each tone, compares diversity combinations, selects the tone-shifted signal to d.c. signals as discussed in chapter 7. The encrypted d.c. signals are patched via the nonsecure communication panel to the crypto equipment where they are decrypted. The decrypted d.c. signals are then patched through the secure communication panel to the TTY receive equipment.

LF RECEIVERS AN/SRR-19 & 19A

The HF MULCAST transmissions are capable of being transmitted over long distances with considerable less power used than with the LF broadcast. The LF transmissions, however, (although limited in range) are not as susceptible

to interference problems as the HF transmissions.

Radio Receiving Sets AN/SRR-19 and 19A are dual-conversion superheterodyne receivers for use in the frequency range of 30 to 300 kHz. The AN/SRR-19A is shown in figure 8-8.

General Description

The receivers consist of a two-section drawer in a common cabinet. The lower section (deck) contains the RF tuning, frequency conversion, and IF amplification circuits. The upper deck contains the amplifier-detectors, crystal oscillator, frequency dividers, and the power supply circuits. A fan assembly provides for the cooling of the receiver.

Signal voltages at the receiver antenna are fed to the preselector circuits through a manually variable attenuator and a coupling device which offers protection against damage from excessively high signal voltages. The frequency range is divided into four frequency bands, and the tuning circuits are equipped with direct-reading counters to facilitate band selection and

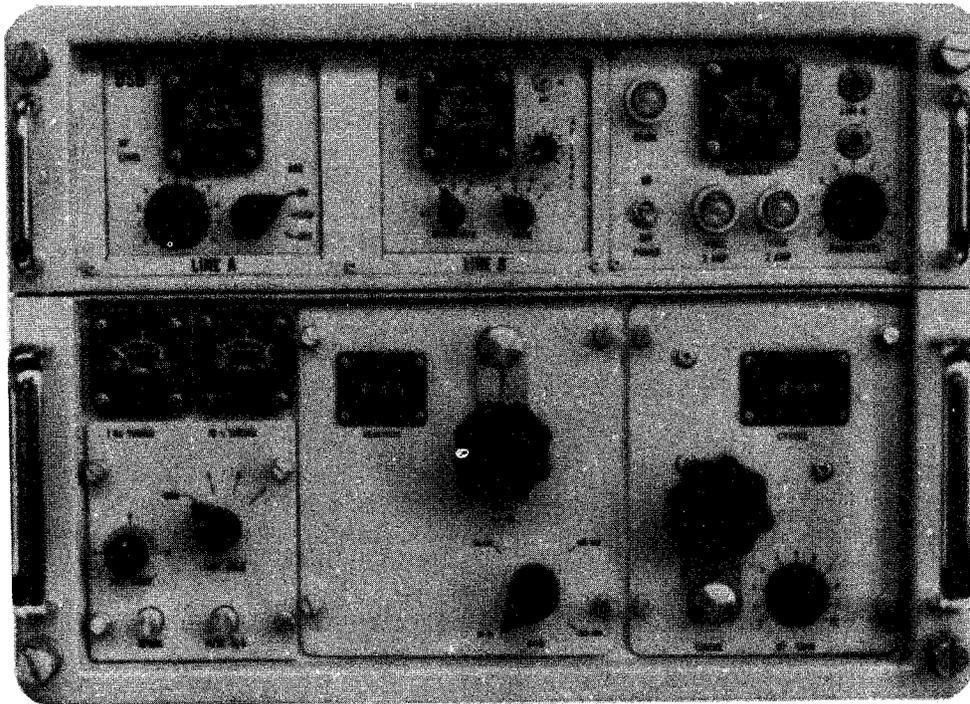


Figure 8-8.—Radio Receiver AN/SRR-19A.

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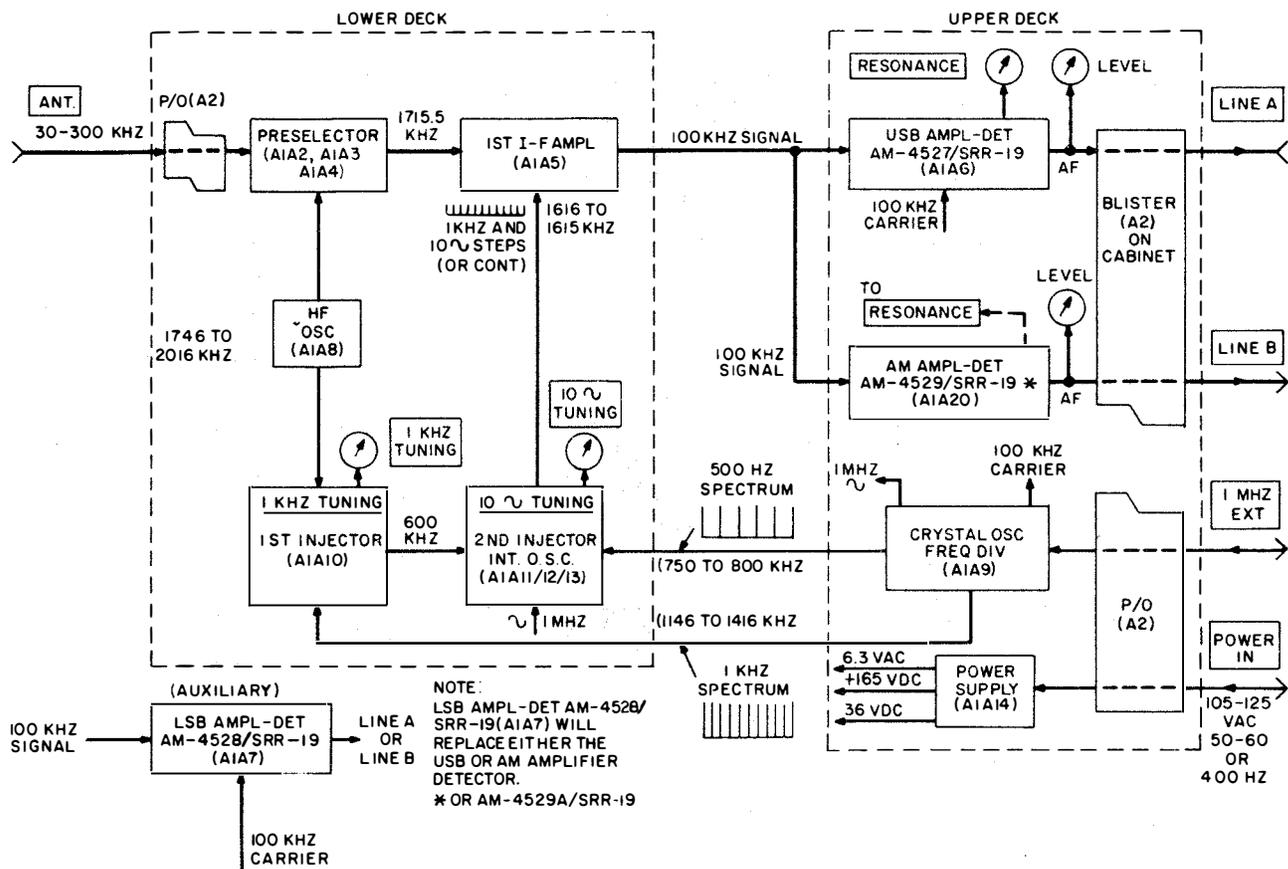
tuning. The tuning of each band may be incremental or continuous. In the former method, a crystal-controlled internal frequency standard permits extremely accurate settings in increments of 10 Hz. Continuous tuning (in 1 kHz steps), must be used for frequencies which terminate in divisions of other than 10 Hz. For incremental tuning drift cancellation of the local oscillators permits a frequency stability of 1 part in 10^8 (one Hz in 100 MHz).

After the processes of tuning, double frequency conversion, and IF amplification have been performed in the lower deck, the IF signal goes to the upper deck for further amplification, demodulation, and audio amplification. The upper deck contains the USB amplifier-detector and the AM amplifier-detector. Separate AGC circuits permit control of the receiver gain by either amplifier-detector. The upper deck also contains the receiver power supply and the crystal-oscillator frequency standard and divider circuits. The frequency dividers consist of a number of color-coded plug-in modules, and all frequency division is performed by binary flip-flop circuits encapsulated in the modules.

Functional Description

A simplified functional block diagram of the receivers is shown in figure 8-9 with the main signal path indicated by a heavy line. The basic relationship between the RF tuning circuits in the lower deck and the detectors, amplifiers, and frequency standard in the upper deck is shown. For simplicity, some blocks represent more than one major circuit.

An RF signal, selected by the preselector (A1A2, A1A3, and A1A4), is converted to 1715.5 kHz and amplified by the 1st IF amplifier (A1A5). Following a second conversion to 100 kHz, the signal is applied to the USB and AM amplifier-detectors (A1A6 and A1A20) for detection and amplification. Initial receiver tuning is performed by the HF oscillator (A1A8) and the 1st injector (A1A10), comprising the 1 kHz incremental tuning circuits. Secondary tuning in 10 Hz steps (or continuously) is performed by the interpolator oscillator (A1A13) and the 2nd injectors (A1A11 and A1A12). The 1 kHz TUNING and 10 \sim TUNING meters permit accurate



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Figure 8-9.—Radio Receiving Sets AN/SRR-19 and AN/SRR-19A functional block diagram.

adjustments of the tuning controls to these increments.

The first injection frequency from 1746 to 2016 kHz is generated by the HF oscillator. The 1616 to 1615 kHz second injection frequency is obtained from the 2nd injectors and occurs in precise increments of 1 kHz as the set is tuned by the main tuning control, sub-divided into 10 Hz steps (incremental tuning) or tuned 1 kHz range (continuous tuning) by the secondary tuning control. A third 100 kHz injection frequency is applied to the USB amplifier-detector as a carrier frequency, inserted for SSB demodulation.

The crystal oscillator - frequency divider (A1A9) provides all standard frequencies for circuit operation, including the precise 1 kHz and

500 Hz frequency spectrums for incremental tuning. It contains a stable 1 MHz crystal oscillator with provisions for oscillator calibration using an external frequency standard. The power supply (A1A14) provides heater and plate voltages to all circuits, and a separate voltage regulator (not shown) regulates the heater and plate voltages for the HF and interpolator oscillators.

A blister module contains all connections for external cables to or from the receiver, and contains low-pass filters for the POWER IN circuit and the LINE A and LINE B output circuits. The auxiliary LSB amplifier-detector module, shipped with the equipment, replaces either the USB or the AM amplifier-detectors to extend the reception modes. A fan module (not shown) provides air flow for cooling.

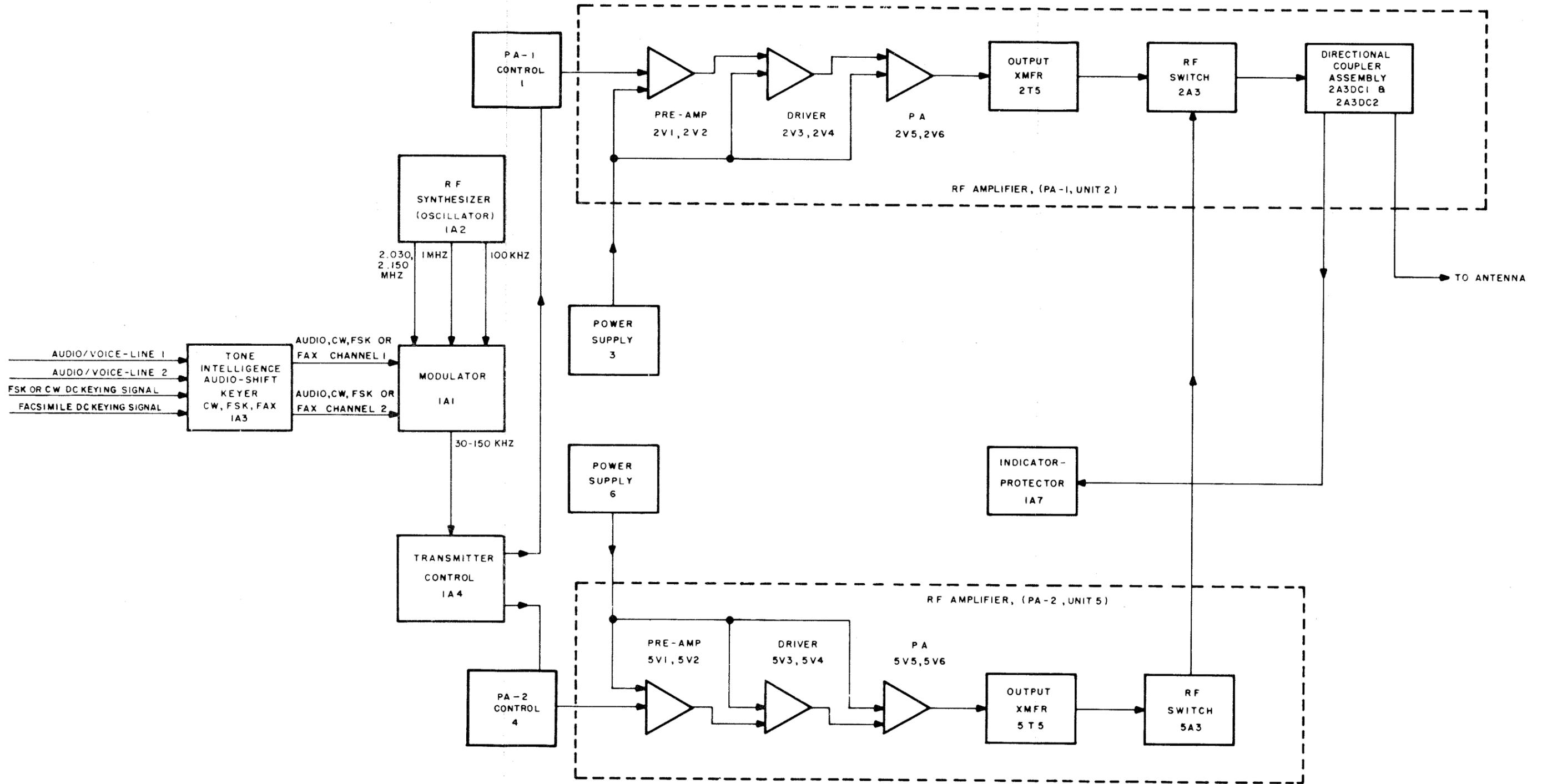


Figure 8-6.—Radio Transmitting Set AN/FRT-72 functional block diagram.

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CHAPTER 9

SATELLITE COMMUNICATION SYSTEMS

Historically, long-range communications between commands afloat and ashore have been accomplished by HF radio communications methods in various modes. The principle disadvantage of HF communications is that they are dependent upon the density of the ionosphere to refract and reflect the HF radio signal beyond the horizon to attain the desired distances. When the ionosphere dissipates, the effectiveness of HF communications diminish. Propagation of satellite communication frequencies is not dependent upon reflection or refraction, and is affected only slightly by atmospheric phenomena. The reliability of satellite communications, therefore, is limited essentially only by the reliability of the equipment used, and the skill of the operating and maintenance personnel.

Satellite communication systems were discussed in chapter 5 of this manual. This chapter builds upon the information presented in that chapter by discussing the latest shipboard satellite communication terminal, the AN/WSC-1(V).

AN/WSC-1(V) GENERAL DESCRIPTION

Shipboard Satellite Communication Terminal AN/WSC-1(V) consists of a radio set group and an antenna group. It may be installed in various configurations of one to five modems (modulator-demodulator units) in the radio set group, and one or two antennas and associated equipment in the antenna group. The terminal provides communication via a synchronous orbiting satellite in FM (analog) voice, teletype, and vocoder (digital voice) modes. A single modem terminal provides full-duplex FM voice or half-duplex data (digital voice and teletype) communication. The multimodem terminal provides full-duplex communication in all modes.

The transmitter power is variable to 1 kilowatt in the frequency range of 300 to 315 MHz. Reception occurs at 240 to 260 MHz. A large ship

configuration of the terminal consists of the receiver-transmitter rack, the multimodem rack, and the antenna group, as shown in figure 9-1 at the end of this chapter.

Receiver-Transmitter Rack

The receiver-transmitter rack (rack No. 1, fig. 9-1) contains the transmit-receive equipment and other units, assemblies, and sub-assemblies necessary for single modem operation. This equipment and its location in rack No. 1 are shown in figure 9-2. All functional units use solid state parts and integrated circuits. Only one electron tube is used in the terminal. This tube is located in RF Amplifier AM-6138/URC.

A system of filtering and bandpass shaping is used because of the signal levels, signal characteristics, and frequencies involved. Electrically synthesized frequencies and binary coded decimal (BCD) switching gates provide for instantaneous frequency switching. No mechanical tuner or channeling period is required.

Two frequency synthesizers (7 and 8, fig. 9-2) are used, one for receive operation and one for transmit. This feature, together with a diplexer, permits full-duplex operational capability in voice mode operation. In the data modes (teletypewriter and vocoder) the multimodem configuration permits full-duplex operation, as stated previously. Beacon acquisition is accomplished in a receive mode only; no transmission is required. During beacon acquisition, a signal from a frequency standard in the main receiver is phase compared with the signal received from the beacon, and the frequency standard is adjusted to zero beat with the beacon signal. This provides optimum operation of the terminal with the satellite. A terminal self-test loop operates in a nonradiating mode using a dummy load to dissipate transmitter power.

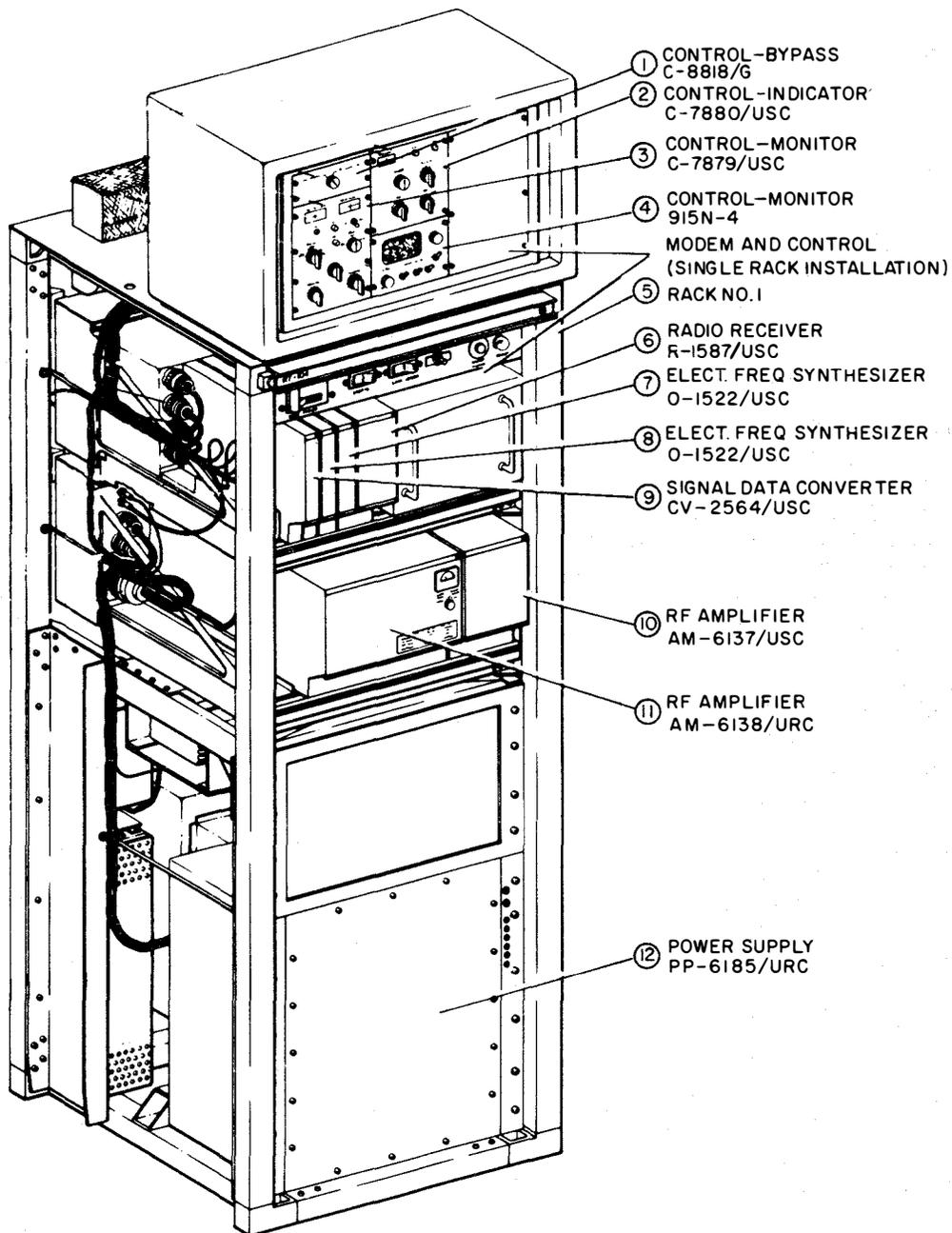


Figure 9-2.—Receiver-transmitter rack.

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Transmitter power output is controllable from 1 watt to 1 kilowatt. A closed-loop automatic level control (ALC) circuit maintains the output power at the selected level. Power output is controlled by setting the bias level in the 100-watt RF amplifier (10, fig. 9-2). For power

output levels of 100 watts or less in single modem operation, the 1-kilowatt RF amplifier (11, fig. 9-2) is bypassed, and the output of the 100-watt RF amplifier is fed to the diplexer. In test mode operation, the output power of the 1-kilowatt RF amplifier is reduced by 3 db.

Control Case

The control case (mounted on top of rack No. 1 (fig. 9-2) contains Control-Bypass C-8818/G, Control-Indicator C-7880/USC, and Control-Monitors C-7879/USC and 915N-4. Control-Monitor C-7787/UCA-1 for the No. 1 modem and Control-Amplifier C-8202/WSC-1(V) are located in a remote control console in the multi-

modem configuration of the terminal. The front panels of these assemblies are shown in figures 9-3 through 9-5.

The CONTROL-BYPASS C-8818/G (fig. 9-3A) selects either single or multimodem transmission.

The CONTROL-INDICATOR C-7880/USC (fig. 9-3B) provides functions for system testing. When all controls are set for the test condition,

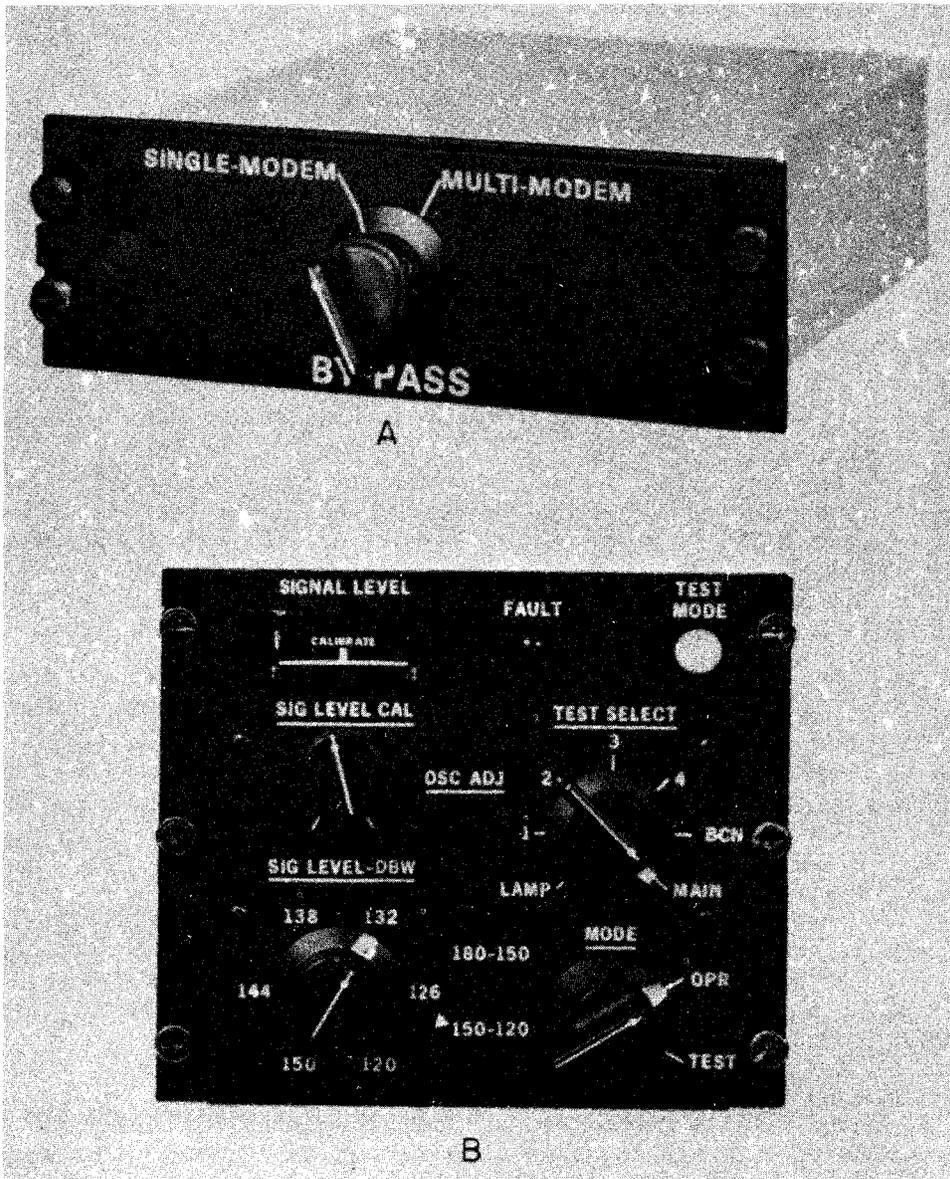


Figure 9-3.—Control-Bypass C-8818/G and Control-Indicator C-7880/USC.

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the operator can check out the communication system and use the information provided to assist in locating faults.

The control-indicator develops an RF signal that is mixed and processed with a sample of the up-link transmitted signal. The resulting down-link receive frequency signal provides a test signal for the system receiver. Fault signal output of the two synthesizers, converter, and power supply can be switched to the fault indicator for indication of module condition.

CONTROL-MONITOR C-7879/USC (fig. 9-4A) provides the system control and monitoring functions. The control-monitor is basically a switching unit. In addition to the front panel controls and indicators (shown in figure 9-4A), the unit contains four relays, a delay network, a voltage divider, and a frequency strapping panel. The frequency strapping panel is a terminal board with a number of standoff solder terminals. The frequency scheme is preset by soldering jumper wires to appropriate terminals. This procedure is called "strapping."

In the Control-Monitor C-7879/USC (fig. 9-4A) the MODE control selects the operating mode for the overall system and selectively enables the equipment required for operation in the selected mode. This control also activates the appropriate key lines and routes the modulating capabilities according to the mode selected. In the OFF position, operating power is removed from all units of the communication system. Selection of voice mode operation supplies an enabling ground to the power enabling circuits of the system which enables all the equipment basic to the communication system. Selection of the TTY mode enables the teletypewriter and modem in addition to all the basic units. Vocoder selection removes the enabling ground from the TTY and enables the vocoder instead; the modem remains enabled.

In all operating modes, the RF circuits are enabled either intermittently or constantly according to the selected mode. In voice mode operation, pressing the microphone push-to-talk button activates the RF circuits and routes the microphone audio to the modulator for processing and transmission. In TTY and vocoder mode operation, the modulation is routed through the modem prior to being impressed on the carrier.

The Control-Monitor C-7879/USC provides control and monitoring functions for transmitter power output and monitoring functions for standing wave ratio. It also provides a key-line interlock and delay network to minimize arcing when

switching transmitter power levels. Control functions are provided by the FWD-REFL toggle switch and a concentric PWR CONTROL. The PWR CONTROL consists of a 3-position rotary switch (outer knob) to select the power operating range and a potentiometer (inner knob) to set the power level within the selected limits. Each selected monitoring function is displayed on the XMTR PWR meter.

The XMTR PWR meter normally indicates forward power output. Reflected power may be measured by holding the FWD-REFL toggle switch in the REFL position. The switch returns to the FWD position when released. Sensing devices and gating circuits are included in the high-voltage power supply and in the RF power amplifiers. When a high-voltage or VSWR fault is sensed in the 100-watt power amplifier, a gated signal enables the FAULT indicator on the control panel.

Selection of an operating channel and its corresponding assigned frequency is accomplished by the SATELLITE and CHANNEL controls. The SATELLITE control, a 5-position rotary switch, selects one of five broad frequency bands. The CHANNEL control, a concentric rotary switch, selects the transmit and receive operating frequencies (for FM voice operation) within the broadband. The outer knob positions a 12-position switch to select a beacon or 1 of 11 FM receive channels. The inner knob controls an 11-position switch to select 1 of 11 FM transmit channels. The system is normally operating in the receive condition; transmit operation is initiated by keying the transmitter.

