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MARK V IFF/UNB SYSTEM

This is the second in a series of CONFIDENTIAL descriptive and technical discussions. The information presented is based on material contained in reports prepared by ComOpDevFor and the Combined Research Group of N.R.L.

This is the second in a series of discussions on the components and operation of the Mark V IFF/UNB System. The first in this series provided a general description of the system and its components (See Jan. 1950 ELECTRON). Since the interrogator-responsor and the transpondor are the primary elements in any IFF system, this discussion will be devoted to the particular types of each utilized in the Mark IV IFF/UNB System. In view of the fact that the chain of events in identifying a target normally originates in the interrogator-responsor, and since the basic principles of interrogation and reception are practically identical in each of the three types of I-R's used in the system, a detailed operational description of only the AN/CPX–3 will be given.

Interrogator-Responsor

The AN/CPX–3 is a high-powered shipboard or land-based interrogator-responsor designed for use with the most simple or the most complicated systems. This interrogator-responsor and the radar with which it operates are interconnected either directly or through an interconnection assembly. When interconnected with a radar the interrogations are normally set in motion by a synchronizing pulse from the associated radar. Tracing this synchronizing pulse from the radar to the interrogator-responsor we first come to the trigger input facilities; therefore these facilities will be described before the other features of the equipmnt.

Figure 1 is a portion of the Modulator Power Unit of the AN/CPX–3 showing the trigger input channels, relays, pilot lights, etc. Notice that there are three trigger inputs for synchronizing the transmitter section. These are labeled 1ST TRIGGER, 2ND TRIGGER, and 3RD TRIGGER. When operating with a single input, such as from a radar direct or through an interconnection assembly, the input trigger is coupled to the 1st trigger jack. For the three-mode interlaced system, an input trigger is connected to all three of the above-mentioned jacks, PI to 1st trigger, IFF to 2nd trigger, and FLI to 3rd trigger. If the REMOTE-LOCAL switch on the front of the AN/CPX–3 is in LOCAL, then the local mode selector switch is used to select the mode of interrogation desired from the unit. If the REMOTE-LOCAL switch is in REMOTE, the mode of interrogation is selected by the operator at the remote station. When no interconnection assembly is used with the radar I-R hookup, it is obvious that only one remote operator can control the mode of interrogation. This is true in all cases except where an interlaced challenging interconnection assembly is connected in the system.

When in LOCAL control, the mode selector switch on the front panel of the AN/CPX–3 energizes the mode relays (Nos. 1 and 2) in such a manner that the incoming trigger pulse will be fed to the correct channel, either PI, IFF, or FLI. When in REMOTE control, the mode selector switch on the remote control box actuates these relays and performs the same functions of channel selectivity. It will be noted from Figure 1 that the input trigger channels all connect to S–605 which is a monitor switch provided to monitor different waveforms to a jack on the front panel of the equipment. In addition to these connections to S–605 each channel connects to an individual plug and jack which feeds the trigger pulses to the Coder Unit.

Figure 2, the block diagram of the Coder Unit is the next step in the series to generate paired interrogation pulses from single input trigger pulses. It will be seen from this figure that the incoming trigger pulses are impressed on one of three input stages, depending on the mode in use. Assume the incoming trigger is on the IFF channel. The trigger pulse first passes through the input amplifier V–501 (A&B) to the grid of the 1st trigger generator V–504. Two outputs are taken off V–504, one from the plate, the other from the cathode. The pulse from the cathode triggers a 6D4 which generates the first pulse in the pair of interrogation pulses. The output from the plate of V–504 is passed through a 3-microsecond delay line to the 2nd trigger generator which has two outputs. The output from the cathode triggers a 6D4 which generates the second pulse in the pair of interrogation pulses. The outputs of the 1st and 2nd pulse generators are connected together to enable feeding the paired pulses to the modulator. It will also be noted from Figure 2 that a gate and GTC trigger is taken off the plate of the 2nd trigger generator while a display trigger is taken off the cathode. The action in the PI and FLI channels are the same as in the IFF except that the delay lines are 5 and 8 microseconds respectively. The IFF channel has one feature which is not present in either the PI or FLI channels. In case of loss of synchronizing triggers from the associated radar, the AN/CPX–3 may be shifted to internal triggering. When placed on internal triggering the input amplifier V–501 (A&B) is connected to operate as a free-running multivibrator at a frequency of approximately 200 pps. Since only V–501 can be so connected, the unit can only interrogate in the IFF mode when on internal synch.

The paired pulses from the Coder Unit are coupled through a transformer, as shown in Figure 3, to the grid of the modulator driver V–611. The output of this driver is applied to the parallel grids of the four modulators, V–612, V–613, V–614, and V–615. As can be seen from the figure, the outputs of these four modulators are tied together and coupled to T–605. T–605 furnishes two outputs—one to T–101 (Figure 4) and the other to J–608 to be used as a suppressor pulse in other units of the system.

