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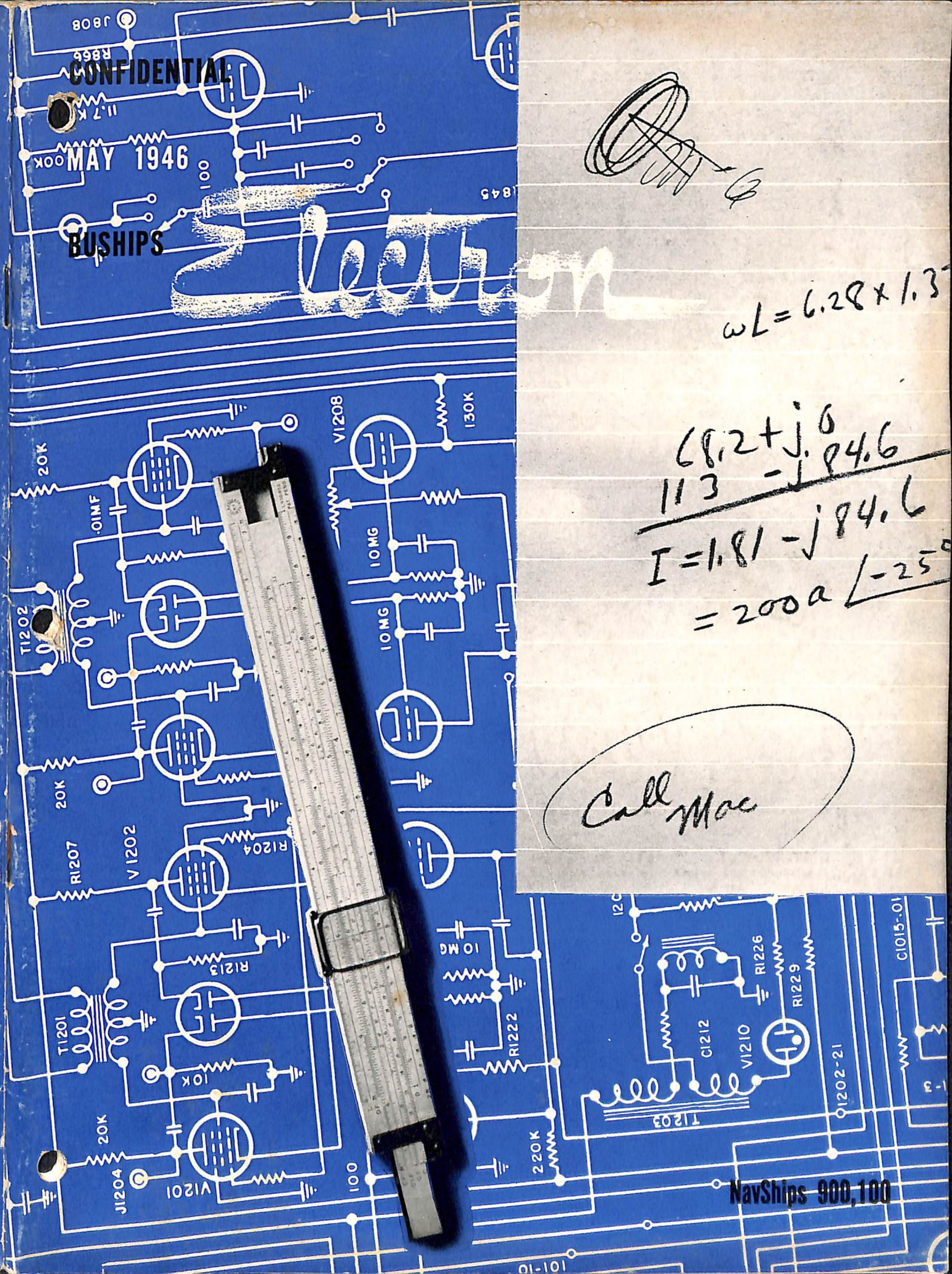
MAY 1946

BUSHIPS

Electron



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BUSHIPS Electron

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BUREAU OF SHIPS — NAVY DEPARTMENT

Components Affecting Radar Ranges

Based on an article by Luther Davis, Jr.,
Radiation Laboratory, MIT

■ The range or coverage of a radar equipment is affected by a number of factors such as power output, antenna gain, receiver sensitivity, character of the target, atmospheric properties, and others. Of these, the following six system factors can be examined and adjusted to a greater or lesser degree by the maintenance man.

Transmitter power output.
Transmitter frequency.
Transmitter spectrum width.
Receiver sensitivity.
Receiver frequency.
Receiver bandwidth.

The radar components which affect these factors are primarily located in the r-f assembly, commonly referred to as the "r-f head". This is a unit including the transmitter, anti-TR box, TR box, mixer, and the front end of the receiver. With the exception of trouble in transmission line and antenna, practically all causes of a decrease in radar performance will be found among the above-mentioned components of the r-f head. The reader will note the similarity in the schematic diagram and parallel-circuit equivalent of the waveguide r-f head to those of the coaxial r-f head (figures 1 and 2). In general, the two are fundamentally of the same principle, differing only slightly in the placement of components as regards wavelength. It is interesting to note what happens to the transmitter when one of these elements in the r-f head becomes faulty.

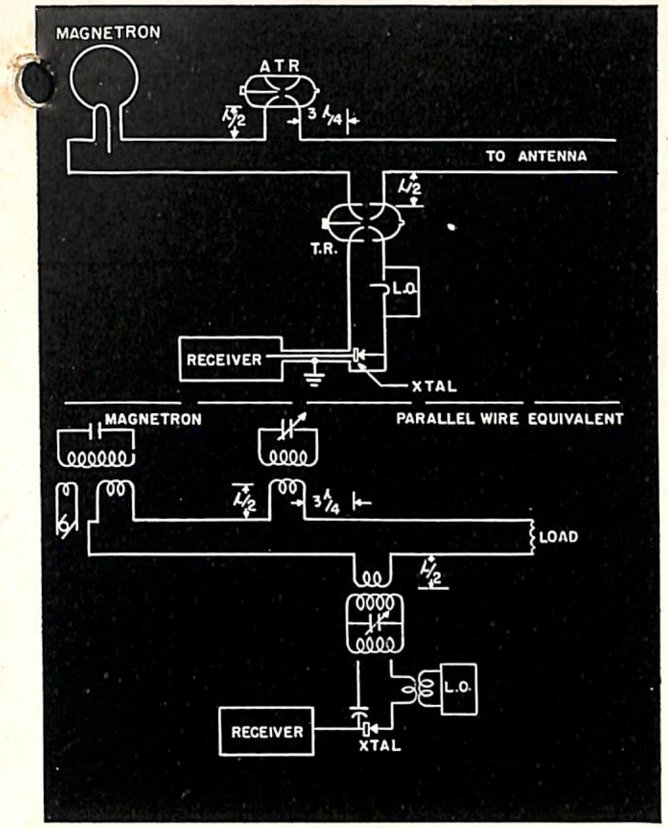


FIGURE 1—*Waveguide r-f head schematic and parallel-wire equivalent, showing wavelength spacing of the TR and anti-TR boxes.*

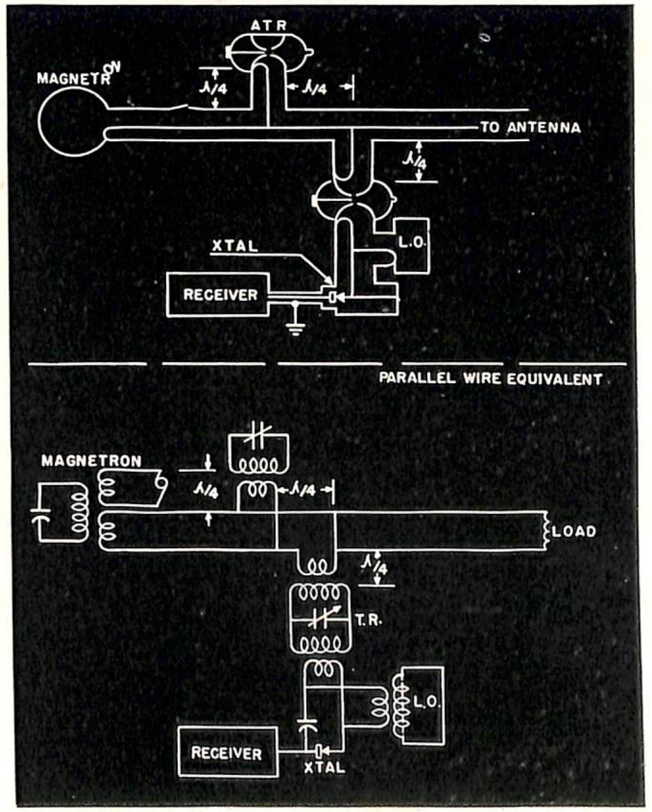


FIGURE 2—*Coaxial r-f head schematic and parallel-wire equivalent. Note the difference in wavelength spacing compared to schematic in figure 1.*

TRANSMITTER TUBE

The transmitting tube of a radar, such as a magnetron, is directly affected by applied voltage, magnetic field strength, and load. Since a magnetron is a rather complex tube in which the oscillator and tank circuits are closely related, the frequency of oscillation may be affected by the physical size of the cavities and by the loading of these cavities. There are two forms of loading; that caused by the external r-f load, and that caused by the electrons in the oscillator. The tube is designed to give a good spectrum when the r-f load applied is at or near the characteristic impedance of the prescribed transmission line and when the electron loading fulfills the proper voltage and current conditions. In general a departure from either of these two conditions will cause a poor spectrum and a probable diminution of power. It is sometimes possible, however, to balance one deviation by a slight variation of the other.

As can be seen from figure 3, the magnetron draws very little current at low voltage but the current rises very rapidly at the operating point. Since the oscillations of a magnetron are primarily a function of current, the chief requisite of a pulse is a very flat top, while the sides are not too important. Except for the necessity of a moderately fast rise-time so that the tube will commence operating in the proper mode, the top 20% of the pulse is the only part that will have any bearing on the transmitted pulse envelope. The top of the pulse should be flat to within 20% in order to prevent a bad spectrum. Oscillations across the top will cause no trouble as long as there is no large spike at the beginning of the pulse. A great percentage of oscilloscope presentations showing a pulse envelope with oscillations across the top are erroneous in that the oscillations are due to faulty equipment being used to view the pulse, rather than in the pulse itself. Figure 4 shows what a good voltage pulse should resemble when viewed on an oscilloscope.

From the chart of operating characteristics of a magnetron (figure 5) the role played by the magnetic field strength and applied voltage can be seen. If we assume an operating point of 12 kv and 11 amperes, we will have to use a magnetic field strength of about 5000 gauss and will get about 55 kw peak power at 9063 Mc. If the magnetic field should drop in strength there would be a great increase in current, assuming the voltage remained constant. This increased current would shortly damage the cathode of the tube and if the increase was sudden and of sufficient amplitude it would completely ruin the magnetron in a very short space of time. To correct for a decrease in field strength, the voltage must be dropped in order to arrive at about the same current which automatically results in a loss of power. It is probable that, even with a proper current, if the field is very low a poor pulse spectrum will result. It may be possible by a slight voltage adjustment to obtain a good spectrum again, but the rated current of the magnetron must not be exceeded. From the above, it is apparent that the greatest source of trouble will be too much drop across the top of the voltage pulse, as a fall of voltage below 11 kv will result in very rapid frequency variations in a region where frequency curves are close together. This is the reason for the previous statement that less than 20% drop is desirable.

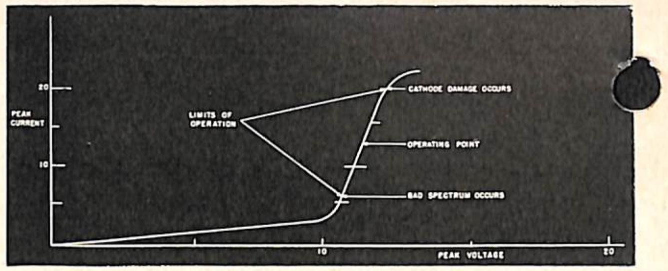


FIGURE 3—*Operating curve of a typical magnetron, showing rapid rise in current when voltage approaches the optimum value.*

The best way to obtain optimum results if the tube does not operate satisfactorily under the prescribed conditions (due to improper loading, etc.) is to adjust the magnetic field (if this is possible) while holding the current at the rated value until the best spectrum is obtained. If the field is not variable, the adjustment of voltage for optimum spectrum, without exceeding rated current, is most desirable. If no test equipment is available to observe the spectrum, the current must be adjusted to the rated value; and if the field strength is adjustable, it should be varied simultaneously to give the proper power output. However, good power output is of less value and effect if the spectrum is poor. When the transmitter is a triode, the frequency depends on tank circuit, load, and applied voltage. (The spectrum is dependent primarily upon the applied voltage.)

FACTORS CAUSING PULLING

As has been previously stated, the power output and spectrum of the transmitter are dependent upon the impedance into which the transmitter works. One way of expressing impedance is in terms of VSWR (voltage standing-wave ratio). That is, an impedance other than that of the characteristic impedance of the line will introduce reflections which will cause a standing wave in the line. A VSWR (maximum-to-minimum voltage) of 1 means that the transmission line is terminated by its characteristic impedance, and that at any point along the line one would see the terminating impedance. In the case of microwave radars, the transmitter has been designed to work into the characteristic impedance of the type of transmission line used. If at any point along the transmission line there is some irregularity which will affect the impedance at this point, a VSWR will be set up which will present to the transmitter some impedance other than the characteristic impedance of the line and will result, in all probability, in less power and a poor pulse spectrum. It can be seen in figure 1 that the iris (loop) coupling into the anti-TR box is spaced one-half wavelength from the transmission line. The iris is effectively the primary winding on a transformer as is shown in the parallel wire schematic. When the anti-TR breaks down due to a high power pulse from the transmitter, a low impedance is presented at the iris and reflected as a low impedance to the junction in the waveguide (one-half wavelength will give 1-to-1 transformation of impedance). The low impedance at the junction of the main line is, for all practical purposes, the same as a little brass cover for this gap in the line. Hence the transmitted pulse effectively sees unaltered waveguide at this point. When the equipment is operating there will be no pulling by the anti-TR box. To obtain this condition the box should be resonant and the gap should fire, since the gap fires more readily when the box is tuned to resonance. If the performance of the equipment is poor, one thing that may be affecting the operation is the anti-TR being off resonance enough to "pull" the magnetron, thus changing the loading. A method of checking this is to remove one of the tuning plugs in the Anti-TR cavity. If the gap ceases to fire it indicates that the box was off resonance before the plug was removed, which fact might have caused it to "pull" the magnetron. If the gap continues to fire after the plug is removed it indicates that the box was resonant before the plug was removed and that it was not "pulling" the magnetron. The anti-TR contacts should be clean and should make good connections.

The TR box works essentially in the same manner. As far as crystal protection is concerned, the tuning of the TR box is, in most cases, immaterial, the only thing of importance being the breakdown of the gap in the tube. For those TR boxes which are tuned by the spacing of the points in the tube, the crystal protection may be slightly dependent upon the tuning of the box; but if this is the case, the tube is faulty. In the case of the TR box, lack of crystal protection will be noted long before any detrimental effect on the transmitter. It is for this reason that the life of the anti-TR will, in general, be greater than that of the TR, and that no keep-alive voltage need be applied to the anti-TR. The conditions for optimum r-f pulse out of the r-f head are to have the pulse voltage of correct shape and amplitude, the magnetic field strength correct, and the TR and anti-TR boxes firing.

EFFECT OF ANTI-TR, TR, AND TRANSMITTING TUBE ON THE RETURNED SIGNAL

Assuming that a returning signal has safely passed all possible hazards in the antenna and transmission line, upon entering the r-f head it will first arrive at the duplexer (section of line into which the TR, anti-TR, and transmitter are connected), and here see the accumulative impedances of the cold transmitting tube (between pulses), the anti-TR box, and the TR box. In figure 1 we see the ideal case, where the anti-TR and TR boxes are both resonant at the frequency of the incoming pulse; the impedance of the anti-TR (now a resonant circuit) will appear high at the coupling iris and hence at the waveguide junction. This high impedance is transformed through the three-quarter wavelength as a low impedance at the junction of the main line with the TR-box arm.

This effectively presents a short at this point and seals off the waveguide, preventing any power from going down toward the transmitter and leaving only the alternative of going through the TR box. The TR tube acts not as a simple resonant circuit, but as a resonant transformer as illustrated in the parallel-wire transmission-line schematic, and hence we get a 1-to-1 transformation between the two irises when the TR box is on resonance, with a very small loss through the cavity. The signal is then mixed with the local oscillator power in the nonlinear detector (crystal) and the intermediate frequency goes through the i-f amplifier out of the r-f head to the receiver.

If the anti-TR box is slightly off resonance, its impedance will still be high enough to give only slight loss to the received signal due to signals going toward the transmitter. However, in the case where the impedance of the transmitter is reflected along the transmission line to the anti-TR box junction in such a manner as to cancel the reaction of the slightly mistuned anti-TR, a considerable loss—as much as 15 db—may be experienced. This will in general never occur during radar search, as the impedance of the transmitter when off resonance will be such that it cannot cancel the reaction of the anti-TR except at frequencies some 20 or 40 Mc away from its transmitting frequency. Such cancellation is a rather rare occurrence, but is found very often in the case of the APS-4 when used on beacon frequency with the anti-TR tuned to radar search. This can be rather easily improved by the expedient of detuning the anti-TR slightly from radar search to favor beacon reception. This is often known as "cold-resonance effect".

In the case of the TR box, however, large losses will always be experienced (as much as 20 db) with the box detuned from the frequency of the incoming signal, as

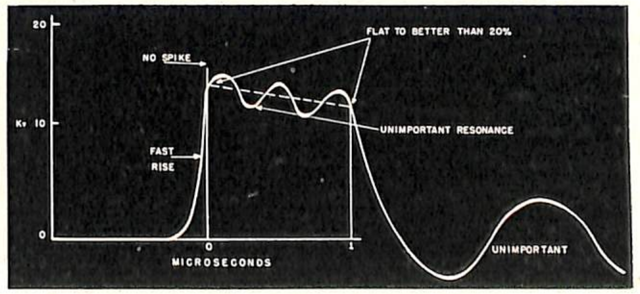


FIGURE 4—*Good Pulse formation showing a fast rise time, relatively flat top, and no undesirable spike at the leading edge.*

such a resonant transformer becomes very inefficient when off resonance. It must be remembered that any reactive component in the load presented to the transmission line by the crystal will appear across the output winding of the resonant transformer as either inductive or capacitive, and hence change the resonant frequency of the transformer. Thus any replacement of the crystal, or even crystal current change, necessitates the retuning of the TR box, as well as the local oscillator coupling. If these readjustments are not made, the loss may be as great as 3 to 5 db. The TR contacts must be clean to prevent losses at that point.

RECEIVER COMPONENTS

The crystal itself is the primary source of large losses in performance of a radar, due chiefly to the fact that it is so sensitive to burn-out and shock. As much as 50 db can be lost by a seriously damaged crystal. A crystal found in such a state would immediately point the finger of suspicion at the TR box, as one would assume insufficient protection from the high power pulse. With the TR keep-alive voltage off, instances of crystal burnout due to transmitted pulses from other radars have been observed. Such burnouts cannot be attributed to the TR box and therefore due precautions should be taken to prevent an inactive radar from being "looked at" by the antenna of another one in operation.