The CONTROL-MONITOR 915N-4 (fig. 9-4B) provides amplification, control, and monitoring functions for AF signals within the satellite communications system. It performs the following functions:

1. Amplifies the audio output from the communications receiver to drive an internal speaker, an external audio level meter, and a remote receive audio line
2. Amplifies the audio input from an external microphone to supply voice modulation for the transmitter
3. Contains the squelch threshold adjustment for the receiver
4. Provides sidetone audio which is mixed with the receive audio to drive a remote receive audio line, an internal speaker, and an external audio level meter. Sidetone audio level is independent of receive audio level

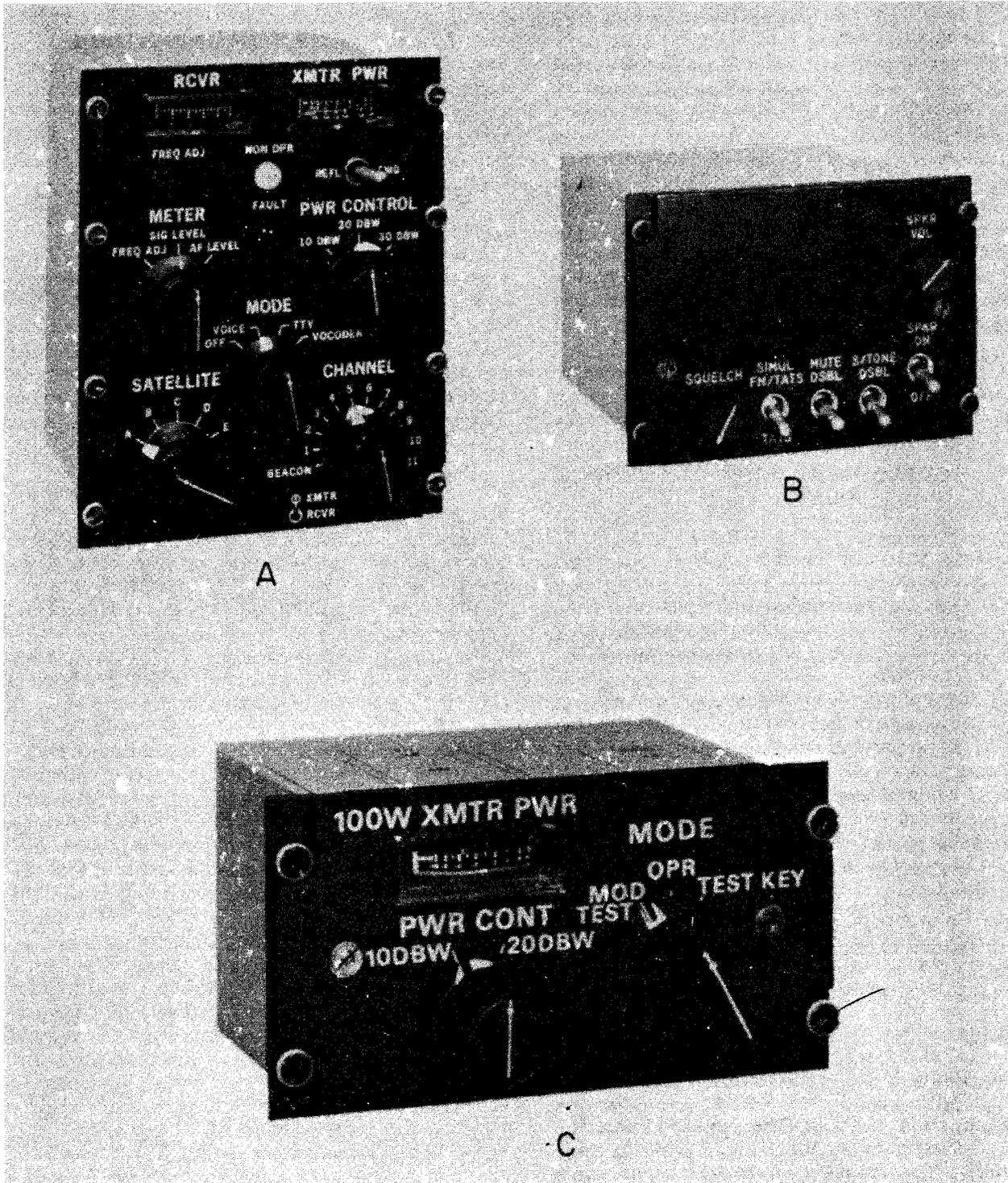


Figure 9-4.—Control-Monitors C-7879/USC and 915N-4, and Control-Amplifier C-8202/WSC-1(V).

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5. Provides a ground for the FM key line when 12 volts d.c. and ground is supplied from an external source
6. Disables sidetone when the S/TONE DSBL switch is in the up position or when an external ground is applied to the sidetone disable input line
7. When keyed externally and the FM-TATS switch is placed in the SIMUL FM/TATS position, provides a ground for the simultaneous FM and RF key line—The modems used in the AN/WSC-1(V) are a modified version of the Tactical Transmission System (TATS) modem. Thus they are sometimes referred to as TATS modems
8. When the FM-TATS switch is placed in the TATS position, provides + 28 volts d.c. switched to Control-Amplifier C-8202/WSC-1(V)

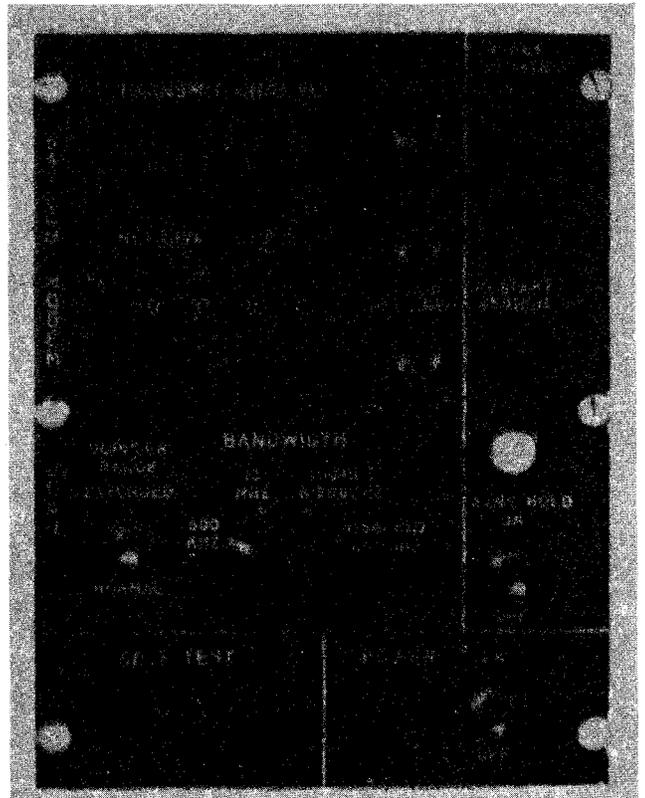
The CONTROL-AMPLIFIER C-8202/WSC-1(V) (fig. 9-4C) performs the following functions:

1. Sets the modem for tests and normal operation
2. Keys the associated RF amplifier AM-6137/USC, Signal Data Converter CV-2564-USC, and Power Supply PP-6185/URC
3. Enables 70 MHz command to the modem (The modem generates a 70 MHz signal that is used to set the power level of the associated RF Amplifier AM-6137/USC.)
4. Measures and adjusts the output power level of RF Amplifier AM-6137/USC when the bypass switch on Control-Bypass C-8818/G is in the MULTI-MODEM position.

The CONTROL-MONITOR C-7787/UCA-1 (fig. 9-5) controls and monitors operation of the modem. (The modems have no front panel controls or indicators.)

Receiver

The Radio Receiver R-1587/USC (fig. 9-2) is used with associated equipment to form a communication system. The receiver unit includes a frequency standard and converter sub-assembly. The frequency standard generates a reference frequency used in the receiver and throughout the terminal. The converter produces control and reference signals used for injection, translation, and synchronization.



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Figure 9-5.—Control-Monitor C-7787/UCA-1.

The receiver accepts and processes FM voice and digital data signals in the frequency range of 240 to 260 MHz. It functions in voice, modem, and beacon modes. Selection of operating mode is accomplished remotely; operating voltages are applied or removed according to the requirements of the selected mode.

All received RF signals are processed through a common front end. In modem mode operation, the receiver uses a single frequency conversion, and the signal is then routed to an external modem for demodulation. In voice and beacon mode operation, the receiver uses a second frequency conversion, and the signal then is demodulated. Separate demodulation channels are used for the two modes.

Signal Data Converter

The Signal Data Converter CV-2564/USC (fig. 9-2) contains four subassemblies which generate, combine, and process signals and translate an RF injection signal to a modulated RF

carrier. The carrier is then supplied at a level suitable for driving a power amplifier. The sub-assemblies are the audio processor and power supply, the 9 MHz frequency modulator, the 5 MHz crystal oscillator bank, and the IF-RF translator.

The converter provides the following functions:

1. Generates a 9 MHz signal and a 4.795 to 5.205 MHz signal for internal use in frequency translation
2. Accepts injection inputs of 56 MHz and 110.0 to 122.5 MHz for use in frequency translation
3. Accepts analog voice, code burst FSK, modem, or alert message input signals for use in modulation of the RF carrier
4. Combines and translates signals to a modulated 300 to 315 MHz RF carrier at a power level that is suitable for driving a power amplifier
5. Supplies regulated + 18 and + 5.25 volts d.c. power to associated units of the communication system

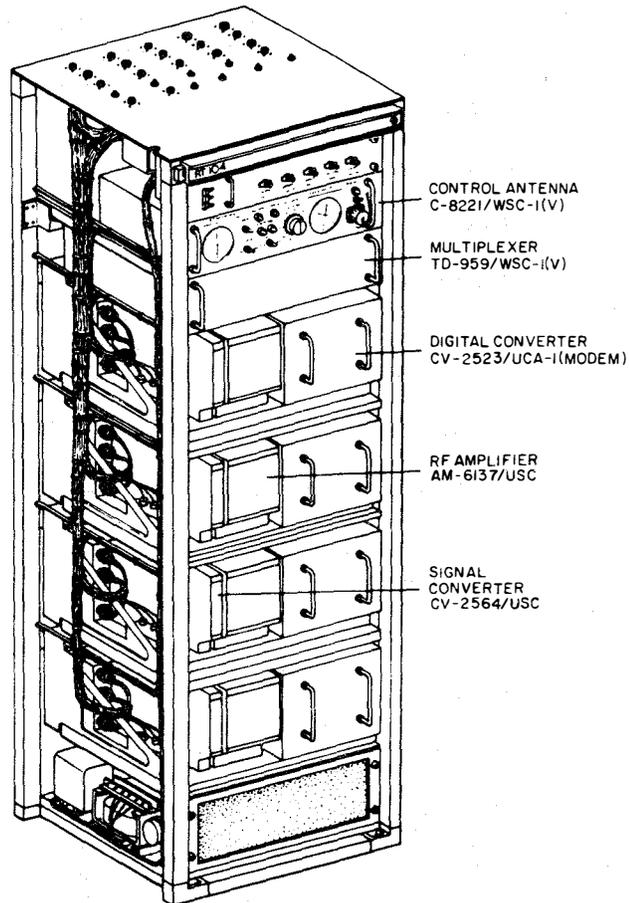
Power Supply

The Power Supply PP-6185/URC (fig. 9-2) operates from a 3-phase, 60 Hz input power source and supplies operating voltages for a 1-kilowatt RF power amplifier. The operating voltages supplied by the power supply include plate and screen bias, and filament voltages. The power supply also provides interface connections to permit external control and monitoring of power supply performance.

MULTIMODEM RACK

The multimodem rack (rack No. 2, fig. 9-1) contains antenna indicators and controls, a multiplexer unit, and four modems with their associated RF amplifiers and signal data converters. The location of these modules in rack No. 2 is shown in figure 9-6. The Control-Amplifiers C-8202/WSC-1(V) and Control-Monitors C-7787/UCA-1 associated with the modems are remotely located.

The Control-Antenna C-8221/WSC-1(V) includes controls for manual rotation of the antennas in azimuth, and indicators which indicate the position of the antennas in azimuth and elevation, and the ship's heading. Also included on the panel are indicator lights which indicate



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Figure 9-6.—Multimodem rack.

antenna radiation hazard blockage, low coaxial cable pressure, and antenna(s) in operation. A sound-powered telephone jack box is installed in the lower right-hand corner of the panel.

Multiplexer TD-959/WSC-1(V) provides the terminal with a multichannel capability. The multiplexer assembly includes four subassemblies: a power combiner, and three distribution amplifiers. The power combiner functions to linearly combine up to five 100 watt amplifier outputs. Two distribution amplifiers provide the modems with the receive 70 MHz signal, and the 1 MHz frequency reference signal on individual isolated lines. The third distribution amplifier supplies the signal data converters with the translation frequency from the transmit synthesizer.

The modems are digital data converters which can transmit and receive in a narrow

bandwidth of 800 kHz or a wide bandwidth of 10 MHz. The wide bandwidth is used only at SHF frequencies. (The AN/WSC-1(V) is capable of transmitting and receiving wide bandwidth modulation, but this mode is not authorized for use at UHF frequencies.)

ANTENNA GROUP

The antenna group (fig. 9-1) includes two antennas, two amplifier-filter units, two coax switch assemblies, and two relay assemblies. The amplifier-filter units, although actually considered part of the radio set group, are listed with the antenna group for installation purposes.

Antenna AS-2410/WSC-1(V) (fig. 9-1) is a circularly polarized crossed-dipole type antenna. The antenna includes four crossed-dipole elements, a 90-degree hybrid, two combiners, and a dummy load. The antenna is mounted on an antenna pedestal that contains the azimuth and elevation reversible 3-phase, 208-volt, 60-Hz induction motors; two elevation synchro transmitters; three azimuth-controlled differential transmitters; and a switch used to disable the antenna subsystem. The elevation section also contains up-down limit switches, and the azimuth section contains radiation hazard limit switches. Each motor is protected by thermal overload switches. Fail-safe brakes are released when power is applied. External connections are made to the antenna through three connectors and a sound-powered phone jack. Connections to the elevation power and control circuits are made through sliprings.

Amplifier-Filters AM-6205/WSC-1(V) shown in figure 9-1 include a coax switch, a diplexer, and an RF amplifier. The amplifier-filters (sometimes referred to as the deck boxes) and the bulkhead mounted equipment are shown in figure 9-7 (fold in end of chapter). Relay Assemblies RE-1025/WSC-1(V) provide power control for the antenna azimuth and elevation drive motors.

AN/WSC-1(V) FUNCTIONAL DESCRIPTION

Frequency synthesizers develop injection frequency signals used in receive and transmit conditions of the terminal. Two synthesizers are used, one for receive and one for transmit frequencies. The units are identical and interchangeable; both are required to provide full-

duplex operational capability. The frequencies produced by the synthesizers are phase locked to the standard through the 25-kHz reference frequency.

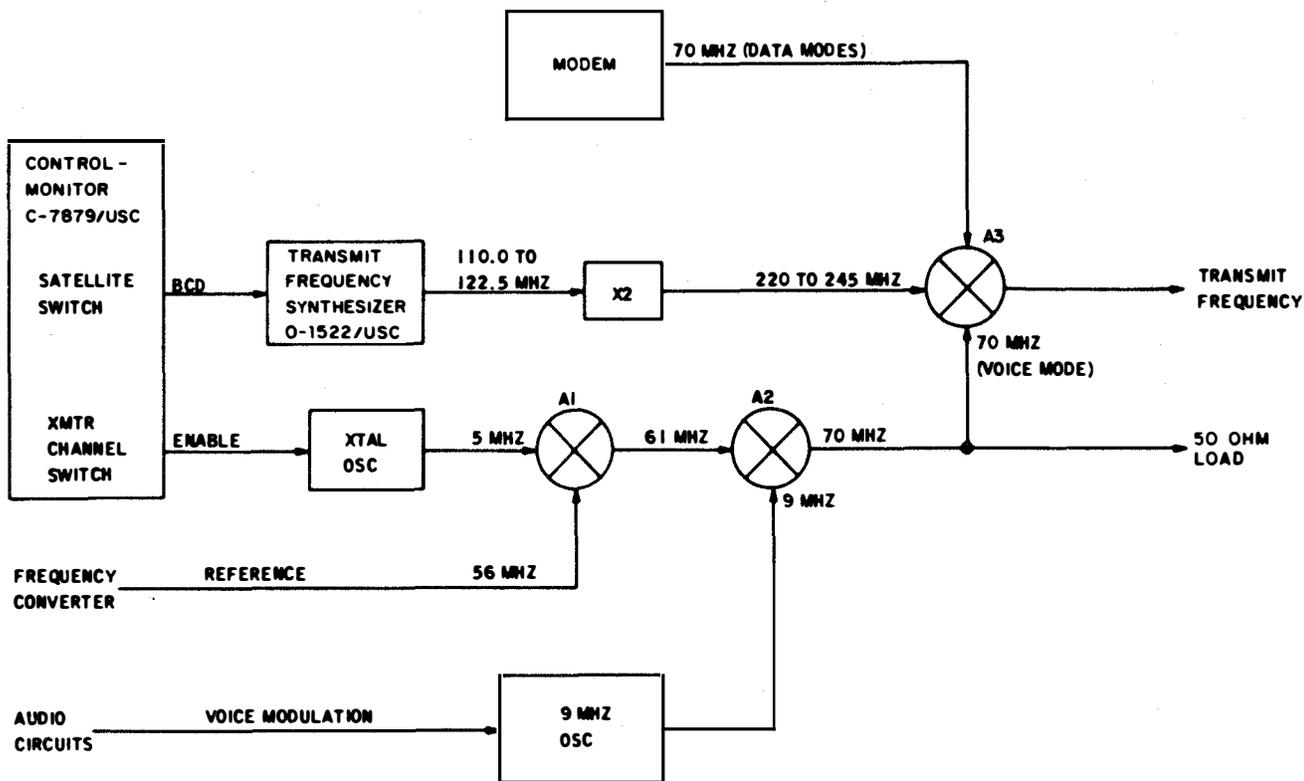
Initial frequency selection is made at the SATELLITE switch on Control-Monitor C-7879/USC. Selection of the satellite band applies a BCD control signal to the frequency synthesizer. The synthesizer then produces an RF signal at a frequency depending on a strapping arrangement in the control. The synthesizer output signal is used in the translation of the terminal transmit and receive frequencies.

TRANSMIT FREQUENCY GENERATION

In data transmit operation, the output frequency of the transmit frequency synthesizer (110.0 to 122.5 MHz) is routed through the multiplexer to the signal data converter. In the converter the synthesizer frequency is doubled and applied to summing mixer A3 (fig. 9-8). The other input to the mixer, supplied by the modem, is a modulated signal with a 70 MHz nominal center frequency. The 220 to 245 MHz and the 70 MHz signals are mixed to produce the 290 to 315 MHz transmit frequency. (The AN/WSC-1(V) transmits in the range of 300 to 315 MHz only.) The transmit frequency output of the signal data converter is routed through the 100-watt RF amplifier, multiplexer (for multimodem operation), the 1-kilowatt RF amplifier, and then to the antenna subsystem for transmission.

In voice transmit operation, the frequency synthesizer produces the same RF signal as in data transmit operation. This signal is doubled in the signal data converter and applied to the mixer as in data transmission. The 70 MHz signal input to the mixer, however, is derived in a different manner. The FM XMTR CHANNEL switch at Control-Monitor C-7879/USC selects an enabling ground for the crystal oscillator in the signal data converter. The ground enables 1 of 11 crystals of a crystal oscillator bank. The enabled oscillator signal (at a frequency within the range of 4.795 to 5.205 MHz) is applied to summing mixer A1.

The other input to the mixer is a 56-MHz reference signal from the main receiver. The mixer output (basically a 61-MHz signal) is applied to another summing mixer, A2. The other input to this mixer comes from the 9 MHz oscillator in the signal data converter. The 9 MHz oscillator signal is voice modulated from the audio circuits of the radio set. The



162.190

Figure 9-8.—Transmit frequency generation.

70 MHz output is also mixed with the 220 to 245 MHz to produce the 290 to 315 MHz transmit frequency as in data transmission.

RECEIVE FREQUENCY TRANSLATION

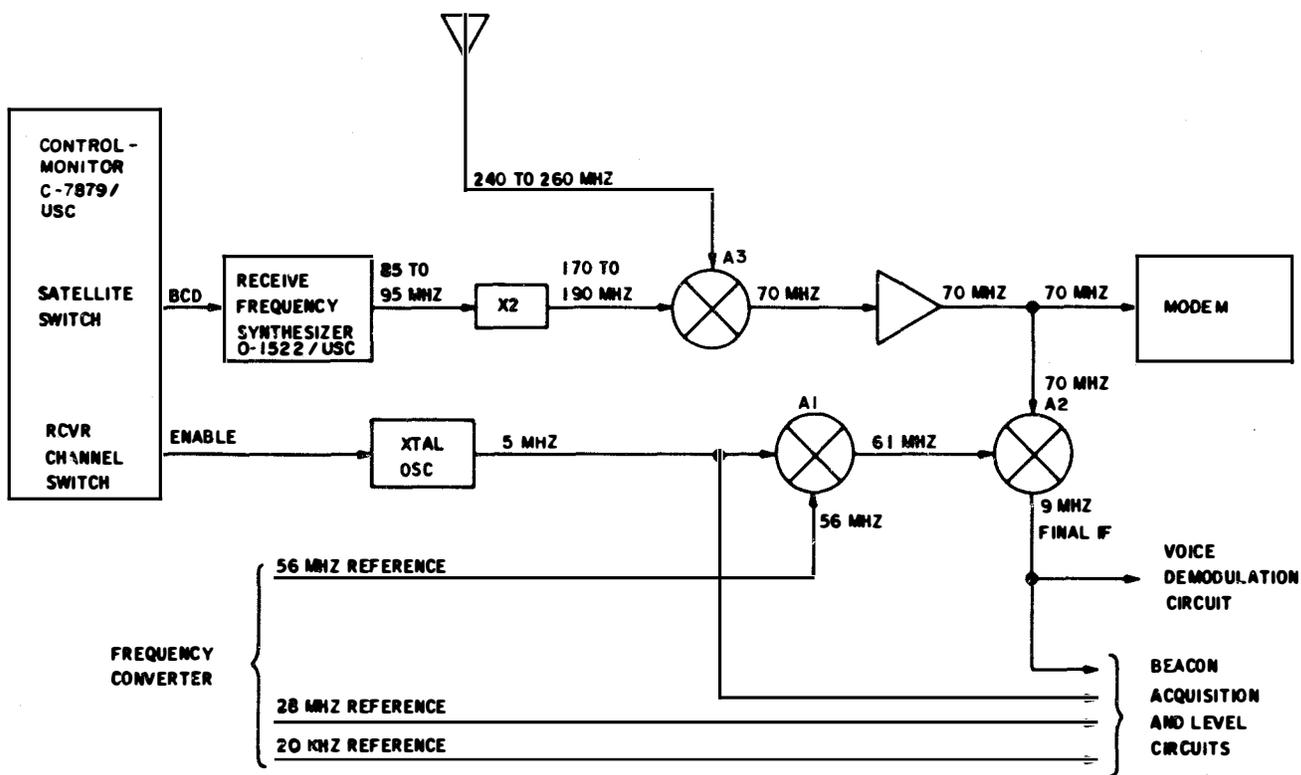
In data receive operation, the **SATELLITE** switch position and the strapping arrangement at **Control-Monitor C-7879/USC** determine the control input to the receive frequency synthesizer. The frequency synthesizer produces a frequency within the range of 85 to 95 MHz. The synthesizer output is routed to the main receiver where it is doubled and then applied to difference mixer **A3** (fig. 9-9). The received RF signal in the frequency range of 240 to 260 MHz is also applied to the mixer. The resultant 70 MHz signal (with the modulation intact) is routed to the modem for demodulation.

In voice or beacon receive operation, the received and translated injection signals follow the same initial paths as in data receiver operation. The 70 MHz signal is fed to difference mixer **A2**. The other input to this mixer is a 61 MHz signal. The position of the **FM RCVR**

CHANNEL switch on **Control-Monitor C-7879/USC** selects an enabling ground for the main receiver. The ground enables 1 of 11 crystals of a crystal oscillator bank in the main receiver. The enabled oscillator signal (at a frequency within the range of 4.795 to 5.205 MHz) is applied to summing mixer **A1**. A 56 MHz reference signal from the frequency standard (in the receiver) is also applied to the mixer. The sum frequency, 61 MHz, is then combined with the 70 MHz signal in difference mixer **A2**, to provide the 9 MHz signal. In voice receive operation, the 9 MHz signal is supplied to a voice demodulator circuit to provide an audio output from the receiver. In beacon operation, the 9 MHz signal is supplied to the beacon acquisition and level circuits to provide the receiver outputs.

MAIN SIGNAL FLOW

Main signal paths through the system modules in the various modes of operation are illustrated in figure 9-10 (foldin end of chapter.



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Figure 9-9.—Receive frequency translation.

FM (Analog) Voice

For single modem operation, FM voice operation is initiated at Control-Monitor C-7879/USC by selecting the VOICE position on the MODE control. For multimodem operation, FM voice operation is initiated at Control-Monitor 915N-4 by placing the SIMUL FM/TATS-TATS switch to the SIMUL FM/TATS position. Operation is narrow band FM using five frequency bands between 300 and 315 MHz for transmit, and three bands between 240 and 260 MHz for receive. Each band contains 11 discrete frequency channels, eight below and three above the band center frequency. Communication between one terminal and any other terminal is relayed both ways via the satellite. The terminal is normally in the receive condition.

In the transmit mode, the input audio signal is first applied to the Control-Monitor 915N-4 (fig. 9-10) where it is amplified and fed to Signal Data Converter CV-2564/USC. (A portion of the transmit audio signal is also routed to the receive amplifier to provide sidetone.) The audio

signal is used to modulate a 9 MHz oscillator in the signal data converter. The modulated RF signal is then translated to the satellite up-link frequency range and fed to the 100 watt RF Power Amplifier AM-6137/USC.

The 100 watt Power Amplifier AM-6137/USC amplifies the signal data converter output to the level required to drive the one kilowatt Amplifier AM-6138/URC. The gain of the 100 watt power amplifier is externally controllable, which allows the output power level to be adjusted from 1 to 112 watts. The 100 watt power amplifier output is connected to bypass relay K1, which switches the signal directly to the input of the one kilowatt power amplifier in the single channel mode or indirectly, via the combiner section of Multiplexer TD-959/WSC-1(V), to the input of the one kilowatt amplifier in the multichannel mode. The combiner is used to combine the outputs of two, three, four, or five 100 watt power amplifiers in order to provide a multichannel transmit capability. Because the combiner is passive in operation, each input signal is subject to a loss, the amount being determined by the number of

channels the system is set up for. When the single channel mode is selected, the combiner is bypassed by K1 and the power loss is avoided, making full power available to channel one. Channels two through five transmit capabilities are disabled in the single channel mode.

The one kilowatt Power Amplifier AM-6138/URC is a fixed gain, linear RF amplifier with a rated maximum power output of 1000 watts ± 5 db. The input power may be varied from approximately 10 to 100 watts which will result in an output power level from 100 to 1000 watts. A typical input may be a composite signal represented by 20 watts from each of five channels for a total power of 100 watts or 100 watts from channel one. In either case the total power amplifier output would be 1000 watts.

The output of the one kilowatt amplifier is connected to the RF sampler, which routes a small portion of the signal to Control-Indicator C-7880/USC for test purposes. The main signal flow is through the HI-PWR coax switch to one or the other of the amplifier-filters (deck boxes). In the deck box the signal passes through the up-link filter to the transmit portion of the diplexer. The diplexer allows simultaneous transmission and reception on a single antenna. The antenna port of the diplexer is connected through a dow key coax switch to the antenna. The transmit signal is beamed into space toward the satellite (provided the operator has properly positioned the antenna). The test coax switch (fig. 9-10) switches the line from the antenna to the dummy load for test purposes.

The receive signal begins at the antenna. Separation of the transmit and receive signals is accomplished by the diplexer. The output of the preamplifier (RF amplifier in fig. 9-7) is connected to the main receiver via the LO-PWR coax switch (RCVR coax switch in fig. 9-7). The main receiver functions in a conventional manner in the FM mode. The voice output from the receiver is fed to the receive input of Control-Monitor 915N-4 (fig. 9-10) where it is amplified and fed to the front panel speaker.

Data Modes

As stated previously, the AN/WSC-1(V) is used in configurations containing one to five data circuits. Each data circuit consists of a signal data converter, 100 watt RF power amplifier, modem, and controls for the amplifier and modem. Teletype or vocoder equipment is connected to the data circuits (note 2 fig. 9-10).

The modems (fig. 9-10) use a unique modulation scheme in which the input data is coded and then modulated on a frequency-hopped carrier. The modulated frequency-hopped signal is centered at 70 MHz, 409.6 kHz wide in the narrow bandwidth mode, 10 MHz wide in the wide bandwidth mode, and the output level is 0 dbm. The modem 70 MHz transmit output is fed to the signal data converter, where it is amplified and translated to the satellite up-link frequency. The remainder of the data mode transmit signal flow is identical to FM voice.

The data mode receive signal flow, from the antenna to the receiver, is identical to FM voice described previously. The receiver amplifies the input signal from the antenna and translates it down to 70 MHz. Receiver gain in the data mode is from 3 to 6 db.

The 70 MHz receiver output is connected to the 70 MHz receive distribution amplifier, which distributes the receive signal to the five modems. The modem demodulates the receive signal, using a special process which analyzes the modulation components of the signal. The data is converted to the proper form in the modem output buffer.

ANTENNA GROUP

The antenna pointing system involves circuitry in the antenna control unit, the relay assembly units and the antenna pedestals. Antenna elevation is controlled with front panel switches on the antenna control unit. Either or both antenna elevation axes may be controlled by making the proper switch selection. Pressing the ELEVATION CONTROL to the UP or DOWN position connects a ground to the corresponding control line which operates the appropriate relays in the relay assembly(s). The relay assemblies apply the correct phase of 208 volt 3-phase a.c. to the elevation drive motors in the antenna pedestals. Synchro transmitters, mechanically driven by the antenna elevation drive, transmit elevation position information for display by the ANT ELEVATION indicator.

Antenna azimuth pointing is referenced to the ship's heading synchro input. The ship's heading information is fed to the input of a synchro repeater (A1, fig. 9-11) which provides four identical outputs for use in the system. One of these outputs (CX4, fig. 9-11) provides an input to the antenna control unit and the antenna position indicator unit SHIP'S HEADING indicators. See figure 9-11 (foldin end of chapter).

Two of the outputs (CX1 and CX2) are connected by the azimuth indicator switch to two control differential transmitters in the selected antenna pedestal. The rotors of these control differential transmitters are mechanically driven by the antenna azimuth drive. The ship's heading input is added to or subtracted from an angle represented by the rotor position, resulting in an electrical output which represents the true antenna bearing. This information is fed back to the antenna control unit, where it is routed through the azimuth indicator control to the ANTENNA position indicators. The duplication in this circuit is provided to drive the duplicate indicators in the antenna control and the antenna position indicator unit.