The transmitter trigger pulse from the modulator is coupled through T–101 (Figure 4) to the transmitter oscillator, V–201, a unit of the Radio-Frequency Head RF–31(XN–21)/CPX–3. A clipper tube, V–101, is inserted in the pulse path to clip the positive overshoots. The negative pulses of approximately 4500-volt amplitude are impressed on the cathode and grid of the transmitter oscillator V–201. The plate of V–201 is grounded, thus the effective pulse voltage is the only potential difference between the cathode and plate. Z–202 has the physical form of a re-entrant half-wave line, which is connected between the plate and grid and tuned to the desired transmitter frequency by means of front panel controls. Proper phase relationships for oscillation are obtained by the capacitor C–201 and by the interelectrode grid-to-cathode capacity C_{gk}, thus forming a circuit similar to a Colpitts oscillator. During the 1-microsecond interval of each pulse, the circuit oscillates and generates a high-voltage r-f pulse. Between pulses, the cathode receives no "B" voltage and therefore no oscillation occurs. The output from the oscillator circuit is coupled through an antenna coupling link to the coaxial cable for transmission to the antenna.

In addition to the transmitter oscillator and its associated tank circuit, the r-f head contains preselectors, local oscillator, crystal mixer, T-R switch tube, protective relay and common antenna couplings for the transmitter oscillator output and the preselector input. The tuning of the channels, both for transmission and reception, is accomplished through a detent tuning assembly which may be manually controlled at the transmitter or through detent tuning motors and control switches from a remote position.

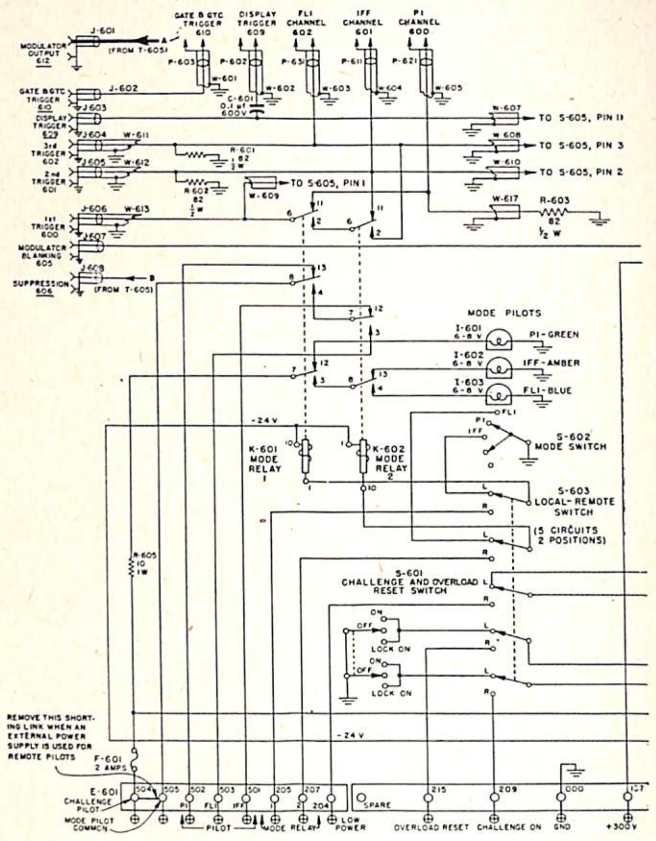


FIGURE 1. Portion of the schematic diagram of the modulator power unit of the AN/CPX–3 I-R showing the synchronizing trigger input channels, relays, pilot lights, etc.

When a transpondor generates a reply to an interrogation, it is transmitted through an omni-directional antenna and received by the interrogator-responsor located on board ship, in an aircraft or at a ground station. This reply is received on the same antenna used by the interrogator and passes through the coaxial cable transmission line to the receiver input circuits. First in this line are the preselectors and the duplexing stage. The preselectors are a pair of tuned lines which accept the desired signals, and attenuate any signals received at other frequencies, image rejection being at least 35 db. These tuned lines are located between the antenna post and the mixer coupling post. Each line is approximately a quarter-wave long and the two are coupled by mutual inductance rings, or "slugs." In addition to providing image rejection, the two preselectors, aided by the T-R switch tube V–202 and the solenoid protective relay K–201, permit duplex operation of the interrogator and responsor and prevent strong signals from damaging the crystal CR-201. The output of the local oscillator V–203 is mixed with the incoming reply signals to produce an intermediate frequency which is low enough to permit stable amplification. In the AN/CPX–3 the intermedi-