The minimum signal which can be detected by a microwave superheterodyne receiver is limited by the noise inherent in the receiver. At *S*-band frequencies there are only two important sources of noise, the crystal and the first stage of the i-f amplifier. At frequencies higher than this the local oscillator will also contribute some noise. Under normal conditions at *S*-band frequencies the noise is about equal from both crystal and i-f amplifier. At *X*-band frequencies the local oscillator contributes an equal quantity of noise. In the case of a noisy crystal, i-f amplifier, or local oscillator, however, this equality may no longer be true. A local oscillator detuned from the center of its mode may cause as much as 3 db excess noise in the receiver. A noisy local oscillator may contribute as much as 6 db additional noise. At higher frequencies a balanced mixer may be used to eliminate the noise from the local oscillator. In the case of a noisy first i-f amplifier tube, as much as 4 db additional noise is commonly experienced, and the noise from the crystal may rise to about 10 db. The TR tube never contributes noise and is never lossy unless discoloration is present due to copper sputtering onto the glass walls. With the radar properly tuned, and with a good crystal, in some cases, a poor minimum discernible signal is still found. This will indicate a noisy local oscillator or i-f amplifier, assuming that no anti-TR magnetron resonance is present.

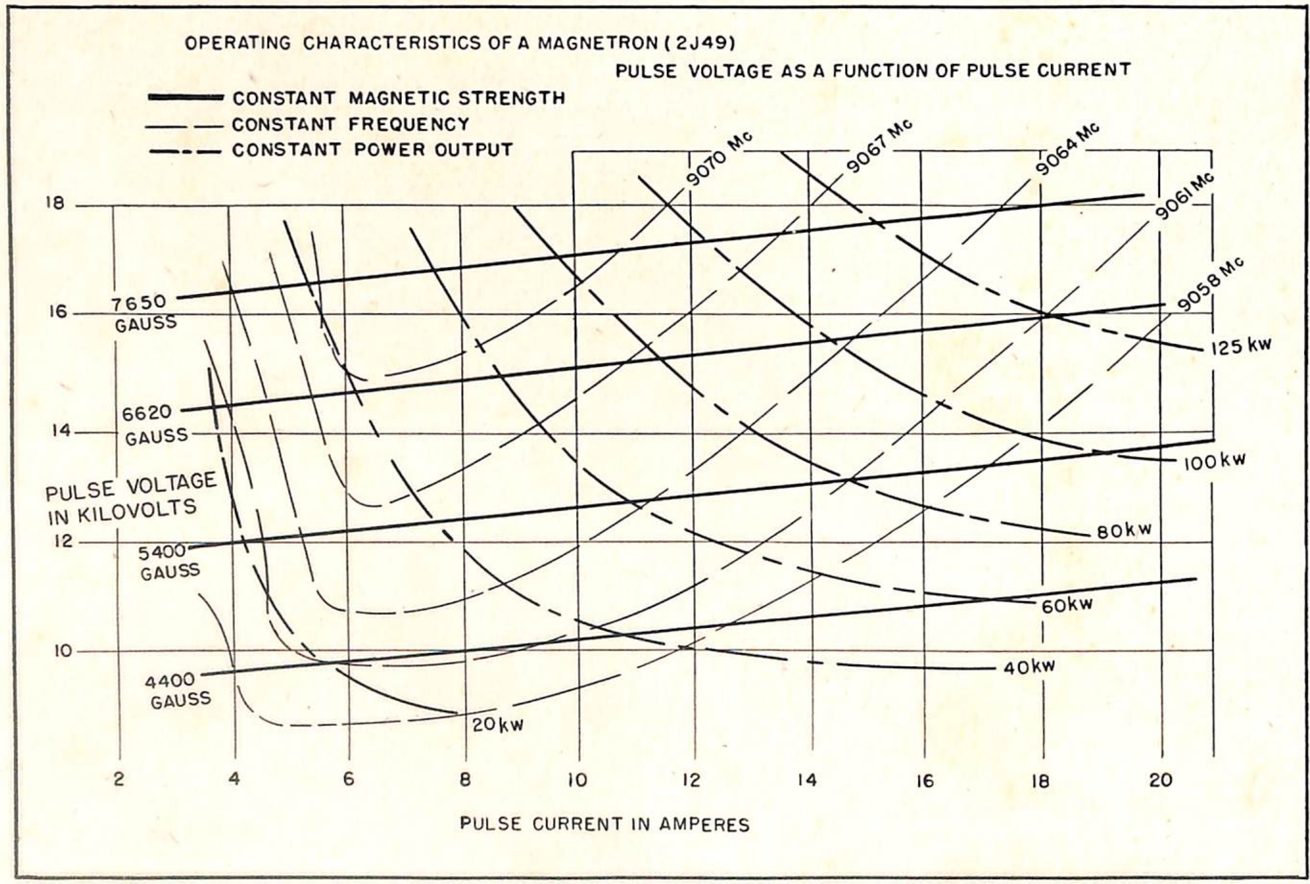


FIGURE 5—*Typical operating characteristics of a 2J49 magnetron, showing frequency and power output as a function of voltage, magnetic field strength and pulse current.*

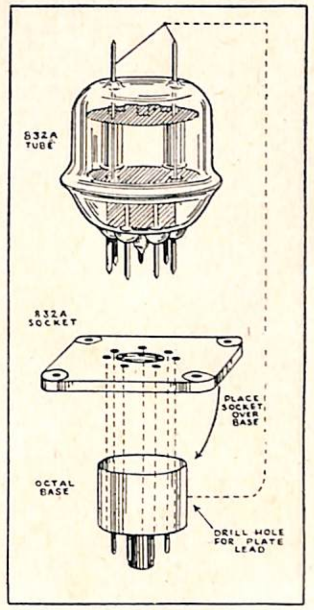
In the case of a radar using automatic frequency control, it is essential that the transmitter have a good spectrum in order that the automatic frequency control lock at the proper frequency. Also, the output from the local oscillator over the range which the AFC circuit sweeps should be essentially flat, so that the output of the discriminator will vary only due to frequency error and not due to a change in the power output of the local oscillator. It should be remembered that most AFC circuits are designed to work only with the local oscillator on a specific side of the transmitter frequency.

ADDITIONAL COMPONENTS IN HIGH-POWER RADARS

Some high-power radars have, in addition to the above-mentioned components of the r-f head, an additional anti-TR box which is used to ensure that the resonance between the anti-TR box and the transmitter cannot occur. In case the resonance is present between one anti-TR box and the transmitter, the second anti-TR tube will give the proper impedance. Also, in the case of high power radars, a pre-TR may be found. This is a TR in series with the present TR, and gives added protection against the extreme high power which may have a high enough harmonic content to burn out the crystal (TR offers very poor protection against harmonics). Such a tube is not built like the conventional TR tube, but is instead merely a section of waveguide filled with a gas which breaks down across the windows at the end when the high power is applied. These tubes will not cause any trouble other than increasingly long recovery time until they no longer fire, at which point the transmission loss will not necessarily increase, but crystal protection and transmitter spectrum will become poor. Loss is sometimes experienced when the contact springs around the periphery do not make good contact, or become worn due to arcing.

The foregoing article has described briefly the operation of an r-f head, the difficulties encountered in the components, and the methods of detecting some of the faults. It is hoped that a knowledge of what can go wrong in this assembly will facilitate correct interpretation of results obtained from the test equipment and locating the faulty component for tuning or replacement if necessary. Attention is invited to two previous articles in ELECTRON, page 5 in the October and page 21 in the November issue, for additional information on r-f phenomena and sensitivity in radar receivers.

Testing 832 A's in the OZ



Special adapter which can be made up to permit testing of 832A tubes. ▶

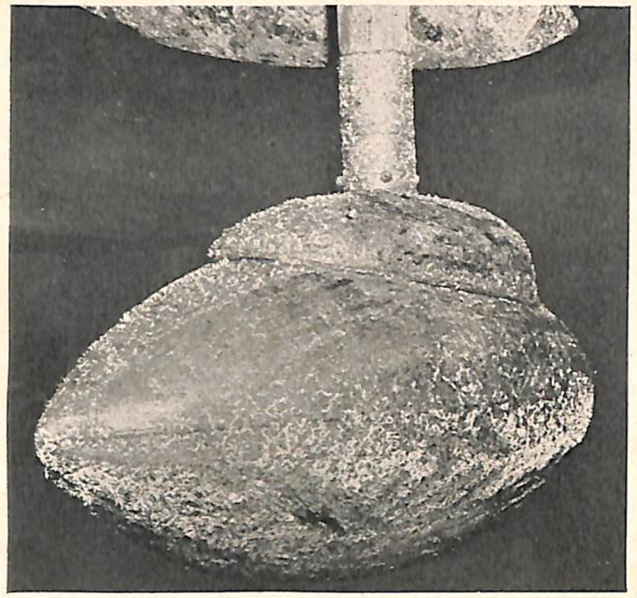
It has been considered impossible to check the 832A with the Navy Model OZ (Hickok 540), since the OZ provided no socket to accommodate this push-pull r-f amplifier tube. However, the Naval Research Laboratory has determined that the 832A can be successfully tested in the OZ by the use of a simple adapter which can be made easily by field activities.

The special adapter may be made up from an octal base taken from a discarded tube and an 832A socket, as shown in the figure. Wire the adapter so that pins 2 and 7 of the octal socket connect to the 832 heaters, No. 3 to the plates of the 832A, No. 4 to the screen grid, No. 5 to the control grids, and No. 8 to the cathode.

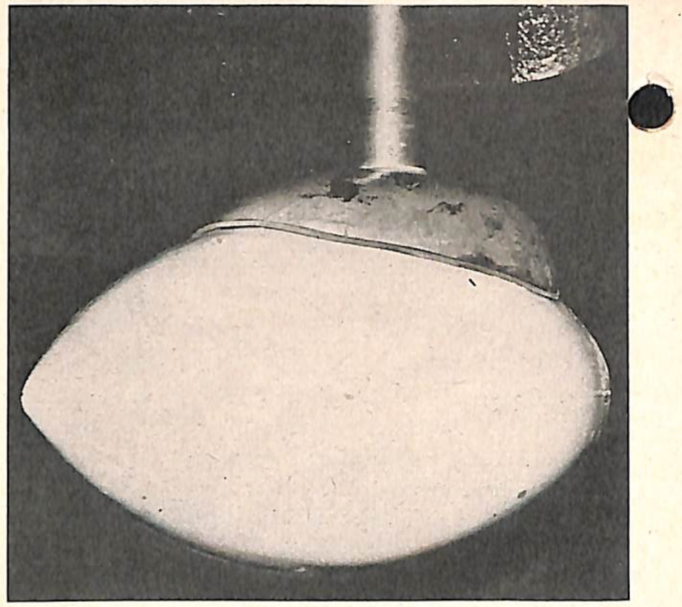
The OZ controls should be set as follows:

A = 8
B = 5
Fil = 12.6
L = GM
R = 21
(Meter range switch set to 15,000 micromhos.)

Since the 832A has an indirectly heated cathode it requires three minutes to attain optimum operating temperature. The line voltage meter should be set with the AMPL button depressed. Read the mutual conductance meter 15 seconds after the AMPL button is depressed. The tube may be tested with both units connected in parallel or each unit may be tested separately. If each is tested separately, the grid and plate of the unit not under test are left floating. When testing the tubes with both sections in parallel, those having a mutual conductance of less than 5000 should be rejected. When testing each unit separately, reject those with mutual conductance less than 2500.



Fish type dome showing moderate amount of calcareous growth before cleaning.



The same dome after being properly cleaned. Note smooth contour of metal surface showing that proper methods and materials have been used.

Fouled Domes, Transducers, and Sea Chests

■ Reports have reached the Bureau that considerable difficulty is being experienced by the various repair and inactivation activities in cleaning barnacles and calcareous growths from sonar domes, transducers, and sea chests. Such drastic methods as applying steel wool, metallic scrapers, sand-blasting, etc., have been resorted to in cleaning the sound-transparent windows. Such methods of cleaning are strongly disapproved by the Bureau of Ships because of the resulting mechanical damage. When these components suffer mechanical damage such as dents, pitting, pinholes or thinning of the metal by the use of abrasives the very purpose of corrosion resistant steel has been defeated because the scratching (with steel wool wire brushes and metallic scrapers) and roughing (by sandblasting) of the mirror-smooth corrosion-resistant surface invites adhesion of corrosive elements and exposes the alloyed impurities to electrolytic action.

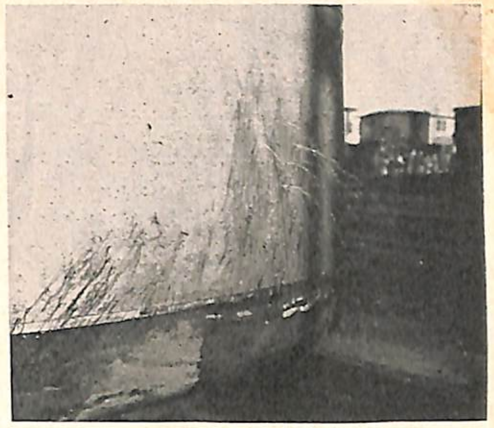
The bureau has issued explicit instructions on the methods and materials to be used in the process of cleaning these submerged units of sonar systems. These instructions were issued to all repair and inactivation activities for compliance. However, since the personnel of ships concerned have a vital interest in the maintenance and repair undertaken by these activities, they should assist in every way possible to insure that these instructions are followed. To insure coordination and cooperation between repair activities and shipboard personnel, a copy of the instructions is given here for information to all shipboard personnel.

STEEL WINDOWS

Steel sound-transparent windows on domes and transducers, including those for sonar sounding equipment:

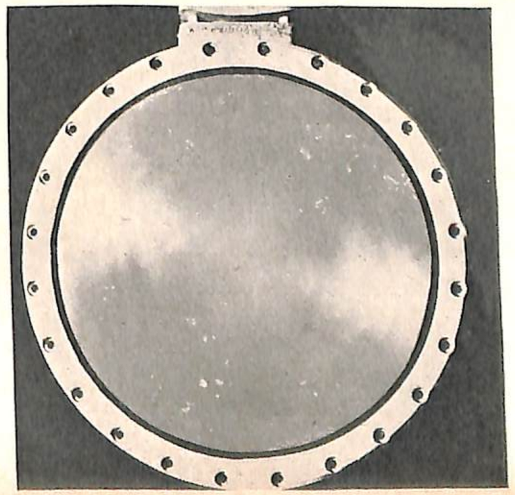
1--Remove the fouling (barnacles, etc.) with wooden scrapers and non-metallic, non-abrasive brushes as soon after drydocking as practicable in order to take advantage of the soft condition of the wet fouling. When performing this operation use extreme caution not to puncture, dent, or otherwise damage the unit. Play a water hose on the wet sea growth to help keep it soft during the process of removal. Once the calcium encrustation dries and hardens it defies removal and greatly increases the chances of injury to projector diaphragms and dome sound windows.

Expanded metal dome immediately after drydocking, showing water streaming out of minute holes in the metal. Proper cleaning methods would have prevented this corrosion of the metal. ▶



◀ *Projector face before cleaning, showing pitting and sea growth.*

Projector face has been cleaned by some sort of abrasive, probably steel wool, as indicated by the deep scratches in the metal surface. ▶



◀ *Projector face that has been properly cleaned and treated.*

2—Removal of fouling can be greatly facilitated by swabbing the effected parts with a solution of one volume of commercial nitric acid to five volumes of fresh water. Apply the solution with long-handled cloth swabs. Allow the solution to soak a few minutes. Wipe with a rag or non-abrasive brush. Repeat the application if the surface still retains some carbonate film. When satisfactorily cleaned, wash the swabbed areas thoroughly with rich soapy water (preferably hot) and flush with fresh water. If the surface shows any traces of oil or grease residue after the soapy water scouring, carbon tetrachloride may be used to dissolve such persistent traces.

CAUTION: Wear goggles, rubber gloves, and do not splash the nitric acid solution. If any skin area does get affected with the acid solution treat immediately with a strong solution of soda and fresh water. Flush the injury copiously When using the carbon tetrachloride exercise caution because the fumes are poisonous. This compound should be used only in open air or blower-ventilated spaces.

3—Paint window in accordance with the following:

(a)—It is imperative that the window be thoroughly cleaned. Use any good paint solvent freely to remove last traces of grease due to finger prints or other causes. (b)—Spray one mist coat of zinc chromate primer (AN-TT-P-656A) on the window, allowing 15 to 30 minutes drying time. Do not become disturbed by the green appearance of this first coat as the hiding power of zinc-yellow pigment is very poor. (c)—Spray second coat of zinc chromate primer and allow to dry for three hours. This coat should be applied full, but extra precaution should be taken not to spray so heavily that sags or runs develop. (d)—Spray first coat of M-559 Anti-Fouling Paint and allow to dry for 30 minutes. (e)-(j) Inc.—Spray the second, third, fourth, fifth, sixth, seventh, and eighth coats of M-559 paint, allowing from 1 to $1\frac{1}{2}$ hours drying time between each coat, depending on drying conditions. Allow at least four to eight hours before immersing in sea water and preferably twelve to twenty-four hours for best results.

When mixing the primer and anti-fouling liquids, the following ratios should be adhered to:

Primer

1 part AN-TT-P-656A (zinc chromate)
2 parts thinner, consisting of 50% toluene (Navy Spec 52-T-7a) and 50% dry cleaning solvent (Federal Spec P-S-661a).

Anti-fouling

4 parts anti-fouling paint—BuAer Spec M559 (Navy Specification 52-P-178)
3 parts thinner, consisting of 50% toluene (Navy Spec 52-T-7a) and 50% dry cleaning solvent (Federal Spec P-S-661a).

The coats of anti-fouling paint are to be applied full and wet, but here again caution should be exercised to prevent running or sagging. Drying times are minimum for optimum performance. Longer drying periods are helpful between coats, except that in no case should more than 24 hours elapse between the application of any two coats. Difficulty has been experienced in making this anti-fouling paint stick to stainless steel. It is therefore requested that the Bureau of Ships be furnished information as to the success encountered in both anti-fouling properties and lack of peeling.

RUBBER WINDOWS

Rubber sound-transparent windows (on domes and transducers including those for sonar sounding equipment), rubber-surfaced baffles, and transducers.

1—Remove the fouling with scrapers and nitric acid similar to the method used for steel windows EXCEPT omit the use of *carbon tetrachloride* as it causes deterioration of the rubber. Do not gouge, pick, or roughly clean the rubber surface, since such treatment of the top rubber surface increases deterioration.

2—The rubber should *not* be painted with BuShips formula 94 (chlorinated rubber in xylol, plasticized in castor oil). Tests have shown that this solution is not satisfactory as a preservative, and the bureau has issued orders to discontinue its use.

SEA CHESTS

Sea chests and non-sound-transparent portions of transducers and domes.

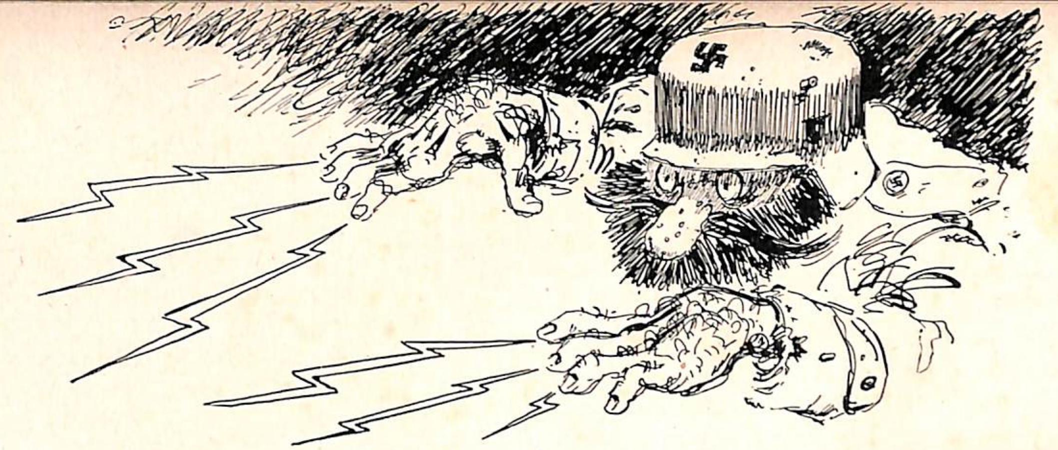
1—These parts can be cleaned with metallic scrapers and wire brushes. Great care must be taken not to scrape or wire brush the adjoining edge of the transducer diaphragm or the dome sound window.