The fourth output of the ship's heading synchro repeater (CX3) is connected to a control differential transmitter in the antenna control unit. The mechanical input is the front panel AZIMUTH CONTROL. The output of this control differential transmitter represents the angular difference or sum of the ship's heading and the true bearing selected on the AZIMUTH CONTROL. This signal is fed to control transformers in both antenna pedestals which receive a mechanical input from the antenna azimuth drive. When the electrical signal input and the mechanical input represent the same angle, the antennas are pointing at the selected true bearing, and the control transformer output is zero volts. If the ship's heading or the AZIMUTH CONTROL is changed, the control transformer electrical and mechanical inputs no longer rep-

resents the same angle and an output error voltage is developed. The amplitude of this error voltage represents the amount of the error, and the phase represents the direction of the error.

These outputs are connected back to the antenna control where they are limited, demodulated and fed to the relay control circuits. When the error signals are of sufficient amplitude, the relay control circuits send a clockwise (CW) or counterclockwise (CCW) control signal to the associated relay assembly. The relay assembly applies the correct phase of 208 volt 3-phase a.c. to the azimuth drive motor in the antenna pedestal. The motor rotates the antenna to the position at which the two inputs to the control transformer agree, and the output error signal is again zero volts.

Programmed switch cams in the antenna pedestals send radiation hazard signals to the antenna control unit when such a condition exists. Normally, the antenna selection switch cams will cause the antennas to be switched before the condition exists. However, if the system is in the single antenna mode, or both antennas constitute a radiation hazard condition at a common azimuth, a relay in the antenna control will be deenergized. When the radiation hazard relay is deenergized, the RF interlock circuit is opened, which disconnects the +28 volt d.c. from the 100 watt control units when the system is in the MULTIMODEM mode or disconnects RF key line number one in the SINGLE-MODEM mode, in either case preventing the system from being keyed.

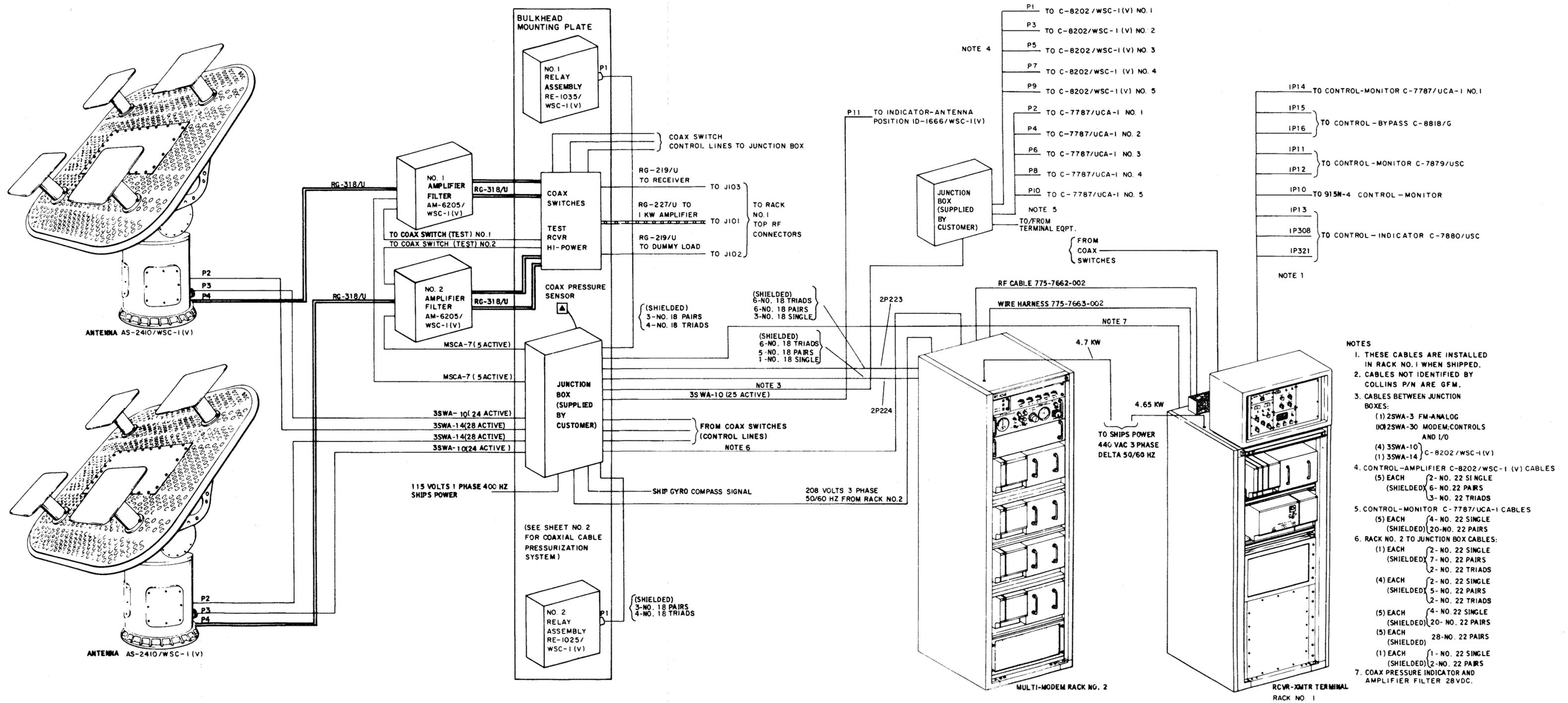


Figure 9-1.—AN/WSC-1(V) large ship configuration.

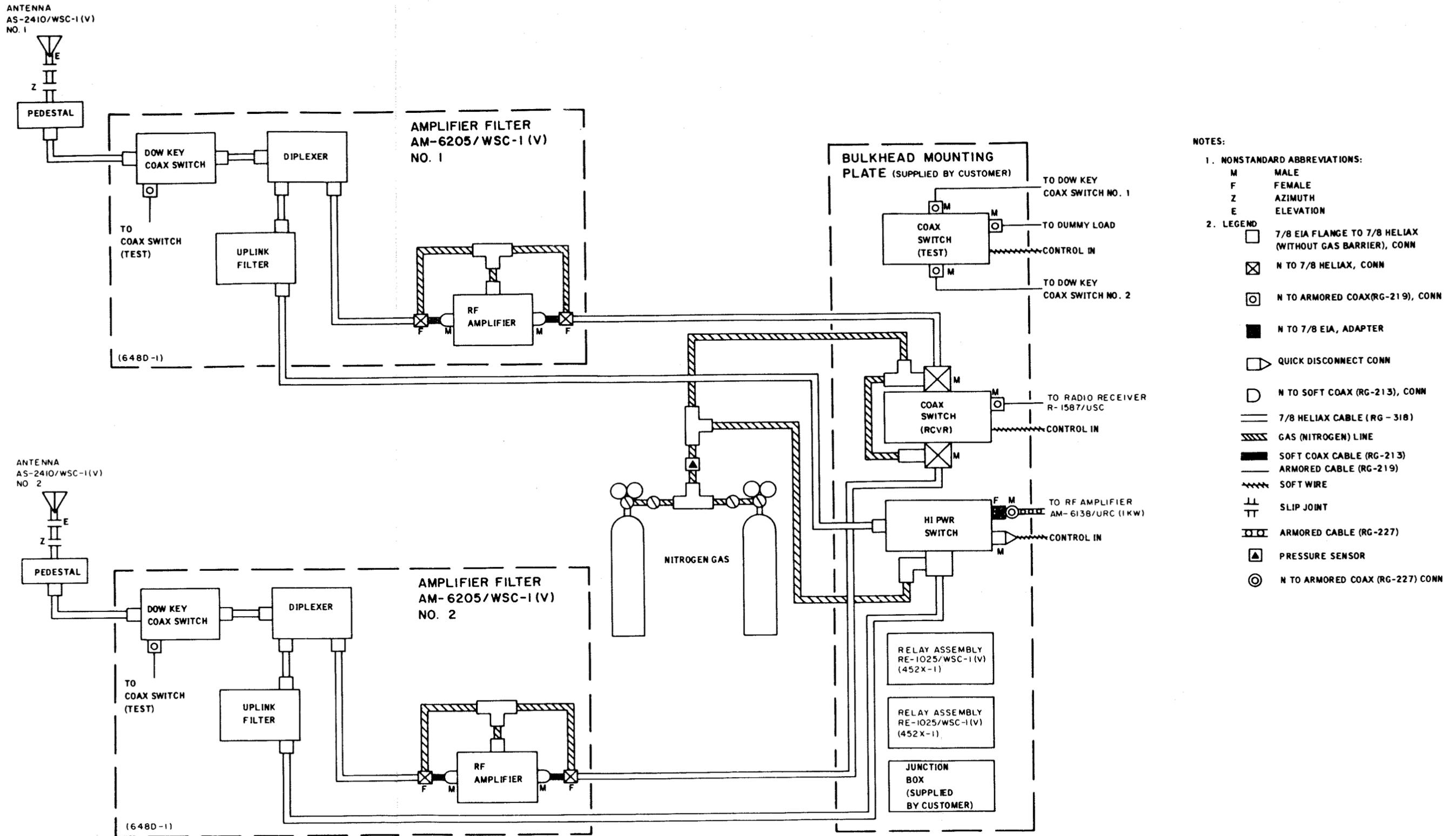
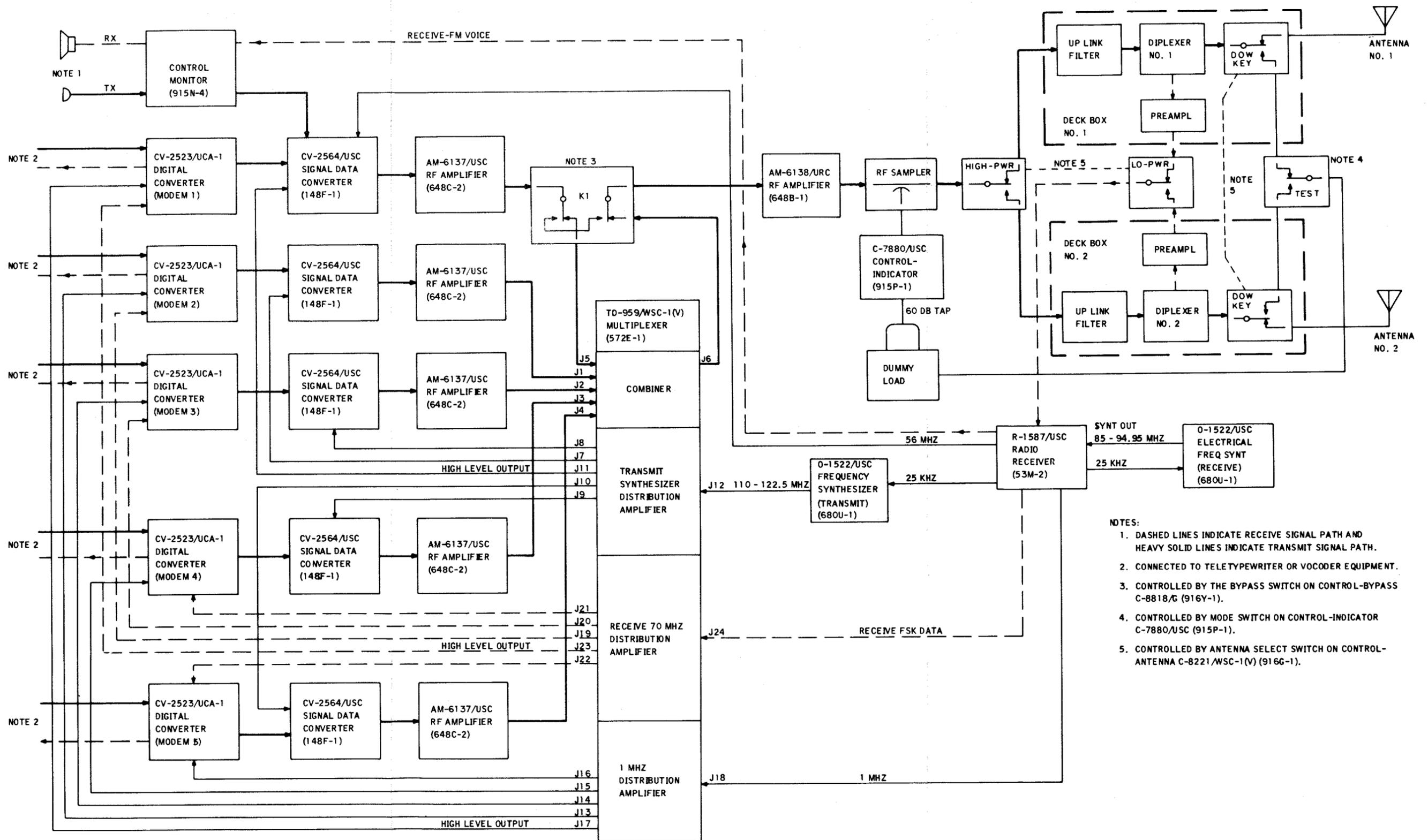


Figure 9-7.—AN/WSC-1(V) deck boxes and bulkhead mounted equipment.



- NOTES:
1. DASHED LINES INDICATE RECEIVE SIGNAL PATH AND HEAVY SOLID LINES INDICATE TRANSMIT SIGNAL PATH.
 2. CONNECTED TO TELETYPEWRITER OR VOCODER EQUIPMENT.
 3. CONTROLLED BY THE BYPASS SWITCH ON CONTROL-BYPASS C-8818/G (916Y-1).
 4. CONTROLLED BY MODE SWITCH ON CONTROL-INDICATOR C-7880/U.S.C (915P-1).
 5. CONTROLLED BY ANTENNA SELECT SWITCH ON CONTROL-ANTENNA C-8221/W.S.C-1(V) (916G-1).

Figure 9-10.—AN/WSC-1(V) main signal flow block diagram.

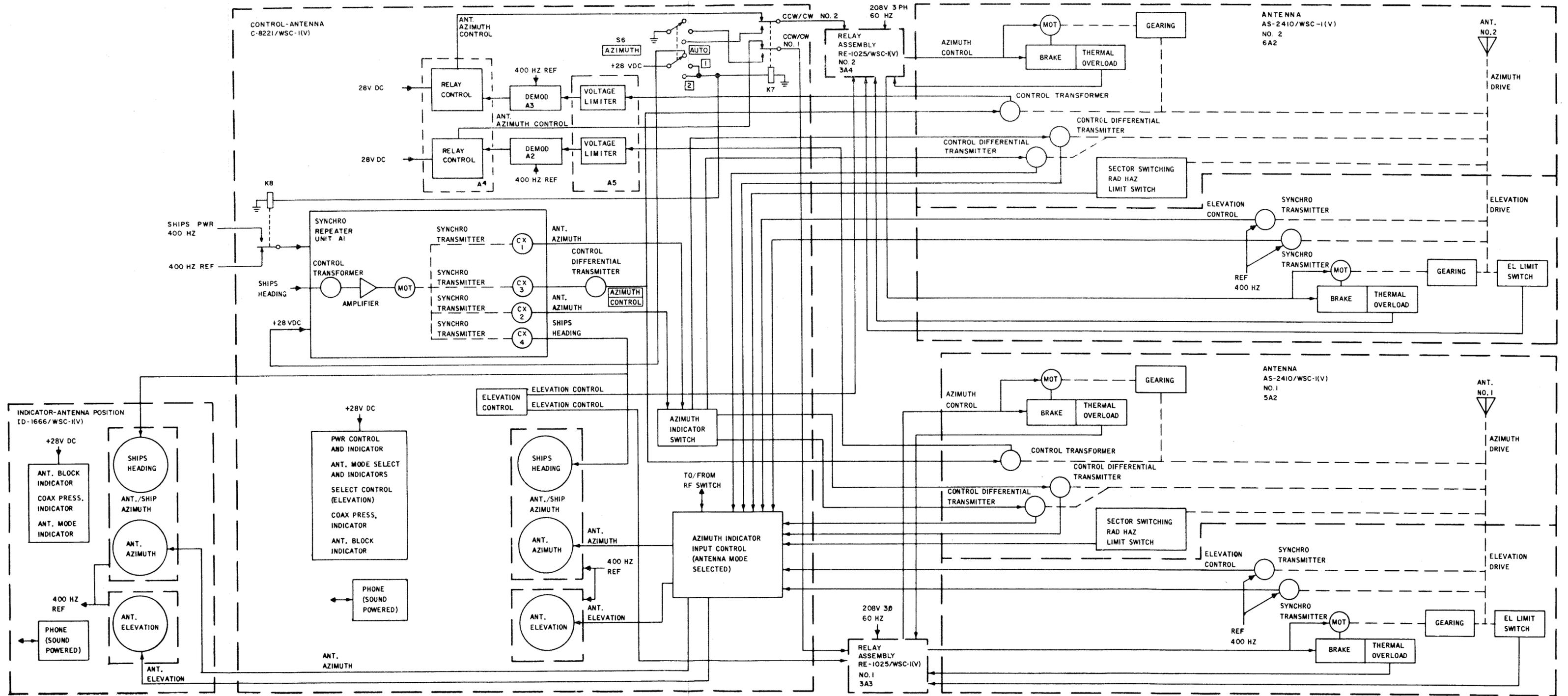


Figure 9-11.—Antenna group functional block diagram.

CHAPTER 10

FACSIMILE SYSTEMS

As discussed in chapter 5 of this manual, facsimile systems provide a method of transmitting pictorial and graphic information by wire or radio and reproducing it in its original form at the receiving station. The most common use of facsimile systems by the Navy is transmission of plotted and analyzed weather charts.

Facsimile signals may be transmitted by radio by the audiofrequency tone shift (AFTS) or the radiofrequency carrier shift (RFCS) method. Conventional superheterodyne receivers are used to receive either type of transmission. The output of the receivers is AFTS signals in which 1500 Hz represents the maximum (black) signal, and 2300 Hz represents the minimum (white) signal, or AFTS signals in which 2300 Hz represents the maximum signal, and 3100 Hz represents the minimum signal. In either case an 800 Hz shift is maintained between the maximum and minimum signal outputs from the facsimile transmitter at the sending station.

SIMPLEX SYSTEM

A simplified block diagram of a simplex facsimile system is shown in figure 10-1. On the transmit side a 2400 Hz carrier (amplitude modulated corresponding to the various shades of the copy to be transmitted) is produced at the output of the transmitter section of Facsimile Receiver-Transmitter TT-321A/UX and fed to Radio Modulator MD-168A/UX. The MD-168A/UX converts the AM signals to AFTS signals which modulate the RF carrier generated by the transmitter. The transmitter carrier is modulated plus or minus 400 Hz.

If the RFCS method of transmission is to be used, the facsimile receiver-transmitter output is fed to Keyer Adapter KY-44C/FX. Keyer

Adapter KY-44C/FX converts the TT-321A/UX AM signal output into d.c. keying signals suitable for use with a frequency-shift exciter unit.

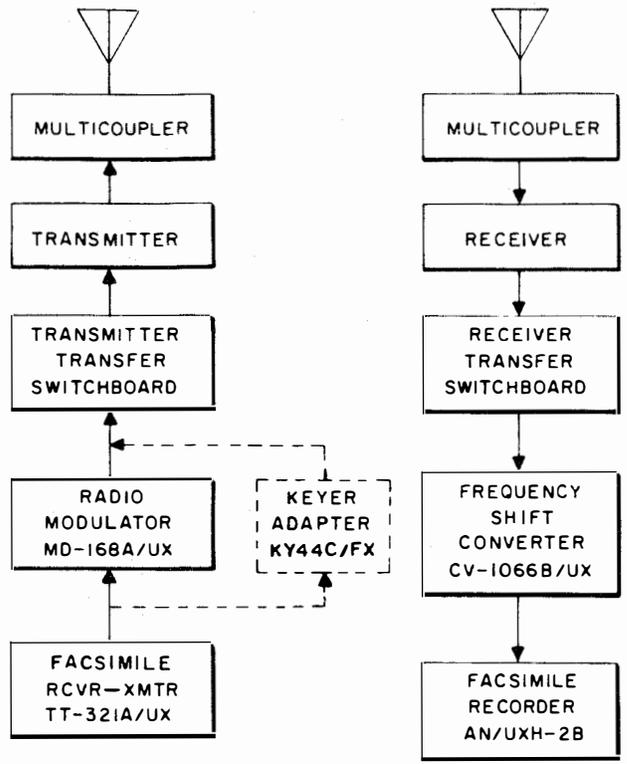
The receiver output (fig. 10-1) is AFTS signals from 1500 Hz to 2300 Hz or 2300 Hz to 3100 Hz, depending upon the setting of the receiver BFO. These AFTS signals are fed to Frequency-Shift Converter CV-1066B/UX where they are converted into equivalent AM signals suitable for operating the facsimile recorder. The Facsimile Recorder AN/UXH-2B, Facsimile Receiver-Transmitter TT-321A/UX, Radio Modulator MD-168A/UX, Keyer Adapter KY-44C/FX, and Frequency Shift Converter CV-1066B/UX are discussed later in this chapter.

The data mode is also used for the transmission of facsimile signals as shown by figure 10-2. The AM signals from the TT-321A/UX (fig. 10-2) are fed to the A/D (analog/digital) converter where they are converted into equivalent digital data signals and fed to the modem unit. The modem unit converts the digital data signals into AFTS signals, which modulate the transmitter carrier.

On the receive side, the receiver output signals are fed to the modem unit, where they are converted to digital data signals and fed to the D/A (digital/analog) converter. The D/A converter converts the digital data signals back to AM signals suitable for operating the facsimile recorder. Secure facsimile systems are produced by connecting security equipment between the modem units and the A/D and D/A converters.

FACSIMILE RECEIVER-TRANSMITTER TT-321A/UX

Facsimile Receiver-Transmitter TT-321A/UX, used with Power Supply PP-86F/TXC-1,



162.194

Figure 10-1.—Facsimile system, AFTS and RFCS modes.

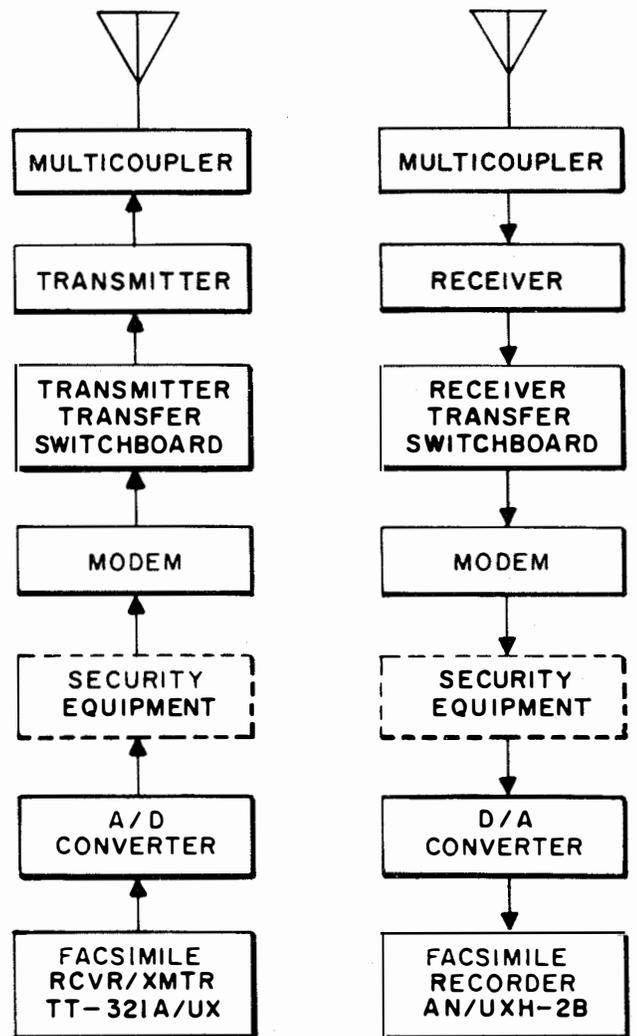
is an electromechanical-optical facsimile set of the revolving drum type for the transmission and reception of page copy. The facsimile set is used for transmission of maps, photographs, sketches, and printed or handwritten text over regular voice-communication channels (either wire or radio) between fixed stations. Colored copy may be transmitted, but all reproduction is in black, white, or intermediate shades of gray. Received copy is recorded either directly on chemically treated paper or photographically in either negative or positive form. The facsimile set will transmit or receive a page of copy 12 by 18 inches in 10 minutes at regular speed or in 20 minutes at half-speed operation.

The receiver-transmitter (fig. 10-3) serves either as a facsimile transmitter or recorder, depending upon the setting of a front panel selector switch. Power Supply PP-86F/TXC-1 supplies operating power to the receiver-transmitter and operates from a nominal a.c. power source of 115 volts at 60 Hz.

FACSIMILE TRANSMITTER

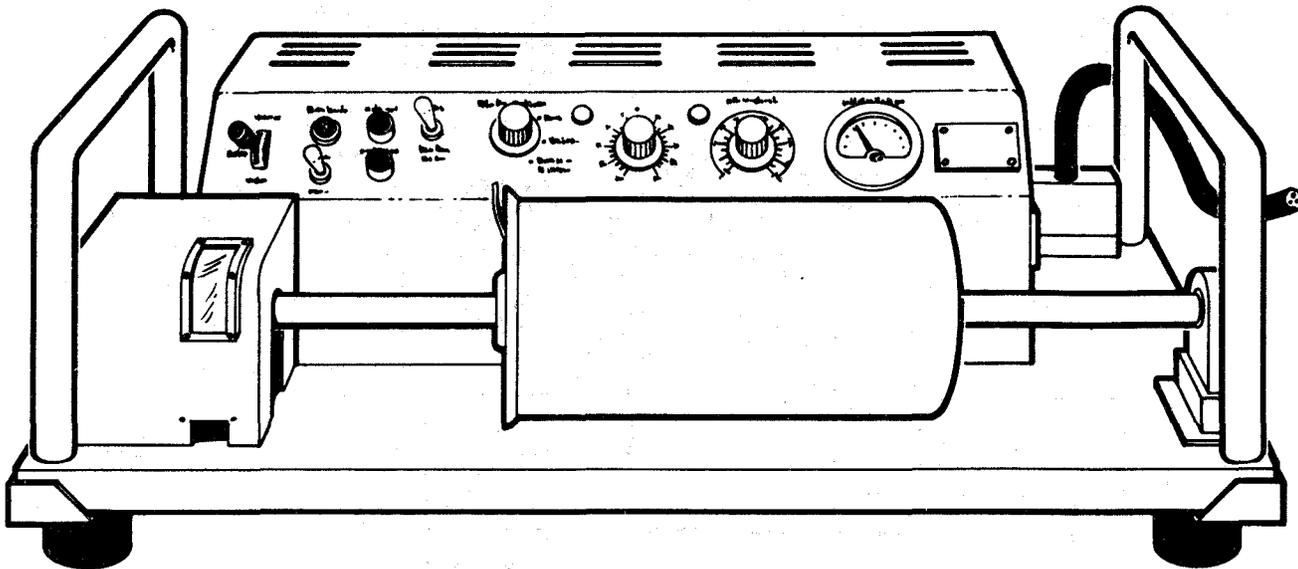
The facsimile transmitter must resolve the copy to be transmitted into very small elemental areas and transmit the average density of each area separately. The size of these elemental areas must be small enough to resolve the smallest intelligence that is to be transmitted.

An exciter lamp is used as a source of uniform illumination of the copy, and a phototube is used to determine the brightness of each elemental area. The copy to be transmitted is clamped on a drum at the facsimile transmitter. An image of the copy is focused upon an aperture plate, which is located immediately in front of a



162.195

Figure 10-2.—Facsimile system, data mode.



13.70(162A)

Figure 10-3.—Facsimile Receiver-Transmitter TT-321A/UX.

phototube. The size of the hole in the aperture plate determines the area of the copy image (the elemental area), which passes through to the phototube.

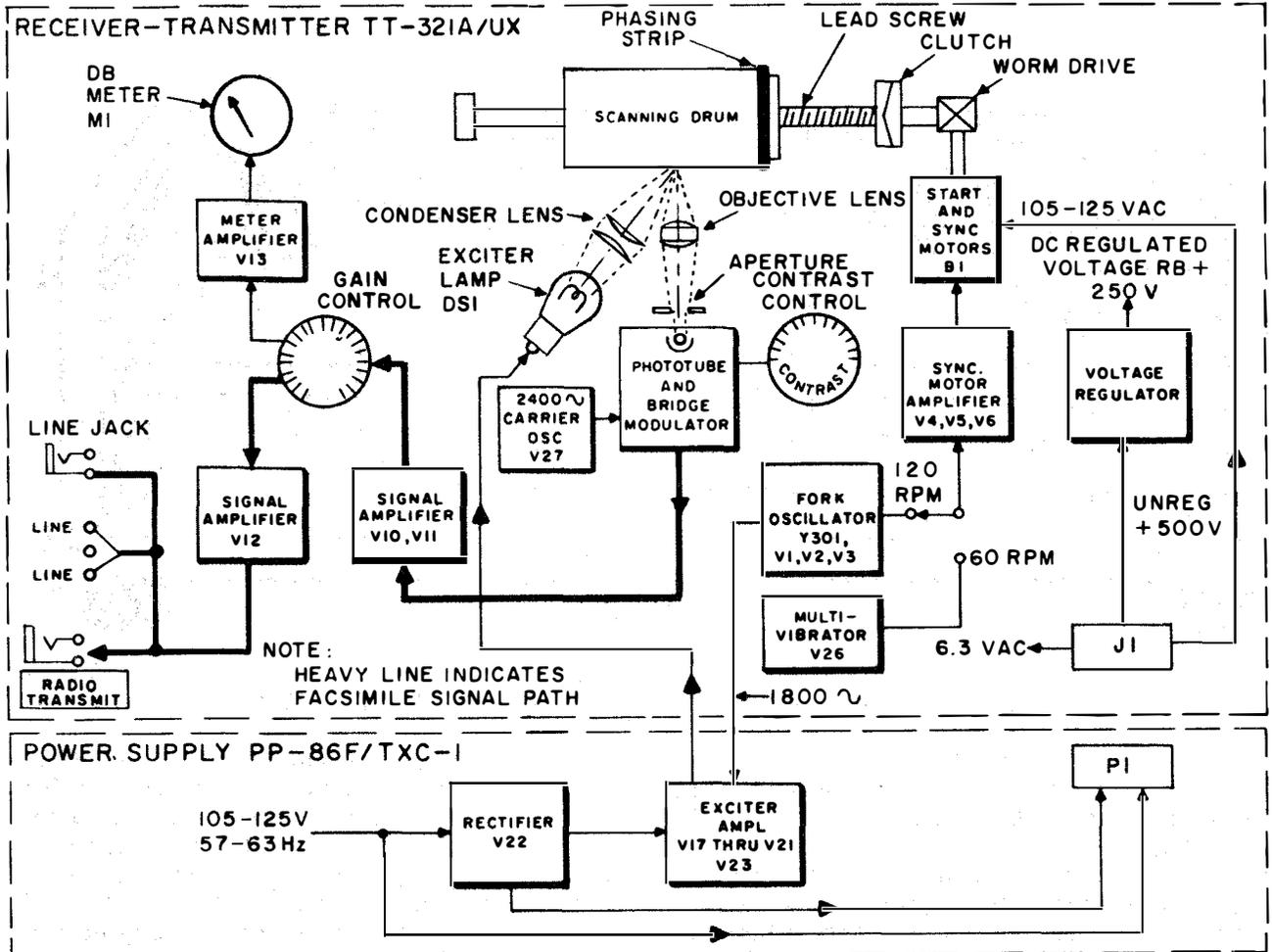
The phototube acts as a valve in a modulator circuit to control the amplitude of a carrier frequency or tone. When a dark area of the copy is seen by the phototube through the aperture, the phototube allows a maximum signal to pass through the modulator circuit. When a white area is seen by the phototube, a minimum signal results. This signal from the phototube modulator is the facsimile signal which is transmitted to the facsimile recorder.