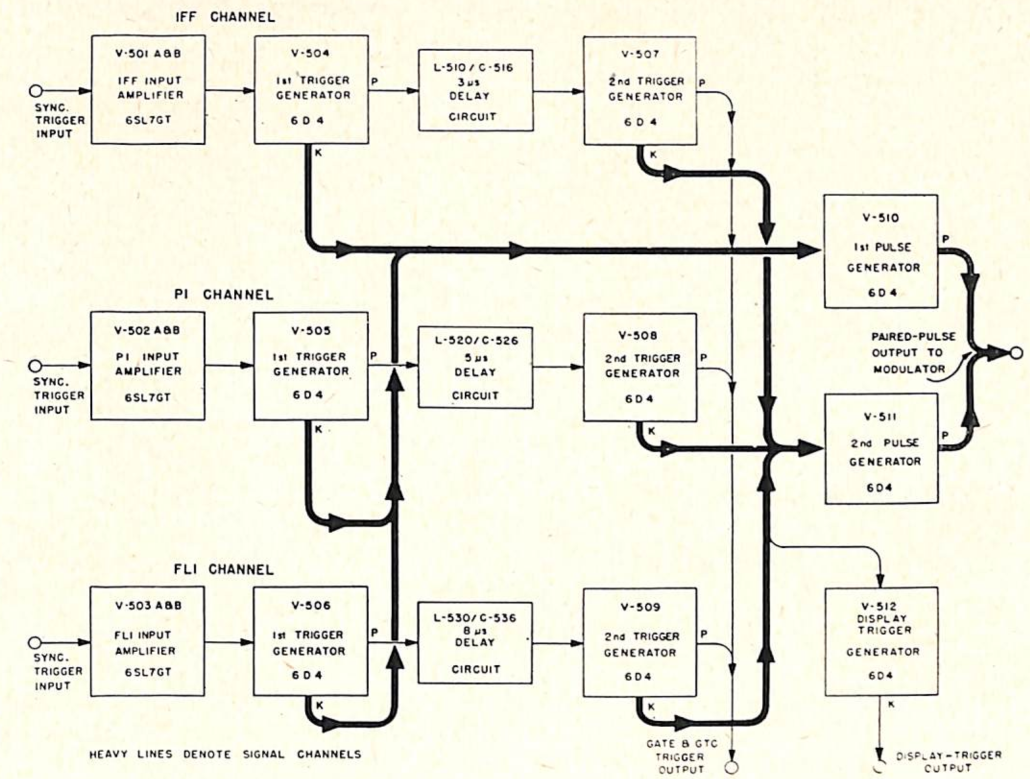


FIGURE 2. Functional block diagram of the coder unit of the AN/CPX–3 I-R.

ate frequency is 60 Mc with local oscillator tuned that amount above the incoming signal frequency.

After converting the incoming r-f signals to i-f signals by virtue of the local oscillator and mixer, the i-f signals are passed by coaxial cable (50 ohm) to the i-f amplifier strip (Figure 5). This i-f strip consists of seven intermediate-frequency amplifier stages, a tuning indicator diode, detector and a detector follower. The amplification through this strip is conventional; however certain functions are incorporated in the i-f amplifier which are noteworthy. GTC (gain time control) voltage is applied to the 1st and 3rd i-f amplifiers. GTC in this application operates in the conventional manner of lowering sensitivity with each transmitter pulse, and allowing it to recover to full level a certain time later, dependent on the adjustment of the R-C components of the GTC voltage waveform generator. GTC adjustments are made on each individual installation, and must take into consideration the antenna in use, the basic function of the system (air or surface search) and the amount of signal desired at different ranges. These adjustments should normally be made by the installing engineers as they are very critical and once made should not be disturbed. Manual and remote gain control adjustments are connected so that they will affect only the 2nd and 4th i-f amplifiers. Also connected to the 2nd and 4th i-f amplifiers is the gating voltage. Gating is an automatic gain control, which turns the responsor i-f circuits abruptly "on" immediately after the second pulse in each paired-pulse interrogation and "off" at the end of a predetermined period usually corresponding to the range being searched by the associated radar. Two gating voltages are available "short gate" and "long gate." It is usually customary to adjust the short gate to a length equivalent to slightly over 80 miles and the long gate to a length equivalent to 200 miles. In this manner, the short gate can be used on a VJ indicator on all sweeps up to and including the 80-mile sweep, while the long gate can be used when operating on the 200-mile sweep. Gating effectively permits the responsor to operate at the desired gain level (as adjusted either manually or remotely) while transpondor replies are expected, and holds the gain to a no-reception level at all other times. This reduces the average I-R noise output and helps to clarify the display. It is pointed out that the gain obtained during the gated reception periods is determined by the setting of the i-f gain control, which applies a steady d-c bias. Gating may be switched off, if desired, in which case the responsor operates steadily at the gain level set by the gain control.