2—After cleaning, these parts should be treated in a manner similar to the ship's bottom. Care must be taken to mask off the sound-transparent surfaces when applying ship bottom paint.

3—Be careful not to scratch machined surfaces such as guides, bearings, and shafts. After cleaning, these parts may be polished with brightwork polish and coated with a film of water-displacing, rust-preventive compound, Navy Spec. 52-C-18 Grade I.

All existing instructions which conflict with the preceding are hereby cancelled. Appropriate revisions will be made to all affected BuShips publications.

German Fighter Direction



■ Just how far the enemy had advanced in research and development of weapons is now being brought to light by special technical committees placed in the vanquished countries. Since the war was conducted to a great extent by electronics, it follows that much of the research by the enemy was concentrated in the electronics field. Many startling developments have been uncovered by these committees, one of which will be of interest to all technicians and fighter-director personnel. The germans had designed, but did not get into production, a system of fighter direction which differed considerably from that used by us. This new system had some advantages but also some disadvantages which the reader will undoubtedly observe. This fighter director system was designated Nachtfee (Night Fairy) Ground-Control System. The goal of the system was to provide the ground station a means of passing fighter direction commands to the plane without the use of additional circuits such as voice, c.w., etc.

The Nachtfee System includes both ground and airborne installations. Those units installed on the ground, referred to as the Freya-Zusatz, consist of a radar transmitter (IFF interrogator), operating on about 150 Mc, a receiver, an indicating device using two cathode ray tubes, and a ten-channel master oscillator with individual crystal control for each channel. The 10 channels cover a frequency band from 492 to 510 cycles, each separated from the next by 2 cycles. To conserve quartz and to obtain maximum frequency stability the crystals used in both the ground and airborne installations were ground to a frequency thirty times greater than the desired frequency. For example, for a basic frequency of 500 cycles, the crystal would be ground to 15,000 kc. The output of the master oscillator was then passed through three frequency-divider stages in cascade, the dividers having ratios of 5-to-1, 3-to-1, and 2-to-1. These frequencies are not to be confused with the carrier frequency of the IFF interrogator, as they have no bearing or effect on the carrier frequency.

The basic repetition rate of the interrogator, when being used for IFF only, is 500 cycles. The airborne system consists of a receiver, a master oscillator with the same frequency coverage as the oscillator on the ground but using only one crystal, an indicator using one cathode ray tube, and a transpondor.

Before the fighter planes take off, each of their master oscillators is set on one of the frequencies mentioned above (492, 494, etc.). If large numbers of planes are to be controlled by one ground station it is necessary to set several planes on the same frequency. Obviously all planes on the same master oscillator frequency should be in the same group since they will all receive the same commands if and when the ground station desires to pass commands to planes on that frequency during the flight. It is possible for one ground station to control planes on any of the ten master-oscillator frequencies, but not simultaneously. It is necessary to switch frequencies at the ground station to get in synchronism with the airborne frequency desired.

After the planes are in the air, if the ground station desires to pass commands to a plane or group of planes whose master oscillators are on a certain frequency it is first necessary to alert the pilot(s) to the fact that the ground station is going to take command.

Before explaining the technical features of the system let us briefly examine the physical aspects of the set-up which tells the pilot what commands are being passed. The entire system of commanding is based on a code of signals derived from points on a circle. For example, the 20-degree point might mean "turn right 90 degrees" etc. The circle is laid off with the 0-degree point at the top, and is graduated clockwise in regular intervals around the circumference. With ten-degree separations, a total of 36 distinct commands can be used, the one desired being pointed out to the pilot. This number can be increased by introducing variations, such as causing the pointer to wobble back and forth across the mark. For example, if the pointer were steady on 20 degrees the meaning might be "turn right 90 degrees", but if the pointer were caused to wobble a few degrees either side of 20 degrees it could mean something entirely different, like "altitude 3 thousand". This would make the system extremely flexible and make available a large number of different and distinct commands which could be passed.

The problem of placing a circle in the plane on which to indicate these various commands was comparatively simple. A cathode-ray tube with a circular-sweep presentation filled this requirement. However, the method of pointing out the various points on this circular sweep presented more technical difficulty. Several points had to be considered before the system could be put to practical use. First was a means to alert the pilot to the fact that he was being taken under ground control; second, synchronizing the ground equipment with the airborne equipment to provide accurate control; third, maintaining the synchronism between these two stations; and fourth, actual passing of commands.

When the plane is flying without ground control, the IFF system works in the normal way; that is, the incoming IFF pulses from the ground station pass through the receiver and trigger the transpondor. The output of the master oscillator in the plane (basic frequency as assigned) is triggering off the sweep of the circular-trace cathode ray tube. Of course nothing else appears on the scope except the circular sweep, which is being started at the 12 o'clock position. This is the condition when the plane is not being controlled from the ground.

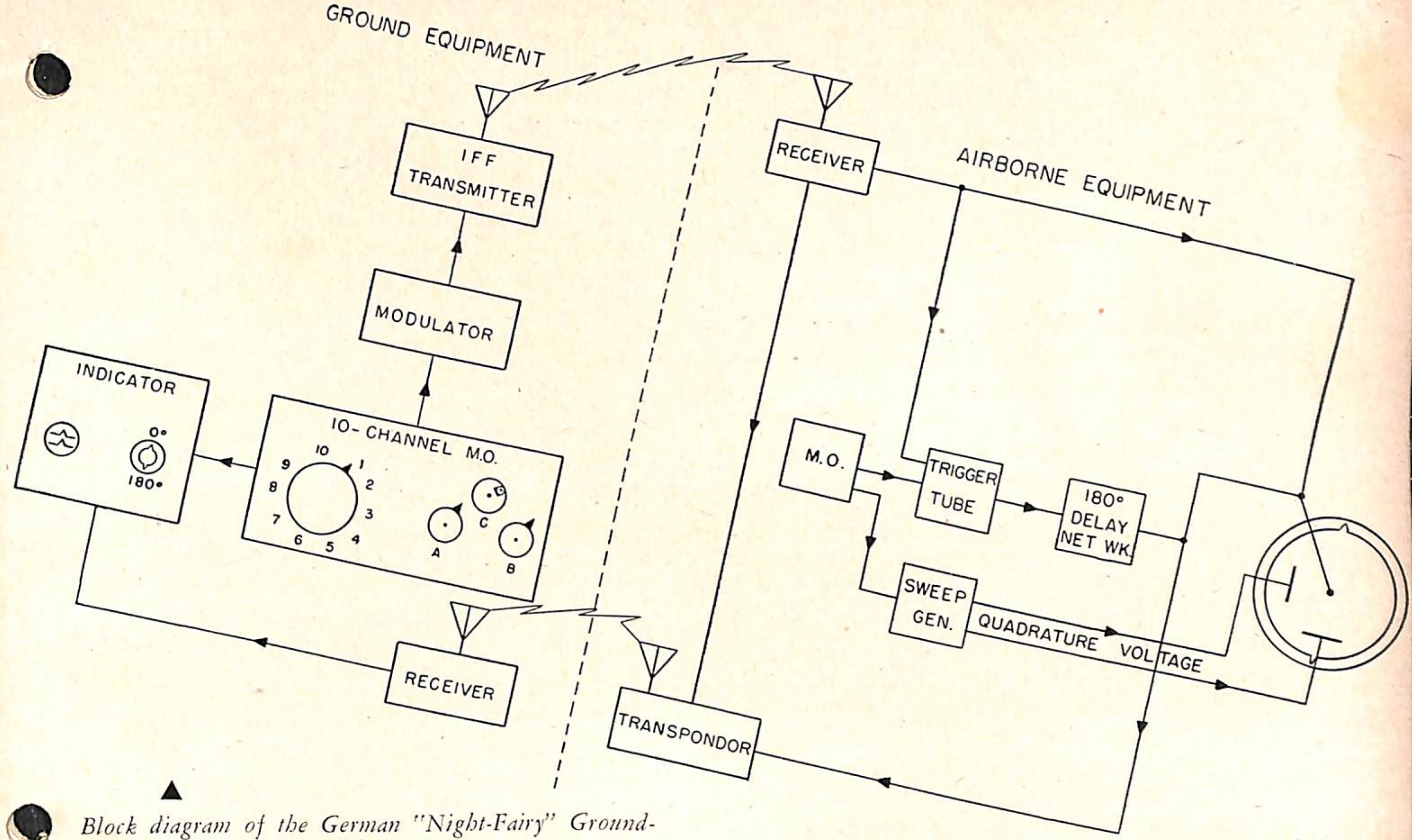
The ground station must of necessity be the controlling point in the entire operation. It is here that synchronism must be maintained between the two stations, because the pilot does not have the time or facilities to perform this operation. Also the ground station must constantly make the necessary adjustments and corrections to compensate for changes in range of the plane.

The ground unit contains two scopes. One uses a circular sweep identical to the one in the plane, and the other is a double horizontal sweep produced by a two-gun (see p. 37, Sept. ELECTRON) cathode-ray tube. The circular-sweep scope duplicates the presentation being produced on the scope in the plane only after synchronization has been established. The double-beam scope is used to check synchronization between ground station and plane when the ground station has the plane under control.

A lengthy discussion of the step-by-step action of the system is impractical in this explanation, although the major steps of taking a plane under control and passing commands are of interest. Assume a plane is in flight, and its master oscillator has been previously set to a frequency of 496 cycles. The ground station desires to pass commands to this plane. As has been previously stated, the ground station has a 10-channel M. O. with individual crystal control. Each channel has a control, called the phase control, provided to vary the basic frequency slightly in order to compensate for frequency drift of the M. O. in the plane. When the ground station shifts to the frequency of the plane, the IFF transmitter is then triggered by the output of the M. O. channel in use. The frequency stability requirements of the crystals used in both ground and airborne equipment are quite critical. After the ground channel in use has been synchronized with the plane by the vernier control the drift must be such that they will remain synchronized without readjustment by the vernier control for a period of at least 20 seconds. Synchronization is indicated by the use of the double horizontal sweep on the two-gun tube. The sweeps are so arranged that the pulse from the ground station will appear on the upper trace and the pulse activated by the plane's oscillator through the transpondor will appear on the lower. When these two are in synchronism they will be aligned vertically, one on the upper and the other on the lower trace. The 180° phase displacement will be explained later. Since these sweeps are actually time bases, any changes in range will cause the two pips to drift along the sweep. A second control, the Range Control, is used to compensate for changes in range and keep the two pips centered on the traces. During the setting up of synchronism and adjustments to bring the two pips into alignment and centering them, the third control, the Command Control, is in a neutral position.

Thus far we have only discussed the technical aspects of the ground equipment. A look into the pilot's cockpit would reveal an entirely different picture. It must be remembered that when the plane is not under ground control the pilot sees only the circular sweep appearing on his cathode ray tube. Then as the ground station starts to shift to the frequency of the plane the presentation in the plane starts to change. At first there will be jittery pulses appearing on the circular sweep, at approximately 0° and 180° (12 o'clock and 6 o'clock respectively). Then as the ground station makes adjustments with the phase control, bringing the two into synchronism, these pulses will become less jittery until they steady down. There will then appear a pulse at 0° and a second pulse at 180°.

As can be seen from the block diagram, the output of the master oscillator (496 cycles) is used to trigger the sweep generator which places the circular sweep on the scope. The starting point of the sweep is at 0°. It will be noted that a second output of the M. O. is applied to the grid of a trigger tube which is biased beyond cutoff. Also applied to this tube is the output of the receiver which would effectively be the pulse received from the IFF transmitter on the ground. But the tube is so biased that neither of these pulses, individually, will cause it to conduct. When both occur simultaneously however, the combined action of the voltages is sufficient to cause the trigger tube to conduct and results in a pulse in the output. This pulse is passed through a delay circuit which delays it from the input pulse by 180°. This delayed pulse has two applications. One output is applied to the video signal pin in the center of the C. R. O. tube and the second output is used to trigger the transpondor. The output of the receiver is also applied to the video signal pin on the scope.



▲ *Block diagram of the German "Night-Fairy" Ground-Control System.*

It becomes obvious that, as the ground station is brought into synchronism with the plane, the two pulses appear at the grid of the trigger tube simultaneously. Since they are occurring simultaneously, the pulse from the receiver will then appear at 0° on the circular sweep because this is the point where the sweep starts, triggered by the M. O. pulse. After the trigger tube output has been delayed and applied to the video signal pin it will appear as a pulse at 180°. At the same instant this second pulse appears on the sweep, the transpondor will be triggered and the eventual output will be twice the repetition rate of the IFF transmitter on the ground, but only so long as the two frequencies are synchronized and no commands are being passed. When the pilot sees the two pips on his scope he is alerted that commands are to follow.

The ground station and the plane are now in synchronism and the system can be used to pass fighter-director commands. On the ground, the command control is now brought into use. This control is a synchro system with the stators energized by the output from the master oscillator channel. The phase displacement or position of the pulse on the circular sweep is determined by the position of the rotor at any instant, for the output is taken off this rotor. This displacement is in reference to the input, which is a derivative of the master oscillator frequency. Since this input has been synchronized previously with the master oscillator in the plane, it follows that the displacement is also in reference to the pulse coming from the master oscillator in the plane, which is the controlling factor in the entire system. All that remains is for the control station to move the pulse or control to a certain setting in degrees on the circle and the same movement will occur in the plane on the circular sweep. One other point that should be noted is that when commands are actually being passed, the 180° pulse on the circular sweeps will not appear because the two pulses will not appear at the trigger tube simultaneously, thus it will not conduct and there will be no delayed pulse.

Checking and Aligning SR-2 Synchros

■ As a rule the technician on board ship is not directly concerned with checking and aligning synchro systems during an installation which is accomplished by a naval shipyard or other repair activity. However, after the installation has been completed and checked, the equipment upkeep and maintenance then becomes the direct responsibility of the shipboard personnel. At a later date there may be reason to believe that the Synchro system is not properly aligned. RCA has promulgated complete instructions to their field engineers for carrying out this checking and alignment. These instructions are considered of special interest and value to technicians and are outlined in the following paragraphs.

The synchro system of the SR-2 Radar will normally be properly aligned on electrical zero reference at the factory. Thus installation and maintenance problems should, in most cases, be limited to correct phasing when interconnecting the various elements of the system. Occasionally stator and rotor leads get mixed up during the installation resulting in such conditions as reversed rotation, over-heating of synchro units, or fixed errors of 180°, 120°, etc. These conditions are fairly obvious to those experienced in the art and can be located and corrected if the technician is familiar with the system as a whole and individual locations of components that make up the system. To perform the checking and alignment of the system, the technician should adhere to the following instructions:

1—Place the SR-2 in complete operation, including the DG Synchro Amplifier which is usually on a separate power supply. It will be necessary to have the transmitter actually radiating in order to observe the PPI sweep trace.

2—Assure that ship's gyro is energized in order that gyro information can be transmitted to the radar equipment.

3—With True-Relative switch on bearing indicator unit in RELATIVE position, rotate antenna with handwheel until antenna relative bearing indicator reads 0°. The true bearing indicator and PPI should also read 000 since synchro motors B-802 and B-804 as well as control transformer B-502 are controlled directly by synchro generator B-1301 when the True-Relative switch is in the Relative position. As a check on interconnections, direction of rotation of the various units should be observed while the antenna is being positioned for 000 reading. If the rotation of the hand crank is clockwise, the antenna, relative bearing indicator, true bearing indicator and PPI sweep should all rotate in the direction of increased readings. If any unit deviates from this rule the wiring to that unit should be checked and corrected. If, after this condition has been established, all three synchro units do not read 000, one of the two synchro motors should be electrically zeroed by any one of the procedures outlined in the Synchro Manual. Experience has proven that the easiest method of zeroing a free synchro is as follows:

a—Turn off power.

b—Isolate questionable synchro from external circuit by removing synchro leads from terminal board E-804. (Leads on terminals R57, R58, R59, D102A and D-403A are S1, S2, S3, R1, and R2 respectively for B-802. Leads on terminals B-83, B-81, D-102B and D-403B are S1, S2, S3, R1, and R2 respectively).

c—Jumper together terminals R1 and S2.

d—Jumper together terminals R2, S1, and S3.

e—Apply 115 volts a-c between R1 and R2. The rotor of the synchro motor will instantly lock in zero position.

f—Loosen clamps on body of synchro and rotate until indicator reads 000.

g—Reclamp body of synchro, rechecking zero when clamped.

h—Remove power and jumpers from synchro. Replace external connections.

i—Place equipment back in operation.

After the one synchro has been electrically zeroed, compare readings between it and the other two synchro units. If error of 180, 240, 060, etc., is observed, check external wiring. If wiring is correct or error is of such value that it could not be caused by incorrect polarity of windings, shift synchros in mountings until reading agrees with unit known to be on electrical zero. The synchros to be adjusted are B-802 for antenna bearing, B-804 for true bearing indicator, and B-502 for PPI sweep trace. Interlocks will have to be shorted out to energize equipment for comparison of readings while adjusting position of PPI sweep.

4—At this point it is advisable to check the antenna position to determine whether the antenna relative bearing indicator readings are correct. Due to extremely sharp beam characteristics of the SR-2 antenna as compared to the SA antenna, it will be necessary to use more care in alignment. To align the antenna, it is suggested that the system be energized as above, and the antenna slewing motor handle turned to align the relative indicator dial on 000. Turn the antenna safety switch OFF at the antenna pedestal before engaging in any further activities in this vicinity. By climbing on rear support member of antenna frame, sight through the center line of same and align line of sight across the dipole centers in "basket" assembly. Antenna should be moved physically until this line of sight lies along the center line of the ship. On usual types of ships, the jack staff on the bow will be a handy reference. However, on carriers where the mast is off the center line, some other reference must be selected. In all cases, the line of sight through the antenna should be parallel to the keel or center line of the ship. Inasmuch as any corrective movement of the antenna will shift the antenna relative bearing indicator on the bearing indicator unit, it will be necessary to make a corresponding readjustment of synchro generator B-1301, in the pedestal, to bring the antenna information into alignment with the system.

This can be accomplished by loosening the spanner-type lock ring that secures this synchro and rotating the body of the synchro until the relative bearing indicator dial again reads zero. If no communication is available between pedestal and console, an a-c voltmeter can be connected across terminals R57 and R59 (terminal board E-1302 in pedestal) and the synchro body adjusted for absolute minimum voltage reading, using low scale (5-10 volts full scale) for final adjustment. The technician is cautioned that it is possible to be 180° in error when this method is used; therefore a check should be made at the console to make sure that correct minimum has been obtained and that the relative bearing indicator reads 000. Before leaving the antenna platform be sure to close safety switches.

5—With the equipment set up as specified at the beginning of step 3, throw the True-Relative switch to TRUE position. The antenna relative bearing indicator may shift as much as 3 degrees, but when it is reset by handwheel to read 000, the true bearing indicator and PPI sweep should read the ship's gyro heading. The actual ship's heading can be ascertained by observing the reading on bearing repeaters that are usually located nearby or by calling the gyro room. If ship's gyro system should happen to be setting on zero, no shift should take place and observations will not be too conclusive. In most cases the gyro electrician will precess the compass to give another reading when and if requested.

If the new reading on the PPI sweep and true bearing indicator do not agree with the ship's heading, it is fairly certain that the DG synchro amplifier has been incorrectly zeroed. Before further checks are made, be sure that the 0-1915 stowing device is completely unlocked and that microswitch interlock S-1902 is making contact. To eliminate the possibility of wiring errors it will be necessary to have the compass precessed or make observations while the ship is underway. While the compass is being precessed, all indicators should be checked for relative direction of rotation and fixed error.