In order to scan each elemental area of the copy, the drum upon which the copy is clamped rotates and, at the same time, moves laterally from right to left so that the relative position of the optical system shifts by one elemental area for each drum revolution. When the optical system has completely scanned the copy, all of the elemental areas on the copy have been seen by the phototube, and a signal of corresponding amplitude has been transmitted for each elemental area.

Figure 10-4 shows functions of the various stages of the facsimile set during transmission.

The material being transmitted is affixed to the rotating drum on which the condenser lens system focuses light from the exciter lamp. Amounts of light proportional to the copy density are reflected back through the objective lens and aperture to the phototube. The varying light intensities are converted into varying electrical resistance. Change in the phototube resistance controls the amplitude of a 2400 Hz carrier signal in the bridge modulator. This modulated signal is amplified by a voltage amplifier (V-10 and V-11), the proper signal level is established by a GAIN control, and the signal is boosted further by a power amplifier (V-12) before reaching the output terminals. A separate meter amplifier drives the db meter which indicates the relative signal level. The fork oscillator supplies an 1800 Hz tone which is amplified in the exciter lamp power supply and keeps the exciter lamp at constant brilliancy. The 1800 Hz tone is also amplified and used to operate the synchronous motor, which drives the drum at a constant speed.

The low voltage power supply, contained in Power Supply PP-86F/TXC-1, provides operating voltages for the transmitting section from a 115-volt, 60 Hz source. The voltage regulator is physically located in the receiver-transmitter.



70.12(162A)

Figure 10-4.—Transmitting section functional block diagram.

FACSIMILE RECEIVER

The facsimile receiver amplifies the facsimile signal and converts it back into corresponding density variations on the recording sheet. This is done in direct recording by amplifying the received facsimile signal and applying it to a small stylus needle which is in contact with the recording paper on a drum similar to that of the transmitter. The drum of the facsimile receiver rotates at the same speed as that of the facsimile transmitter so that the two drums are always in the same relative position. When a black area of the copy to be transmitted is seen by the phototube, a maximum amplitude signal is transmitted, which is

amplified at the receiver and impressed upon the recording paper by the stylus to print out a corresponding elemental area of maximum density (black). When a white area is seen on the transmitter drum, the signal passed by the phototube is so low that no signal records in the corresponding elemental area of the sheet at the facsimile receiver.

In photographic recording the received facsimile signal is amplified and applied to a light source. Light from this source shines through an aperture focused on the photographic paper or film. If recording on photographic paper, when a black area of the copy to be transmitted is seen by the phototube, a maximum amplitude signal is transmitted, amplified at the receiver

and applied to the crater lamp so that the photographic paper is exposed to maximum illumination. When a white area is seen on the transmitter drum, the signal passed by the phototube is so low that a small signal is applied to the lamp and little light reaches the photographic paper. If recording on photographic film, maximum signal is transmitted when a white area is seen on the transmitter drum, and a minimum signal is transmitted when a black area is seen on the transmitter drum.

Functions of the various stages in the receiving section are shown in figure 10-5. The signal from the line is attenuated by a GAIN control, then amplified by a voltage amplifier and a power amplifier. The db meter, driven by a meter amplifier, indicates the relative level of the signal being used for recording. The power

amplifier drives either the recorder lamp for photographic recording or the recording stylus for direct recording. Another connection from the power amplifier sends phasing pulses to the phase amplifier circuit which operates the phase actuator during the phasing process before each transmission. The fork oscillator serves a single purpose on receiving. It generates an 1800 Hz signal which is amplified to operate the synchronous motor at the same speed as the motor in the transmitting facsimile set.

RADIO MODULATOR MD-168A/UX

Radio Modulator MD-168A/UX (fig. 10-6) is designed to convert amplitude modulated facsimile signals from a facsimile transmitter (for example, the TT-321A/UX acting as a

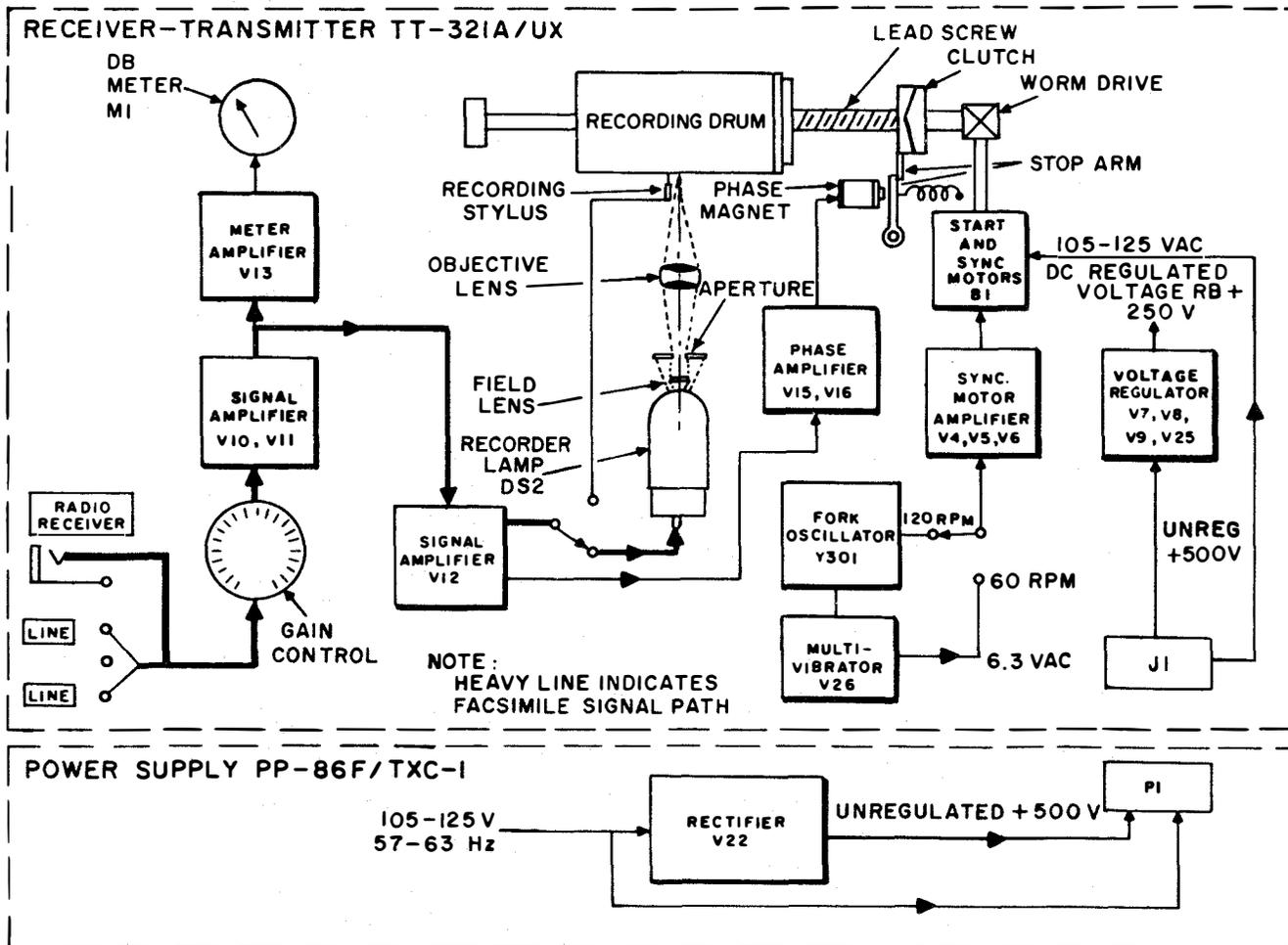


Figure 10-5.—Receiving section functional block diagram.

70.13(162A)

transmitter, to audiofrequency-shift facsimile signals of 1500 to 2300 Hz suitable for modulating a radiophone transmitter.

A block diagram of the modulator is illustrated in figure 10-7. Basically, the unit consists of a preamplifier; a keyer (detector); a variable-frequency, phase-shift oscillator; a frequency indicator; and a power supply (not shown). The amplifier increases the received facsimile signal to the proper level for operating the phase-shift oscillator and a pair of earphones. The input signal to the modulator may be monitored by using the phone jack. The frequency limits of the output signal may be monitored by means of a dual-type, tuning-eye indicator.

The input signal to the modulator has a frequency of 1800/2400 Hz and an amplitude that varies in accordance with the light and dark segments of the picture being scanned at the facsimile transmitter.

The output signal from the modulator is an audio signal in which 1500 Hz represent the maximum signal input (in amplitude) and 2300 Hz represent the minimum signal input (in amplitude) to the modulator from the facsimile transmitter. Amplitudes between maximum and minimum signals are changed to corresponding frequencies between 1500 and 2300 Hz. The output from the modulator is connected to the audio modulator section of a radio AM transmitter.

The variable-frequency, phase-shift oscillator is caused to change its frequency in accordance with the variations in the magnitude of the d.c. output voltage from the detector by means of a reactance modulator stage. The phase shift network is so connected that changes in the plate resistance of the reactance modulator (caused by the varying magnitude of the d.c. voltage applied to its grid) cause a change in the time constant of one branch of the oscillator phase shift network. This action introduces a change in phase shift through the network, which, in turn, changes the frequency of the oscillator.

The operating controls and indicators are located on the front panel (fig. 10-6). The pilot lamp operates when the set is turned on. Both sides of the powerline are fused.

The adjust 2300 control is a potentiometer used to adjust the output frequency of the unit to 2300 Hz when the amplitude of the input facsimile signal is at minimum.

The adjust 1500 control is a potentiometer used to adjust the output frequency of the unit to 1500 Hz when the amplitude of the input facsimile signal is at maximum.

The 2300-1500 frequency indicator is used to indicate the proper frequency limits of the output audiofrequency-shift signal. The left half of the indicator closes when the output signal has a frequency of 2300 Hz, and the right half closes when the output signal has a frequency of 1500 Hz.

The gain of the amplifier is such that when the adjust 1500 control is set at the proper position, the audible level at the earphones will be comfortable.

When the power ON-OFF switch is in the OFF position, power is removed from the entire unit.

When operating the unit, throw the power switch on and allow a 5-minute warmup period.

Turn the adjust 1500 control to the extreme clockwise position. When an incoming signal is being received, the 2300-1500 tuning eye indicator will flicker; monitoring with the headphones will indicate when maximum and minimum levels are being received.

When the input signal to the modulator is maximum, adjust the "adjust 1500" control until the 1500 side of the frequency indicator closes.

When the input signal to the modulator is minimum, adjust the "adjust 2300" control until the 2300 side of the frequency indicator closes.

Because the adjust 2300 and adjust 1500 controls are interdependent, repeat the preceding two adjustments.

KEYER ADAPTER KY-44C/FX

Keyer Adapter KY-44C/FX is designed to convert amplitude-modulated audiofrequency facsimile signals into d.c. keying signals for use with frequency-shift exciter units in radio transmitter equipment. It can also be used as an unfiltered detector of amplitude-modulated signals, or as an audio line amplifier. All operational controls, switches and meters are located on the front panel as shown in figure 10-8.

Keyer Adapter KY-44C/FX is rated to receive amplitude modulated facsimile signals at levels from -20 to +6 dbm. The carrier frequency may be from 1500 to 7000 Hz and the modulation rate may be from 0 to 800 Hz.

The unit can amplify and detect the amplitude-modulated signal to give output levels up to 25 volts with minimum distortion.

Meters are provided to monitor the input and output signals. Controls are available on the front panel for selecting the type of output

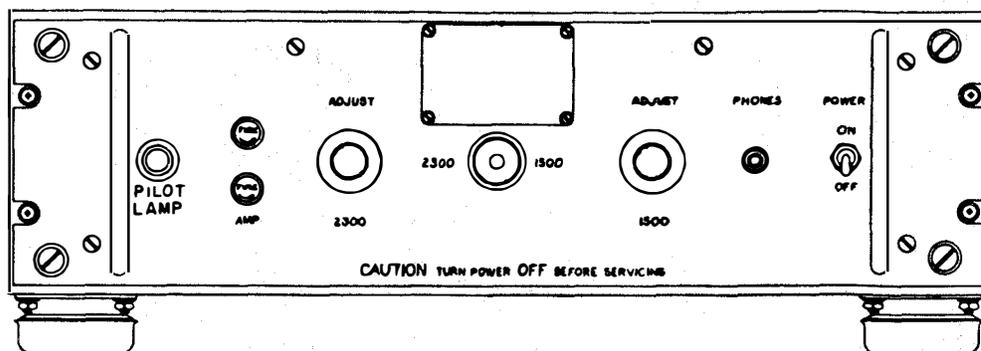


Figure 10-6.—Radio Modulator MD-168A/UX front panel.

70.82(162A)

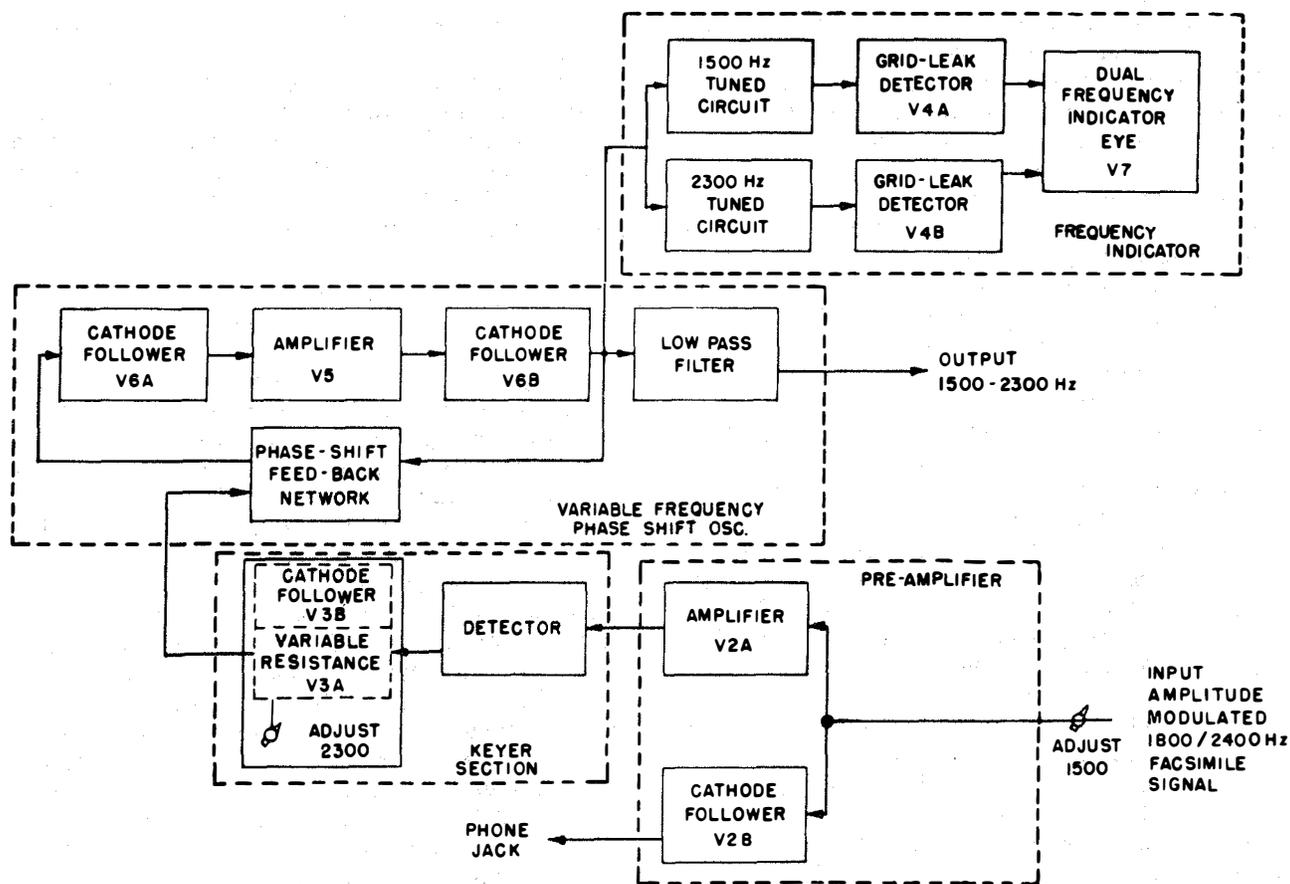
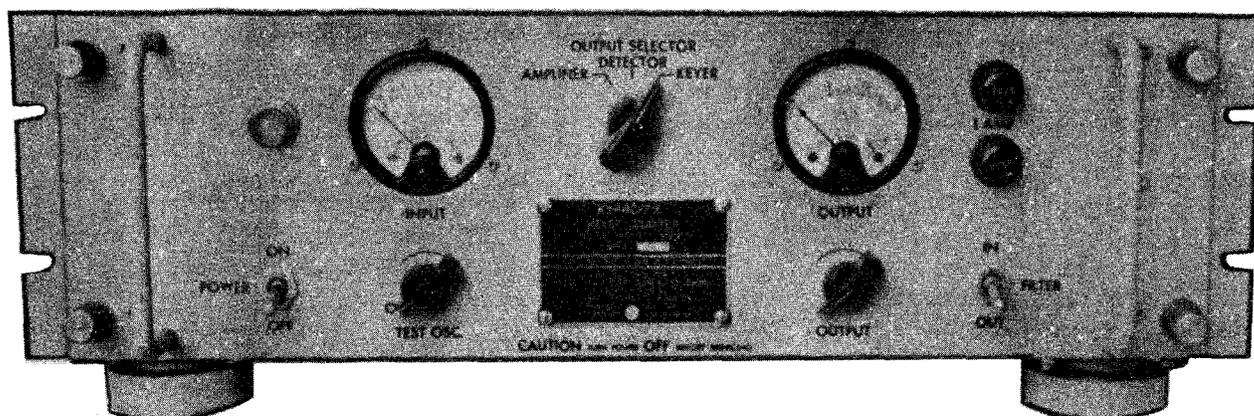


Figure 10-7.—Radio Modulator MD-168A/UX functional block diagram.

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70.81(162A)A

Figure 10-8.—Keyer Adapter KY-44C/FX front panel.

signal and for adjusting the output level. Provision is made on the terminal strip at the inside rear of the cabinet to permit grounding either side of input and output signal lines.

The power source requirement is approximately 40 watts at 115 volts a.c., 60 Hz. With a minor change, the unit may be connected to operate from a 230 volt a.c. source.

The incoming amplitude-modulated facsimile signal, is fed through an RF filter to a multistage amplifier (fig. 10-9). An INPUT meter monitors the db level of the incoming signal. The FILTER switch is normally in the OUT position; however, it may be thrown to the IN position to insert a band pass filter after the RF filter in case the incoming signal has excessive hum or noise. The signal level applied to the first stage of the multistage amplifier is controlled by the OUTPUT control. After the signal is fed through three stages of voltage amplification, it is fed into a phase inverter to split the signal into two phases 180° apart for operating a push-pull power amplifier. Part of the output of the power amplifier provides degenerative feedback to the third stage for stability and good frequency response.

The output from the power amplifier is used according to the position of the OUTPUT SELECTOR switch. When the OUTPUT SELECTOR switch is in the AMPLIFIER position, the amplified facsimile signal is fed directly to the OUTPUT terminals. When the switch is in the DETECTOR position the facsimile signal is detected and fed, unfiltered, to the output terminals. In the KEYER position, the output from

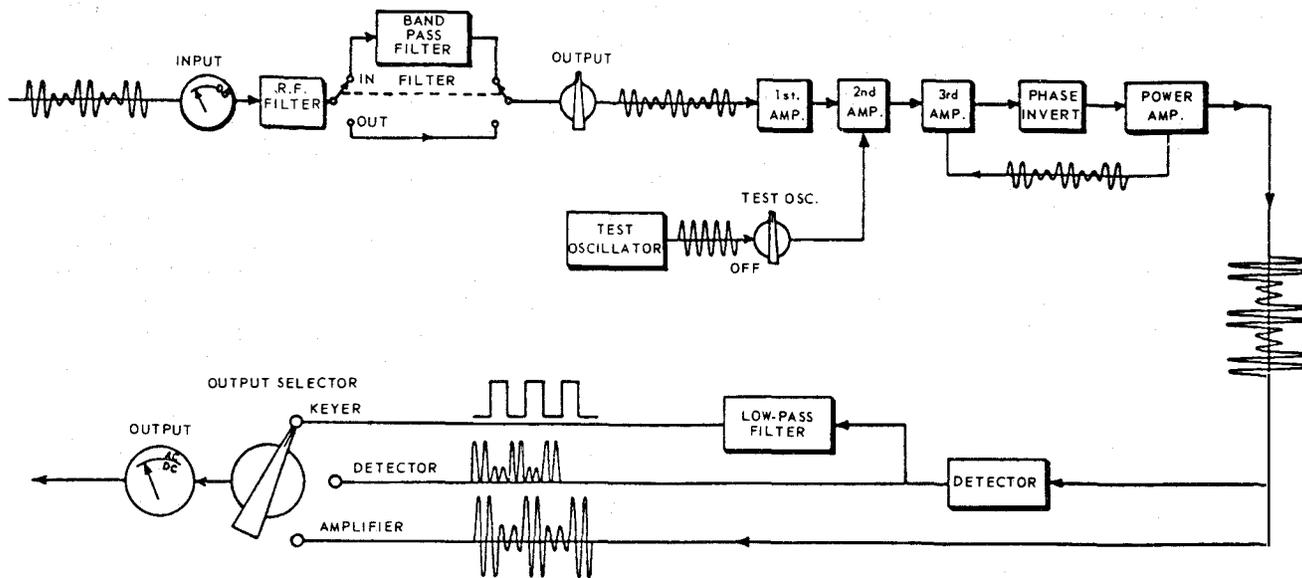
the detector is fed through a low-pass filter in order that the envelope of the amplitude-modulated facsimile signal may be fed to the output terminals.

For alignment purposes a test signal from an internal audio oscillator may be fed to the second stage. The TEST OSC control is used to turn on the audio oscillator and adjust for the desired output level. The frequency of the test oscillator is approximately 1800 Hz.

FREQUENCY SHIFT CONVERTER CV-1066B/UX

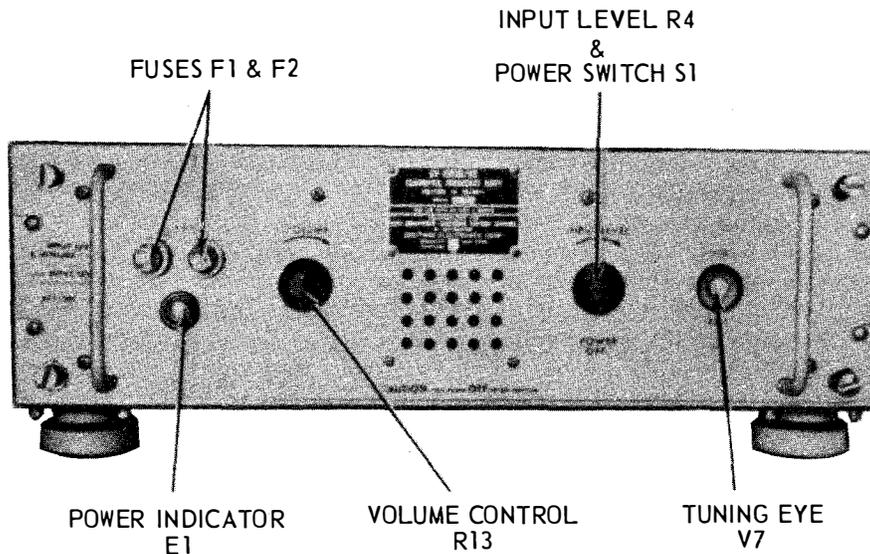
Frequency Shift Converter CV-1066B/UX converts AFTS signals to equivalent AM signals suitable for operating a facsimile recorder. Figure 10-10 shows the location of the converter controls and indicators and lists their function. After the controls have been set, operation of the converter is continuous and automatic.

The frequency shift converter changes a frequency shift signal between either 1500 to 2300 Hz or 2300 to 3100 Hz to an equivalent amplitude modulated signal of the same frequencies. The amplitude of the radio receiver output varies as much as 40 db. At the output of the converter, however, the amplitude of the 1500 Hz signal is fixed at approximately 0.4 volt a.c. The 2300 Hz signal is fixed at approximately 0.1 volt a.c., and the amplitude of the 3100 Hz signal is fixed at approximately 0.025 volt a.c. Signals between the upper and lower frequency limits have corresponding and fixed levels below the 1500 Hz signal.



70.81(162A)B

Figure 10-9.—Keyer Adapter KY-44C/FX functional block diagram.



F1 & F2—1 AMP. A.C. LINE FUSES; E1—GLOWS WHEN CONVERTER IS ENERGIZED WITH A.C. POWER; R13—CONTROLS LEVEL OF SIGNALS MONITORED BY SPEAKER; S1—A.C. POWER SWITCH, GANGED TO INPUT LEVEL CONTROL; V7—MONITORS RECEIVED FACSIMILE SIGNALS; UPPER HALF OF EYE CLOSES ON 3100 Hz SIGNALS AND LOWER HALF CLOSES ON 2300 Hz SIGNALS

70.85(162A)A

Figure 10-10.—Frequency Shift Converter CV-1066B/UX controls and indicators.

The difference in levels between the maximum signal (black) and minimum signal (white), commonly referred to as contrast, is usually stated in db. Thus, if the amplitudes at the output of the converter are 0.4 volts a.c. at 1500 Hz and 0.1 volt a.c. at 2300 Hz, then the voltage ratio of 0.25 (0.1 to 0.4) is equivalent to 12 db of contrast. $db = 20 \log \frac{E_2}{E_1}$

The functional sections of the frequency shift converter consist of an amplifier, limiter, frequency discriminator, frequency indicator and power supply as shown in figure 10-11.

The amplifier (fig. 10-11) amplifies the incoming signal to the level required to drive the limiter and the loudspeaker. The loudspeaker provides audible indication of the presence of incoming signals and the functioning of the amplifier.

The limiter is placed between the input and output to provide a constant-amplitude reference for the facsimile signals. (Although the intelligence of the incoming signal is insensitive to amplitude variations, it does vary by a considerable degree.) If these variations were reflected

in the output, which is sensitive to amplitude variations, noise would constantly appear in the output.

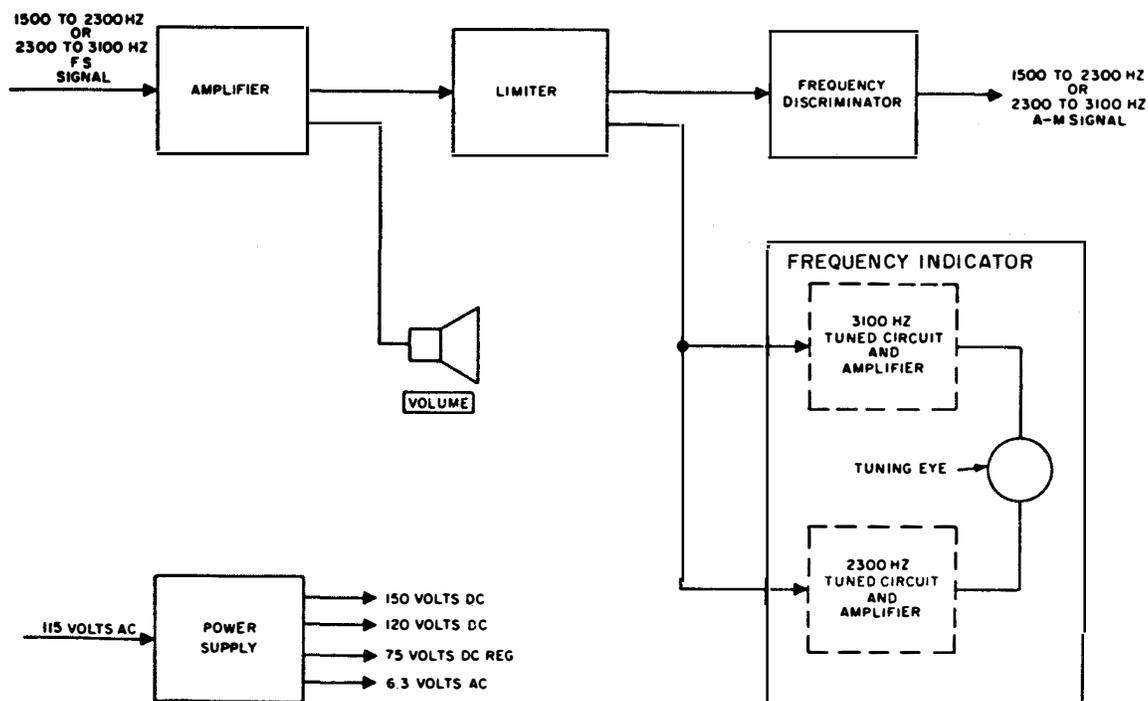
The frequency discriminator provides the contrast between the incoming frequency limits. The frequency discriminator introduces a linear attenuation from approximately +12 db at 1500 Hz to 0 db at 2300 Hz to -12 db at 3100 Hz.