The output of the 7th i-f amplifier is coupled through a transformer to the tuning indicator diode and the detector diode, both halves of a 6AL5. The detector diode operates on the linear portion of its characteristic curve, and delivers its output from the cathode providing positive video pulses for the detector follower, a 6AK5. The tuning indicator diode is included to provide a video signal to the panel milliammeter for tuning purposes. A second output is taken off the grid circuit of the detector follower to measure the detector voltage on the front panel milliammeter. The detector follower is nothing more than a cathode follower to provide an output for the video through a coaxial cable to the video amplifier.

The video amplifier contains three video amplifier stages, a diode clipper and a video follower. In addition to these stages, the amplifier strip also includes a tuning amplifier, two gate amplifiers, a gate booster, a GTC amplifier and a GTC limiter. The video circuits are designed to pass a band of video frequencies approximately 10-Mc wide. The input to the 1st video amplifier is a positive video pulse from the i-f amplifier strip previously discussed. This input is applied to the grid with the output taken off the plate circuit. A diode clipper, to prevent positive overshoots or excursions from appearing at the grid of the 2nd video amplifier, is interposed between the 1st and 2nd video amplifiers. The output of the 2nd video amplifier is coupled through a video follower with cathode output to the video output amplifier. The output amplifier provides two outputs, one from the plate—a high level negative video—and another from the cathode—a low level positive video. These outputs are fed directly to the display devices or to an interconnection assembly if one is used in the system. Usually the positive video is employed, but in some cases there is a need for the negative video.

The AN/CPX–3 has several subsidiary circuits which affect the overall operation of the equipment and associated units. Some of these such as GTC and gating have already been covered in this discussion. However, there are others which are believed worthy of mention. The responsor's video gain for both the negative and positive outputs may be adjusted with a video gain control (screwdriver control mounted on the video amplifier chassis) and may be increased by the connection of a shorting link in the cathode circuit of the first video amplifier. The voltage amplitude of the positive video output may also be adjusted with an output (screwdriver) control on the video amplifier chassis. These adjustments are intended to be made only during the installation of the equipment, or by authorized maintenance personnel. It must be remembered that after the video amplitude has been adjusted to a certain point (best signal-to-noise ratio) any further increase in signal amplitude will only result in a corresponding increase in noise, and clutter up the presentation.

It will be recalled that while discussing the circuits in the transmitter, the subjects of display trigger and suppression pulses were mentioned. The display triggers are used in the system to trigger associated display de-

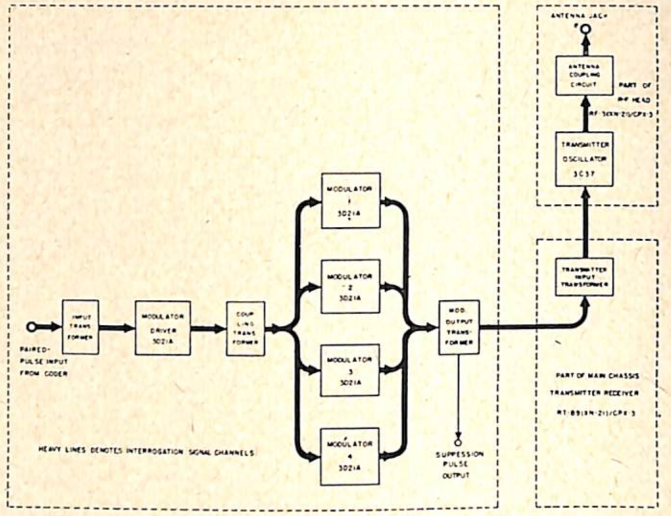


FIGURE 3. Modulator of the AN/CPX–3 I-R showing the paired pulse output from the coder unit applied to the input transformer.

vices or interconnection assemblies or both. Suppression pulses are utilized when a Mark V IFF/UNB transpondor is located near the I-R. The suppression pulse disables the transpondor while the I-R is sending out an interrogation pulse; otherwise the I-R pulses would trigger the transpondor and cause a reply to be generated which would be misleading and also tend to increase the amount of interrogations to which the transpondor would be replying. This overload of interrogations would materially increase the possibility of saturating the transpondor so that bonafide interrogations from some other ship or station could not be answered.