With the SR-2 equipment in full true operation, (antenna train TRUE, emergency train NORMAL, and slewing motor OFF) the PPI sweep trace and true bearing indicator dial should not move when the compass is precessed. The relative indicator dial should, however, move in the opposite direction to the gyro. That is, when the gyro dial is showing increasing readings, the relative bearing indicator should show decreasing readings. If any of the units show reversed direction of rotation, the check should be interrupted long enough to correct the wiring error, then resumed to make sure that the trouble has been cleared. If a fixed error exists, the gyro should be set at 000.

6—The following checks will be helpful in locating trouble in the DG Amplifier:

a—With the gyro thus set and information being transmitted to the SR-2 Radar System, connect an a-c voltmeter between terminals 51 and 53 of the DG Amplifier terminal board K-1901. The voltmeter should read zero volts during this check. If the indicated voltage is zero, it means that the correct information is being fed into the DG synchro amplifier system. If this condition is not obtained, the indication is that ship's gyro is not properly set at 000 or that errors exist in the wiring between unit and gyro system.

b—If proper gyro information is being received at the terminal board of the DG amplifier, a reading should be taken at terminals R-57 and R-59 or terminal board E-1903. If the antenna is still in 000 position, the voltage reading obtained here should also be zero. If not, check and correct the wiring to the pedestal.

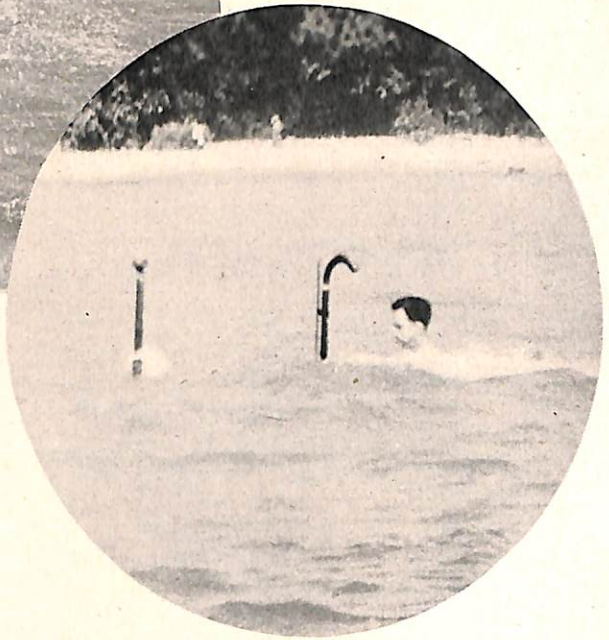
c—Check voltage between terminals T-57 and T-59 of terminal board E-1903. If a zero-voltage reading is not obtained, the error lies in the DG amplifier unit and can be due to either synchro amplifier circuit trouble, synchro controls B-1903 and B-1904 not correctly zeroed, synchro B-1901 not correctly zeroed, or defective motor B-1905.

The data on the DG synchro amplifier incorporated in the SR-2 instruction book in section VII, Corrective Maintenance, paragraphs 22A through 22C, should be studied carefully before attempting any adjustments to the DG amplifier.

◀ *A Jeep which has been modified for water-fording plunges into deep water.*

The Jeep cruising along fully submerged after installing water-fording conversion kit.

▼



The "MIGHTY JEEP" Takes to Water

By Wm. P. Boyer & Andrew P. Massey,

Marine Corps Installation & Maintenance.

■ No, we have not found out how to make one run on water instead of gasoline, but you will agree that it is quite an accomplishment to drive any automobile, including the "mighty jeep", around for several hours in water up to the driver's chin. Of course, the jeep has been able to do this for some time for a few minutes, during landing operations, by covering its vulnerable points with waterproof grease. That achievement is not to be be-littled, because it was one of the factors that aided in winning a war that was largely landing operations. It was a crowning achievement to the men who devised it and to those who put it into use. But now the "water-fording" jeep can be ready to go overboard on a few seconds notice simply by closing a couple of valves from the dash panel.

Early in the War in the Pacific Area, the jeep proved a boon to the Marine Corps by providing both a carrier and a husky power supply for short-range radio equipment to supplement hand-generator and dry-battery radio sets. The previous use of the car ignition battery as a radio power supply had severely limited the range of any radio equipment used in moving military vehicles prior to the development of the power-takeoff generator. This generator, rated at 12 volts, 55 amperes, 660 watts, taking its power directly from the jeep drive shaft, gave a steady dependable power supply. Because of this the jeeps were used to carry many types of radio equipment up to and including the 75-watt SCR-193. Its principal use was with the TCS as an MZ radio communication equipment.

So many installations were made in jeeps and used for landing operations where the jeep had to "wade" ashore from a landing craft, or was used in fording island streams, that the Bureau of Ships was soon urged to provide integral water-proofing of the radio equipment as part of the installation. This would save much effort being expended before and after each of these operations in preparing the radio equipment to prevent its being damaged by water. Late in 1944 designs were completed to provide "submersion-proofing" for all the radio cases used. These were placed in production about the middle of the contract for Model MZ-2 production.

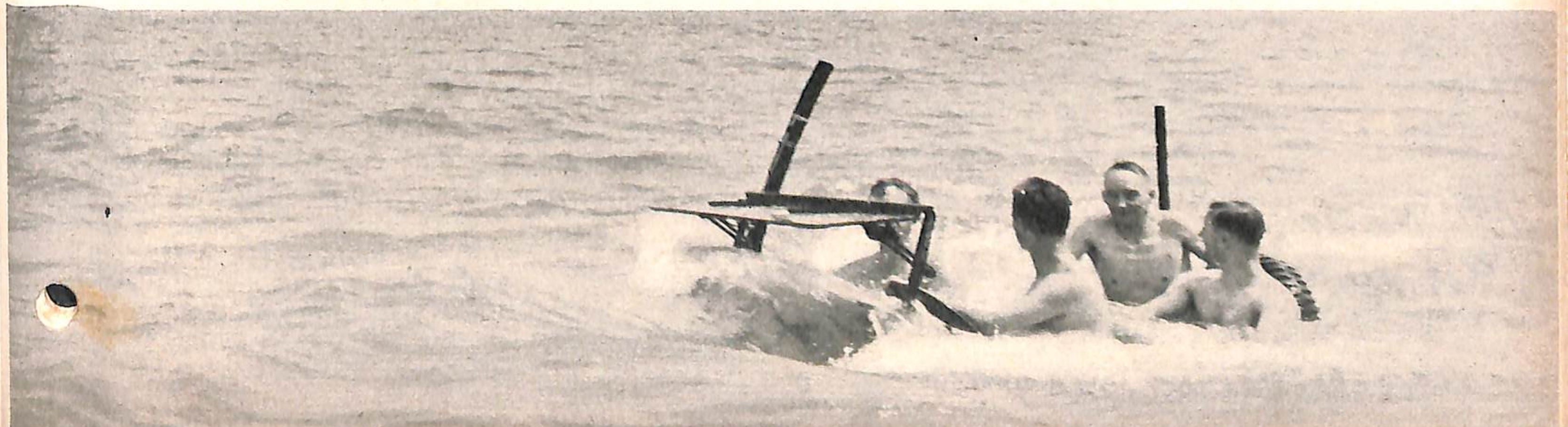
In February 1945 the Model MZ-3 installation plans were completed for an entire jeep and radio equipment submersible in 5 feet of water and capable of driving ashore or across the rivers through this depth of water. Production on these had been under way a month when the War ended in August.

With the stopping of the jeep assembly lines shortly thereafter, it seemed for a while as though no further production would be practical. This has now been overcome by supplying a complete kit for submersion-proofing the Model TCS radio equipment, known as the MX-590/MRC Kit (for the SCR-508 series, the MX-566/MRC-Kit), and for use with any Willys-Overland Jeep, a kit known as the "deep-water-fording" Kit (MX-735/MR Kit). A 12-volt, 55-ampere corrosion-resistant generator and the power-takeoff assembly (MX-736/MR Kit), plus two 6-volt batteries, are needed to provide the complete Model MZ-3. This model MZ-3 radio equipment will be quite similar to all prior model MZ equipments with the principal exception that it will be completely submersion-proof. It was not intended that the radio equipment be operated under water—just that it should be ready to operate without damage immediately after removal from the water. The 12-volt power-take-off generator was not made water-proof because ventilation was necessary to prevent overheating. However, the coils and all vulnerable parts were given special treatment to give them more resistance to corrosion by salt water.

Two vent pipes, one for the exhaust and the other the air intake for carburetor and gas tank, and the operator's head will be all that is visible above the water. The gasoline motor with sealed-off spark plugs, generator, dash instruments, etc., carry merrily on, operating as well under water as above. On reaching the bank of the stream the water-proof doors are opened and the radio turned on,—after coming through the ducking dry as a bone. Thus, time marches on for the Marine Corps in their living up to the saying "The Marines have landed and have the situation well in hand".

To obtain the fullest benefit from this piece of equipment, the Model MZ-3, the jeep and the PTO generator should be run for about an hour after dunking to dry out the generator and force the water out of certain vulnerable parts of the jeep. Furthermore, at the earliest opportunity, though this may be several days, the generator should be opened up and thoroughly cleaned. Meanwhile, it is an excellent idea to pour several gallons of clean fresh water through the PTO generator as soon as possible after dunking in salt water to clear out any salt or sand that may have collected in the interior. This may be easily accomplished by using a hose, or a syphon from a water container, allowing the water to run into the brushes of the generator while the generator is running. This treatment, the dunking and flushing, applies only to the more recently developed corrosion-resistant PTO generator, which may be quickly identified by means of the white stainless-steel brush holders and the use of red Glyptal on the insulating washers for the brush-holder rivets and the power terminals of the generator itself. The older type generators have brass brush holders. The earlier models of this generator not identified as above must be especially prepared before submerging and need urgent cleaning if they are submerged by accident. Like all special-purpose equipment, the entire "water-fording" jeep will require a higher degree of maintenance to keep it fit for this new use. However, with the water-fording equipment, the radio jeep will fare better when stored over a period of time in the open.

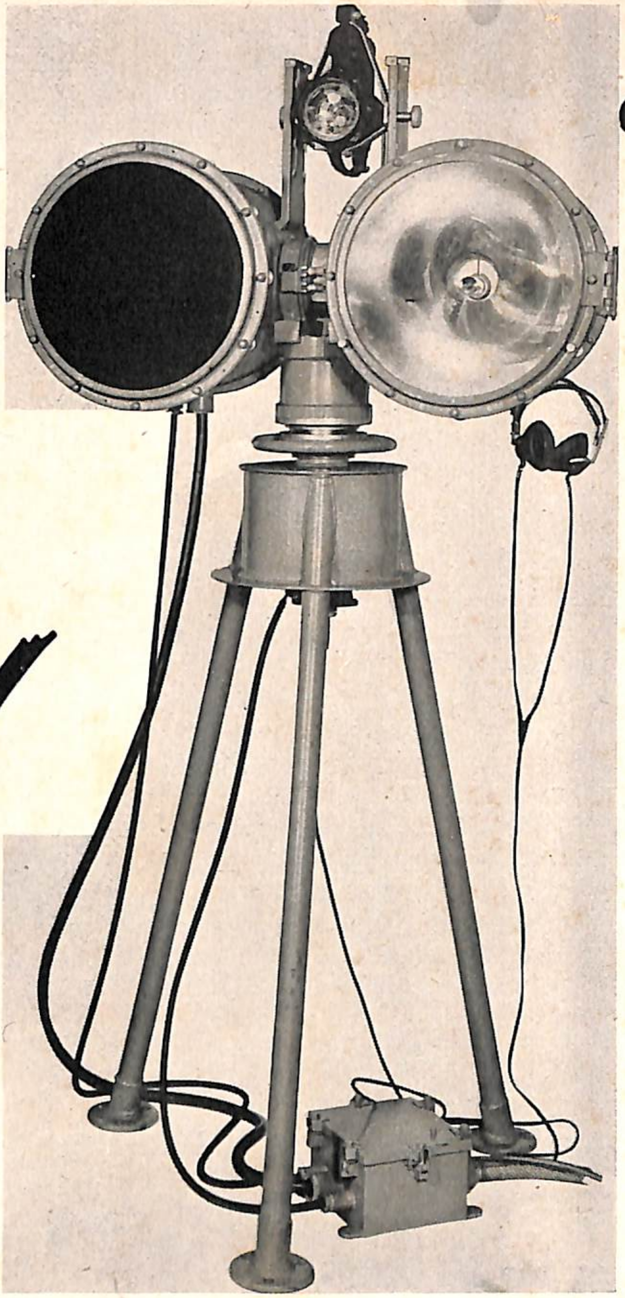
There was a lot of good-humored joshing around the Bureau before the end of the war as to the intentions of the Marines in using these water-fording jeeps. It was popularly whispered they would be equipped with periscopes, loaded with Marines, and driven directly from San Francisco to Tokyo. Well, we may have to do it that way if there's another war.



Type-E NANCY Communication System

■ The type-E *NANCY* communication system is a means of transmitting voice or code messages over a beam of invisible light. This is made possible by the use of a light source having a light output which is proportional to the current flowing through it over the voice range of frequencies, and receiving this modulated light by means of a photocell and converting it back into sound. The light is made invisible by placing a filter before the source. The filter passes only the infrared portion of the radiation and cuts down the visible portion, so that the source is not visible beyond about 400 yards.

The transmitting system uses a microphone and speech amplifier (or a tone oscillator), an amplifier-modulator, and a special lamp and its auxiliaries. The receiver consists of a photocell, preamplifier, amplifier, and speaker or headphones. The major units are a control panel and two transceiver heads, one of which is mounted on each side of the ship to obtain full horizontal coverage.



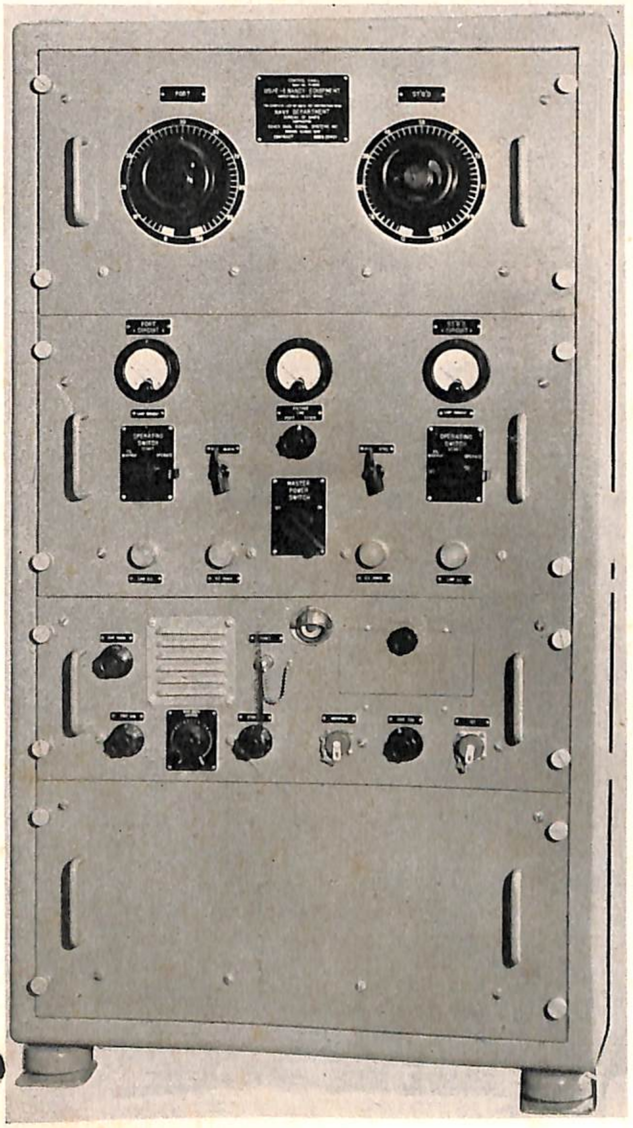
Front view of one transceiver head of the Type-E Nancy Communication System showing the transmitter drum, the receiver drum, and the infrared image receiver.

Each transceiver head consists of two aligned drums mounted on a tripod so that they can be trained by hand in both azimuth and elevation. The transmitting drum contains the special caesium-vapor lamp and its reflector with an infrared filter over the front. The receiving drum contains the photocell with its reflector, and a preamplifier for raising the signal to such a level that it can be transmitted to the control panel.

The control panel is a cabinet with four drawers. The top drawer contains ballast resistors through which the lamp is connected to the d-c line. The d.c. is necessary to form a "carrier" or steady value on which the a-c signal can be superimposed. The next drawer contains the starting circuits for the lamp, and the operating controls. The third drawer contains the main amplifier for the receiver as well as the voice pre-amplifier and a tone oscillator for the transmitter. The bottom drawer contains the transmitter power amplifier and the power supplies.

To establish communication, each ship must know the location of the other ship, as the Type E cannot be used until both equipments are trained on each other. Broad-beam optics (approximately 15°) are employed so that the equipments can be aligned despite a reasonable amount of roll and pitch. To aid the operator in keeping the equipment lined up on the other ship, a type C-3 infrared image receiver is provided on the transceiver head which may be sighted on a beacon on the other ship. Also, the outboard operator is equipped with headphones so that he can monitor the conversation, which also helps him to keep the equipment in line.

Control panel of the Type-E Nancy Communication System showing the arrangement of controls and switches. This unit is located below deck.



The operation of this type of equipment is seriously affected by the clarity of the atmosphere. In average clear weather (visibility 8 miles), the operating range of the equipment when using voice is approximately 5 nautical miles, and with tone-modulated code approximately 7 miles.

TRANSMITTING CIRCUITS

When transmitting voice, the microphone is connected to the preamplifier V-14. A high-pass filter is provided to attenuate frequencies below 1000 cycles. This filter is needed because the capability of the transmitting lamp is limited, and by eliminating the lower audio frequencies, the high-frequency input to the lamp can be increased. The low frequencies have been chosen for attenuation because they contain a considerable amount of the energy present in speech, but they are not necessary for intelligibility.