The frequency indicator features a tuning eye which peaks at 2300 Hz and 3100 Hz. For the 2300 to 3100 Hz shift range, the tuning eye provides visual indication of both frequency limits, but the 1500 to 2300 Hz shift range can only use the 2300 Hz portion of the tuning eye as a visual indication.

The power supply provides operating voltages of 150 and 120 volts unregulated, and 75 volts regulated for the limiter section. In addition, the power supply furnishes filament voltages of 6.3-volts a.c.

FACSIMILE RECORDER SET
AN/UXH-2B

Facsimile Recorder Set AN/UXH-2B (fig. 10-12) is a continuous page facsimile recorder



70.85(162A)B

Figure 10-11.—Frequency Shift Converter CV-1066B/UX functional block diagram.

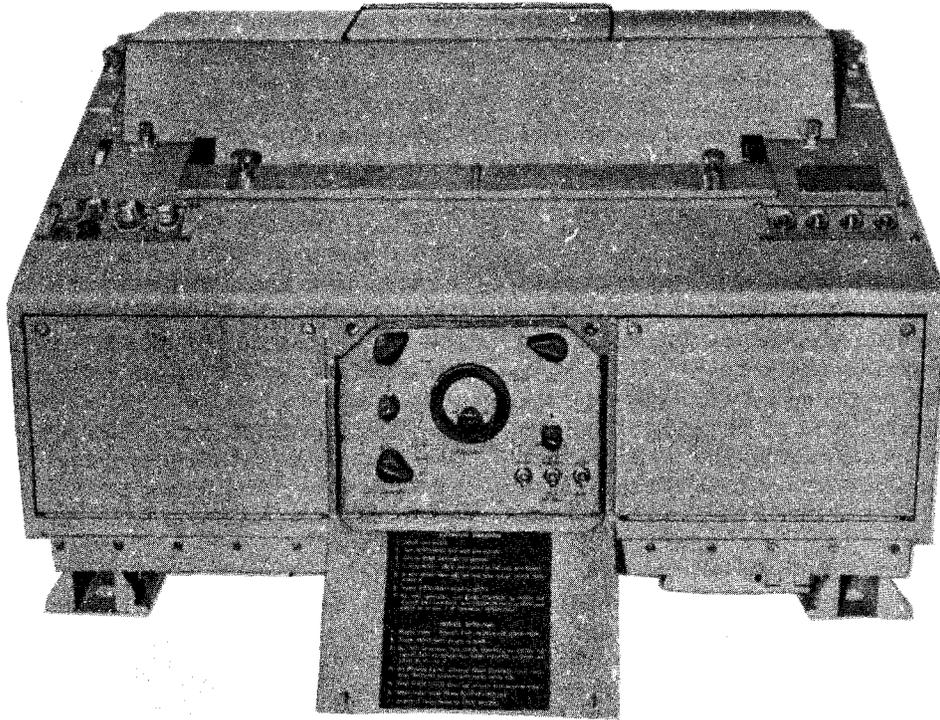


Figure 10-12.—Facsimile Recorder Set AN/UXH-2B.

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designed to make direct recordings of weather maps, tactical graphic information, sketches, typewritten, printed or handwritten data, transmitted over land lines or radio.

When receiving from a transmitter which sends the proper control signals, the recorder set will operate automatically. A control signal from the transmitter will start the recording and paper feed mechanisms. On receipt of phasing signals, the recorder unit will position the stylus needles so that the edge of the recorded copy is properly related to the edge of the paper. When copy signals are received, the stylus needles will print as the paper advances, the density of the recording being automatically adjusted to the desired level by the control circuits of the recorder. When the stop signal is received, the stylus needles stop, and the paper ceases to advance. The copy is legible as soon as it is recorded.

The equipment is operated manually when the transmitting station is not able to transmit the necessary control signals. In manual operation the equipment is phased, the recording started

and stopped by means of controls on the front panel.

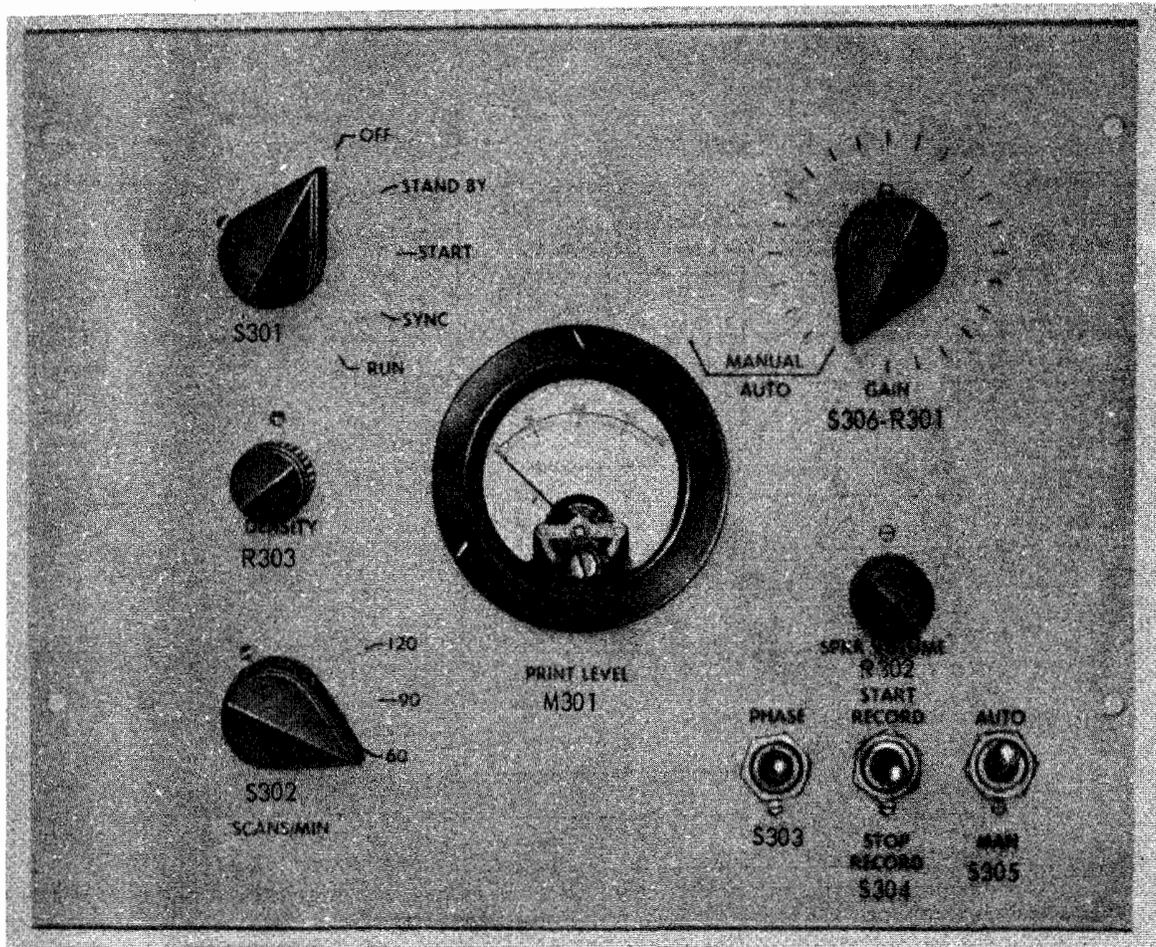
In either automatic or manual operation, the operator may use a front panel DENSITY control to adjust the density of the printing. The operating controls are accessible by lowering the door in the front center of the set. These controls and their functions are shown in figure 10-13.

MAJOR UNITS

The AN/UXH-2B consists of three major units. These units are Electrical Control Amplifier AM-4218A/UXH-2A, Facsimile Recorder R0-293/UXH-2B, and Power Supply PP-1901A/UXH-2 as shown in figure 10-14.

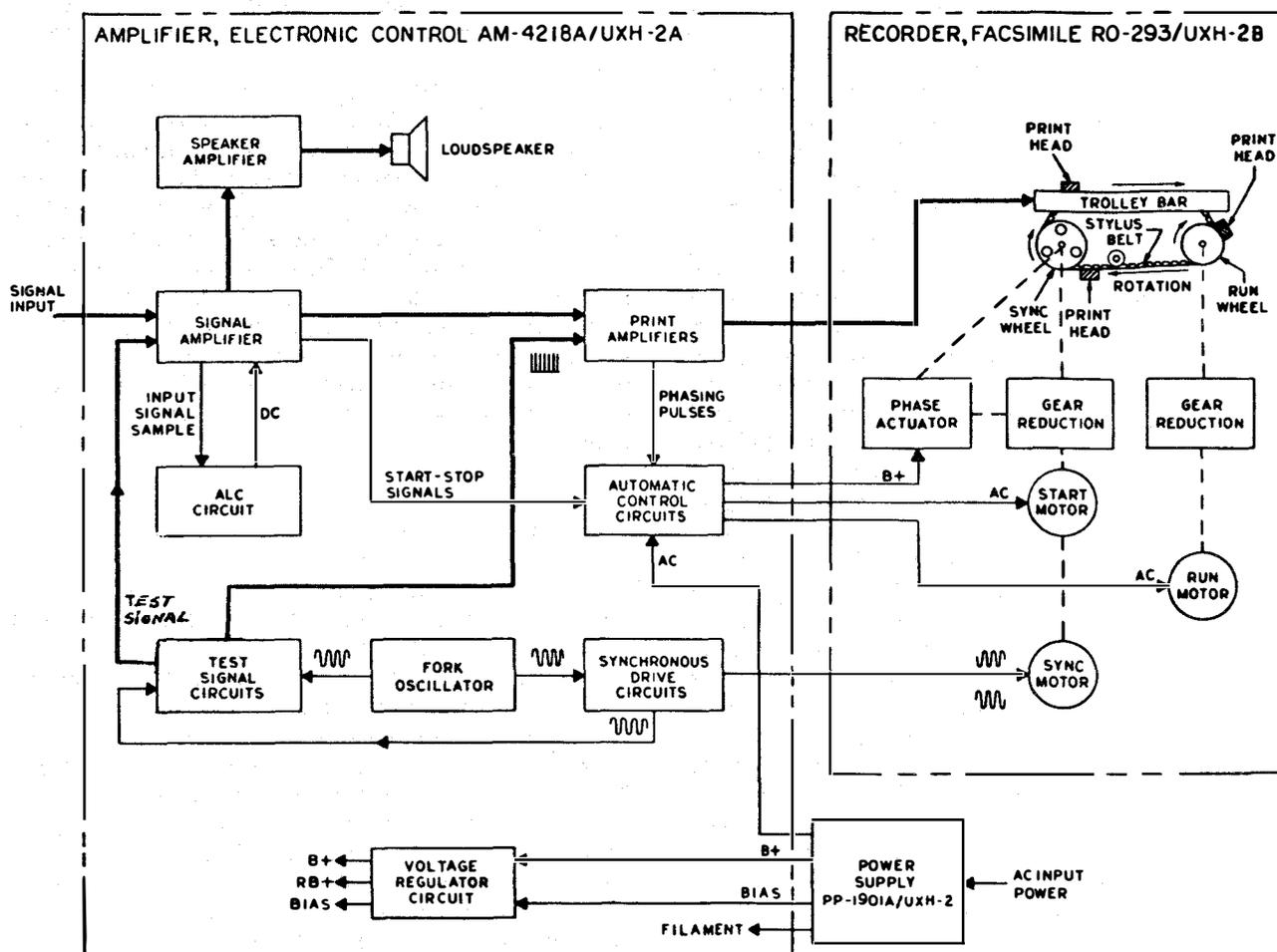
Electrical Control Amplifier

The incoming signal to the recorder appears across an input transformer in the signal amplifier. From the secondary the signal is fed through a GAIN control. If the GAIN control is



S301--IN THE OFF POSITION POWER IS REMOVED FROM ALL SECTIONS OF THE RECORDER EXCEPT THE AUXILIARY POWER OUTLET; IN STAND BY POSITION POWER IS APPLIED TO B+, TUBE HEATERS, AND BIAS CIRCUITS; IN START POSITION B+ IS REMOVED FROM THE PRINT AMPLIFIERS AND VOLTAGE IS APPLIED TO THE START MOTOR; IN SYNC POSITION POWER REMAINS APPLIED TO START MOTOR AND POWER IS APPLIED TO THE SYNC MOTOR; IN RUN POSITION POWER IS REMOVED FROM THE START MOTOR AND SYNC MOTOR LOCKS INTO SYNCHRONOUS SPEED. R303--VARIES THE D.C. VOLTAGE ON THE SCREENS OF THE PRINT AMPLIFIERS TO CONTROL THE RECORDING DENSITY. S302--SELECTS THE SPEED AT WHICH THE RECORDER OPERATES, MUST COINCIDE WITH THE SCAN RATE OF THE TRANSMITTER. M301--INDICATES SIGNAL LEVEL AT THE PRINT AMPLIFIERS. S306-R301--ADJUSTS THE INPUT SIGNAL LEVEL TO THE PRINT AMPLIFIERS WHEN USE OF THE ALC CIRCUIT IS IMPRACTICAL. R302--CONTROLS THE VOLUME OF THE MONITORING SIGNAL FROM THE LOUDSPEAKER. S303--RELEASES PHASING MAGNET WHEN PHASING SIGNALS ARE BEING RECEIVED. S304--USED TO START OR STOP THE RECORDING. S305--SELECTS EITHER MANUAL OR AUTOMATIC OPERATION.

Figure 10-13.—Facsimile Recorder Set AN/UXH-2B operating controls.



70.91(162A)

Figure 10-14.—Facsimile Recorder Set AN/UXH-2B overall block diagram.

in the AUTO position, the ALC circuit will control the bias on the signal amplifier stages so that the bias will follow the maximum amplitude (black) signal. If the MANUAL position is selected, a fixed bias voltage is applied to the amplifier stages, and the GAIN control is used to control the output signal from the signal amplifier. The speaker amplifier is connected directly to the secondary of the input transformer and is independent of the other circuits. It is used to monitor the incoming signal.

The print amplifier consists of a driver stage and a class B push-pull stage. A contrast potentiometer is used to control the bias on the grids of the push-pull stage so that the tubes are cut off with no driving signal. The signal must be strong enough to overcome this fixed bias before any print power is obtained. This

gives a threshold limiting effect, which eliminates the signal transmitted by the background of the original copy.

During automatic operation the SELECTOR switch is in the RUN position and the AUTO/MAN switch is in the AUTO position. With no signals applied the machine is in the STANDBY mode. An incoming AM, 300 Hz start signal switches the machine into the PHASING mode. Phasing pulses consisting of the carrier at a black level, interrupted once per second by a change to the white level, are transmitted for 15 seconds. These phasing pulses are amplified and fed to the phase actuator. After phasing is completed, the start-record signal (the carrier signal modulated with 60 Hz) causes power to be applied to the run motor, keeps the phase actuator energized, and applies plate voltage to the

push-pull stage of the print amplifier. At the end of the transmission, a stop signal (the carrier modulated with 450 Hz) is received and deenergizes the run motor and removes the plate voltage from the print amplifiers.

For manual operation the AUTO/MAN switch is placed in the MAN position, and the SELECTOR switch is in the RUN position. The machine is now in the STANDBY mode. When a phasing signal appears on the line, the operator activates the PHASE switch. The incoming phasing pulses are fed to the phase actuator. After three phasing pulses, the operator releases the PHASE switch. When the copy signals start, the operator momentarily moves switch S-304 to the START RECORD position. Power will be applied to the run motor, the phase actuator is kept energized, and plate voltage is applied to the print amplifier.

When the transmission is ended, the operator momentarily moves switch S-304 to the STOP RECORD position. Power is removed from the run motor, and plate voltage is removed from the print amplifier. An end-of-paper switch stops the recording mechanism and activates the END OF PAPER indicator when the supply of paper becomes exhausted. The 3600 Hz output of the tuning fork oscillator is applied to a locked oscillator which can be locked at 1200 Hz, 900 Hz, or 600 Hz depending upon the setting of the SCANS/MIN switch. The output of the locked oscillator is amplified and used to drive the sync motor. The speed of the sync motor is directly related to the input signal frequency. For example, for 90 scans/min, the input frequency to the motor is 900 Hz and the motor speed is 900 rpm.

Two test circuits are used in the AN/UXH-2B Recorder. One circuit simulates the control tone signals that would be sent by an automatic transmitter. A second circuit supplies a test signal to the print amplifiers for use during stylus indexing adjustments. The transmitter control signals are simulated by the use of four switches (located on the electrical unit chassis) marked STEADY, START, RECORD, and STOP. The carrier signal for the tests is the 3600 Hz output of the fork oscillator.

The start-stop test oscillator is tuned to either 300 or 450 Hz depending upon the test switch used. The 60 Hz start-record signal is obtained directly from the filament supply. The 3600 Hz carrier signal is not modulated when the STEADY button is pressed and is modulated by 300 Hz, 450 Hz, or 60 Hz when the START, STOP,

or RECORD buttons are pushed. The output of this test circuit is applied to the signal amplifier.

The CHOPPER test switch operates in conjunction with a relaxation oscillator to provide a test signal input to the print circuits. The input for the oscillator is obtained from the sync drive circuits. The input signal synchronizes the relaxation oscillator at the selected motor drive signal (600, 900, 1200 Hz). The output from the relaxation oscillator consists of a series of spikes that are fed to the print amplifier. These spikes correspond to a black signal from the transmitter and, when recorded, produce a series of black vertical lines on the recording paper.

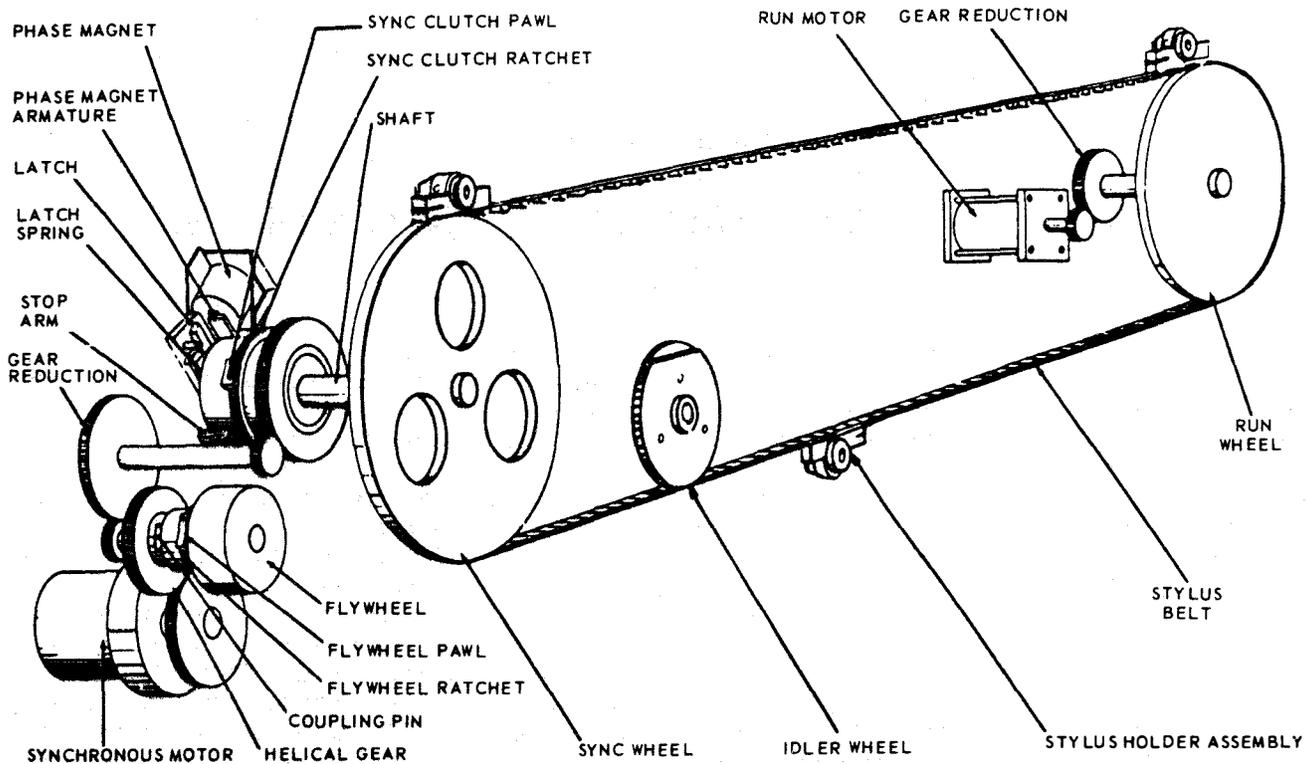
Facsimile Recorder

Recorder Facsimile RO-293/UXH-2B records by means of three stylus needles mounted on a rubber belt that is driven by two pulleys. As the pulleys rotate, the stylus needles (one at a time, at sync speed) move across the recording paper while the paper feeds from a roll in a direction perpendicular to the stylus movement. The two wheels in figure 10-15 serve as pulleys for the rubber stylus belt that conveys the stylus needles across the recording paper. The run wheel, which is geared to the run motor, drives the stylus belt assembly. Both the run and sync wheels have indentations which engage the teeth of the stylus belt, thus giving positive coupling between the run and sync wheels. In addition, an idler wheel, located between the sync and run wheels, maintains the stylus belt at the proper tension.

The mechanical unit consists of four functional sections: the sync mechanism, run mechanism, stylus belt assembly, and paper feed assembly.

The sync mechanism acts as a governor to control the speed of the stylus needles. It is coupled to the stylus belt through a unidirectional drive assembly, which allows the sync motor to rotate even when the stylus belt is stationary. The sync motor is not self-starting but is brought up to speed by a start motor the rotor of which is keyed to the sync shaft.

The run mechanism drives the belt above the synchronous speed, until it catches up with the unidirectional drive assembly in the sync mechanism. The stylus needles are then maintained at sync speed by the sync motor.



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Figure 10-15.—Synchronous drive and run system.

The stylus belt assembly consists of a rubber belt on which are mounted three electromagnetic print heads. The print head mounted on the moving stylus belt, rides on two trolley rails placed in front of the paper. These rails guide the print head to provide the proper line structure, space the print head in relation to the paper feed roller, and also act as conductors to supply power to the print head through inside contact wipers. The stylus needle, which is held in place in the print head by a retaining spring, consists of an iron plunger with a free-rolling carbide-tungsten ball mounted on its forward face. The stylus is free-floating and strikes the surface of the pressure sensitive recording paper, backed up by a steel feed roller, when the magnet is energized.

The paper feed assemblies hold the rolls of recording paper and feed the paper past the stylus needles. A gear train couples the paper feed assembly to the run motor to maintain the

proper relationship between the rate of paper feed and the stylus speed.

Power Supply

The power supply circuit consists of Power Supply PP-1901A/UXH-2 and the RB+ and bias voltage regulators contained in the electronic control amplifier unit. The power input voltage is 115 or 230 volts, 60 Hz, single phase. B+ voltage consists of unregulated 400 volts d.c. The bias supply circuits furnish -105 volts to the bias voltage regulator. The voltage regulator circuit in the electronic control amplifier unit provides regulated B+ voltage (RB+) of 225 volts d.c. and the four regulated bias voltages needed for the operation of the equipment. If the bias voltage supply should fail, the regulator circuit will reduce RB+ to a low value for the protection of the print and sync amplifier circuits.

CHAPTER 11

MAINTENANCE OF COMMUNICATION SYSTEMS, PART I

Maintenance of communication systems consists of performing the periodic tests, inspections, and other preventive maintenance procedures (as prescribed by the Planned Maintenance Subsystem) and the troubleshooting and repair of equipment. This chapter presents information relating to inspecting, cleaning, and lubricating communication equipment, and the maintenance of communication antennas. Also discussed are communication receiver sensitivity and bandwidth measurements, and teletype signal distortion measurements.

The next chapter, MAINTENANCE OF COMMUNICATION SYSTEMS, PART II, discusses troubleshooting communication systems.

INSPECTING, CLEANING, AND LUBRICATING

A regular schedule of inspection, cleaning, and lubricating must be carried out on a continuing basis to ensure trouble-free operation of communication and other types of electronic equipment. When making inspections, check for cleanliness of equipment and all areas around, behind, and under cabinets and consoles. Dust, dirt, and other foreign matter should not be tolerated.

Dirt and other foreign matter, if allowed to collect on heat dissipating parts, act as thermal insulation, which prevents internally created heat from dissipating into the air. When this happens, the electronic parts affected operate at abnormally high temperatures. This condition shortens the life of the parts and causes a breakdown of the equipment itself. Periodic cleaning of the interior of radio transmitters and other equipment using high voltage is particularly important. Potentials in excess of 3000 volts are often present in these equipments, and dust on insulators or other high voltage parts forms a convenient path for arc-overs. In addi-

tion, a mixture of dust and lubricant forms an abrasive which can do considerable damage to moving parts.

Periodic lubrication is required for most moving mechanical parts of electronic equipment. Failure to lubricate or improper lubrication (such as using the wrong type of lubricant or overlubricating) shortens the life of the moving parts or parts concerned and may cause damage to other parts or circuits. Lubrication must be performed as specified by the Maintenance Requirement Card (MRC) for the specific equipment concerned or by the equipment technical manual. An MRC for a communications antenna coupler group is shown in figures 11-1A and 11-1B.

PRECAUTIONS

Care must be exercised when cleaning electronics equipment to avoid damage to the equipment parts and injury to personnel. Steel wool or emery cloth must not be used for cleaning. When using a vacuum cleaner, use one with a nonmetallic nozzle. Use solvents for cleaning only when absolutely necessary. When using solvents (such as trichloroethane), the following precautions must be observed:

1. Use only in well ventilated spaces. A portable blower, wind chute, or wind scoop may be used to blow fresh air into the space.
2. Do not work alone when using solvents.
3. Do not use solvents around any open flame. Although the solvent may be nonflammable, a poisonous phosgene gas may be formed.
4. Do not apply solvents to hot equipment or parts as this increases the toxic effects of the solvent.
5. Do not breathe the vapor of any cleaning solvent for a prolonged period of time. A five minute break in an area free of the solvent fumes

| | | | |
|--|---|---------------------------|----------------------|
| SYSTEM Communication and Control | COMPONENT OA-4794,4794A/ SRA-34(V) Antenna Coupler Group | M. R. NUMBER C-344 A-1 | |
| SUB-SYSTEM Radio Communication | RELATED M. R. M-1 | RATES ET3 | M/H 1.0 |
| M. R. DESCRIPTION 1. Clean, inspect, and lubricate antenna coupler group. | | TOTAL M/H 1.0 | ELAPSED TIME: 1.0 |
| SAFETY PRECAUTIONS 1. Observe standard safety precautions. 2. Short across all capacitors to electrical ground, using a shorting probe. | | | |
| TOOLS, PARTS, MATERIALS, TEST EQUIPMENT 1. Vacuum cleaner with non-metallic nozzle 2. 1" Soft-bristle brush 3. Warning tag 4. Shorting probe 5. Clean, lint-free rag 6. Grease, MIL-G-7421 7. No. 2 Phillips screw- driver 8. 6" Normal duty screw- driver 9. Grease brush | | | |
| PROCEDURE 1. <u>Clean, Inspect, and Lubricate Antenna Coupler Group.</u> a. Set electrical equipment cabinet POWER switch at OFF. b. Turn OFF and tag main power distribution switch. c. Loosen captive screws on lower front panel and open panel. d. Short across all capacitors to electrical ground, using a shorting probe. e. Wipe accessible surfaces with a clean rag. f. Use brush to remove dust and dirt from areas not easily accessible. g. Remove remaining dust and dirt with a vacuum cleaner. h. Inspect interior of equipment. Look for bulged or leaking capacitors, discolored, or scorched resis- tors, cracked or frayed insulation, and loose con- nections. i. Close lower front panel and tighten captive screws. (Cont'd on Page 2) | | PAGE 1 OF 2 | 59 RQ12 |
| LOCATION | DATE 1 February 1969 | A | |

MAINTENANCE REQUIREMENTS CARD
OPNAV FORM 4700-1 (REV. 7 65)

98.176

Figure 11-1A.—MRC for antenna coupler
group (front).

| | | | |
|--|-------------|------------|---|
| Procedure (Cont'd) j. Remove coupler A2 from cabinet. (1) Loosen captive screws; push latch levers upward and slide chassis out to lock position. (2) Turn captive fasteners fully counterclockwise. (3) Pull chassis out and lift from cabinet slides. (4) Remove top dust cover. (5) Remove subassembly dust covers. k. Repeat steps l.d. through h. l. Reinstall dust covers. m. Apply a thin film of grease on cabinet slide rails with brush. n. Reinstall coupler in cabinet; tighten captive screws. o. Repeat steps l.j. through n. for couplers A3, A4, and A5. p. Return equipment to normal condition. q. Perform MR M-1. | PAGE 2 OF 2 | 59 RQ12 | A |
|--|-------------|------------|---|

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Figure 11-1B.—MRC for antenna coupler
group (back).

is recommended every fifteen minutes. One hour per day is considered maximum exposure for one man.

6. Wear rubber gloves to avoid coming into direct contact with the solvent.

7. Do not spray solvents on electrical windings or insulation. (Ultrasonic cleaning with solvents and detergent solutions is described in the EIMB General Maintenance Handbook, NAVSHIPS 0967-000-0160.)

CLEANING AIR FILTERS

Cleaning air filters is exceedingly important for the proper operation of electronic equipment. Air filters are sometimes neglected or disregarded until excessive heating causes a breakdown of the equipment.

Forced air cooling is used in most modern transmitters and receivers. This type of cooling system moves a large volume of air over the hot portions of the equipment. The air is filtered to keep dust and other foreign particles out of the equipment. If the filters are efficient, they remove most of this foreign material from the air that passes through them. Dust and dirt tend to clog the filter and prevent the air from moving through. The result is that the equipment becomes overheated and may be ruined.