Modulator blanking facilities are included in the AN/CPX–3 to suppress the interrogating circuits while antenna lobes are being switched, when the equipment is being operated with a lobe-switching antenna. However, this facility is also used quite frequently when servicing the receiver of the AN/CPX–3. Normally the MOD BLANK jack located on the side of the transmitter-receiver cabinet is capped, grounding the bias used for blanking, so that the blanking circuit is disabled. However, when measuring receiver sensitivity it is desirable to disable the transmitter and feed in a synthetic signal generated in either the UPM–4 or the UPM–6 test equipment. By removing the cap on the MOD BLANK jack, the blanking bias is applied so that the transmitter will not fire, and receiver sensitivity measurements will not be adversely affected.

To check the tuning of the local oscillator and preselectors, a tuning indicator diode (mentioned previously) is coupled in parallel with the detector diode at the output of the i-f amplifier stages. This diode is resonated sharply at 60 Mc and its output amplified by a 6AK5 tuning amplifier. The output of the tuning amplifier then passes through the panel meter selector

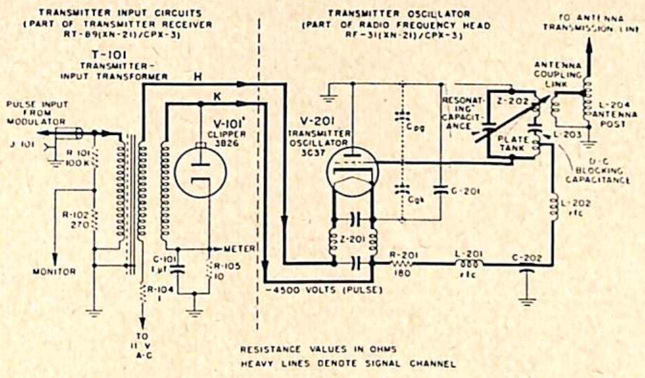


FIGURE 4. Schematic diagram of the transmitter oscillator and associated circuits in the r-f head of the AN/CPX–3 I-R.

to the panel milliammeter, where a pronounced decrease in tuning amplifier current is visible (under signal reception conditions) if preselectors and local oscillator frequencies are correctly aligned.

The meter selector and the panel milliammeter mentioned above also facilitate the measurement of currents and voltages in seven other important circuits of the transmitter-receiver during standby and normal operation. In addition to the meter selector and panel milliammeter provided for checking the operation of the equipment, still another servicing device is made available. On the front panel of the equipment is a MONITOR SELECTOR SWITCH and a MONITOR SCOPE JACK. Through these facilities the technician can monitor any of sixteen waveforms taken at critical points throughout the equipment. An AUXILIARY TRIGGER jack is mounted on the front panel and connected in parallel with the 1st trigger jack mentioned previously. This AUXILIARY TRIGGER jack provides a means of triggering the coder from an external source such as the UPM–4 test equipment or taking a trigger out of the AN/CPX–3 for use in synchronizing external equipment, such as the UPM–4, while making maintenance adjustments. When the equipment is triggered through the auxiliary jack no interlaced modes of operation are possible, but any one of the three modes (IFF, PI, or FLI) can be obtained separately in this manner.

Last but far from least in its usefulness and importance in maintenance operations is the r-f probe (Figure 6) located on the front panel of the equipment. This probe is included in the AN/CPX–3 to permit a small amount of energy to be tapped from the antenna line for test purposes. This probe assembly consists of a loop, a resistor, a panel jack and a short interconnecting cable. The probe does not introduce a standing wave into the line because it absorbs only a small fraction of the total power, 0.1%. The probe is carefully calibrated so that it offers 30-db (± 0.5) attenuation to forward power at the mid-band of the frequency range. This probe has proven extremely

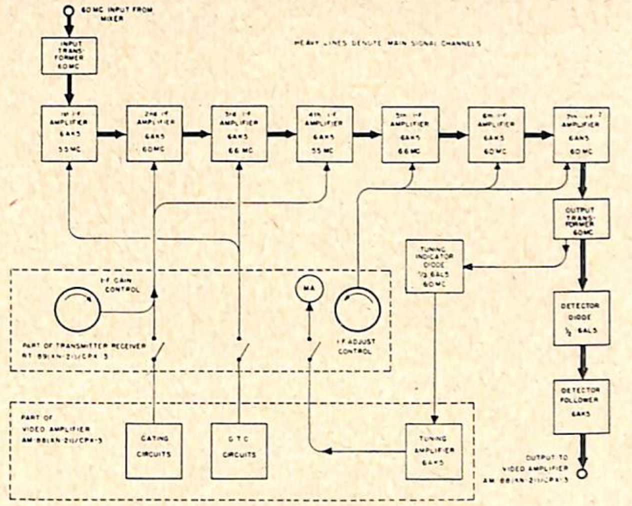


FIGURE 5. Functional block diagram of the i-f amplifier of the AN/CPX–3 I-R.

useful in making such measurements as transmitter power output, tuning and adjusting frequency channels in the equipment and checking spacing of paired pulses generated in the unit.