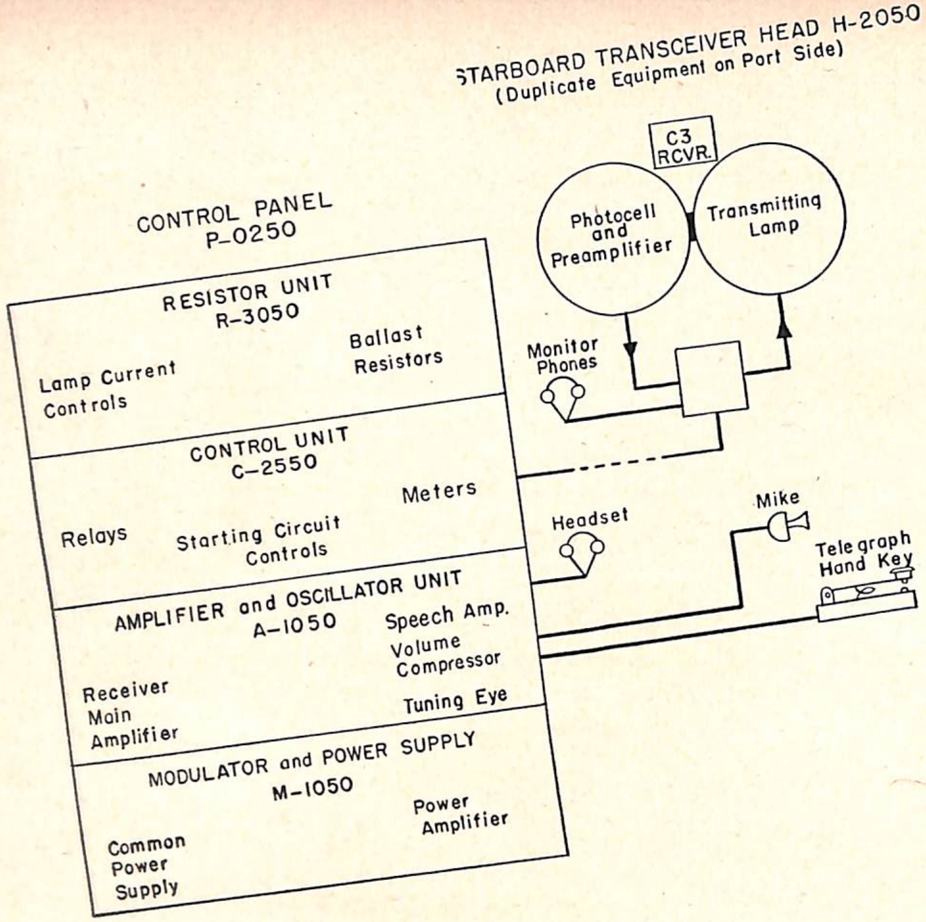
The output of the filter is fed into grid #1 of V-15, a 6SA7 tube, through the compression control. The compression control circuit, consisting of tubes V-15, V-17, V-16, and V-26 and their associated circuits, keeps the audio output of V-15 constant for widely varying microphone inputs. This volume-compression circuit performs somewhat the same function as an automatic volume control. A magic-eye tube V-26 is connected so that it indicates 20 db of signal compression when fully closed.

The signal is amplified to a sufficient level in the following stages to drive the power amplifiers V-22 and V-23. The output of these tubes is coupled to the audio-power line through a transformer, which provides 60 watts of audio power to modulate the lamp.

When transmitting in code, the 1500-cycle audio tone oscillator is connected to V-18 by means of the switching circuit. Keying is accomplished by breaking the circuit between V-18 and V-19.

In order to ignite the transmitting lamps, it is necessary that the two filaments in each lamp be preheated for a period of approximately one minute in order to vaporize some of the metal deposit on the walls of the lamp. (This is somewhat the same procedure as must be followed when starting a mercury-vapor rectifier tube.)

After the filaments have been heated, a high a-c voltage is applied between them. This high voltage ionizes the gas within the tube and causes it to break down and conduct. As soon as the lamp breaks down the high voltage is removed and ballast resistors and d-c current from the ship's supply are cut in, so that the lamp continues to function on the d-c circuit.



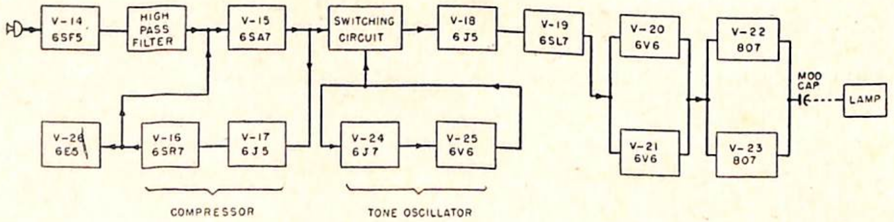
Block diagram of the Type-E Nancy Communication System showing the arrangement and interconnection of major components.

This d-c circuit is thoroughly filtered to eliminate commutator ripple so that the ripple frequencies will not be transmitted by the lamps. Next the audio output from the modulator is applied across the lamp through an 800-μf dry electrolytic capacitor.

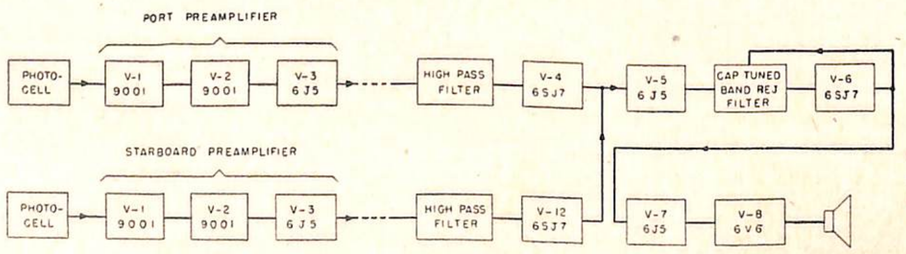
RECEIVING CIRCUITS

When receiving, the modulated light beam is collected by a parabolic mirror and focused on the photocell in the receiving drum. Resulting variations in photocell current, in the form of an audio signal, are amplified in the three-stage preamplifier before being transmitted to the main amplifier in the main control panel by means of a 500-ohm line.

At the main amplifier, the signal passes through a high-pass filter and is amplified sufficiently in subsequent stages to drive a loudspeaker. V-6 has a capacity-tuned band-rejection filter which introduces negative feedback into this stage at all frequencies except that to which it is tuned. This feedback circuit improves the selectivity of the system when adjusted properly by means of controls provided on the panel.



Block diagram of the Type-E Nancy Communication System transmitting circuits showing the path of the signal from the microphone or tone oscillator to the transmitting lamp.



Block diagram of the Type-E Nancy Communication System receiving circuits showing the path of the signal from either photocell to the loudspeaker.

Pulse Modulation

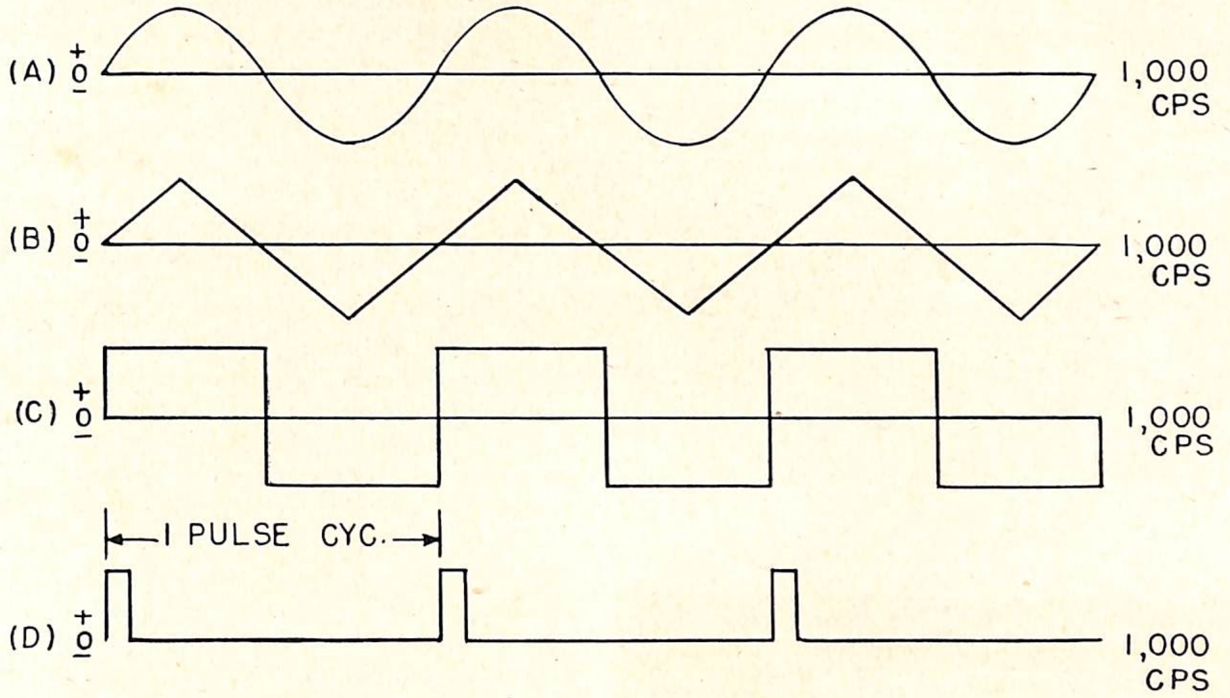


FIGURE 1—*Four types of waves having the same frequency; three possess mirror symmetry while the fourth (D) does not, since it has no negative-voltage excursion.*

Based on material obtained from the Warrant Officers' Radio Engineering School, Naval Research Laboratory, Washington, D. C.

■ Any comprehensive study of pulse modulation must include a discussion of wave analysis, as the pulsed emission from a radar transmitter or from a radar jamming transmitter is essentially a complex wave. Waves which are said to be complex consist of an integral number of sine waves of various frequencies and phase relationships. An analysis of a complex wave may reduce it to its equivalent sine waves. This is possible mathematically by use of the *Fourier series,* which deals with harmonic relationships in an exact quantitative manner. However, where the reader is interested from a purely functional standpoint and is not concerned with exact quantitative information, it is possible to develop the subject in a very straightforward manner.

To avoid misconceptions, it is necessary to plainly set forth all premises and definitions. First, the term frequency will be considered. As used conventionally it means that a certain number of cycles are completed per second. Thus a rate per second is established. It is not necessary that any minimum number of cycles be generated to create a rate. In the case of 60-cycle power, by simply dividing the number of cycles per second into one second we learn that 16,666 microseconds are required for the completion of one cycle. Where a cycle of events is completed in 16,666 microseconds, the rate (or frequency) is said to be 60 c.p.s. This rate is equally applicable to the first cycle created, or to another created an indefinite time later, so long as they are completed in 16,666 microseconds. Thus it is evident that frequency and repetition rate are not necessarily synonymous.

When one thinks conventionally of so many *cycles per second* he has a mental picture of a series of sine waves, progressing through both positive and negative voltage excursions at a sinusoidal rate, the shape of the positive alternation, or half-cycle, being identical to the negative alternation. If the positive alternation were folded downward below the zero axis line, it would exactly duplicate the negative alternation. Such waves are said to possess *mirror* symmetry. This statement holds true in the case of triangular or square-shaped waves. If a series of sine waves, triangular waves, and square waves were sketched in such a manner that the time required for the completion of one cycle was the same for each, as shown in figure 1, all three would have the same frequency and would possess mirror symmetry. But suppose that a wave is so complex that it has a positive voltage excursion only. This is the case in pulse modulation where, in the period between the pulses, the wave is entirely suppressed. A study of the shape of the three symmetrical waves reveals that they are true waves, as they progress through loops and nodes and the two polarities in the manner of wave motion. The fourth pattern in figure 1 also represents waves, but they are very complex, wherein, by the nature of pulse modulation, only positive voltage excursions are created after long intervals in which the voltage level is held at zero. This type of wave does not possess mirror symmetry.

FIGURE 2—*Carrier modulated by 1000 cycles, showing relative amplitude versus frequency in the side bands.*

The long time-interval between pulses is required in radar work to permit the receiver to receive the returning reflections of the radio wave. This would not be possible if the transmitter were modulated by a wave that would cause it to be on the air all the time. It is necessary to have a very narrow pulse, in point of time, to be able to receive echoes on the radar from nearby objects. A second vital factor in the determination of pulse width is range *resolution*—that is, the ability to discriminate between objects close together in range.

An investigation of the four patterns shown in figure 1 will reveal any characteristics common to all four. It is immediately apparent that their frequency is the same, because in each of the four cases a complete cycle of events occurs in .001 second or at a frequency of 1000 cycles per second. In the case of a radar which is pulse-modulated at a rate of 1000 cycles, we find that its radio-frequency wave as emitted is amplitude-modulated at 1000 cycles. This is only a part of the complete picture of the modulation, for the emission will additionally be modulated by harmonics of 1000 cycles. The effect of any frequency or amplitude modulation on the pattern emitted in the frequency spectrum is to bring about the presence of side bands. If a plot of the relative amplitudes of these side bands *vs* frequency is made on graph paper, it becomes evident that the so-called side bands plot as a new signal frequency, whose separation from the carrier frequency to either side is equal to the frequency of modulation. This is briefly illustrated in figure 2, which shows the pattern created in the radio-frequency spectrum by amplitude modulation of a carrier by a pure sine wave 1000-cycle voltage. The side-band frequencies exist because of the fact that, when two frequencies are mixed, frequencies equal to their arithmetical sum and difference (*heterodyne* frequencies) are created. If the modulation voltage is not a pure 1000-cycle sine wave, but instead is a complex wave possessing harmonics, the pattern represented in figure 2 will no longer apply.

The wave shown in figure 1 (D) is very complex, so in order to determine what harmonics of 1000 cycles will modulate the radio-frequency output of a radar such as the one mentioned, it will be necessary to determine what harmonics are generated. To determine this fact involves a study of how these harmonics are generated. Harmonics, to exist, must be reinforced from time to time so that circuit losses will not eventually reduce their amplitude to zero. To sustain a harmonic, the reinforcing voltage must arrive at such a time and phase relationship as to bring about an increase in the strength of that harmonic. A harmonic cannot be sustained if the reinforcing voltage is electrically 180° out of phase with the harmonic. So it is seen that harmonic generation is essentially a matter of timing. Consider a 1000-cycle quasi-sinewave, such as that shown in figure 3, on which is drawn the second and third harmonics. The phase relationships developed here are typical of even and odd harmonics, respectively, and will hold true for *any* even or *any* odd harmonic. The fundamental (first harmonic) progresses through its first alternation or one-half cycle, following which it arrives at zero voltage. When the amplitude of the fundamental falls to zero it will be noted that the amplitude of any or all harmonics fall to zero at the same time provided they have begun in phase with the fundamental. For this reason it is not possible to have a fractional harmonic. All harmonics are *integral* (whole-number) harmonics.

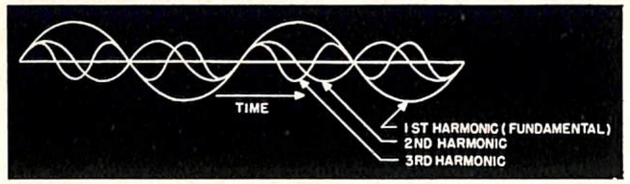


FIGURE 3—*Phase relationships between the fundamental, 2nd harmonic, and 3rd harmonic in a sine wave.*

Again in figure 3, note that at the time of the completion of a cycle of the second harmonic, where it falls to zero, it is progressing in a positive direction. At this point, if it is to exist, it must go positive. However, the fundamental is going from zero in a negative direction at that same instant. It is evident then that a sine wave, or any wave possessing mirror symmetry, will exert equal power in initiating and in stopping any even-order harmonic. For this reason the average power put into an even-order harmonic is zero in symmetrical waves, and only odd-order harmonics will appear in such waves. From the above it is evident that the waves which are not symmetrical may contain both even- and odd-order harmonics. If the symmetrical wave is a pure sine wave, only the fundamental will be present.

The pulse cycle shown in figure 1 (D) is not symmetrical because there are no negative voltage excursions in such a modulation voltage. Both odd- and even-number integral harmonics may therefore be present in the pulse cycle. However, if we restrict the study to the period of the pulse alone, it is seen that the pulse proper is one-half of a square wave which, due to its mirror symmetry, possesses no even-order harmonics. This situation presents the phenomena whereby such a complex wave, when used to modulate a transmitter, will cause the generation of even and odd harmonics of the pulse-cycle frequency, but only odd harmonics of the frequency corresponding to the pulse-base width.

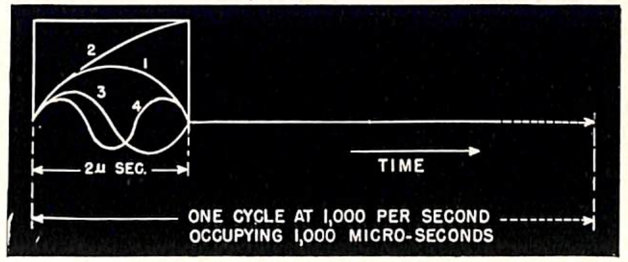


FIGURE 4—*Harmonic relationship in a typical square-wave pulse.*

By expanding one pulse cycle it is possible to determine the limiting number of harmonics that may be present. The pulse in figure 4 is seen to initiate several waves. The half-cycle which begins and ends its positive-voltage excursion with that of the pulse (curve 1 of figure 4) will possess the same repetition rate as the pulse itself,—that is, 1000 times per second. It becomes evident that, although this half-cycle is initiated only 1000 times each second, it is produced at a *rate* equivalent to 1000 times the number of whole cycles that could be completed within each cycle of that 1000-cycle wave. Now, the total number of whole cycles that could be embraced within one cycle of a 1000-cycle wave is equal to 1000 microseconds divided by 4 microseconds (the time required for a full cycle of the 2-microsecond pulse) or 250. Within one full second's time, then, 1000 times 250, or 250,000 cycles, could be produced. This might be easier to understand if explained on the basis of *time*. The time required to complete any one cycle of a 1000-cycle wave is 1000 microseconds. Also, if a sine wave requires 2 microseconds to complete a half-cycle, it follows that it will require 4 microseconds to complete a full cycle. In a 2-microsecond pulse, the fundamental sine-wave frequency will therefore have a time period of 4 microseconds, thus allowing 250 positive excursions in 1000 microseconds, or 250,000 in 1 full second. Thus the 2-microsecond pulse (which has the same width as the positive excursion of a complete 4-microsecond sine-wave) will generate the 250th harmonic of the pulse cycle. This figure represents the 250th harmonic of the pulse repetition rate and the first harmonic (actually, the *fundamental*) of the pulse frequency.

For harmonics of the pulse repetition rate from the first to the 250th, assuming a perfectly square 2-microsecond pulse, the absolute level of power in the harmonic varies downward from the 1st to the 250th. Referring again to figure 4, curve 2 represents those frequencies between 1 and 250 kilocycles which, to exist, must be harmonically related to the pulse-repetition frequency. They must have such time relationship as to terminate at the end of the 1000-microsecond pulse cycle in a positive-going alternation. Curve 3 in figure 4, though starting out in phase with the pulse, is out of phase with the pulse at the common terminal point of curve 1 and the pulse. The frequency represented by this harmonic may be arrived at directly by dividing unity by the pulse width, which in the case illustrated is 2 microseconds, giving 500 kc. At this frequency, which is the 500th harmonic of the pulse repetition rate and the second

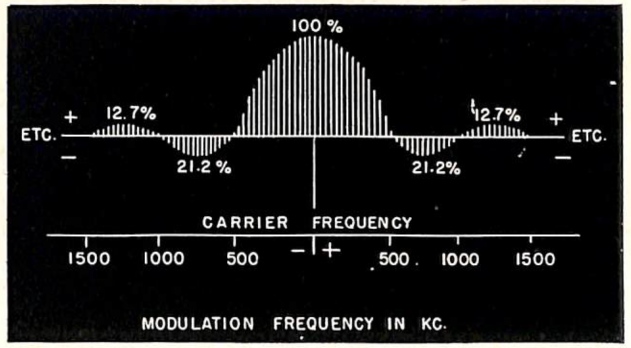


FIGURE 5—*Distribution in frequency, showing relative amplitude and polarity of the various side bands generated by a radar with a repetition frequency of 1000 cycles and a pulse width of 2 microseconds.*

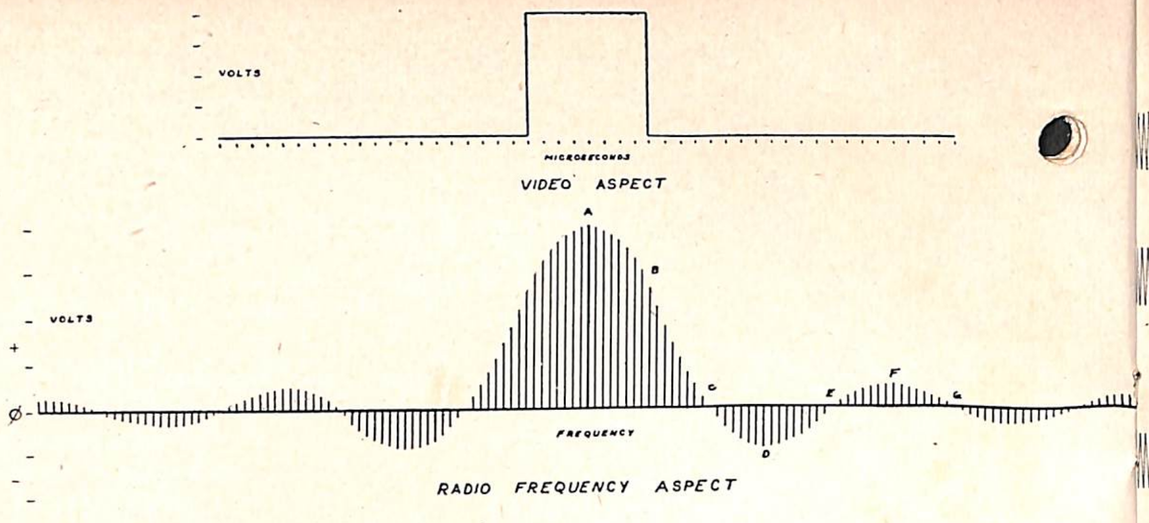


FIGURE 6—*Rectangular pulse analysis, video aspect versus radio-frequency aspect.*

harmonic of the pulse frequency in the case of a perfectly square wave, there will be zero power as the pulse will be acting to start and to stop this harmonic with equal force. The pulse decreases through a potential exactly equal to the potential that it rises through. Therefore at 500 kc there will appear a null in the distribution of power in the side bands emitted by a transmitter modulated by such a square wave. The position of this null in the frequency spectrum is a boundary, with the carrier center as the opposite boundary, in setting the limits of the so-called "band-width" in the radio-frequency spectrum.