Some air filters are designed to be installed with a film of oil on the filter element. Filters of this type provide effective filtration with a minimum reduction of air flow. When this type of filter is used without an oil coating, the filter effectiveness is greatly reduced. The major disadvantage of the oiled filter is in cleaning. They may be cleaned by washing the filter element in a standard shipboard dishwashing machine. Many ships have a special room designated as the filter cleaning room. This room is used by all divisions for cleaning filters according to a weekly schedule.

RECEIVER SENSITIVITY MEASUREMENTS

Communications receivers are composed of a series of selective RF and AF circuits, each stage of which is designed to amplify the output of the preceding stage. The lowered efficiency of any one tube or transistor, or a change in any one circuit parameter, usually results in lowered overall efficiency of the receiver. The one measurement that provides maximum information about receiver condition in field operation is the sensitivity measurement.

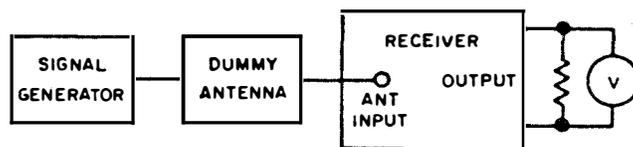
The sensitivity of a radio receiver is an indication of its ability to give a satisfactory output with a weak signal input. Although there may be some variation in the exact wording of the definition, sensitivity is the value of input carrier voltage (in microvolts) that must be applied from the signal generator to the receiver input to develop a specified output power at a specified signal-to-noise (signal-plus-noise to noise) ratio. The settings of the various controls are specified as well as the modulation frequency and percentage of modulation.

In many Navy receivers, sensitivity is the magnitude of signal voltage (in microvolts) that must be fed to the receiver antenna terminals in order to produce a signal-to-noise ratio of 10 db at 6 mw across a 600-ohm noninductive resistance substituted for the headphones or other device at the receiver output terminals.

This measurement ordinarily requires that the signal generator be connected to the antenna terminals of the receiver through an impedance, which approximates that of the antenna with which the receiver is to be used. This impedance is known as a DUMMY antenna. The dummy antenna (fig. 11-2) ensures that the signal current in the input circuit of the receiver is the same as would appear with the calibrated signal voltage induced in an ideal receiving antenna. It also ensures that the input circuit of the receiver is "loaded" the same as it would be by an ideal antenna.

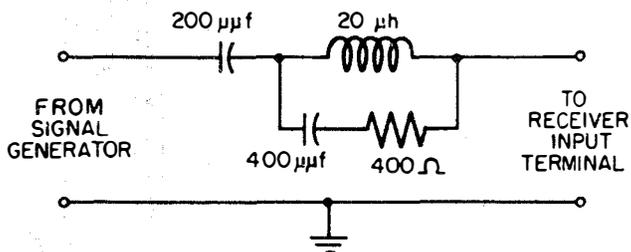
A dummy antenna that may be used with high-impedance input receivers is shown in figure 11-3. In the case of low-impedance, a signal generator with a 50-ohm output may be directly connected without the use of an external dummy antenna. Other generator impedances may require special dummy-antenna networks to load the generator and the receiver properly.

A typical sensitivity measuring procedure for A-3 reception is as follows: a 400 Hz carrier modulated 30 percent is applied to the dummy antenna. The RF gain control is set at maximum



162.204

Figure 11-2.—Equipment arrangement for measuring radio receiver sensitivity.



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Figure 11-3.—Dummy antenna circuit.

with AGC on and the BFO off. Both the input signal level and the AF gain control are progressively adjusted until the receiver output noise level is 0.6 milliwatt (0.6 volt across 600 ohms) with the signal generator modulation OFF, and the signal plus noise output is 6 milliwatts (1.9 volts across 600 ohms) with the signal generator modulation ON. This produces a signal-plus-noise to noise ratio of +10 db. The receiver sensitivity, in terms of input voltage, is then read from the signal generator voltage calibration.

High-impedance headphones may be used in shunt with the load for monitoring the output. Low-impedance headphones would load the output appreciably. The output voltage is measured with a high-impedance audio voltmeter capable of accurate indication from 0 to 10 volts. Although some receivers are equipped with audio output meters, their meters may not indicate the required standard noise levels with sufficient accuracy.

Detailed instructions for making sensitivity measurements are included on the MRC and in the equipment technical manual. An MRC for measuring the receiver sensitivity of Radio Set AN/URC-9 is shown in figures 11-4A and 11-4B.

SELECTIVITY AND BANDWIDTH MEASUREMENTS

Selectivity is the property which enables a receiver to discriminate against transmission other than the one to which it is tuned. It is usually expressed in the form of a curve obtained from a plot of the strength of a standard modulated-carrier signal that is required to produce a constant (standard) output, versus off-resonance frequency. Figure 11-5 shows a typical AM receiver selectivity curve with the carrier signal strength at resonance used as a reference.

The bandwidth of a receiver is usually used to define that portion of the selectivity curve that represents the frequency range over which the amplification is relatively constant. For most receivers, the bandwidth represents the usable portion of the curve, and has a direct relation to the fidelity of the modulated intelligence. Practically, the bandwidth is measured at the half-power (3-db-down) points, or, for certain applications, at the 6-db-down points. The bandwidth is represented by the frequency range between the two points on a response curve expressed as relative response in db versus frequency, as shown in figure 11-6. However, the bandwidth at the 3-db (or often the 6-db) points, when compared with the bandwidth at the 60-db-down points, gives a good indication of the selectivity of the receiver. In most receivers, the overall bandwidth is determined by the IF amplifiers; therefore, bandwidth is sometimes considered as, fundamentally, an IF characteristic measurement.

When making bandwidth measurements, the receiver AVC should be disabled (grounded), connected to a source of fixed bias, or turned off, and the volume control set to maximum. The signal generator is set at the receiver frequency, and, if applicable, modulated 30 percent at 400 Hz. The output of the generator is set to a value which will place the receiver well below the point of overload (no limiting action), and the receiver RF gain is adjusted for a convenient reference receiver-output voltage. The signal generator output is then increased by 3-db (1.4 times the voltage of the original setting) for measurement at 3-db-down points, or 6 db (2 times the voltage of the original setting) at the 6-db-down points. The generator frequency is then varied to one side of resonance until the receiver output gain indicates the reference level; the procedure is then repeated on the other side of resonance. The bandwidth is the total frequency displacement between the 3-db points (or 6-db-down points), whichever is applicable.

The MRC for measuring the receiver bandwidth for Radio Set AN/SRC-20 is shown in figures 11-7A and 11-7B.

ANTENNA MAINTENANCE

The worst enemies of shipboard antenna installations are salt spray and stack exhausts, which cause corrosion that eats into the antennas, mounting brackets, and associated hardware. They also cover the installations with salt and

| | | |
|--|------------------------------------|--|
| SYSTEM Communications and Data | COMPONENT AN/URC-9 Radio Set | M R NUMBER C-362 M-1 |
| SUB SYSTEM Communications Transceivers | RELATED M R None | RATES RM2 M H 0.8 |
| M R DESCRIPTION 1. Measure receiver sensitivity. | | TOTAL M/M ELAPSED TIME 0.8 0.8 |
| SAFETY PRECAUTIONS 1. Observe standard safety precautions. | | |
| TOOLS, PARTS, MATERIALS, TEST EQUIPMENT 1. Signal Generator, AN/URM-26B or equivalent 2. Electronic Voltmeter, AN/USM-143 or equivalent 3. Headset plug adapter, FSN 9N-5935-283-1235 4. 620-ohm 1-watt Resistor, FSN 9N-5905-279-2629 | | |
| PROCEDURE <u>Preliminary</u> a. Turn ON test equipment; allow a 15-minute warmup. b. Set radio set switches and controls: (1) POWER to POWER (2) CHAN SEL to MANUAL (3) MODE to NOR (4) SQUELCH to OFF (5) VOLUME fully counterclockwise (6) METER to S METER c. Disconnect antenna cable from ANT jack. d. Insert headset plug adapter in HEADSET jack. e. Set signal generator OUTPUT level control to zero. f. Use test cables to connect signal generator output, through 6db attenuator, to ANT jack. g. Connect resistor across voltmeter leads and insert leads in headset plug adapter. h. Set electronic voltmeter RANGE switch to 1. 1. <u>Measure Receiver Sensitivity.</u> a. Set radio set MANUAL FREQUENCY switches to 225.0 Mhz. | | PAGE 1 OF 2 40 BV30 M |
| LOCATION | DATE January 1970 | M |

MAINTENANCE REQUIREMENTS CARD
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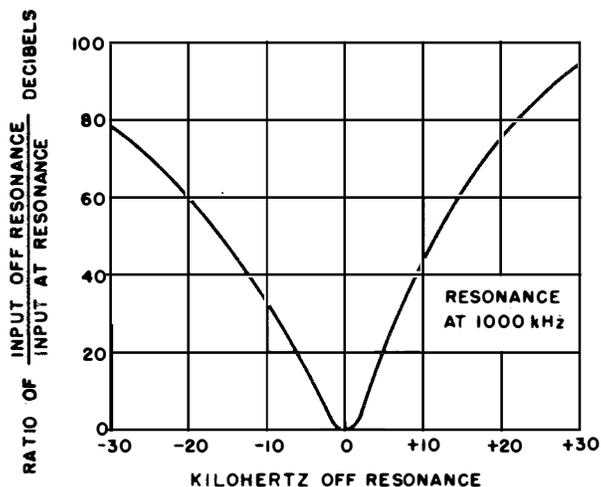
Figure 11-4A. —MRC for receiver sensitivity check (front).

| | |
|---|--|
| Procedure (Cont'd) b. Set signal generator controls for: (1) Frequency of 225.0 Mhz. (2) Modulation of 1000 Hz at 30 percent (3) Output level of 6 microvolts c. Adjust receiver VOLUME control for -8 db indication on voltmeter. d. Adjust signal generator frequency control for a peak indication on voltmeter. e. Adjust receiver VOLUME control for +2 db indication on voltmeter. f. Turn signal generator modulation to OFF. Meter indication should decrease 10 db or more. g. Repeat steps 1.a. through 1.f. for frequencies 312.0 and 399.9 Mhz. h. Disconnect test equipment. i. Reconnect antenna cable to ANT jack. j. Return equipment to desired condition. | PAGE 2 OF 2 40 BV30 M |
|---|--|

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Figure 11-4B. —MRC for receiver sensitivity check (back).



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Figure 11-5.—Selectivity curve.

soot deposits, which, if allowed to accumulate, may short the antennas to ground by providing a path for current flow across the insulators.

Careless painting is another cause of trouble in antenna systems. Paint with a metallic base is a good conductor of electricity, and if used on an insulator, it will short the antenna in the same manner as salt and soot deposits.

Antenna maintenance consists mainly of visual inspections for physical damage, cleaning insulators, making resistance tests for leakage resistance or insulation breakdown, and checking RF connections.

INSPECTIONS

Wire antennas should be lowered at frequent intervals and inspected for signs of deterioration, particularly at clamps, and where they connect to transmission lines. Avoid nicking or kinking the wire while inspecting as the wire will be weakened at these points.

It is a good policy to wire-brush antennas while they are down, as this removes soot and salt deposits as well as revealing any signs of weak or broken strands. (Insulated-type receiving antennas should be wiped rather than wire-brushed).

Whip-type antennas are usually hollow and have a tendency to collect moisture inside. A small hole is drilled near the base of metal antennas to permit moisture to drain out. Whip antennas usually can be inspected without being lowered. Look for corrosion spots and blisters,

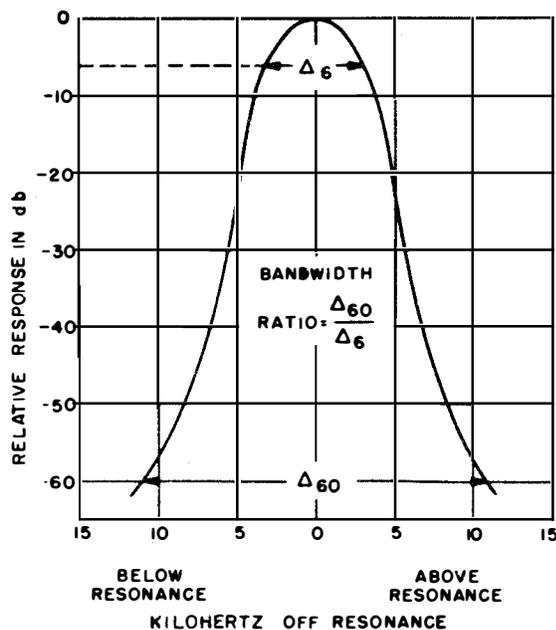
loose mounting bolts, and loose or frayed connections. As with wire antennas, check all insulators for chips, cracks, and cleanliness.

Any insulators on dipole antennas should be carefully cleaned of any paint, salt, or soot deposits. Care should be taken not to damage the glazed surfaces of the insulators. The mechanical condition of dipole antennas should be checked for loose mountings and rust spots.

Maintenance of VHF and UHF antennas is complicated by their inaccessibility. It is often necessary to climb masts or stacks to inspect them properly for damage. For this reason, they sometimes are neglected until a major casualty occurs. These antennas are as susceptible to rust, loose mountings, and broken connections as are other antennas, and must be inspected regularly. Many of the problems experienced in UHF communications can be traced to faulty antennas.

CLEANING INSULATORS

Antenna insulators have a glazed surface to which foreign material does not adhere readily, and which tends to wash clean during rain storms. Although helpful, you cannot depend upon an occasional rain to keep insulators free of salt spray, soot, and dirt. For this reason, insulators must be cleaned periodically. The time between



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Figure 11-6.—Receiver response curve.

| | | | |
|--|---------------------|---------------------------|-----|
| SYSTEM | COMPONENT | M/R NUMBER | |
| Communication and Control | AN/SRC-20 Radio Set | C-193 | S-1 |
| SUB SYSTEM | RELATED M/R | RATES | M/H |
| Radio Communication | None | RM2 | 0.6 |
| M/R DESCRIPTION | | TOTAL M/H ELAPSED TIME | |
| 1. Measure IF bandwidth. | | 0.6 0.6 | |
| SAFETY PRECAUTIONS | | | |
| 1. Observe standard safety precautions. | | | |
| TOOLS, PARTS, MATERIALS, TEST EQUIPMENT | | | |
| 1. Warning tag 2. 6" Normal duty screwdriver 3. Signal Generator AN/URM-25D, or equivalent 4. Electronic Counter AN/USM-207, or equivalent 5. Electronic Multimeter AN/USM-116C, or equivalent | | | |
| PROCEDURE | | PAGE 1 OF 2 | |
| 1. Measure IF Bandwidth. | | | |
| a. Turn OFF and tag main power switch. | | | |
| b. Disconnect antenna cable from ANT jack; loosen four retaining screws on receiver-transmitter unit. | | | |
| c. Turn extractor knob counterclockwise to limit of travel. | | | |
| d. Turn extractor knob clockwise three revolutions, stopping with slot horizontal. | | | |
| e. Disengage extractor by pushing extractor knob down. | | | |
| CAUTION: Support chassis while withdrawing it to prevent it from striking deck. | | | |
| f. Withdraw receiver-transmitter chassis from cabinet and place it on its left side. | | | |
| g. Connect receiver-transmitter maintenance cable, CX-7240/T, between receptacle inside of cabinet and receptacle on back of receiver-transmitter. | | 19 | |
| h. Turn ON signal generator and electronic multimeter; allow a 15-minute warmup. | | RM50 | |
| (Cont'd on Page 2) | | | |
| LOCATION | DATE | S | |
| | 1 Sept 1968 | | |

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Figure 11-7A.—MRC for measuring IF bandwidth (front).

| | |
|--|-------------|
| Procedure (Cont'd) | PAGE 2 OF 2 |
| 1. Adjust signal generator frequency to 3.5 MHz, CW mode, with zero output. | |
| j. Connect signal generator RF output to the orange test point (J-303) on right side of receiver-transmitter. | |
| k. Adjust electronic multimeter to measure -DC volts and connect it between yellow test point (J-504) on bottom side of receiver-transmitter and ground. | |
| l. Remove tag and turn ON main power switch. | |
| m. Turn ON radio set and set it to any frequency with TENTHS control at .5. | |
| n. Set SQUELCH control at OFF. | |
| o. Connect a test cable between signal generator open circuit jack and electronic counter signal input jack. | |
| p. Set signal generator carrier range switch to X 200K. | |
| q. Adjust signal generator frequency and output level until electronic counter indicates 3.5 MHz. Set signal generator carrier range switch to X MULT. | |
| r. Adjust signal generator output for a -0.5 volt indication on electronic multimeter. | |
| s. Note signal generator RF output. | |
| t. Adjust signal generator RF output level to twice the amount indicated in step l.a. | |
| u. Increase signal generator frequency until electronic multimeter again indicates -0.5 volts. | |
| v. Set signal generator carrier range switch to X 200K. | |
| w. Note electronic counter frequency. | |
| x. Set signal generator carrier range switch to X MULT. | |
| y. Decrease signal generator frequency below 3.5 MHz until electronic multimeter again indicates -0.5 volts. | |
| z. Set signal generator carrier range switch to X 200K. | |
| aa. Note electronic counter frequency. | |
| ab. Verify that difference between frequencies noted in step l.w. and aa. is at least 80 kHz. | |
| ac. Return equipment to normal condition. | |
| | 19 |
| | RM50 |
| | S |

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Figure 11-7B.—MRC for measuring IF bandwidth (back).

cleaning insulators is dependent upon the type of ship, the type of operations, and the area of operation.

To clean insulators use a sharp knife and a small amount of paint thinner to remove any paint that may be on the insulators. Use the sharp knife carefully to avoid nicking the insulator. NEVER USE STEEL WOOL, SAND PAPER OR OTHER ABRASIVES. Wash them with soap and water, and follow this with several rinsings with clean fresh water. The insulators then should be polished with a dry, soft cloth to restore their glaze.

RESISTANCE TESTS

The most common fault in an antenna system is low resistance to ground. Moisture in coaxial lines, dirty insulators, and breakdown of insulation all cause varying degrees of shunting resistance. These faults must be guarded against if maximum efficiency is to be maintained.

The megger is the test equipment commonly used for testing an antenna system. As discussed in Basic Electricity, NAVPERS 10086-B, the megger is a hand-driven d.c. generator and a megohmmeter combined. The megohmmeter measures the value of resistance through which the generated current flows. The output of the megger is approximately 500 volts. This voltage is sufficient to break down and reveal weak spots in the insulation if any exist.

Before testing an antenna, the antenna should be inspected for intentional d.c. shorts such as those in receiver protective devices. These protective devices, found in most general-purpose receiving antennas, usually consist of a fixed resistor of about 1/2 megohm connected from line to ground. This resistor protects the receiver by draining off any accumulated static charges on the antenna. To prevent a constant and misleading resistance reading from being obtained, the resistor must be disconnected before testing the antenna and transmission line.

After protective devices are disconnected from the antenna, proceed as follows:

1. Connect the ground lead of the megger to the hull of the ship.
2. Disconnect the transmission line at the equipment, and connect the high side (line connection) of the megger to the inner conductor of the transmission line.
3. Crank the handle of the megger until a steady reading is indicated on the megohmmeter.

For insulation resistance, the following values are suggested:

1. A resistance of 200 megohms or more to ground indicates an antenna in good condition.
2. A resistance of 5 to 100 megohms to ground indicates the need for cleaning the insulators.
3. A resistance of less than 5 megohms to ground indicates an excessive leak in the system. Immediate steps must be taken to locate the leak and restore the antenna system to its original condition.

The preceding values do not apply to VHF and UHF antenna systems that normally are short circuits to d.c. voltages.

Junction boxes usually hold a resistor that is used to drain off static electricity from antennas. The junction boxes should be opened and inspected at least every six months. The resistor should be measured and inspected to ascertain if it is in good condition. The connections within the box should be critically inspected to make sure they are all in good shape and well protected. The gasket on the box should be inspected and replaced if necessary, then the box well sealed and all bolts or screws installed and tightened down to prevent water or salt spray from entering the junction box.

While the junction box is open and the static drain resistor is out of the circuit, the coaxial line from the antenna patch should be checked for grounds and continuity from the radio central end of the cable. A reading in the high megohm range will show if the antenna and the center conductor of the coaxial cable are free from ground, but does not prove that junction boxes, connectors, and cables have continuity through them. Next, ground the antenna near its base and check with an ohmmeter for continuity to ground from the center conductor of that particular antenna outlet on the receiver antenna patch panel in radio central, or wherever the antenna appears inside the ship. The reading should not be more than 1 or 2 ohms. Then remove the short, and again megger for short to ground. If a high reading is not obtained, it is possible that the coaxial cable will have to be replaced.

When antennas are being meggered, remember that dry salt is an insulator, and the salt deposit will not become conductive until it becomes damp. For this reason, the antenna should be meggered early in the morning while the morning dew is still present.

Theoretically, any antenna transmissionline system should read infinity on the megger, but this is not always possible to obtain. Abrupt changes in the weather, high humidity, or other natural causes often result in low readings. It is safe to say that any antenna reading under 100 megohms to ground for several successive daily readings should be investigated. In many cases, insulation resistance may be raised by cleaning the insulators or couplings. The coaxial cable and other cables and fittings used to connect the equipment together should also be tested.

RF CONNECTIONS

Checking the antenna with a megger will show up dirty insulators and moisture problems but will give no indication of bad RF connections. As soon as a gap forms between any mechanical connection, oxidation forms a high resistance RF connection. In many cases, this connection is bad enough to be measured with an ohmmeter as a d.c. resistance. This oxidation is further worsened by stack gases and water.

If the bottom (lower) section of a whip antenna fitting in the socket above the insulator is at all loose in the socket, it is especially susceptible to the collection of water and stack residue. The large nut that tightens this connection (as well as those that tighten other RF connections) must be kept tight. Generally it is not possible to check the RF connections of any but the first section of a whip antenna without removing the whip. Shaking the whip vigorously will usually reveal any loose sections. If any loose sections are noted, the whip must be removed, disassembled, and cleaned. It is recommended that this be done at least every six months. All grounding straps should be checked at this time and repaired or replaced as necessary. In addition, the antenna should be treated for corrosion prevention as described in EIB 785 of 24 August 1970.

TELETYPE SIGNAL DISTORTION

Any deviation of a signal parameter (such as time, amplitude, or waveshape) from that of the ideal signal is called distortion. Distortion in teletype signals is due to various causes and is controlled by design and proper maintenance. The overall or total resultant distortion of signals for a given telegraph circuit is the combined effect of two principal types of distortion. These types are systematic and fortuitous.

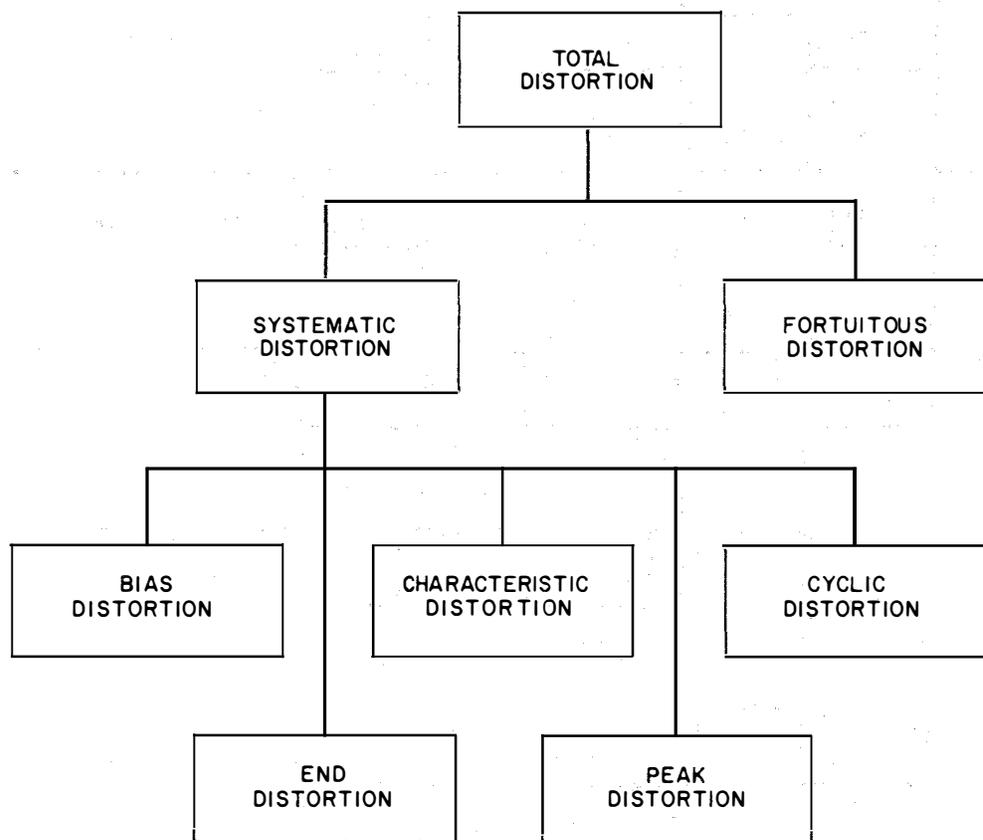
Assume that a given character is sent continuously over a telegraph circuit, and that each repetition of the character is considered perfect as sent. Measurements of the distortion of each of the unit marks (elements) in a large number of successive repetitions of the character at the receiving end will generally indicate that the distortion differs from element to element in a given repetition of the character, and from character to character for a particular element in the character. The average of a large number of distortions for a particular element is designated as systematic distortion. The individual departure of the distortion from the average of a given measured distortion is designated as fortuitous distortion. The total distortion of each signal element is the algebraic sum of the systematic and fortuitous distortions, and is the amount of deviation between the sent and received signals.

Systematic distortion may be subdivided into bias, end, characteristic, cyclic, and peak distortion, as shown in figure 11-8.

BIAS DISTORTION

Bias distortion is the uniform lengthening or shortening of the mark or space elements, one at the expense of the other (fig. 11-9, parts A, B, and C). The lengthening of the marking elements is called marking bias distortion, and the lengthening of the spacing elements is called spacing bias distortion. The degree of bias distortion is expressed as a percentage of the unit interval. In start-stop operation, bias appears as the displacement of the space-to-mark transitions with respect to the initial mark-to-space transition of the start element. These transitions are advanced (early) if the bias is marking, and delayed (late) if bias is spacing.

The nature of bias distortion is such that interchanging the functions of the two current values will change the sign of the systematic distortion, but not its magnitude. In a polar telegraph system, in which marks and spaces are sent by means of currents equal in magnitude but opposite in sign, systematic distortion may be caused by unequal voltages at the transmitting end. If the positive voltage is greater than the negative voltage, the circuit causes the marks to be lengthened when positive current is used for transmitting marks. Conversely, rearranging the system so that negative current is used for transmitting marks will cause the marks to be shortened proportionately. In systematic



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Figure 11-8.—Teletype signal distortion.

distortion, interchanging the functions of the two current values used changes the sign of the systematic distortion, but not its magnitude. The distortion is called bias because a lack of symmetry in the circuit is indicated.

Some of the more common causes of bias distortion are improperly adjusted relays, earth potential differences, leakage currents, unbalance of artificial line on repeaters, and unequal battery tap resistance or potentials.

END DISTORTION

In start-stop operation, end distortion is the shifting of the end of all marking pulses from their proper positions in relation to the beginning of the start pulse (fig. 11-9, parts D and E).

If the mark-to-space transitions are delayed, the effect is to lengthen the marking pulses and shorten all spacing pulses. This type of distortion is called marking-end distortion. If the mark-to-space transitions are advanced, the effect is to

shorten the marking pulses and lengthen all spacing pulses. This is called spacing-end distortion. It is an artificial sort of distortion, usually deliberately produced for maintenance purposes by a test signal generator.

CHARACTERISTIC DISTORTION

Characteristic distortion is the displacement of signal transitions resulting from the persistence of transients caused by preceding transitions.

This characteristic distortion results from various causes, which are usually different from those associated with bias distortion. Consider a telegraph system in which the sending battery potentials are equal and opposite in sign, and the marks and spaces are formed by corresponding currents, equal but opposite in sign. Also, owing to the characteristics of the given system, the current is slow in building up to the normal mark or space value. If the current does not have

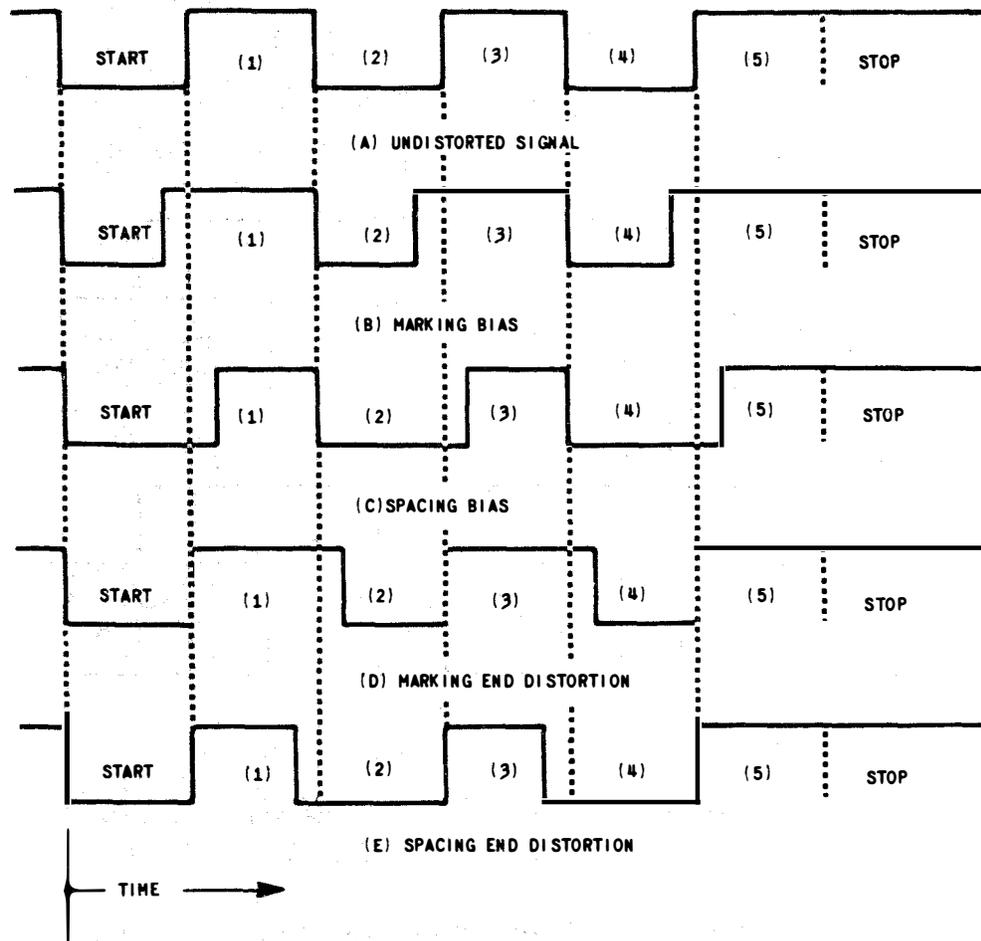


Figure 11-9.—Bias and end distortion.