A second shipboard or landbased interrogator-responsor is the AN/CPX–4. This I-R differs from the AN/CPX–3 in the following categories:

1—It is a smaller unit, both in size and weight.

2—No facilities are provided for three-mode interlaced interrogation.

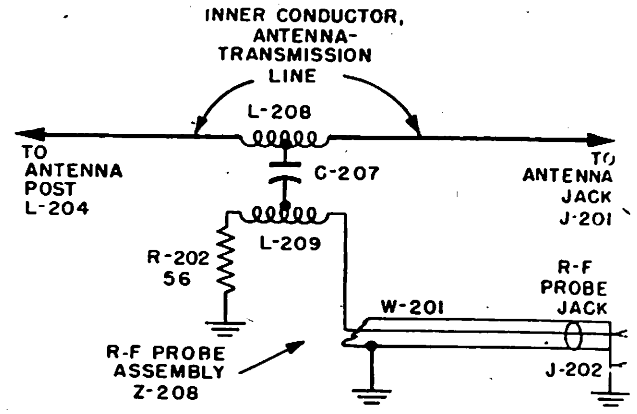
3—Lower power output (1500 watts as compared to approximately 8000 watts).

4—Slightly lower receiver sensitivity. However the basic principles of both transmitter and receiver operation of the two are comparable.

5—Self triggering is available but the free running multivibrator output is approximately 10,000 pps and must be counted down.

The basic principles of operation of the airborne interrogator-responsor, AN/APX–7, are similar to the AN/CPX–3 or AN/CPX–4 insofar as the generation of interrogation pulses, transmission of same, and reception of the replies from a transpondor are concerned. However, by virtue of its being airborne, the equipment has additional applications aside from conventional interrogation and receipt of replies which are considered of interest to the reader.

First a complete list of equipment included in the AN/APX–7 includes: 1—Transmitter-receiver, 2—power supply unit (for the indicator), 3—an indicator unit having a cathode-ray tube for displaying reply pulses, 4—one of three antenna systems and 5—control box. As pointed out above, the transmitter-receiver is similar in operation to those in the AN/CPX–3 and AN/CPX–4, so nothing further will be said concerning it. The equipment is designed for use with either an omni-



HEAVY LINE DENOTES MAIN SIGNAL CHANNEL.

FIGURE 6. Equivalent schematic of the R-F Probe Assembly, Z-208, of the AN/CPX-3 I-R.

directional antenna, a split lobe-switched antenna, or a rotating lobe-switched antenna.

Operation of the equipment can be initiated either by radar sync pulses or by internally generated pulses from a multivibrator. When radar-triggered, a counter multivibrator circuit prevents the IFF interrogator from firing on each radar pulse unless the repetition rate of the radar is 300 pps or lower. IFF reply pulses may be displayed on either the AN/APX-7 indicator or on the associated radar display device. The AN/APX-7 utilizes an L-type presentation whereby lobe switching permits replies to be shown on either side of the sweep line. When an omni-directional antenna is used, lobe-switching is omitted so the display becomes an A-type scan. The sweep is vertical in either case, starting from the bottom. When the IFF reply is injected into a radar display it appears in one of the forms described in the first article of this series (See Jan. 1950 ELECTRON), dependent on the type of scope in use.

When using either the split lobe antenna (AS-280/APX-7 or the rotatable antenna (AS-220/APX-7), azimuth bearings may be determined if the AN/APX-7 indicator is used. The split antenna system consists of two directional antennas rigidly mounted on the aircraft so that their major lobes cross each other in the direction toward which the antenna system (and aircraft) is facing. A switching circuit couples the video pulses alternately to the right and left deflector plates of the indicator tube in synchronism with and in the same sense as the antenna system. When the antenna is pointed directly toward the source of the replies being received, the lobes on the sweep will be of equal amplitude and the aircraft will be headed directly toward the target.

With the rotating lobe-switched antenna, bearings can be taken on transponder-equipped craft without changing the direction of travel of the interrogating craft. The antenna is rotated until the reply pulses from the transpondor are of equal amplitude indicating that the antenna