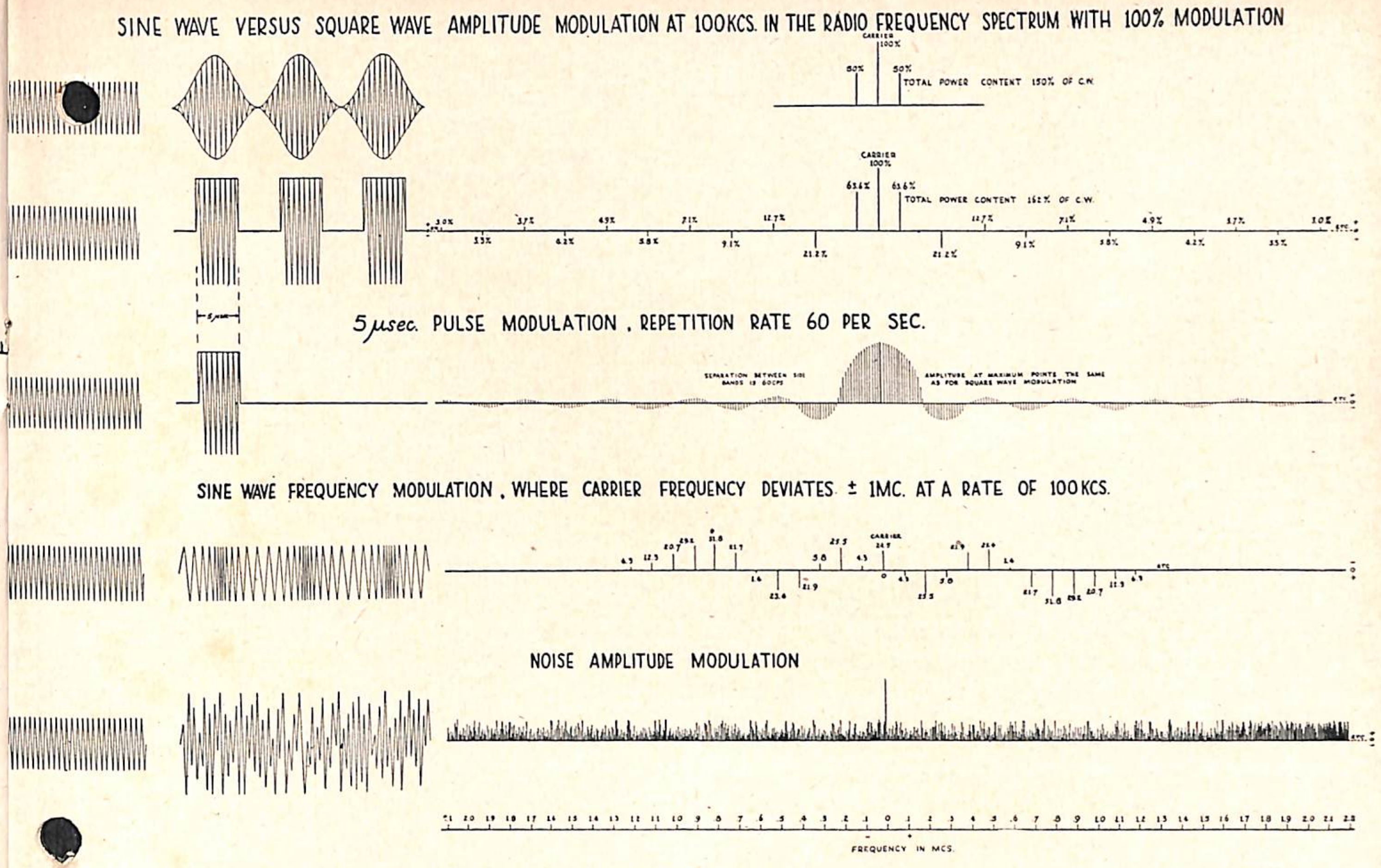
Curve 4 in figure 4 shows a wave so related harmonically to the pulse frequency as to be able to receive power from the rise and fall of the pulse. This is the third harmonic of the pulse. Its frequency is 750 kc since it is three times greater in frequency than that in curve 1. Thus at 750 kc there will appear a lobe center in the side-band distribution. It will be noted that this occurs at 1.5 times the modulation frequency at which zero energy is produced.

Figure 5 indicates the distribution in frequency, with relative amplitude and polarity, of the various side bands generated by a radar at a pulse repetition frequency of 1000, and having a 2-microsecond pulse. The pattern presented in figure 5 consists of a series of discrete carriers distributed in frequency at equidistant intervals equal to the pulse repetition rate, which in this case is 1 kc. The relative amplitude of these individual carriers varies in a quasi-sinusoidal manner, commencing at the carrier and progressing outward in either direction. Each successive lobe decays in amplitude but maintains a definite periodicity. Complementary lobes on the two sides of the carrier have the same polarity. The interval in frequency between the carrier and the first crossover is exactly equal to the reciprocal of the pulse-width time.

It should be noted that each individual side band represents a separate signal on the air. Were it possible to tune in on this emission with a receiver of such selectivity as to accept just one side band, the receiver would be presented with a single signal when the modulation is accomplished by a perfectly square-topped pulse of a constant repetition rate. The configuration appearing on either side of the carrier in figure 5 may be referred to as side-band lobes. Their amplitude relative to the carrier depends upon the shape of the pulse and does not change with frequency of emission or pulse repetition frequency. The point of zero amplitude occurring between the lobes will change its position in frequency with changes in pulse width. In the particular case illustrated, a point of zero amplitude occurred at 500 kc to either side of the carrier as this was the frequency corresponding to the second harmonic of the pulse frequency and, as demonstrated earlier, the square-topped pulse being one-half a wave possessing mirror symmetry, contains no even-order harmonics.

Thus it is clearly seen that the band width in the radio frequency spectrum occupied by the energy in the emission from a pulse-modulated transmitter is inversely proportional to the emitted pulse width. As the pulse width decreases, it possesses a higher rate or frequency. This higher frequency then modulates the emitted radio wave, extending the side bands out further from the carrier.

Most receivers which are intended to receive pulsed emissions possess in their intermediate-frequency amplifier a sufficient bandwidth to accept the frequency spectrum covered by the pulsed emission between the plus and minus cross-over points. However, in practice the i-f bandwidth is measured at the point of 70.7% of maximum voltage response. Thus it is seen that quite a good response is obtained outside this receiver bandwidth at reduced sensitivity. In consideration of this fact, it is unnecessary that the i-f bandwidth (as measured) fully embrace the complete radio-frequency spectrum covered


SINE WAVE VERSUS SQUARE WAVE AMPLITUDE MODULATION AT 100KCS. IN THE RADIO FREQUENCY SPECTRUM WITH 100% MODULATION

5μsec. PULSE MODULATION, REPETITION RATE 60 PER SEC.

SINE WAVE FREQUENCY MODULATION, WHERE CARRIER FREQUENCY DEVIATES ± 1MC. AT A RATE OF 100KCS.

NOISE AMPLITUDE MODULATION

by the pulsed emission. When reference is made to the bandwidth in the emitted radio-frequency spectrum, as previously stated, the width is measured from the carrier out to either side to the first cross-over point. Video amplifiers need only a bandwidth adequate for this dimension in frequency, as they follow a detector which has removed one set of side bands. This is a minimum ideal requirement. In practice, due to several design considerations, the bandwidth of present-day video amplifiers in radar systems is made equal to the i-f bandwidth.

By reference to figure 5 it is seen that very little would be gained by going to an i-f bandwidth of more than one megacycle centering on the carrier. Both the major lobes in their entirety are embraced by an i-f bandwidth of one megacycle, with 70.7% or more of maximum response, and the second lobe as well is accepted with some degree of response below 70.7% of maximum. Signal-to-noise ratio is improved by restricting the width of the i-f amplifier as much as practicable. The null points in figure 5 occurring between #1 and #2 lobes counting out from the carrier in either direction (referred to as "first cross-over point") always occur at a harmonic of the pulse repetition rate whose number is equal to the ratio between the width of the pulse cycle and the pulse itself. In the case of the Model SG radar it was found that this ratio was 500.

Let us consider the situation existing in the case of the CXAM equipment. Though this equipment is obsolete, the characteristics lend themselves very well for the purpose of this discussion. The period of the CXAM pulse cycle was approximately 610 microseconds, and its pulse width was approximately 5 microseconds. Thus at the 122nd harmonic of the pulse-repetition-rate frequency of 1640, or 200 kc, we will find the first cross-over point. As a short cut, the modulation frequency at the first cross-over point may be found directly by dividing the pulse width into unity. The effective bandwidth is considered to be between the plus and minus cross-over points. Thus the 200 kc becomes doubled, giving us a 400 kc band width.

The SC-Series radar has a pulse cycle period of 16,666 microseconds. Its emitted pulse width will vary widely with various transmitter tuning adjustments. However, 5 microseconds is a figure quite commonly used for its pulse length. Thus both the CXAM and the SC operate with a 5-microsecond pulse length and the bandwidth of the two receivers is theoretically the same. The sole difference is in the magnitude of the interval between the discrete sidebands where equal power is assumed, as in this discussion.

In the case of the SC-Series, these side bands will be separated by only 60 cycles while in the CXAM they will be separated by 1640 cycles. This makes it evident that the SC places practically a continuous solid pattern across the frequency spectrum within the limits of its cross-over points while the CXAM produces a side band only every 1.64 kc. It is not inferred that a low pulse rate is superior to a high pulse rate solely because of this characteristic. Other factors enter into the situation which bring about a superiority for a high pulse rate over a low pulse rate when amplitude of echo is the only criterion.

From the study of pulse modulation as developed in the preceding paragraphs, we arrive at several definite conclusions of significance to the technician. The first and foremost is the fact that, irrespective of emission or pulse repetition rate, as the pulse width is decreased or increased the bandwidth in the radio-frequency spectrum is correspondingly increased or decreased respectively. In cases where the receiver i-f bandwidth has been set by design for a fixed value, without provisions for varying the bandwidth from the receiver panel, if we change the tuning adjustments on the transmitter so as to bring about a change in its bandwidth in the frequency spectrum a very definite change in overall performance will take place. In the same line, suppose variable i-f amplifier bandwidth is provided and the nature of the design of the pulse-modulated transmitter is such that changes in its pulse length may not be brought about readily. Under these conditions the value of the variable i-f control is largely lost, for if the i-f bandwidth in the receiver is narrowed down the same maximum performance will not be maintained. This is because the receiver will be accepting only a fraction of the energy in the bandwidth of the transmitter's output. For these reasons it has been considered inadvisable to include a variable pulse-length control without variable i-f amplifier bandwidth control and vice-versa. For maximum performance and satisfactory fidelity of pulse-pattern reproduction, the i-f amplifiers in receivers designed to receive pulsed emissions must possess a bandwidth in megacycles which is equal to 1.2 divided by the pulse width in microseconds. The shape of the response curve of the i-f amplifier should be as flat-topped as possible.

It may be proven rigorously by mathematics that, as the shape of a pulse departs from the perfectly rectangular shape, there is a decay in the amplitude of the discrete side bands composing the side-band lobes. The rate of their decay from the carrier outward to either side departs from the quasi-sinusoidal as the square-topped pulse is rounded off. In a radar receiver, the only energy we have following the second detector is that derived from the side bands. Thus it is seen that, for maximum efficiency, a pulse which approaches the square-topped condition as closely as possible must be employed, as less and less power appears in the side bands as the pulse is rounded off.

The foregoing statements may become more evident by referring to figure 6. The number of side bands between the carrier and the first cross over point is determined by the ratio of pulse cycle period to the pulse width. The separation between any two adjacent side bands is equal to the pulse repetitive frequency. Theoretically the side bands may continue on out from the carrier infinitely. However, in practice the number of side bands and their amplitudes are in the final analysis limited by the band width of the circuits they are placed in. Where any side bands are sliced due to passage through circuits of inadequate frequency band width, the effect produced is a rounding of the corners on the video aspect of the pulse and a loss of power in the side bands generally. The optimum i-f amplifier band width equals the dimension in frequency found between positive and negative cross over points. This figure in Mc equals 1.2 divided by the pulse width in microseconds. Video amplifiers require only one-half this width.

The distribution of side bands and their amplitudes relative to the carrier are arrived at mathematically assuming a perfectly rectangular (square topped) pulse with no incidental phase or frequency modulation. Under these conditions, the following aspect is valid; the letters referring to points on Figure 6: A—Carrier amplitude $= 100\% = E$. B—Amplitude at a point one-half way to cross over points, $2E/\pi$. C—First cross over point. Separation in Mc from carrier frequency equals 1 divided by the pulse width in microseconds. D—First side band lobe. Maximum amplitude equals $2E/3\pi$. Its negative polarity has no significance other than phase relative to the other side bands. E—Second cross over point. Separation in Mc from carrier equal to twice that of the first cross over point. F—Second side band lobe. Maximum amplitude equals $2E/5\pi$. G—Third cross over point. Separation in Mc from carrier equal to three times that of first cross over point.

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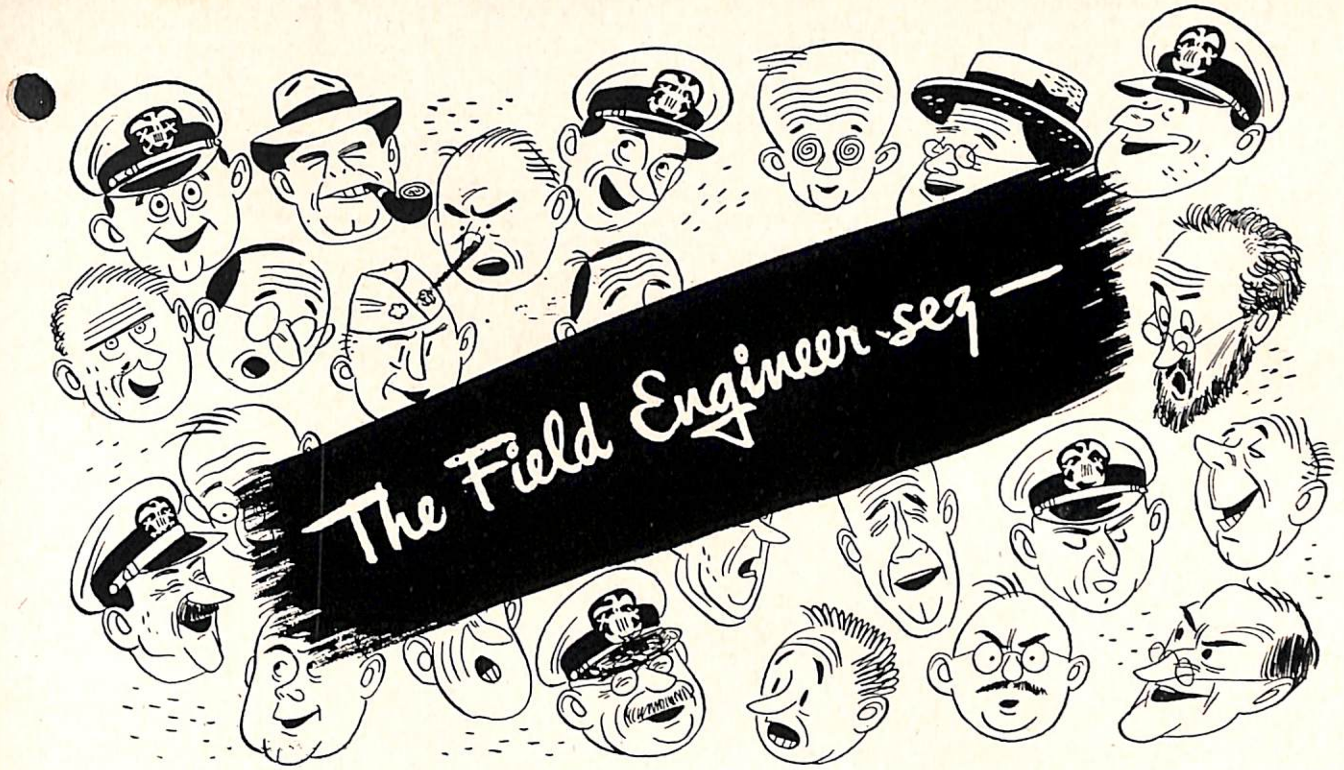
DECLASSIFICATION OF SONAR BDI ATTACHMENTS

On 15 March 1946 the Chief of Naval Operations issued letter OP-413-B23/jeh Ser 928P413 downgrading certain sonar BDI attachments. Those downgraded are the Models X-3 and X-4 developed by Harvard University, the CQA-55098 and CQA-55099 manufactured by Astatic Corporation, the CDI-55136 manufactured by Bogen, the CRV-55149 manufactured by RCA, and the CBM-55104, CBM-55105 and CBM-55137 manufactured by the Submarine Signal Company.



TUNING THE SR-2

Tuning of the SR-2 is considered a rather critical operation since incorrect tuning will result in a frequency shift when changing from one pulse width to another. To assist the technician in tuning and to standardize the procedure to be followed, the manufacturer of the SR-2 has issued the following detailed instructions.

Initial tuning of the equipment is done entirely from the Transmitter-Receiver assembly. The transmitting and receiving circuits of the Transmitter-Receiver assembly have been aligned and adjusted for operation at the factory before shipment, and should only be tuned to the assigned frequency at the time of installation. The transmitter is first peaked for maximum output and then the receiver and duplexer adjusted for maximum response as indicated on the Monitor Scope. A stationary land object should be used for tuning the equipment, or if at sea, the echo box of the receiver is utilized to provide an echo. Assuming that the oscillator tubes have been properly aged, that all the tuning controls have been set to an assigned frequency with reference to the tuning charts on the equipment, and that the equipment has been in RADIATION-ON operation for at least 15 minutes with reduced plate voltage, proceed as follows:

1—Check to see that wave selector switch is in the INCIDENT position, and the pulse length control in the "4" position. Then adjust the cathode tuning control for maximum reading on the reflectometer. Further maximize the reflectometer reading by alternately tuning the load stub No. 2 and load stub No. 1 controls. These controls tune very broadly, and the entire ranges should be covered to make certain that a peak is obtained. Retune, in turn, the cathode tuning, load stub No. 2 and load stub No. 1 controls until no further improvement of the transmitter output can be obtained, as indicated on the reflectometer.