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time to reach its final value on the short-signal elements, the first mark following a long space may be shortened.

In this case, interchanging the functions of the positive and negative currents will not alter the sign or the magnitude of the resulting distortion, since the first mark will be shortened whether it is formed by means of a positive or a negative current. This type of distortion is determined by the electrical, magnetic, and mechanical characteristics of the circuit, which are fixed by design.

CYCLIC DISTORTION

Cyclic distortion, which is neither characteristic, bias, nor fortuitous, is periodic in nature. It originates from some defective or

improperly adjusted device in the circuit, such as induction from power systems, cross talk from adjacent channels, and arcing of relay contacts at repeated intervals. Cyclic distortion values, when included with other distortion components, should not exceed the margin allowances required for the receiving teletypewriters. Cyclic distortion is illustrated in figure 11-10, parts A and B.

PEAK DISTORTION

Peak distortion defines the maximum displacement of signal train transitions occurring during a measuring period. It does not imply that all signals are distorted by this same maximum value. Peak distortion is illustrated in figure 11-10, part C.

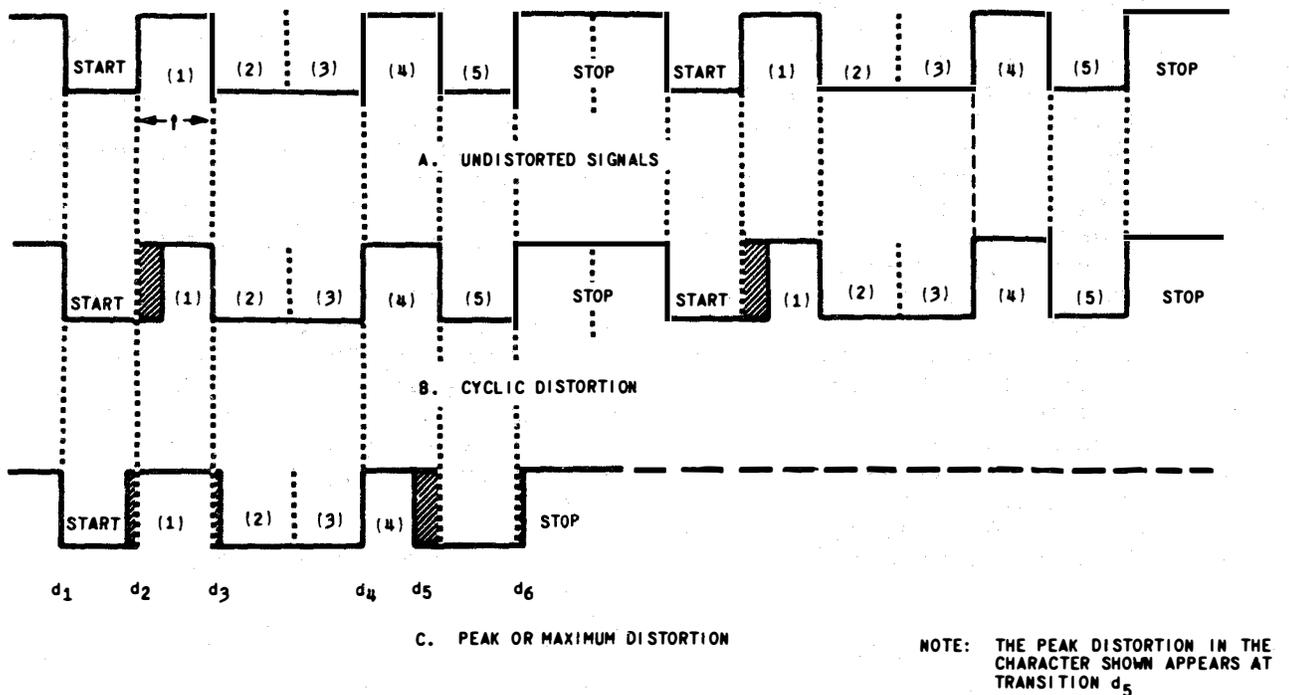


Figure 11-10.—Cyclic and peak distortion.

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FORTUITOUS DISTORTION

Fortuitous distortion is the individual departure of any one distortion from the average (systematic) distortion of a particular element in a large number of successive repetitions of a signal. It displaces miscellaneous received transitions by various amounts in an irregular manner, regardless of the signal combination. At times, it may be large enough to cause a complete failure of the circuit, or the addition of fortuitous distortion to the systematic distortion already in the circuit may result in an error in the received character. This type of distortion is common in high frequency radio circuits where disturbances in the transmission media cause irregular reception of signals. Other causes are accidental irregularities in the operation of the apparatus and moving parts, power induction, momentary battery fluctuations, and line disturbances (hits).

MEASURING DISTORTION

In teletype transmissions a certain amount of distortion can be present without the person at the receiving end being aware of it; that is, he receives good copy. The limits of the

teletypewriter to accept distorted signals and still produce the desired characters are called the "margin" of the teletypewriter.

Margin Measurements

The receiving unit of the teletypewriter machine is equipped with a mechanism whereby the selecting block may be moved throughout the unit segment. This mechanism is known as a "range finder" and is equipped with a scale graduated from 0 to 120. One hundred divisions on this scale represents a movement of the selecting block through a unit segment. This arrangement provides a means of measuring the distortion on received signals.

To measure the total net effect of all kinds of systematic distortion, or the position of received signals, the range finder is first moved in one direction until errors appear in the copy and then moved back slowly until these errors are just eliminated. Similarly, the range finder is moved the maximum distance before errors occur in the opposite direction. These two scale readings then give the operating margin of the signals under test. On perfect signals the margin would be from 10 to 90.

Table 11-1.—TS-2616/UGM controls and indicators

| PANEL IDENTIFICATION | DESCRIPTION | FUNCTION | | |
|---|--------------------------|--|---------------|---------------------------------|
| AC POWER | Toggle switch | Applies primary power to unit. | | |
| AC POWER | Indicator lamp, red | Lights when primary power is applied to unit. | | |
| 1/2 A (2) | Cartridge-type fuse | Fuse both sides of primary power line. | | |
| PERCENT DISTORTION | Meter | Indicates distortion of data signal under test in per cent of unit interval. | | |
| LOOP CURRENT | Meter | Indicates current magnitude, in milliamperes of high-level data signal under test. | | |
| INPUT SELECT | 6-position rotary switch | <u>Sw Pos</u> <u>Function</u> | | |
| | | NEUTRAL 20MA Adjusts input circuits to accept 20-milliamperere neutral signals. | | |
| | | NEUTRAL 60MA Adjusts input circuits to accept 60-milliamperere neutral signals. | | |
| | | POLAR 20/30 Adjusts input circuits to accept 20- or 30-milliamperere polar signals. | | |
| | | POLAR HI-Z Adjusts input circuits to accept high-impedance polar signals. | | |
| | | <u>Sw Pos</u> <u>Function</u> | | |
| | | POLAR LOW-LEVEL Adjusts input circuits to accept low-level polar signals. | | |
| | | SPEC Special input to be wired by user as required. | | |
| | | INPUT POLARITY | Toggle switch | Reverses sense of input signal. |
| | | INPUT FILTER | Toggle switch | <u>Sw Pos</u> <u>Function</u> |
| IN Inserts filter into input circuits to remove transients from input signal under test. | | | | |
| OUT Removes filter from input circuits. | | | | |

Table 11-1.—TS-2616/UGM controls and indicators—continued

| PANEL IDENTIFICATION | DESCRIPTION | FUNCTION | | | | | | | | | | | | | | | | |
|----------------------|--|---|---------------|-----------------|-----|--|------|--|------|--|---------------|-----------------|------------|--|------------|--|-----------|---|
| CODE LEVEL | 3-position rotary switch | Adjusts Analyzer circuits to accommodate input signals of either 5- or 8-element start-stop codes or synchronous signals | | | | | | | | | | | | | | | | |
| RATE BAUDS | 14-position rotary switch | Sets internal time-base generator to correspond to input signals of 37.5, 45.5, 50, 56.8, 61.1, 74.2, 75, 110, 150, 300, 600, 1200, or 2400 bauds. EXT OSC position permits use of external time-base signal (see EXT OSC below). | | | | | | | | | | | | | | | | |
| TRANSITION SELECT | 10-position rotary switch | Selects specific transition (of 1 through 9) to be analyzed or all transitions. | | | | | | | | | | | | | | | | |
| DISTORTION SELECT | 5-position rotary switch | <table border="0"> <thead> <tr> <th><u>Sw Pos</u></th> <th><u>Function</u></th> </tr> </thead> <tbody> <tr> <td>END</td> <td>Adjusts circuits to measure mark-to-space transition displacement.</td> </tr> <tr> <td>BIAS</td> <td>Adjusts circuits to measure space-to-mark transition displacement.</td> </tr> <tr> <td colspan="2"> </td> </tr> <tr> <th><u>Sw Pos</u></th> <th><u>Function</u></th> </tr> <tr> <td>TOTAL PEAK</td> <td>Adjusts circuits to record the maximum transition displacement that occurs during a measuring period (see PEAK RESET below).</td> </tr> <tr> <td>EARLY PEAK</td> <td>Adjusts circuits to record the maximum advanced transition displacement.</td> </tr> <tr> <td>LATE PEAK</td> <td>Adjusts circuits to record maximum delayed transition displacement.</td> </tr> </tbody> </table> | <u>Sw Pos</u> | <u>Function</u> | END | Adjusts circuits to measure mark-to-space transition displacement. | BIAS | Adjusts circuits to measure space-to-mark transition displacement. | | | <u>Sw Pos</u> | <u>Function</u> | TOTAL PEAK | Adjusts circuits to record the maximum transition displacement that occurs during a measuring period (see PEAK RESET below). | EARLY PEAK | Adjusts circuits to record the maximum advanced transition displacement. | LATE PEAK | Adjusts circuits to record maximum delayed transition displacement. |
| <u>Sw Pos</u> | <u>Function</u> | | | | | | | | | | | | | | | | | |
| END | Adjusts circuits to measure mark-to-space transition displacement. | | | | | | | | | | | | | | | | | |
| BIAS | Adjusts circuits to measure space-to-mark transition displacement. | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| <u>Sw Pos</u> | <u>Function</u> | | | | | | | | | | | | | | | | | |
| TOTAL PEAK | Adjusts circuits to record the maximum transition displacement that occurs during a measuring period (see PEAK RESET below). | | | | | | | | | | | | | | | | | |
| EARLY PEAK | Adjusts circuits to record the maximum advanced transition displacement. | | | | | | | | | | | | | | | | | |
| LATE PEAK | Adjusts circuits to record maximum delayed transition displacement. | | | | | | | | | | | | | | | | | |
| PEAK RESET | 3-position toggle switch, nonlocking at MAN position | When set to AUTO, peak distortion readings (above) are reset to zero every five seconds. When momentarily set to MAN, peak readings are reset to zero. | | | | | | | | | | | | | | | | |
| TRANSITION MARKERS | 2-position toggle switch | When set to IN, inserts timing markers (at ideal transition points) into data signal available at SCOPE SIG connector. | | | | | | | | | | | | | | | | |

Table 11-1.—TS-2616/UGM controls and indicators—continued

| PANEL IDENTIFICATION | DESCRIPTION | FUNCTION |
|----------------------|-----------------------|--|
| SCOPE SIG | Connector | Provides output signal to display signal under test on an external oscilloscope. |
| SCOPE GRD | Connector | Provides ground connection for external oscilloscope. |
| SCOPE SYNC | Connector | Provides sync connection for external oscilloscope. |
| EXT OSC | Connector | Provides connection for external time base signal (see RATE BAUDS, above). |
| LO-Z | Jack | Provides connection for low-impedance signal to be analyzed. |
| HI-Z | Jack | Provides connection for high-impedance signal to be analyzed. |
| MARKING | Indicator lamp, white | Lights when bias distortion component is advanced or when end distortion component is delayed. |
| SPACING | Indicator lamp, white | Lights when bias distortion component is delayed or when end distortion component is advanced. |
| SIG IND-M | Indicator lamp, white | Lights when input signal is at mark.* |
| SIG IND-S | Indicator lamp, white | Lights when input signal is at space.* |

*Steady mark or space causes corresponding lamp to glow brightly. Data signal conditions cause both lamps to glow dimly. Relative brightness of lamps indicates the ratio of marks and spaces in signal.

1. Connect 20-, 30-, or 60-milliamperere signal to LO-Z jack. Externally adjust signal current rate for correct indication on LOOP CURRENT meter.
2. Connect low-level or high-impedance signal to HI-Z jack.

Place signal under test in the steady marking condition. SIG IND-M lamp should light. If not, reverse position of INPUT POLARITY switch. Return signal under test to its normal signaling mode.

Set DISTORTION SELECT switch to the name of the component of distortion to be measured. When the switch is set to:

1. END (not used when measuring synchronous signals), the PERCENT DISTORTION meter indicates the average distortion of all mark-to-space transitions. When the MARKING lamp lights, the distortion is late. When the SPACING lamp lights, the distortion is early.
2. BIAS, the PERCENT DISTORTION meter indicates the average distortion of all space to mark transitions. When the MARKING lamp lights, the distortion is early. When the SPACING lamp lights, the distortion is late.
3. TOTAL PEAK, the PERCENT DISTORTION meter indicates the largest distortion that occurs during a given measuring period.

NOTE: With the PEAK RESET switch set to OFF, the measuring period extends until the PEAK RESET switch is momentarily set to MAN, which resets the reading to zero. With the PEAK RESET switch set to AUTO, the reading is reset automatically every five seconds.

4. EARLY PEAK, same as TOTAL PEAK except only early transitions are measured.
5. LATE PEAK, same as TOTAL PEAK except only late transitions are measured.

For start-stop signals under test set the TRANSITION SELECT switch to positions 1 through 9 for each setting of the DISTORTION SELECT switch. Positions 1 through 9 correspond to the 9 transitions between the start element and stop element of 8-level code signals (positions 7 through 9 do not apply for 5-level code signals). The PERCENT DISTORTION meter indicates the end, bias, total, early, or late peak distortion of the selected transition.

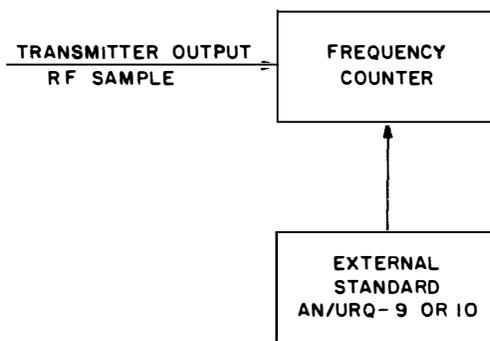
To stop the test set, turn the AC POWER switch to OFF.

FREQUENCY ACCURACY REQUIREMENTS

Determining the correct frequency Navywide is accomplished by the U.S. Naval Observatory. This correct frequency is provided to ships from Reference Oscillators (secondary standards) AN/URQ-9 and AN/URQ-10. (The AN/URQ-10 is discussed in chapter 4.) The Secondary Standards AN/URQ-9 and AN/URQ-10 are calibrated by laboratory (primary) standards periodically. WWV does not provide ships the capability of determining the correct frequency to the tolerance required by modern communication systems. The secondary standard oscillator is the only method available at present to determine the correct alignment of the equipment internal oscillators.

Equipment technical manuals assign a figure specifying the frequency stability of an equipment but this does not guarantee the the equipment's frequency accuracy. The frequency stability of an equipment only indicates the limit as to how quickly the oscillator will drift off frequency. Frequent checks of internal oscillators with the secondary standard will keep frequency errors to a minimum. Figure 11-12 shows a typical test setup for transmitter frequency output calibration.

Frequency Standards AN/URQ-9 and AN/URQ-10 are installed in a system for use as a central frequency reference rather than for use as a piece of test equipment. The basic frequency standard system (fig. 11-13) uses RF Amplifier AM-2123/U for isolation and distribution of the 0.1, 1, and 5 MHz frequencies generated by the secondary standard. This RF amplifier must be used when more than one transmitter or receiver is to be connected to the frequency standard. The



162.200
Figure 11-12.—Transmitter frequency check.

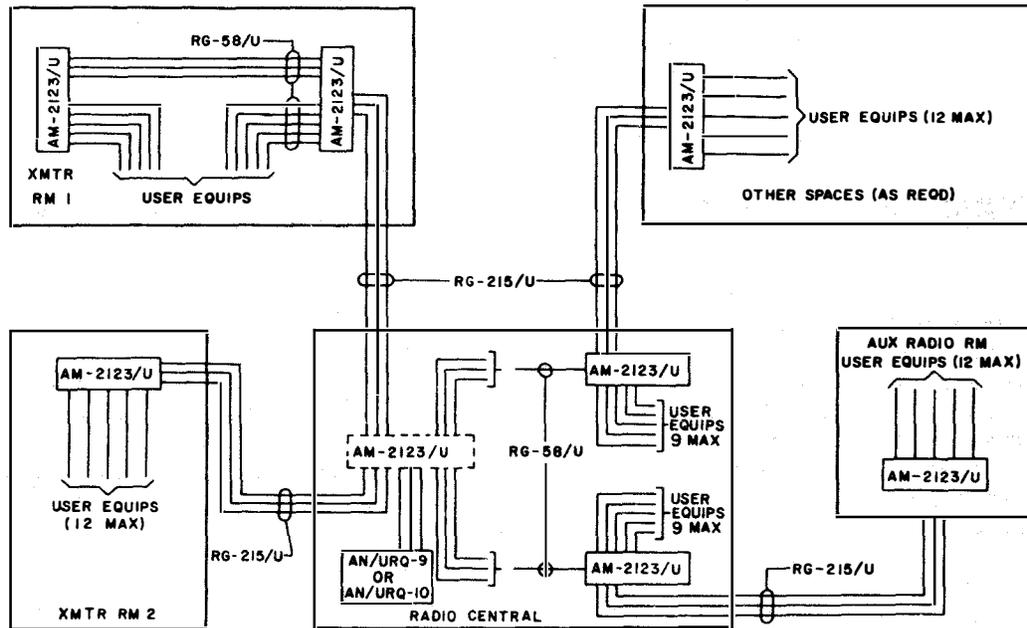


Figure 11-13.—Frequency standard distribution diagram.

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AM-2123/U) accepts the three input frequencies from the frequency standard and provides 12 isolated outputs in any combination of the three input frequencies.

Where there is no installed central frequency reference system, the equipment internal oscillators must be calibrated periodically against an external frequency standard such as a portable AN/URQ-10. When calibrating an equipment in-

ternal oscillator with the AN/URQ-9 or 10 it is essential that the frequency standard be previously energized for an extended period. (Not less than two weeks is preferred).

The procedures for aligning equipment internal oscillators using secondary standards vary depending upon the equipment concerned. These procedures are included in the equipment technical manual.

CHAPTER 12

MAINTENANCE OF COMMUNICATION SYSTEMS, PART II

Most shipboard communications equipment operates at one time or another in some type of system or systems. Thus it is just as important for the ET to know how to perform maintenance at the system level as on the individual equipment. Shipboard communication systems vary from simple to very complex, depending upon the type ship and circuit operation involved. Each requires the integrated use of various types of equipment as shown in figure 12-1 (foldin end of chapter).

To locate and correct troubles in a given system, the technician must know how the different types of communication systems are set up for compatible operation. This knowledge can be gained by studying the system blueprints and diagrams, and working with the operating personnel. This chapter discusses the six-step troubleshooting procedure as applied to systems. Also discussed are some of the typical troubles encountered in shipboard communication systems.

SIX-STEP TROUBLESHOOTING PROCEDURE

The most effective preventive maintenance program will not totally eliminate troubles during system operation. When a system trouble occurs, an experienced operator may have the trouble localized to a piece of prime equipment such as a set or unit before the technician arrives. This will not always be the case, however. Therefore, the technician must be able to systematically isolate the trouble.

The six-step troubleshooting procedure (discussed in Basic Electronics, Vol. 1, NAVPERS 10087-C) is as effective for isolating the cause of a system malfunction as it is for localizing trouble in a prime equipment.

STEP 1

The first troubleshooting step, for locating the problem in a malfunctioning system, is the recognition of a trouble symptom. This may or may not be an easy task depending on the nature of the problem. Disrupted or seriously degraded system performance is obvious and will usually be reported by the operator.

Occasionally, the first trouble symptom will be of a nonrepetitive nature and, while noted by the operator, cannot be duplicated and observed later by the technician. Therefore, when responding to a reported problem, the technician should find out if the operator originally noted any symptoms that are no longer present.

Other, less disruptive, problems may not exhibit readily apparent trouble symptoms during normal operation of a system. The disclosure of such a problem is usually the result of close observations made during the application of readiness tests or at the time the system is initially set up.

Unless the problem has already been localized when the technician arrives, his first step is to establish the nature of the malfunction as concerns the overall operation of the given system. This is normally accomplished at the operator position by correlating the complaint reported with the trouble symptom that may be observed first-hand, such as disrupted or degraded transmission or reception.

STEP 2

In step 2, the technician should attempt to further localize the problem area by looking for other indications, both abnormal and normal, that tend to elaborate on the trouble symptom noted in Step 1. The determination of which indications would be the most beneficial, and how and where they can be observed, depends

upon the nature of the problem, the type of system involved, and the installed arrangement of the equipment actually being used.

STEP 3

Equipped with the information obtained in steps 1 and 2, the technician is able to proceed into Step 3 and, through a process of elimination, make an educated guess as to those equipments that are possibly at fault. To accomplish this, the technician must know how the system operates and the functional relationship of the equipments involved. Based on this knowledge, the technician will find that the nature of the problem will normally allow certain equipments to be logically eliminated as possible sources of trouble. Additional equipments may also be eliminated by observing their front panel indications.

STEP 4

The fourth step requires that the problem area be further localized to only one of the equipments determined to be possibly at fault in step 3. If, in completing step 3, the problem is already localized to only one equipment, step 4 may be omitted. On the other hand, if more than one equipment are logically suspected, it will be necessary to determine which one is actually faulty in this step.

There are no hard and fast rules for determining which of several possible faulty equipments should be tested (or verified) first. For the most part, such a determination is usually based on which equipment is the most probable suspect and/or the least difficult to perform the necessary test on.

After selecting the order in which the tests are to be performed, the technician proceeds to verify the actual status of the suspected equipments. Normally, only a suspected output and/or given input is checked using test points obtained from appropriate technical references.

STEP 5

In step 5, the technician should perform whatever tests are appropriate to systematically isolate the defective circuit stage within the equipment that has been determined to be malfunctioning. The number of checks required to isolate the defective stage depends primarily on the complexity of the equipment involved.

Several systematic checks would undoubtedly be required in order to isolate the defective circuit in fairly complex equipment, such as a receiver or teletype converter. When a piece of multi-unit prime equipment, such as a transmitter, is involved, it may even be necessary to initiate a separate six-step procedure in order to isolate the problem to an internal circuit stage. When a simple unit (such as Control Unit C-1004A/SG, fig. 12-1) is involved, only a couple of checks may be required to isolate (or verify) the defective circuit.

STEP 6

In the sixth and final step, the technician proceeds to systematically isolate and replace the defective part that is causing the identified circuit to malfunction. This is normally accomplished through a logical application of voltage and/or resistance measurements. The exact determination of what checks would be the most effective, in a given situation, depends on the type of circuit involved.

A failure analysis should be conducted, as a part of step 6, as soon as the defective part has been isolated. This is very important as the isolated part may not be the cause of the original problem, in any way, or it may have a companion defect in a cause and effect situation. If neither of these conditions exist, a short study of the failure will logically prove the defect to be both singular in nature and accountable for every observed symptom of the system malfunction. Such an analysis when conducted properly, allows the technician to determine whether correcting the isolated defect will, in fact, enable the system to be restored to full operation.

SYSTEM TROUBLES

The following paragraphs list some typical troubles encountered in shipboard communication systems, and discuss the troubleshooting procedures required to isolate and correct these troubles.

TROUBLE # 1

This trouble occurs after a brief loss of all a.c. power to radio central. After the restoration of power, the following equipment (fig. 12-1) is found to be inoperative: (1) all R-1051/URR Receivers (2) the AN/WRC-1 Transmitter-Receiver, and (3) the AN/SRR-19A Receiver.

Assuming that the Radioman had not performed any steps to localize the trouble, you would immediately attempt to obtain more information concerning the trouble symptoms (step 2 of the six-step procedure). Proceeding with this step, you find that all receiver dial lights are normal, but the receivers have no outputs other than receiver noise. This information leads you to suspect two units that may be faulty (step 3). These units are Frequency Standard AN/URQ-10 and Distribution Amplifier AM-2123/U. The receivers are switched to the internal frequency standards and operation is normal. This confirms that either the AN/URQ-10 or the AM-2123/U is faulty.

Both the AN/URQ-10 and the AM-2123/U have front panel controls and indicators. Therefore, the faulty unit may be localized (step 4) in this case without the use of test equipment. All front panel indications on the AN/URQ-10 are found to be normal. (The AN/URQ-10 front panel controls and indicators are shown in figure 4-7 in chapter 4.) Observing the AM-2123/U front panel (fig. 12-2), you note that the AC ONLY light is lit. You then rotate the METER FUNCTION switch through all positions. Normal meter readings are obtained in the AC and DC POWER INPUTS positions. The meter reads zero in all other positions. Thus the trouble is localized to the AM-2123/U.

To localize the trouble to a specific circuit in the AM-2123/U (step 5) requires the use of

a VTVM and the equipment technical manual. (At this point, it is recommended that you review that part of chapter 2 that discusses the use of the SIMM equipment manual Maintenance Dependency Chart.)

Referring to the Maintenance Dependency Chart (MDC) shown in figure 12-3 (foldin end of chapter), you can assume (due to the meter readings obtained, and the fact that the AC ONLY light is lit) the following:

1. 115 volts a.c. is available across terminals A-C on P1 (extreme left, fig. 12-4 foldin end of chapter)
2. From 22 to 30 volts d.c. is available across terminals A-B on P2
3. Filter subassembly N-FL-1 and a.c. fuses F1 and F2 are good
4. 115 volts a.c. is available across terminals 1 and 2 of transformer T1
5. Assembly C-PS-1 is good, and approximately 12 volts a.c. is available from the positive side of C1 to terminal 4 of T1
6. Resistor R6, filter subassembly N-FL-2, and d.c. fuse F3 are good
7. From 22 to 30 volts d.c. is available from the positive side of C1 to the B terminal on P2, and resistor R7 is good

Proceeding to step 1C on the MDC (fig. 12-3), you remove a.c. fuse F1, and with a VTVM set up to read d.c. volts, you read 24 volts d.c.

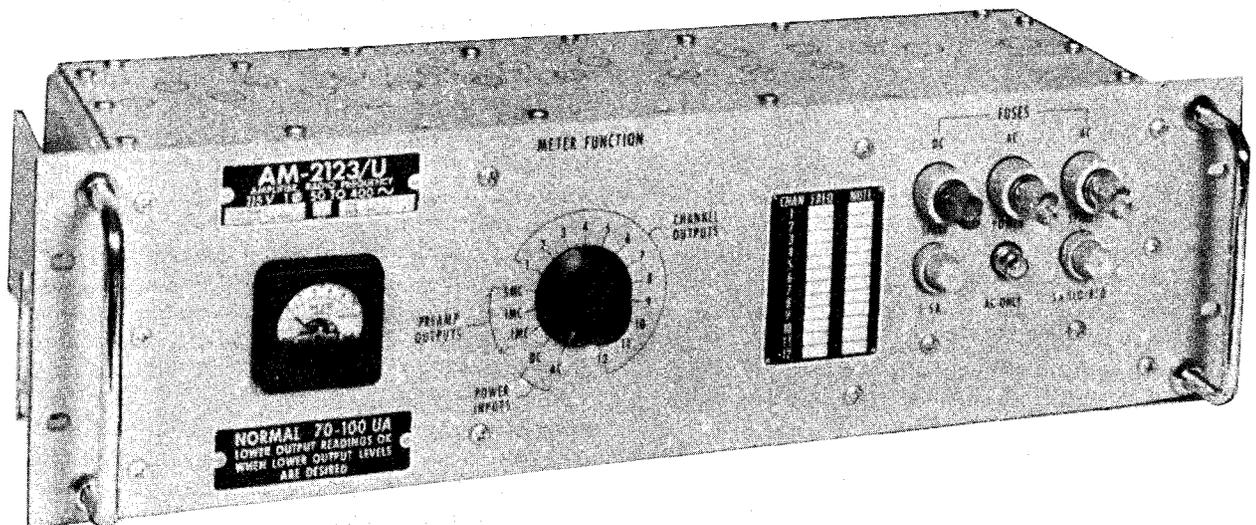


Figure 12-2.—RF Distribution Amplifier AM-2123/U.

across capacitor C1. This tells you that filter subassembly N-FL-4 is good. You then take a d.c. voltage reading from the positive side of C1 to terminal K on J16 (top left corner of fig. 12-4). At this point you get no reading on the VTVM. This is an abnormal reading. The reading at this point should have been 20 volts d.c. as shown by signal specification #7 on the MDC. You can now conclude that the trouble is in either the C-REG-2 (No. 2 regulator) circuit or the N-FL-5 filter circuit.