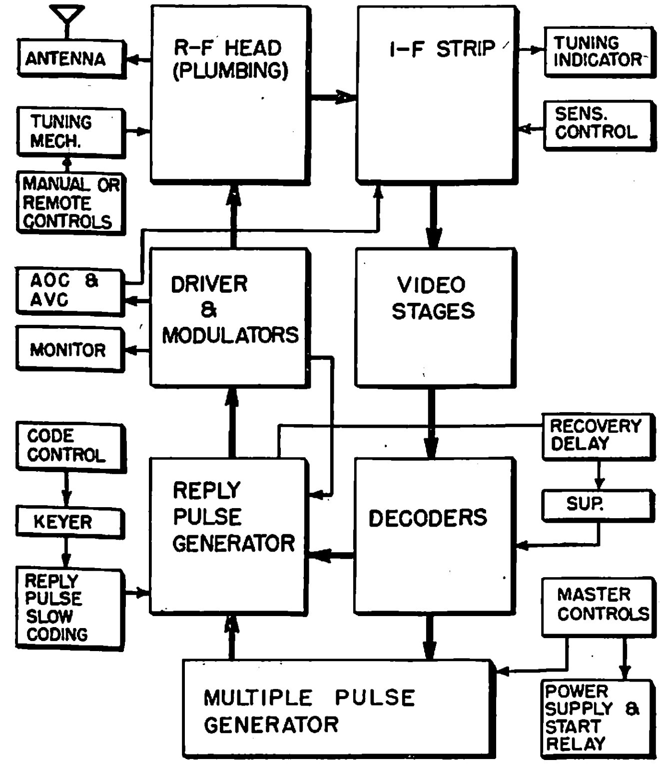


FIGURE 7. Functional block diagram of the Airborne Transpondor AN/APX-6.

is pointing directly toward the transpondor. In this manner the bearing of the transpondor may be determined with relation to the aircraft heading or corrected to true bearing if desired. The antenna is motor-rotated in either direction at a choice of two speeds as determined by the setting of a switch on the antenna control box supplied with the antenna system. A synchro-drive indicator on the same control box rotates in synchronism with the antenna to show the direction in which the antenna is pointing.

When operating with the omni-directional antenna the AN/APX-7 can be operated in one of three applications as follows:

1—Used alone (no radar) the transmitter is self-triggered with replies shown on its own indicator. Only range can be determined. A strobe switch enables replies found in any five-mile interval up to the maximum range of the equipment to be observed with a full cathode-ray tube scan.

2—Associated with radar, the equipment can be triggered by radar synchronizing pulses but with replies presented on the AN/APX-7 indicator. Again only range can be presented on the indicator sweep. Azimuth, if desired, must be determined with the aid of the associated radar equipment.

3—Associated with radar, the equipment can be triggered by radar synchronizing pulses and have replies presented on the radar display device. In this arrangement the system can be operated to show IFF replies plus strobe markers or markers only.

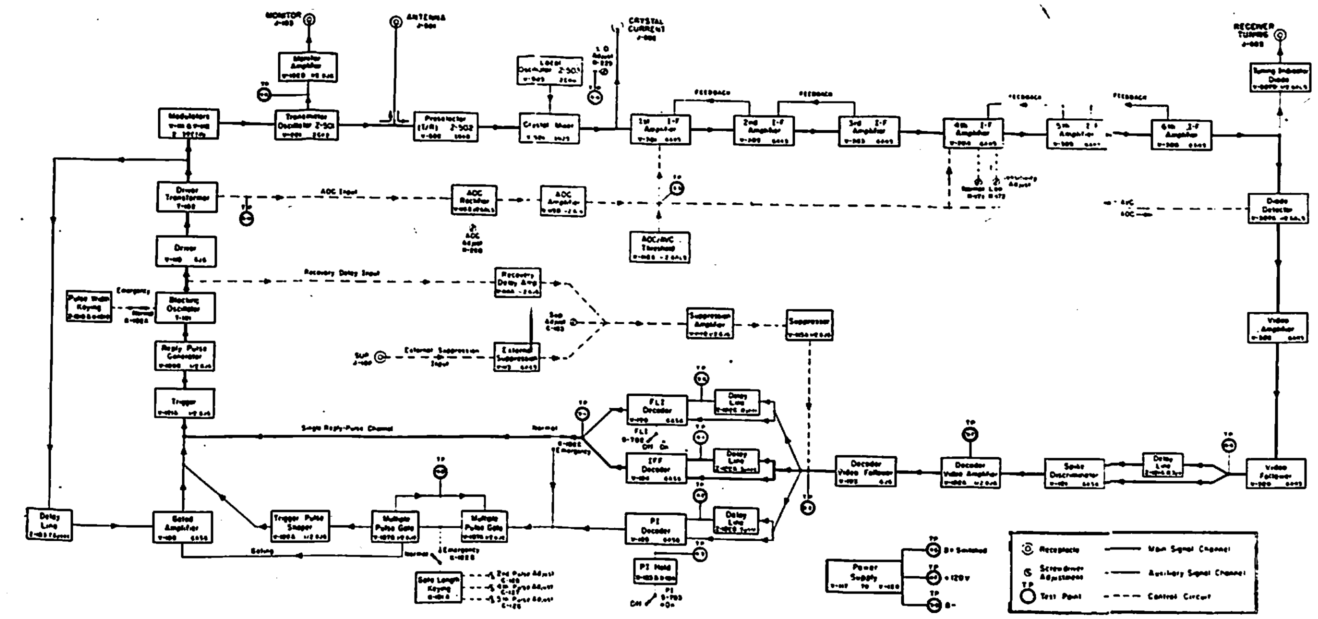


FIGURE 8. Functional stage-by-stage block diagram of the operation of the Airborne Transpondor AN/APX-6.