2—On the front panel of the receiver turn the echo box switch to the ON position. Vary the echo box tuning control for a maximum indication on the echo box output meter, and from the setting of the control the operating frequency may be determined by using the frequency chart on the transmitter door.

3—Adjust focus, intensity, V-center, and H-center controls of the monitor scope for a clean, sharp, centered trace. Adjust the vertical amplifier gain control to get approximately $\frac{1}{8}''$ of grass on the screen. Obtain an echo response on the monitor scope by having the antenna trained on a stationary target. Adjust the sensitivity control on the receiver if necessary. While operating the press-to-tune-r.f. button, adjust the r-f tuning control until the response on the monitor scope screen attains maximum amplitude. If at sea, or otherwise using the response of the echo box, maximum response is indicated on the scope when the foot of the step extends as far toward the right (in the grass) as possible. The nominal range of the echo box is 3000 yards. If the sea is rough and clutter extends beyond 3000 yards, the echo box response will not be seen; however, fairly accurate tuning may be done on the sea clutter.

4—The two duplexer controls on the right-hand side of the transmitter lower-front panel should be varied. The duplexer protective tank tunes sharply, whereas the duplexer decoupling tank tunes broadly. Lock the controls when a maximum response is indicated on the screen of the monitor scope. In case of doubt about the proper operation of the duplexer, remove the right side shield of the transmitter and visually make certain that the duplexer spark gaps are firing properly.

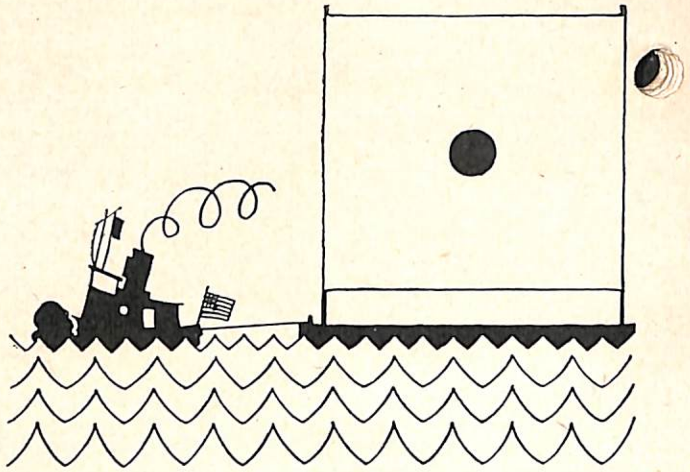
5—Throw the pulse length control to the "1" position. Check to ensure that no re-tuning of the receiver is necessary. Check that re-adjustment of the cathode tuning control does not increase the reflectometer reading. This reading will be slightly less in the "1" position, even for peaked-tune conditions. If no change of tuning is indicated, as is usually the case, return the cathode tuning control to its original setting, throw the pulse length control back into the "4" position, and re-check the receiver tuning. After operating any of the transmitter controls, the receiver peaking should be checked.

6—If the above check test (5) indicates any change of tuning, change the settings of the load stubs to neighboring positions which will not appreciably alter the output indication on the reflectometer. Particular attention should be given to load stub No. 1. The entire range should again be covered, and a setting made on another maximum, if one exists, or near the first setting of the original maximum. After each one of these setting changes, re-peak the cathode tuning, receiver tuning and duplexer tuning, and repeat the check test (5). Correct settings, as shown by this check test, should be obtained after a few trials.

7—Should some particular condition exist whereby the above procedure does not give good results, a slight change of frequency should be made, and the entire tuning procedure repeated, beginning with step 1 as explained above.

8—Increase plate voltage by pressing plate-voltage-raise button, observing the high voltage meter for sharp fluctuations and listening for arcing in the oscillator circuit. The maximum setting used should then be just below the point at which arcing occurs. The card over the high voltage meter specifies 6.5 kilovolts maximum, although this does not imply that this voltage can be reached with all tube combinations as some tubes will generate full power at lower plate voltages. However, at least 6.0 kilovolts should normally be attained; if it cannot, the oscillator tubes and circuit components should be checked. On the upper calibration chart on the transmitter front door, fill in the most favorable settings for stub No. 1 and stub No. 2. (Settings for the other controls were marked on the chart at the factory.)

—*RCA.*



DEFINITION OF GUN CONTROL FUNCTIONS

The terms "Target Indication", "Target Designation", and "Target Acquisition" being closely related, have oftentimes been incorrectly used due to misconception of their over-all meaning. To clarify this situation and to avoid incorrect usage of these terms in the future, the Chief of Naval Operations has issued the following definitions to cover their meanings and functions:

By *Target Indication* is meant the indication, to Command and gun-control stations, of the targets available. When considering a task force (group) (unit), it is the indication, to Command, of the targets approaching the area of gunfire. Target Indication includes all the information necessary for proper designation including the presence, identity, location, size, number, course, speed, and estimate of intention. In addition, CIC must include evaluated factors which are necessary in order that Command has adequate information for proper designation.

By *Target Designation* is meant the selection, by Command, of the target or targets which are to be taken under fire by a particular ship and/or gun batteries.

By *Target Acquisition* is meant the process of transferring a target from a search radar to a fire-control radar and/or optical system in such a manner that the latter may be so positioned in train and elevation that the targets will be imaged in the scope or optics and may be subsequently tracked.

In addition to the definitions given above, the following definitions are quoted from War Instructions for information:

Recognition is the process of determining the friendly or enemy character of others.

Identification is the process of indicating your friendly character.

Classification of Test Equipment

■ The following tables show the latest classifications assigned to test equipment used with various types of electronic installations. Unless otherwise indicated the instruction books for these units carry the same classification as the equipment.

Equipment	*Classification*
AN/UPM-7	R
CU-29/UP	R
CU-90/UP	U
CU-115/UP	U
CU-118/UP	U
CXJQ	U
LD	U
LF	U
LG	U
LJ	U
LK	U
LN	U
LO	U
LP	U
LR	U
LW	R
LX	U
LZ	U
LAB	U
LAC	U
LAD*	U
LAE	U
LAF	U
LAG	U
LAH	U
LAJ	U
LAK	U
OD	U
OE	U
OF	U
OG	U
OH	U
OJ	U
OQ	U
OT	U
OZ	U
OAA	U
OAE	U

Equipment	*Classification*
OAL	U
OAO	U
OAW	U
OBA	U
OBL	U
OBQ	U
OBR	U
OBT	U
OBU*	U
OBZ	U
OCD	U
OCG	U
OCK	U
OCL	U
OCR	U
OCU	U
OCV	U
OCW	U
OZA	U
TS-89/AP	U
TS-173/UR	U
TS-186/UP	U
TS-202/U	U
TS-231/AP	U
TS-268/U	U
TS-270/UP	R
TS-275/UP	R
TS-295/UP	R
TS-310/UP	R
TS-311/UP	R
TS-318/UR	C
TS-323/UP	U
TS-331/UR	U
TS-334/UP	R
TS-349/UP	R
TS-398/UP	R
TS-417/U	U
TS-432/UR	U

Equipment	*Classification*
TS-501/UP	C
47AAL	U
47AAM	U
47AAN	U
60ABC	U
60ABM	U
60ACZ	U
10223	U
22195	U
22196	U
49396	U
49397	U
49398	U
49416	U
49417	U
49992	U
60007	U
60018	U
60039	U
60044	U
60046	U
60055	U
60056	U
60059	U
60068	U
60077	U
60086	U
60089	U
60090	U
60094	U
60098	U
60107	U
60113	U
60123	U
62142	U
62153	U

In addition to the above, the following equipments (with instruction books) are reduced to Unclassified, falling under the categories of test equipment, training equipment, Radiation Laboratory (MIT) prototypes of Navy equipments, developmental or pre-production models of production equipments or accessories. These equipments are concerned directly with loran and should be classified as such.

Test Equipment:
  TS-251/UP Test Set.
  Type CDU-60073 Transmitter Monitor Oscilloscope.
  OCA Transmitter Monitor Oscilloscope.
  OBN Transmitter Monitor Oscilloscope.
  OBM Time Monitor Oscilloscope.

Training Equipment:
  CME-60069 and CME-60069-A Signal Generators.

Pre-Production and Developmental Models:
  CXJD and X-DBE Loran Receiving Equipment.
  X-DBS Loran Receiving Equipment.

Accessories:
  CG-47368 Antenna Coupling Unit.
  CG-301227 Loran Isolation Transformer.
  CAQT-47438 Antenna Coupling Assembly.

RADIATION LABORATORY PROTOTYPES:
  A-1 (Loran) Transmitter Test Oscilloscope.
  Janski and Bailey Type 43A Field Intensity Meter.
  Loran r-f Pulse Generator (prototype of CME-60069).

  A and B Timer.
  B-1 Timer.
  B-1 Timer Switch Gear.
  C Timer.
  C and C-1 Switching Equipment.
  C-1 Timer.
  Loran Synchronizer for B-1 and C Timers.
  Model 108 Transmitters.
  Model 108T Transmitters.
  Model 125T Transmitter.
  Models 575, 575B, 575BC-a Transmitters (plus any accessories for above prototypes).

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* Instruction book RESTRICTED.

New Field Changes

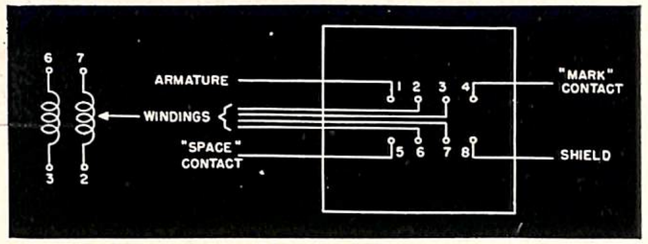
■ Miscellaneous modifications to communication equipment have appeared from time to time in the Communication Equipment Maintenance Bulletin. Many of these are now being converted to Official Field Changes, and having Field-Change Numbers assigned. Following is a list of the Field-Change numbers and titles of those modifications already reissued in the CEMB, together with the page numbers on which they can be found.

EQUIPMENT	Page
DAK DIRECTION-FINDING EQUIPMENT	
No. 1—Modulator Tube Balancer Kit	DAK/DAQ:2
DAQ DIRECTION-FINDING EQUIPMENT	
No. 1—Installation of Improved Loop Antenna	DAK/DAQ:2
DAS and DAS-2 LORAN RECEIVING EQUIPMENTS	
No. 1—Relocate Station Selector Trimmers	DAS:19
No. 2a—Change Time Corrector Circuit	DAS:19
No. 2b—Increase Slow Sweep Length	DAS:19
No. 3—Change DAS to DAS-A (Change pulse rate and improve cathode-ray-tube focus)	DAS:20
No. 4—Remove Filament Ground in Indicator	DAS:20
No. 5—Improve Balance Gain Control Circuits	DAS:20
No. 6—Change Gain and Fine Delay Controls	DAS:20
No. 7—Add Resistor R-285 (no kit)	DAS:20
No. 8—Adjust B+ to 280 volts instead of 300	DAS:21
No. 9—Change DAS-A to DAS-B, and DAS-2 to DAS-2B (Modify coils for four medium frequency channels)	DAS:21
No. 10—Add Two-Microsecond Markers for Monitoring	DAS:21
No. 11—Change Amplifier Balance to R-F Amplifier	DAS:22
DAS-1 and DAS-3 LORAN RECEIVING EQUIPMENTS	
No. 1—Change DAS-1 to DAS-1A (add PRR switch)	DAS:13
No. 1a—PRR Adjustment (if kit for field change No. 1 is not available)	DAS:13
No. 2—Change DAS-1A to DAS-1B (modify coils for four medium frequency channels)	DAS:14
No. 3—Receiver Diode Connection	DAS:14
No. 4—Nameplate Change	DAS:14
No. 5—Grounding Change	DAS:15
No. 6—Insulate Capacitor C-107/C-207	DAS:15
No. 7—Change Slow Sweep Resistor R-167/R-267	DAS:15
No. 8—Change Capacitor C-37/C-137	DAS:15
No. 9—Add Resistor R-31	DAS:15
DAS-4 LORAN RECEIVING EQUIPMENT	
No. 1—Waterproof Antenna Loading Coil	DAS:17
No. 2—Change Feedback Capacitor C-219	DAS:17
No. 3—Reduce Inductance of L-101	DAS:17
No. 4—Change Slow Sweep Circuit Resistor R-269	DAS:18
No. 5—Change Feedback Capacitor C-220	DAS:18
DAU DIRECTION-FINDING EQUIPMENT	
No. 1—Installation of Improved Loop Antenna	DAU:1
LRN-1 and LRN-1A LORAN RECEIVING EQUIPMENTS	
No. 1—Add PRR Switch	DAS:10
No. 1a—PRR Adjustment (if kit for field change No. 1 is not available)	DAS:11
No. 2—Change LRN-1 to LRN-1M, and LRN-1A to LRN-1AM (Modify coils for two medium frequency channels)	DAS:11
No. 2a—Change LRN-1 to LRN-1B, and LRN-1A to LRN-1AB (Modify coils for four medium frequency channels)	DAS:11
No. 3—Change Interconnecting Cable	DAS:11
No. 4—Change CRT Intensifier Circuit	DAS:11
RAK RADIO RECEIVING EQUIPMENT	
No. 1—Providing Concentric Antenna Jack	RAK/RAL:1
No. 2—Replacing Power Supply Resistors R-202, R-203 and R-204 (no kits)	RAK/RAL:2
No. 3—Fusing of the Equipment (no kit)	RAK/RAL:2
RAL RADIO RECEIVING EQUIPMENT	
No. 1—Providing Concentric Antenna Jack	RAK/RAL:1
No. 2—Replacing Power Supply Resistors R-202, R-203 and R-204 (no kits)	RAK/RAL:2
No. 3—Fusing of the Equipment	RAK/RAL:2
RBA RADIO RECEIVING EQUIPMENT	
No. 1—Installation of Type 49509 Plug Adapters	RBA:1
No. 2—Inversion of Power Supply Filter Choke (no kit)	RBA:2
RBB RADIO RECEIVING EQUIPMENT	
No. 1—Installation of Type 49509 Plug Adapters	RBB:1
No. 2—Inversion of Power Supply Filter Choke (no kit)	RBB:2
No. 3—Improvement of Band Switch	RBB:3
RBC RADIO RECEIVING EQUIPMENT	
No. 1—Installation of Type 49509 Plug Adapters	RBC:1
No. 2—Inversion of Power Supply Filter Choke (no kit)	RBC:2
No. 3—Improvement of Band Switch	RBC:3
RBO RADIO RECEIVING EQUIPMENT	
No. 1—Modification of the Audio Circuit	RBO:1
No. 2—Replacing Power Transformer and Rectifier Tubes	RBO:1
No. 3—Connecting for Balanced line Speaker Connection	RBO:1
RCK RADIO RECEIVING EQUIPMENT	
No. 1—Additional Tuning Set Up System (no kit)	RCK:3
No. 2—Noise Suppressor Wiring Correction (no kit)	RCK:4
No. 3—Installation of Type 49509 Plug Adapters	RCK:4
RDP RADIO RECEIVING EQUIPMENT	
No. 1—Extension of Swept Oscillator Shaft (no kit)	RDP:1
REA RADIO RECEIVING EQUIPMENT	
No. 1—Receiver Output Line Connections (no kit)	REA:1
No. 2—AVC Circuit Modification	REA:1
TBA RADIO TRANSMITTING EQUIPMENT	
No. 1—Modification of Meter M-111 By-Pass Circuit (no kit)	TBA:1
No. 2—Balanced Output Operation	TBA:1
No. 3—High Speed Keying (no kit)	TBA:2
No. 4—Modification of the O-5/FR Exciter Unit (no kit)	TBA:3
TBK RADIO TRANSMITTING EQUIPMENT	
No. 1—Meter M-107 Erroneously Labeled	TBK:5
No. 2—Parallel High Speed Keying	TBK:6
No. 3—Modification of the O-5/FR Exciter Unit (no kit)	TBK:6
TBL RADIO TRANSMITTING EQUIPMENT	
No. 1—Modification of Labeling of Band Change Switch	TBL:1
No. 2—Wiring Correction to Audio Output Jack J-101	TBL:1
TBM RADIO TRANSMITTING EQUIPMENT	
No. 1—Installation of Peak Limiting Thyrite Units	TBM:2
No. 2—Parallel High Speed Keying (no kit)	TBM:2
No. 3—Modification of the O-5/FR Exciter Unit (no kit)	TBM:2
TCK RADIO TRANSMITTING EQUIPMENT	
No. 1—TCK Replacement Brush Kits	TCK:3
No. 2—Replacement of TCK-3 Filament Transformers	TCK:3
TCS RADIO TRANSMITTING EQUIPMENT	
No. 1—Modification of Model TCS Relay Circuit (no kit)	TCS:1
No. 2—Modification of Tap Switches (no kit)	TCS:2
No. 3—Modification of the Loading Coil (no kit)	TCS:3
No. 4—Replacement of Motors and Generators	TCS:3
No. 5—Installation of Power Supply Filter CTD-53173 or CTD-53174	TCS:3
No. 6—Type 50159 Noise Limiter Adapter Units	TCS:4
No. 7—Installation of TCS Noise Limiter	TCS:4
No. 8—Replacement of Resistors R-303 and R-304 (no kit)	TCS:4
No. 9—Installation of Radio Interference Elimination Kit	TCS:4
TCZ RADIO TRANSMITTING EQUIPMENT	
No. 1—Replacement of 28-volt Generator Brushes	TCZ:1
No. 2—Removing of Audio Input Ground of Type COL-23410 Remote Control Unit (no kit)	TCZ:1
TDQ RADIO TRANSMITTING EQUIPMENT	
No. 1—Overload Relay K-303 Change (no kit)	TDQ:3
No. 2—Model TDQ Transmission Line Filter Type CRV-53232	TDQ:3
No. 3—Caution Nameplates for TDQ Transmitter	TDQ:4
YE HOMING EQUIPMENT	
No. 1—Installation of Matching Transformer Type CRV-47194 (no kit)	YE:7
No. 2—Modification of Antenna Assembly Drive Unit Heater Circuit (no kit)	YE:8
No. 3—Addition of Capacitors to Gyro Selsyn System (no kit)	YE:9
No. 4—Shorting of Interlock Switch S-114 (no kit)	YE:10
No. 5—Change in Value of Spark Absorbing Resistor R-503 (no kit)	YE:10
No. 6—Elimination of Interference in Radio and Radar Equipments (no kit)	YE:10
YG HOMING EQUIPMENT	
No. 1—Change in Over-the-Bow Keying Circuit (no kit)	YG:2
No. 2—Hood for Barco Joint	YG:3
No. 3—Installation of Improved Contacts for Relay K-101 (no kit)	YG:3
No. 4—Elimination of Keying Relay K-101	YG:3
No. 5—Addition of True Bearing Control Unit Type CAIH-23408	YG:4
No. 6—Improved Insulation for Resistors R-109 to R-112 (no kit)	YG:5