The trouble may be localized to one circuit by taking resistance readings with the VTVM. Before doing this, however, you must secure all power to the unit and discharge the capacitors. With the VTVM set up to read resistance, you determine that neither capacitor C4 or C12 is shorted. This localizes the trouble to the No. 2 regulator circuit.

In isolating the faulty part in the No. 2 regulator circuit (step 6), you must observe the precautions for testing transistors as discussed in chapter 2 of this manual. In the test of series regulator transistor Q1, you get an infinity ohmmeter reading in both directions from the emitter to base and collector to base. This indicates that Q1 is bad (open). After determining that this is the only trouble in the circuit, you replace Q1 and test the unit.

Recall that in localizing the trouble to the faulty circuit, filter subassembly N-FL-5 was tested first. This was because N-FL-5 included only two parts (C4 and C12). An experienced technician, however, may have tested the series regulator Q1 first without eliminating N-FL-5.

TROUBLE #2

The special sea and anchor detail has been set for leaving port. The OOD reports he is unable to raise the tugs on the UHF frequencies. The RM watch supervisor patches a different AN/URC-9 to the remote control unit (C-1138B/UR) on the bridge, but the OOD is still unable to raise the tugs. The RM then switches his remote to the AN/URC-9 and calls the tugs. The tugs reply, "hear you loud and clear." You are called by the watch supervisor to correct the trouble.

Upon arrival, you are informed of the action taken by the RM watch supervisor to establish communications. In addition, you are told that the "carrier on" light on the bridge remote control unit lit when the handset push-to-talk button was depressed; however, there was no transmitter sidetone present when speaking into the mi-

crophone. In this case, the RM gained enough information concerning the trouble symptom (step 2) before your arrival to enable you to immediately list the probable faulty functions (step 3).

You assume that the radio set is not faulty because patching a different set did not establish communications. The fact that communications were established by switching another remote to the AN/URC-9 causes you to suspect either the bridge remote unit or the handset as being faulty. (Remote Unit C-1138/UR is shown in figure 5-13 in chapter 5.)

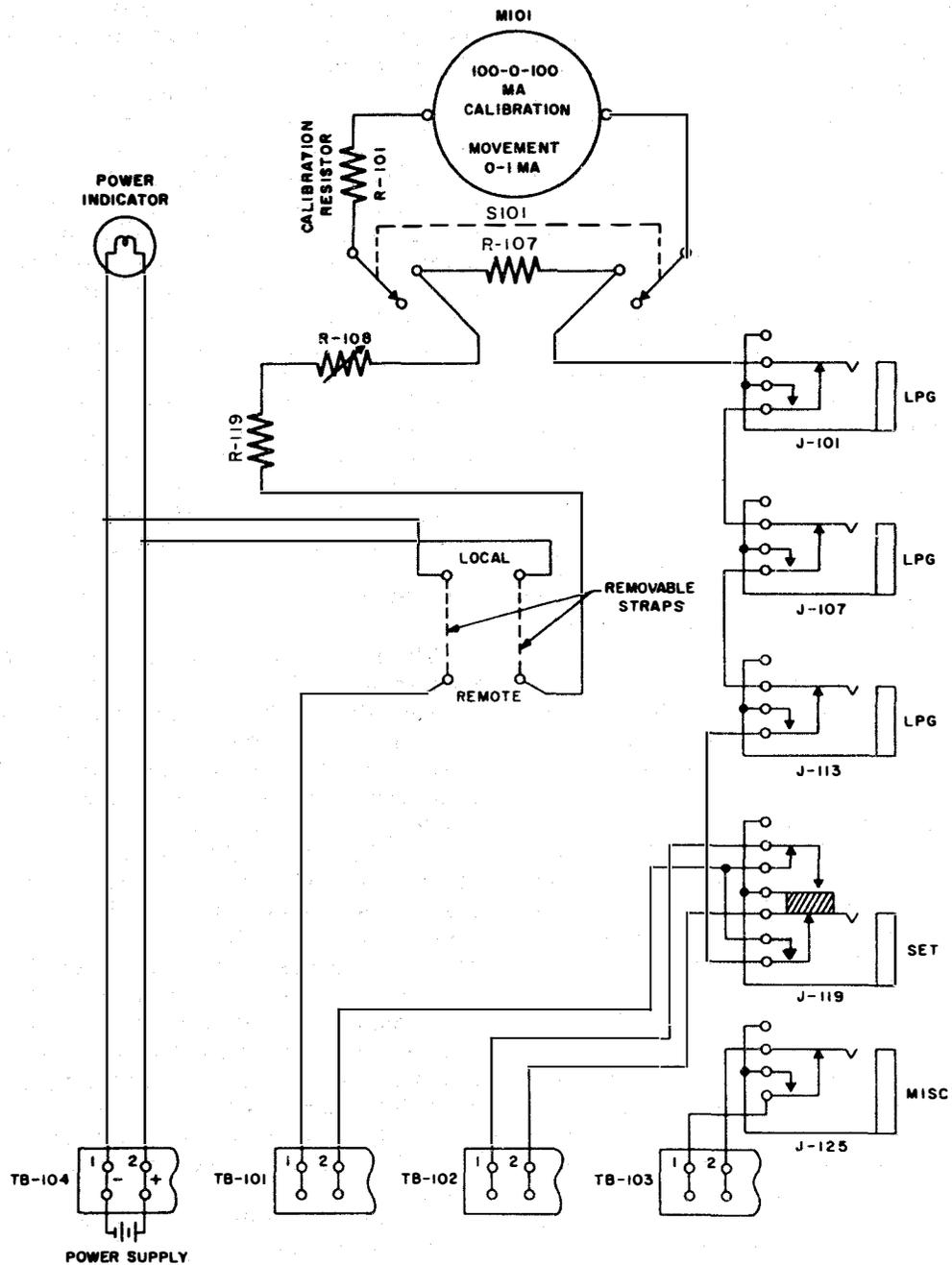
At this point, you jack a test handset into the bridge remote unit and have the RM switch the AN/URC-9 back to the bridge remote. The circuit now tests satisfactory, and the trouble is therefore localized to the handset. You test the faulty handset and find an open microphone wire. You make the repair, reinstall the handset in the bridge remote and test the circuit.

TROUBLE # 3

The RM watch supervisor reports that he has trouble with AN/URA-17 #2. You are called to correct the trouble. Upon arrival, you are told that the RM attempted to use AN/URA-17 #2 (fig. 12-1) to establish the receive side of an FSK send-receive circuit but was unable to get any loop current from it.

To elaborate on the trouble symptom, you place the AN/URA-17 function switch in the TUNE position and check for loop current at the Communication Patching Panel SB-1203A/UG. The meter reads zero. Turning the loop control potentiometer to the maximum CCW (minimum current) position produces approximately 1 ma of loop current. In the maximum CW (maximum current) position, the meter pegs. You immediately turn the control CCW to unpeg the meter. The meter reads zero at any position between the maximum and minimum current positions. This tells you that the loop control potentiometer for this loop is probably open.

To isolate the faulty part, you open up the front panel of the SB-1203A/UG and make a visual inspection. The loop control potentiometer appears normal, however, an open in this type of potentiometer is rarely visible. Troubleshooting communication patching panels must be done, in many instances, with the d.c. power supply on. The loop to be tested may be deenergized by removing the local-remote removable straps for that loop. **WARNING: TO REMOVE THESE STRAPS WITH THE D.C. POWER ON YOU MUST**



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Figure 12-5.—SB-1203/UG single channel simplified schematic.

OBSERVE THE PRECAUTIONS FOR WORKING ON ENERGIZED CIRCUITS AS STATED IN CHAPTER 2 OF BASIC ELECTRONICS, VOL. 1, NAVPERS 10087-C.

Figure 12-5 is a schematic diagram of a single channel of the SB-1203A/UG. The other

five channels are identical. In this case, the AN/URA-17 #2 is connected to terminals 1 and 2 of TB-101, and the potentiometer believed to be open is R-108.

To test R-108 and the other parts associated with the loop, the removable straps (fig. 12-5)

must be unsoldered and removed. To do this with the d.c. power supply on, you must use a nongrounded type soldering iron. As the negative side of the power supply is grounded (and some of the equipment connected to the panel is grounded), touching the removable straps with a grounded soldering iron will either blow the power supply fuses or draw a heavy arc.

You remove the removable straps (observing all safety precautions for working on energized circuits as stated previously) and test R-108 with an ohmmeter. Potentiometer R-108 reads open. After testing the other parts in the loop to ensure that R-108 is the only trouble, you replace R-108 with a spare. You then replace the removable straps (again observing the proper safety precautions) and test the circuit.

TROUBLE # 4

The AN/SGC-1A, TTY # 2, and AN/URC-9 # 4, (fig. 12-1) are being set up for use in the UHF tone-shift send-receive configuration. Calling the net control station does not result in a reply. You are called to correct the trouble.

You depress the "letters" key on the teletype machine and observe the transmit and receive lights on the front panel of the AN/SGC-1A. The receive light stays on. You shift the AN/SGC-1A to transmit manually. The receive light now goes out, and the transmit light lights. This tells you that the AN/SGC-1A is not shifting from receive to transmit automatically.

At the receiver Transfer Switchboard SB-973/SRR you patch the AN/URC-9 # 4 output to a speaker, and the receiver noise is extremely loud. This high noise level locks the AN/SGC-1A in receive. The receiver noise indicates that the receiver squelch control is improperly set, and the high volume indicates that the receiver output volume level is set too high. You reset these controls to correct the trouble.

TROUBLE # 5

You are serving aboard a carrier using an AN/SRC-21 UHF System. There are 20 transceivers and five AN/SRA-33 Multicouplers. Sixteen of the transceivers are controlled by Facilities Control (Radio Central), and four are controlled by Carrier Air Traffic Control Center (CATCC). During normal operations, Facilities

Control reports that transceiver #1 will not receive on channel # 5. You are called to correct the trouble.

Upon reporting to Facilities Control, you get permission to make a radio check. Calling the other station on channel # 5 results in no reply. You then get permission from Facilities Control to use transceiver # 10 for a radio check. Using transceiver # 10, you dial channel # 5 and request a radio check from the other station. They reply that they have been receiving you "loud and clear." You request them to change to channel # 7 and stand by for a check. Dialing channel # 7 on transceiver #1, you obtain a "loud and clear" radio check from the other station. You now return control of transceiver # 10 to Facilities Control and proceed to the UHF radio space.

Upon arrival at the UHF radio space, you turn the LOCAL-REMOTE switch on the C-3866/SRC associated with transceiver #1 to LOCAL and dial channel # 5. You disable the squelch by depressing the CALL LIGHT/SQUELCH DISABLE switch on the RT-581/URC-9. (This switch is located above the middle handle on the RT-581/URC-9, shown in figure 6-42 in chapter 6.) You then turn the LOCAL-REMOTE switch on the RT-581/URC-9 to LOCAL and obtain a "loud and clear" radio check.

After switching the LOCAL-REMOTE switch on the RT-581/URC-9 back to REMOTE, you open the squelch control access drawer and set the squelch control potentiometer for channel # 5 to the maximum CCW position. Turning the volume control to maximum produces a barely audible noise, which is normal. Noting that the CALL LIGHT on the RT-581/URC-9 is on, you rotate the channel # 5 squelch potentiometer CW until the CALL-LIGHT barely goes out and stays out. You now call the other station on channel # 5 from a remote position and they report receiving you "loud and clear."

While transmitting on channel #5 with transceiver # 1, you note that the coupler (AN/SRA-33) for transceiver # 3 is reading a high SWR. (The AN/SRA-33 is shown in figure 6-23 in chapter 6.) Checking the channel on transceiver # 3, you find that it is on channel # 9. At this point, you suspect that channel # 5 and channel # 9 must be very close in frequency. Checking transceivers # 1 and # 3, you find that transceiver # 1 is on 320.5 MHz and transceiver # 3 is on 316.7 MHz. Realizing that these two channels are closer in frequency than the 10

MHZ allowed on the AN/SRA-33 multicoupler, you detune transceiver # 1 and call Facilities Control. Facilities Control informs you that transceiver # 3 is controlled by CATCC.

Although the AN/SRC-21 System has channel lockout, it does not have frequency lockout. Thus, equipment damage can result from tuning

frequencies within 10 MHz into the same AN/SRA-33. Because of this, you hold a training session with the controllers from Facilities Control and CATCC. As a result of this session, CATCC submits a frequency plan to Facilities Control, and Facilities Control provides a copy of an accurate overall UHF plan to CATCC.

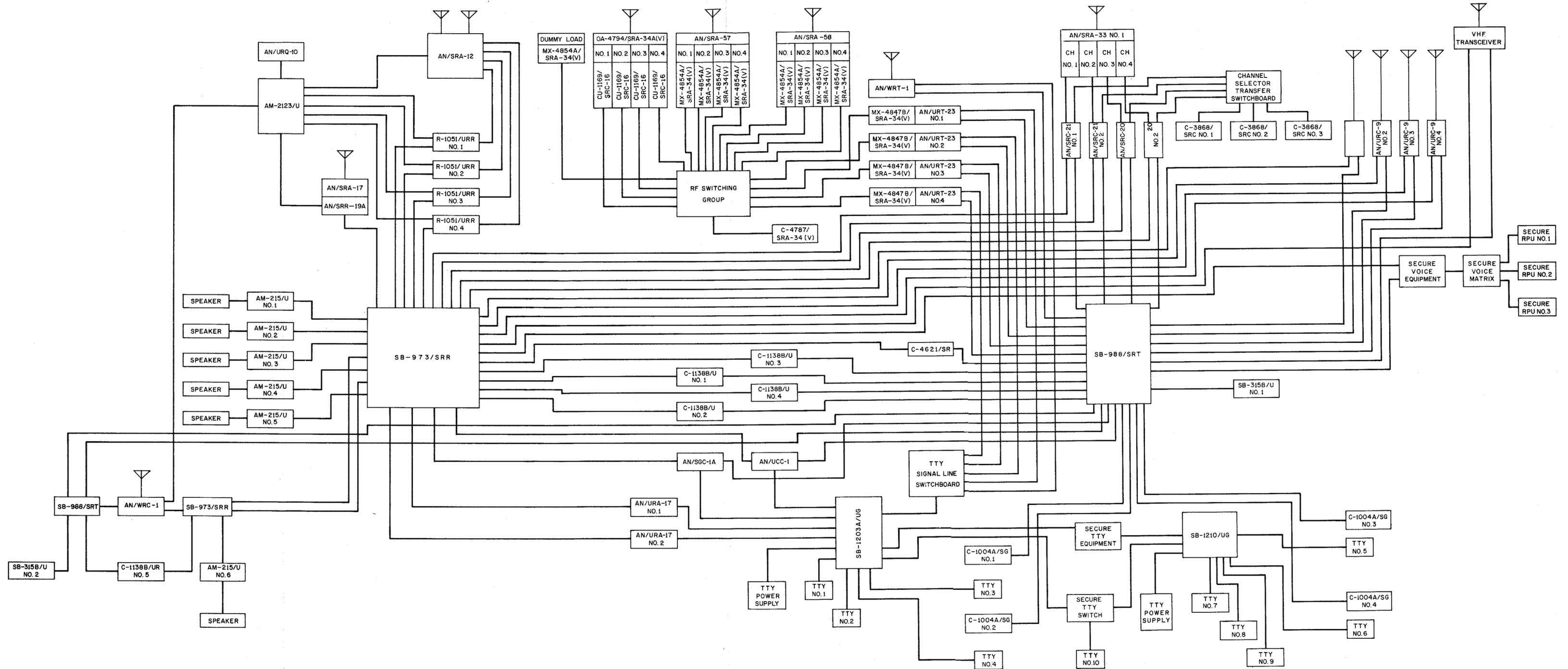


Figure 12-1.—Communication system.

APPENDIX I

THE JOINT ELECTRONICS TYPE DESIGNATION SYSTEM

TABLE OF EQUIPMENT INDICATORS

| INSTALLATION | | |
|--------------|------------------------------|--|
| A | Piloted aircraft | S Water |
| B | Underwater mobile, submarine | T Transportable (ground) |
| | | U General utility |
| D | Pilotless carrier | V Vehicular (ground) |
| F | Fixed ground | W Water surface and underwater comb. |
| G | General ground use | Z Piloted-pilotless airborne vehicle combination |
| K | Amphibious | |
| M | Mobile (ground) | |
| P | Portable | |

| TYPE | | |
|------|--|------------------------------------|
| A | Invisible light, heat radiation | N Sound in air |
| | | P Radar |
| C | Carrier | Q Sonar and underwater sound |
| D | Radiac | R Radio |
| G | Telegraph or teletype | S Special or combinations of types |
| I | Interphone and public address | T Telephone (wire) |
| J | Electromechanical or inertial wire covered | V Visual and visible light |
| K | Telemetry | W Armament |
| L | Countermeasures | X Facsimile or television |
| M | Meteorological | Y Data Processing |

| PURPOSE | | |
|---------|--|--|
| B | Bombing | N Navigational aids |
| C | Communications | Q Special or combination of purposes |
| D | Direction finder, reconnaissance and/or surveillance | R Receiving, passive detecting |
| E | Ejection and/or release | S Detecting and/or range and bearing, search |
| G | Fire control or searchlight directing | T Transmitting |
| H | Recording and/or reproducing | W Automatic flight or remote control |
| K | Computing | X Identification and recognition |
| M | Maintenance and/or test assemblies | |

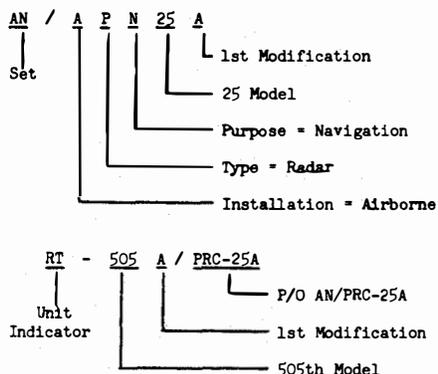
MISCELLANEOUS IDENTIFICATIONS THAT MAY BE P/O A TYPE DESIGNATION

- X, Y, Z---Changes in voltage, phase or frequency e.g., AN/VRC-51X
- T-----Training e.g., AN/APQ-13-T1, AN/APQ-T1
- (V)-----Equipments having a variable complement e.g., AN/FRC-39(V), OA-7667(V)/FYQ-41(V)
- (P)-----Unit accepting plug-ins e.g., R-1329(P)/GRC-103(V)
- (X)-----Developmental indicators e.g., AN/PRC-10(X--), RT-505(X--)/PRC-10
- ()-----Developmental or series "generic" assignment e.g., AN/PRC-10(), RT-505()/PRC-10
- (-ft-in)-Identical items w/varying lengths e.g., CX-1076/U(-ft-in)

TABLE OF GROUP INDICATORS

| Group Ind. | Family Name | Example of use (Not to be construed as limiting the application of the group indicator) |
|------------|---|---|
| OA | Miscellaneous groups----- | Groups not otherwise classified |
| OB | Multiplexer and/or demultiplexer groups---- | Multiplexer groups, demultiplexer groups, composites thereof |
| OD | Indicator groups----- | All types |
| OE | Antenna groups----- | All types |
| OF | Adapter groups----- | All types |
| OG | Amplifier groups----- | All types |
| OH | Simulator groups----- | All types |
| OJ | Consoles and console groups----- | All types |
| OK | Control groups----- | All types |
| OL | Data analysis and data processing groups----- | All types |
| OM | Modulator and/or demodulator groups----- | Modulator groups, demodulator groups, composites thereof |
| ON | Interconnecting groups--- | All types |
| OP | Power supply groups----- | All types |
| OQ | Test set groups----- | All types |
| OR | Receiver groups----- | All types |
| OT | Transmitter groups----- | All types |
| OU | Converter groups----- | All types |
| OV | Generator groups----- | All types |
| OW | Terminal groups----- | All types |
| OX | Coder, decoder, interrogator, transponder groups----- | All types |
| OY | Radar Set groups----- | Do not use if a more specific indicator, such as OE, OR, OT applies |
| OZ | Radio Set groups----- | Do not use if a more specific indicator, such as OE, OR, OT applies |

EXAMPLES OF ASSIGNMENTS



This chart was prepared by the U. S. Army Electronics Command, Administrator of the Joint Electronics Type Designation System. This chart supersedes all previous issues.

22 JUNE 1971 (See Latest Issue of MIL-STD-196 for Details)

TABLE OF UNIT INDICATORS

| Unit Ind. | Family Name | Example of use (not to be construed as limiting the application of the unit indicator) | Unit Ind. | Family Name | Example of use (not to be construed as limiting the application of the unit indicator) |
|-----------|--|--|-----------|---|---|
| AB | Supports, antenna----- | Antenna mounts, mast bases, mast sections, towers | MU | Memory units----- | Memory units |
| AM | Amplifiers----- | Power, audio, interphone, RF, video, electronic control | O | Oscillators----- | Master freq, blocking, multivibrators (for test oscillators, see SG) |
| AS | Antennas, simple and complex | Arrays, parabolic, masthead, whip, dipole, reflector | OS | Oscilloscope, test----- | Test oscilloscope for general test purposes |
| BA | Battery, primary type---- | B batteries, battery packs | PL | Plug-in units----- | Plug-in unit not otherwise classified |
| BB | Battery, secondary type-- | Storage batteries, battery packs | PP | Power supplies----- | Nonrotating machine type such as vibrator pack, rectifier, thermoelectric |
| BZ | Alarm units----- | All types | PT | Mapping and plotting units----- | Electronic types only |
| C | Controls----- | Control box, remote tuning control | PU | Power equipments----- | Rotating power equip, motor generator, dynamotors |
| *CG | Cable assemblies, RF----- | RF cables, waveguides, transmission lines, terminals | R | Receivers----- | Receivers, all types except telephone |
| CM | Comparators----- | Compares two or more input signals | RD | Recorder-reproducer----- | Sound, graphic, tape, wire, film, disc, facsimile, magnetic, mechanical |
| CN | Compensators----- | Electrical and/or mechanical compensating, regulating or attenuating apparatus | RE | Relay assembly units----- | Electrical, electronic |
| CP | Computers----- | Mechanical and/or electronic mathematical calculating devices | RL | Reeling machine----- | Mechanism for dispensing and rewinding antenna or field wire, cable |
| CU | Couplers----- | Impedance coupling devices, directional couplers | RO | Recorders----- | Sound, graphic, tape, wire, film, disc, facsimile, magnetic, mechanical and card punch |
| CV | Converters(electronic)--- | Electronic apparatus for changing the phase, freq, or from "one" medium to "another" | RP | Reproducers----- | Sound, graphic, tape, wire, film, disc, facsimile, magnetic, mechanical, punched tape and card readers |
| CW | Radomes----- | Radomes | RR | Reflectors----- | Target, confusion. Except antenna reflectors |
| *CX | Cable assys, non RF----- | Non RF cables w/terminals, test leads, also composite cables of RF and non RF cond. | RT | Receiver-Transmitter----- | Radio and radar transceiver, composite transmitter and receiver |
| CY | Cases and cabinets----- | Rigid and semirigid structures for enclosing or carrying equip | S | Shelters----- | Protective shelters |
| D | Dispensers----- | Chaff | SA | Switching units----- | Manual, impact, motor driven, pressure operated, electronic |
| DA | Load, dummy----- | RF and non RF test loads | SB | Switchboards----- | Telephone, fire control, power, power distribution |
| DT | Detecting heads----- | Magnetic pickup device, search coil, hydrophone | SG | Generator, signal----- | Test oscillators, noise generators |
| F | Filter units----- | Electronic types; band-pass, low pass, band suppression, noise, telephone, filter networks; excludes non-reparable types | SM | Simulators----- | Flight, aircraft, target, signal |
| FR | Freq measuring devices--- | Freq meters, tuned cavity | SN | Synchronizers----- | Equip to coordinate two or more functions |
| G | Generators, power----- | Electrical power w/o prime movers | SU | Optical units----- | Electro-optical units, such as night vision, auto-collimator, scope, sight viewer, tracker, alignment equip |
| H | Head, hand, chest sets--- | Includes earphone | T | Transmitters----- | Transmitters, all types, except telephone |
| HD | Environmental apparatus-- | Heating, cooling, dehumidifying, pressure, vacuum devices | TA | Telephone apparatus----- | Misc telephone equipment |
| ID | Indicator units, non-cathode-ray tube | Calibrated dials and meters, indicating lights | TB | Towed body----- | Hydrodynamic enclosures used to house transducers, hydrophones, and other electronic equipment |
| IM | Intensity measuring devices | Includes SWR gear, field intensity and noise meters, slotted lines | TD | Timing devices----- | Mechanical and elec timing devices, range devices, multiplexers, electronic gates |
| IP | Indicator units, cathode-ray tube----- | Azimuth, elevation, panoramic | TF | Transformers----- | When used as separate units |
| J | Interface units----- | Interconnecting and junction units. | TG | Positioning devices----- | Tilt and/or train assys |
| KY | Keying devices----- | Mechanical, electrical and electronic keyer, coder, interrupters | TH | Telegraph apparatus----- | Misc telegraph apparatus |
| LS | Loudspeakers----- | Separately housed loudspeakers, intercommunication stations | TN | Tuning units----- | Receiver, transmitter, antenna, tuning units |
| M | Microphones----- | Radio, telephone, throat, hand | TR | Transducers----- | Sonar transducers, vibration pickups |
| MD | Modulators, demodulators, discriminators | Device for varying amplitude, freq or phase | TS | Test units----- | Test and measuring equip not otherwise classified |
| ME | Meters----- | Multimeters, volt-ohm-milliammeters, vacuum tube voltmeters, power meters | TT | Teletypewriter and facsimile apparatus--- | Miscellaneous tape, teletype, facsimile equipment |
| MK | Miscellaneous kits----- | Maintenance, modification | TW | Tape units----- | Preprogrammed with operational test and checkout data |
| ML | Meteorological devices--- | Miscellaneous meteorological equip | V | Vehicles----- | Carts, dollies, vans, peculiar to electronic equipment |
| MT | Mountings----- | Mountings, racks, frames, stands | ZM | Impedance measuring devices----- | Used for measuring Q, C, L, R, or PF |
| MX | Miscellaneous----- | Equip not otherwise classified. | | | |

*Note: Not for use by contractors

APPENDIX II

THE METRIC SYSTEM

MEASURES OF LENGTH

| Metric denominations and values | Equivalents in denominations in use |
|--|---|
| Myriameter 10,000 meters | 6. 2137 miles. |
| Kilometer 1,000 meters | 0. 62137 mile, or 3,280 feet and 10 inches. |
| Hectometer 100 meters | 328 feet and 1 inch. |
| Dekameter 10 meters | 393. 7 inches. |
| Meter 1 meter | 39. 37 inches. |
| Decimeter $\frac{1}{10}$ of a meter | 3. 937 inches. |
| Centimeter $\frac{1}{100}$ of a meter | 0. 3937 inch. |
| Millimeter $\frac{1}{1000}$ of a meter | 0. 0394 inch. |

MEASURES OF CAPACITY

| Metric denominations and values | | | Equivalents in denominations in use | |
|---------------------------------|------------------|---|-------------------------------------|------------------------|
| Names | Number of liters | Cubic measure | Dry measure | Liquid or wine measure |
| Kiloliter or sterc | 1, 000 | 1 cubic meter | 1.308 cubic yards | 264.17 gallons. |
| Hectoliter | 100 | $\frac{1}{10}$ of a cubic meter | 2 bushels and 3.35 pecks. | 26.417 gallons. |
| Dekaliter | 10 | 10 cubic decimeters | 9.08 quarts | 2.6417 gallons. |
| Liter | 1 | 1 cubic decimeter | 0.908 quart | 1.0567 quarts. |
| Deciliter | $\frac{1}{10}$ | $\frac{1}{10}$ of a cubic decimeter | 6.1022 cubic inches | 0.845 gill. |
| Centiliter | $\frac{1}{100}$ | 10 cubic centimeters | 0.6102 cubic inch | 0.338 fluid ounce. |
| Milliliter | $\frac{1}{1000}$ | 1 cubic centimeter | 0.061 cubic inch | 0.27 fluid dram. |

MEASURES OF SURFACE

| Metric denominations and values | Equivalents in denominations in use |
|--|-------------------------------------|
| Hectare 10,000 square meters | 2. 471 acres. |
| Are 100 square meters | 119. 6 square yards. |
| Centare 1 square meter | 1, 550 square inches. |

WEIGHTS

| Metric denominations and values | | | Equivalents in denominations in use |
|---------------------------------|------------------|---|-------------------------------------|
| Names | Number of grams | Weight of what quantity of water at maximum density | Avoirdupois weight |
| Millier or tonneau | 1, 000, 000 | 1 cubic meter | 2204. 6 pounds. |
| Quintal | 100, 000 | 1 hectoliter | 220.46 pounds. |
| Myriagram | 10, 000 | 10 liters | 22.046 pounds. |
| Kilogram or kilo | 1, 000 | 1 liter | 2.2046 pounds. |
| Hectogram | 100 | 1 deciliter | 3.5274 ounces. |
| Dekagram | 10 | 10 cubic centimeters | 0.3527 ounce. |
| Gram | 1 | 1 cubic centimeter | 15.432 grains. |
| Decigram | $\frac{1}{10}$ | $\frac{1}{10}$ of a cubic centimeter | 1.5432 grains. |
| Centigram | $\frac{1}{100}$ | 10 cubic millimeters | 0. 1543 grain. |
| Milligram | $\frac{1}{1000}$ | 1 cubic millimeter | 0.0154 grain. |

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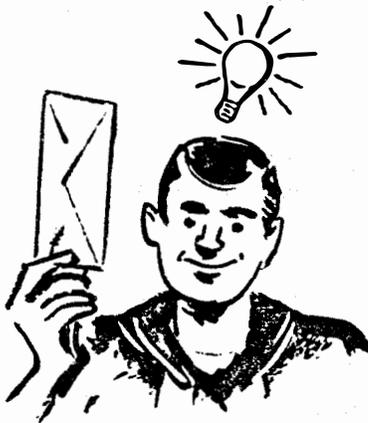
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