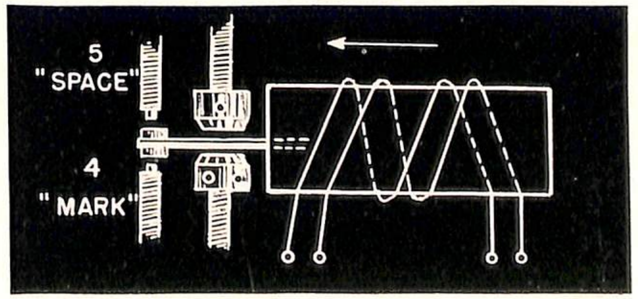
255-A Telegraph Relay

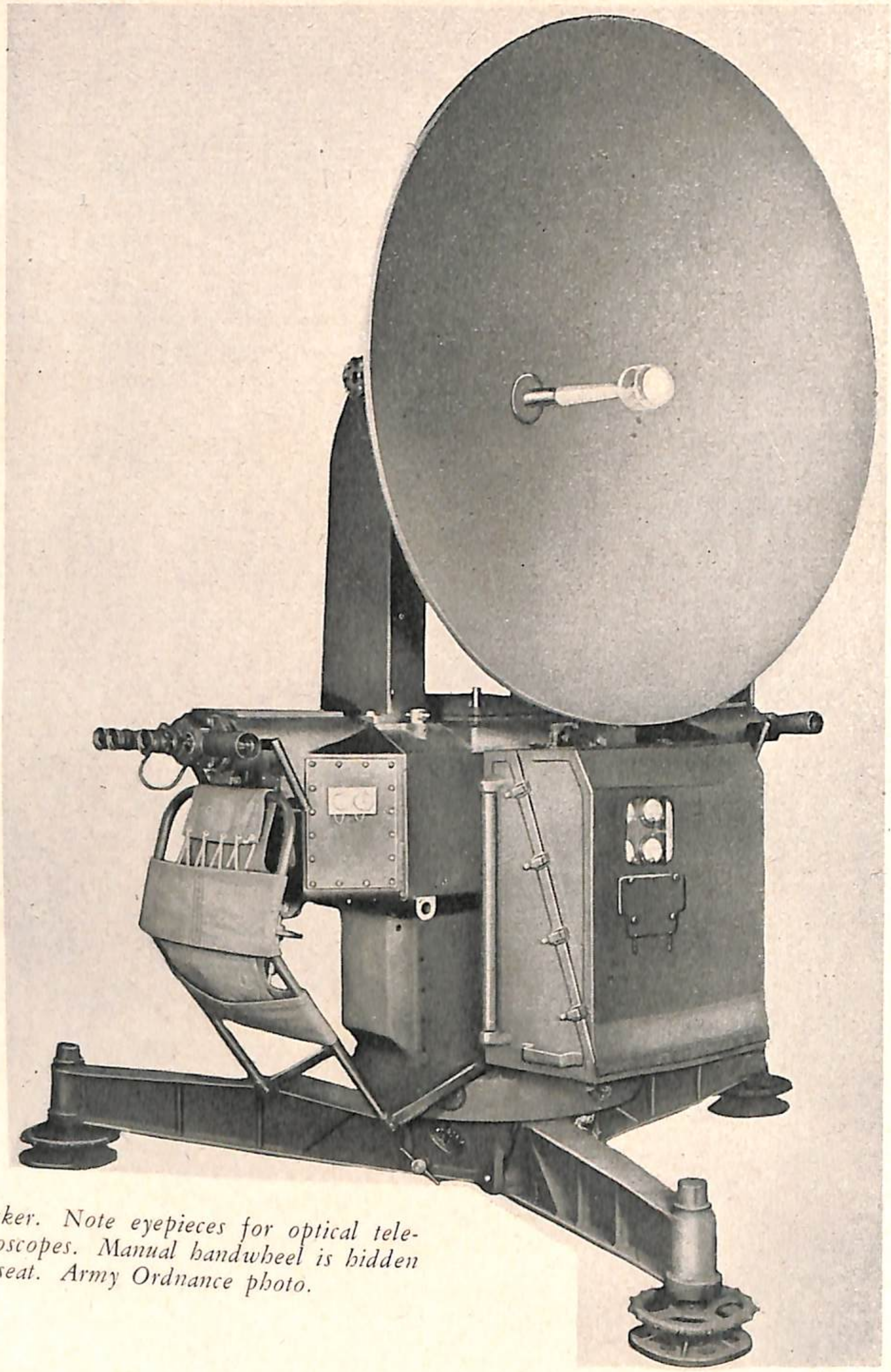
Here is a bit of useful information on the Western Electric 255-A Polar Relay which is used in TTY, FSK and similar types of equipment.

The terminal arrangement illustrated may be considered as a bottom view of the relay base, or a view of the wiring (rear) side of the 18B Connector Block. The phasing arrow alongside the coil spool in the other drawing indicates the direction of current flow (electron theory, or left-hand rule) which will cause the armature to move toward the mark (#4) contact. In other words, the lower-numbered terminal (#2 or #3) of either winding should be connected to positive battery to move the armature to the marking contacts.



The two windings are of 3200 turns each, and have a resistance of 130 ohms. The normal effective current through one winding is 31.25 milliamperes (for 6.25 m.a. loop operation), which is equivalent to 100 ampere-turns. The minimum current required in one winding is 10 m.a. (32 ampere-turns).





AN/TPG-2 Tracker. Note eyepieces for optical telescopes and oscilloscopes. Manual handwheel is hidden by the seat. Army Ordnance photo.

Marine Corps AA Gets a New Radar

By F. A. Ramsey, Jr., Lt. Col. USMC, Bureau of Ships

■ By the end of July the Sperry Gyroscope Company should have delivered twenty new radar fire-control systems to the Marine Corps. These equipments represent the most up-to-date system for antiaircraft fire control and are to replace the SCR-584 Radar and M-7 Director. This new equipment, as delivered to the Marine Corps, is known as the Radar Fire Control Equipment AN/MSG-1.

The AN/MSG-1 consists of eight major units: the Tracker AN/TPG-2 (formerly Tracker T-5), the Remote Control Station (sometimes referred to as the "doghouse"), Computer T-18, Cable System T-6, IFF Equipment AN/TPX-2A, Target Selector T-1, Trailer (Navy Type CAHU-10304 modified to provide means for stowing the equipment), and the Engine Generator Navy Type CAJG-73029.

This fire-control radar is an integrated radar and computer fire-control system of transportable mobile design, the function of which is to provide gun-laying orders to a 90-mm antiaircraft battery. The Tracker AN-TPG-2 shown in the figure is the radar part of the system. This unit operates in the S_G band and is designed as an automatic-tracking radar. The weight of the tracker mount is 2072 pounds and that of the "doghouse" 414 pounds. The peak power output of the equipment is approximately 250 kw with a choice of either a 0.8- or 0.2-microsecond pulse width. The transmitter employs a 2J32 magnetron with hydrogen thyratron modulator. Three bandwidths are provided in the receiver, 3.5, 5, and 10 Mc. The 3.5- and 5-Mc bandwidths are used when the equipment is being employed for searching, while the 10-Mc bandwidth is used when the equipment is on automatic tracking and high discrimination is desired. When on manual search (being controlled by the joystick) the transmitter is modulated with a 0.8-microsecond pulse and the 3.5-Mc bandwidth is effective in the receiver. When it is desired to search automatically, the operator releases the joystick, makes necessary adjustments to front-panel controls, and the equipment shifts into automatic search. When the equipment is being used in automatic search, the transmitter continues to be modulated by the 0.8-microsecond pulse but the 5-Mc bandwidth is effective in the receiver. When it is desired to use the equipment in automatic tracking, two combinations of pulsewidth and bandwith are available. Normally the 0.8-microsecond pulse width and 5-Mc band width will be used. However, in cases of bad clutter, the 0.2-microsecond pulse width with the 10-Mc bandwidth can be employed to afford higher discrimination. The Maximum range when searching is 80,000 yards and, when tracking, 40,000 yards. The antenna is a 72-inch solid aluminum parabolic reflector fed by a conically-scanning dipole having an IFF array mounted on top of the reflector. The approximate gain of the antenna is 30.8 db with a beam width of 5 degrees at the half-power points.

Five electronic indicating devices and two optical systems are provided with the equipment. The Tracker Mount has two 2″ scopes, one for pip-matching in azimuth and the other for pip-matching in elevation. Mounted in the doghouse are a 7″ *A*-scope with range pedestal, and a 5″ *J*- (circular sweep) scope. Facilities are provided for automatic tracking in range, elevation, and azimuth, in addition to manual radar tracking in all of these. If the situation demands it, targets can be tracked optically in either azimuth or elevation but no facilities are provided for optical range finding.

The equipment may be used in any of several manners: full PPI search at 6 rpm, variable automatic sector scan, combination of variable automatic sector scan and variable automatic elevation sector scan, or a PPI fed by a remote radar via cable or radar data link. The major operational controls located on the Tracker Mount are the azimuth and elevation handwheels, while the doghouse contains the "joystick" for manual control in elevation, azimuth and range slewing, and all the IFF challenging controls.

The Tracker AN/TPG-2 and associated doghouse provide, as outputs, continuous present-position data electrically transmitted to the T-18 Computer which is an electro-mechanical computer of advanced design. Its function is to predict the future location of the target in conjunction with the present-position data, rates, time of flight, "dead time", conditions of the atmosphere, ammunition, and guns. The solution is transmitted electrically to the 90-mm gun battery continuously for automatically laying the guns and for fuse setting. The Computer T-18 weighs 1320 pounds and is provided with detachable porter bars.

IFF is provided as an integral part of the system by means of the AN/TPX-2A. This system consists of an AS-109/TPX antenna, which is mounted on top of the radar dish. The remainder of the system is the same as Navy Model BN-2, which should be familiar to all Navy and Marine technicians. Challenging is accomplished by pressing a button located on the joystick, and the display appears on the *A* scope.

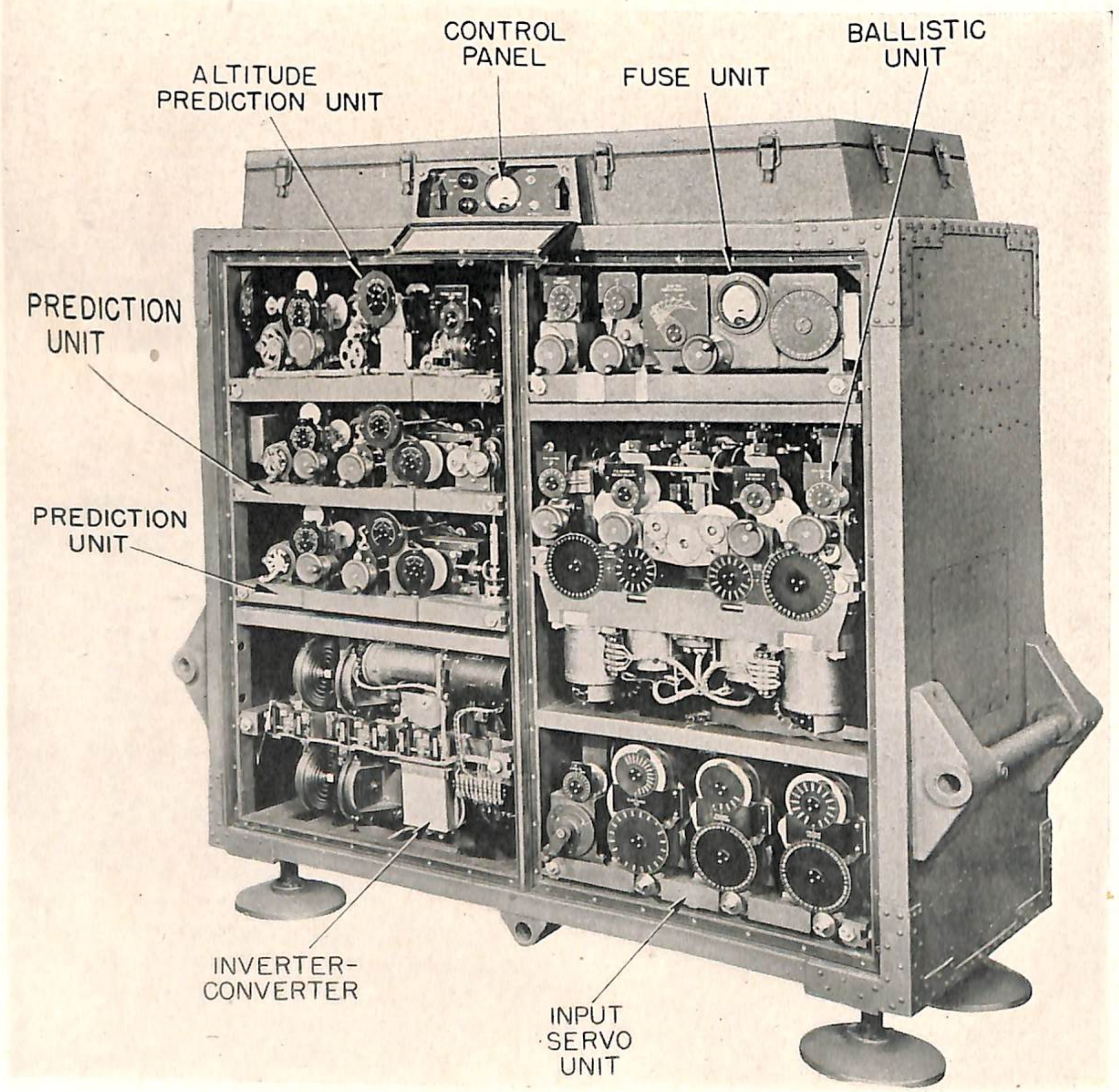
For certain purposes visual target designation to the radar is desirable. An optical telescope, the Target Selector T-1, is therefore mounted on a tripod provided for the purpose. When this telescope is positioned on a target and necessary controls are energized, it will furnish azimuth and elevation data to the tracker servo system electrically, causing the antenna to position itself so that its axis is parallel to that of the telescope.

The radar equipment is stowed in a van-type trailer which is similar to that supplied with Model SK-1M Radar. The engine generator, Navy Type CAJG-73029, is installed in the after compartment of the van. The doors and interior of the trailer have been rearranged to accommodate the radar equipment, which must be disassembled into its transportable packages for stowage. A sliding monorail and hoist which projects through the side door is installed to assist in handling the units. Actually the only portion that must be removed from the trailer for operation is the Tracker Mount. The remote Control Station and Computer may be operated inside or outside the trailer, depending upon the tactical situation. The trailer provides drawers, cabinets, and lockers for mobile and equipment spares and a work bench equipped with d-c low-voltage power supplies for testing and maintenance. Due to the very ample quantity of spares provided, it may be found that some of the equipment spares cannot be stowed within the trailer. Each of the twenty AN/MSG-1 equipments is being furnished with a very complete set of depot test equipment. There is an optional feature whereby the system may take primary power from the gun battery's generator.

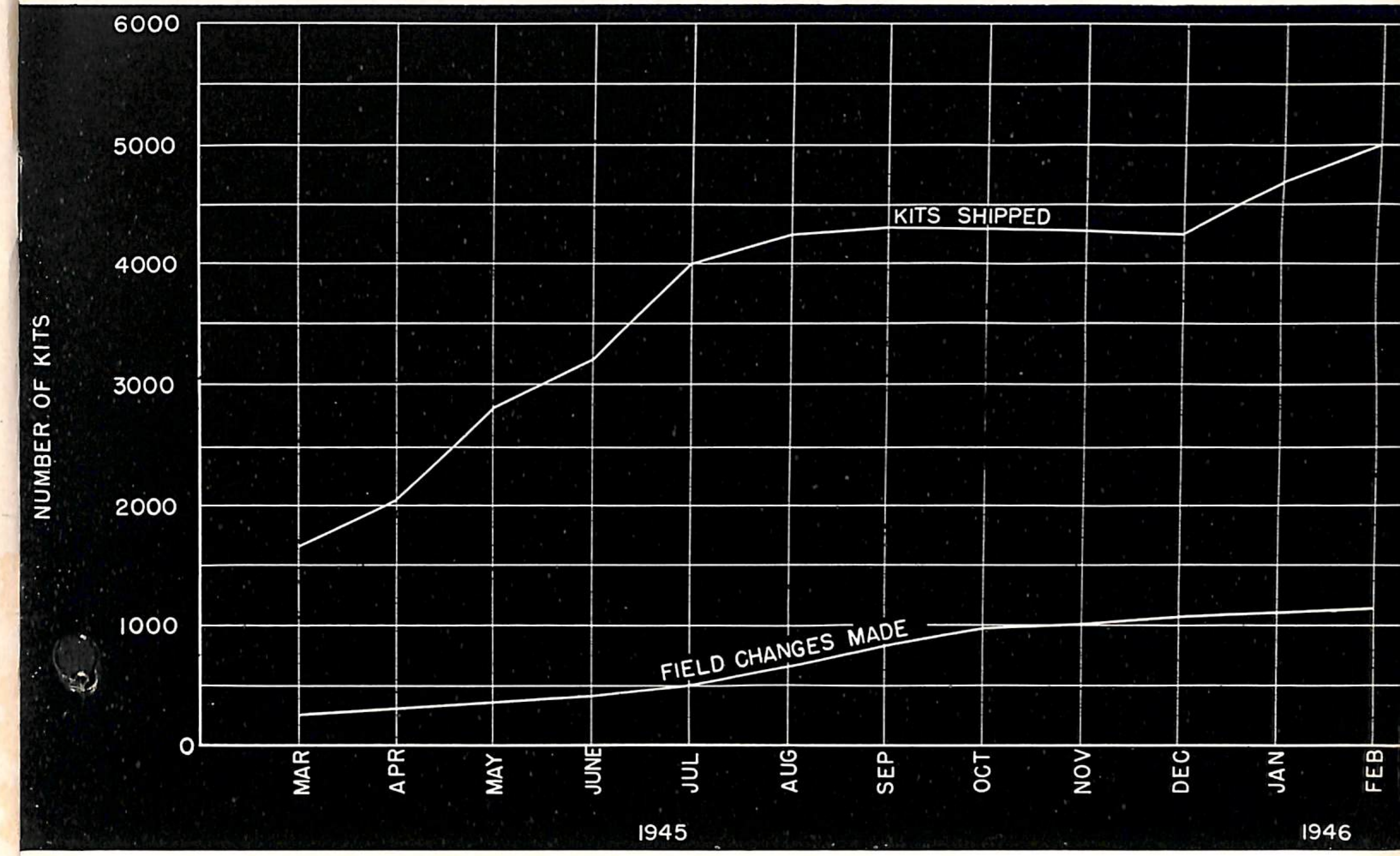
When set up for operation the equipment is interconnected by a cable system, T-6. This system is sufficiently flexible to provide good dispersion.

Normally an operator seated in the doghouse can control all the functions of the tracker. This includes aided manual tracking in range, and manual control of elevation and azimuth of the tracker by means of the joystick. Once having gated the target, auto-tracking of range, azimuth, and elevation is switched on by simply releasing the hands from the palm switches on the joystick. Should it be necessary to employ manual radar tracking of a target, two additional operators are seated on the mount where each is provided with a handwheel and pip-matching scope. They can commence manual tracking on signal from the operator in the doghouse or, should it be necessary, they are provided with switches permitting them to cut out the remote servo-driven tracking and take control using the handwheels. The housing on the tracker mount is so arranged that the optical telescope and pip-matching scope for each operator are placed side by side so that either system can be readily used by the two operators.

In anticipation of the delivery of this new equipment, arrangements were concluded with Sperry Gyroscope Company to conduct a technician's school which commenced on 21 January 1946. Hence the AA outfits will not only receive new equipment, but will get some technicians along with it.



Front view of T-18 Computer with covers removed. Army Ordnance photo.



MISSING: *4000 S. U. Field Change Kits!* Ridiculous, you say. But the graph illustrates that such is the case. Field change kits are often very expensive and represent considerable engineering effort. If the field change is considered sufficiently important to design and manufacture, it is certainly important enough to install. Receipt of NBS Form 383 is the only method the Bureau has of knowing whether this expense and effort are being utilized or wasted. It is also very difficult for the Bureau to evaluate failure reports without knowing which field changes have been made on the equipment. The graph tells the story of the SU only, but this is a typical case. Please help the Bureau keep its house in order so that it may be in a better position to help you. Report all field changes promptly and correctly on Form 383!

Write it down
while it's Hot
send it to
the FORUM