Transpondors

As in all transpondors, the main signal channel of the AN/APX-6 Airborne Transpondor is arranged in the form of a "loop," with the antenna providing the common entrance and exit point of the loop. The equipment is comprised basically of a superheterodyne receiver with broad bandwidth characteristics, whose output actuates a pulse-type transmitter via a decoder, reply pulse generator, and slow-coding circuits. Figure 7 is a functional block diagram of the equipment showing the sequence of events from time of reception until time of transmission. Figure 8 is a detailed stage-by-stage block diagram showing the operation of the main signal channel and subsidiary circuits.

Interrogation pulses received by the antenna pass through the preselector and TR tube to the crystal mixer where they are mixed with the output of the local oscillator to generate a 60-Mc output to the i-f amplifier strip consisting of six i-f amplifier stages, in which degenerative feedback and other broadbanding methods are utilized to provide wide bandwidth characteristics. The output of the i-f amplifier strip is delivered to two diodes, one furnishing a video output to a jack on the front panel for tuning purposes, the other furnishing a video output to a video amplifier and video follower in the i-f amplifier strip. Further video amplification is accomplished by three video amplifiers (one of which acts as a coincidence gate) in another section of the equipment. A 0.3-microsecond delay line is interposed between the output of the video follower in the i-f amplifier strip and the first video amplifier coincidence gate in the rear chassis assembly. This delay line plays a very important role in the operation of the system and in effect is an additional security measure. As pointed out previously in these articles, the spacing between pairs of interrogation pulses as well as the pulse widths, are critical. Therefore by utilizing a 0.3-microsecond delay line in the signal channel such as in the block diagram shown in Figure 2, with the following stage connected as a coincidence gate, the system effectively blocks pulses of less than 0.3-microsecond duration or pulse pairs whose spacing is not within the tolerances designed for the particular mode in use. It is obvious that with the delay line and coincidence gate, any pulse of less than 0.3-microsecond duration, or any pulse pairs whose spacing is greater or less than the designed amount, will not actuate the coincidence gate and consequently will not trigger off the remainder of the loop.

When a correctly spaced pair of pulses of the correct width are applied to the control and suppressor grids of the coincidence gate, the tube will conduct and deliver a negative video output to the following video amplifier. The output of this amplifier is passed to the split-channel decoder circuit through a video follower which is connected as a cathode follower to permit positive output to the decoder channels.

Examination of the split-channel decoder circuit reveals three separate and distinct inputs and decoder circuits. Each decoder acts as a coincidence mixer with a delay line interposed between the video follower and the control grid of the decoder. The characteristics of the three lines are such that delays of 3, 5, and 8 microseconds are placed in the circuits of the IFF, PI, and FLI decoders respectively. At the same time an undelayed pulse of each pair received is applied to the suppressor grids of all three decoders. All three stages of the decoder operate in the same manner except that the PI and FLI decoders have a strong blocking bias applied at all times except when the equipment is switched to accept either PI or FLI replies. The IFF channel on the other hand is prepared to accept an authentic IFF interrogation and generate a reply at any time. Thus, we see why any particular transpondor in an aircraft, ship, or ground station must be advised to switch to PI or FLI when individual identification is desired.

It will be noted that the output of the PI decoder is coupled directly to a multiple pulse gate, and when the equipment is switched to EMERGENCY the output of both the IFF and FLI decoders are connected to this multiple pulse gate circuit. Thus, as mentioned previously, whenever the AN/APX–6 is switched to EMER operation, regardless of the type of interrogation being received the unit will generate an emergency reply. Before discussing multiple pulse generation, a brief outline of single pulse generation will be presented.

For the information of the technician who may be servicing this equipment, the output of the decoders can be considered as the end of the receptive portion of the signal channel loop and the start of the transmitter portion. If an equipment is not generating replies to authentic interrogations, the technician will be wise to first check the output of the decoders to ascertain if pulses are being provided at that point. If pulses are observed emanating from the decoders, he can assume the receiver section of the loop plus the decoders are functioning correctly and concentrate on the pulse generators, coding mechanism and transmitter.

When a single pulse is delivered at the output of the IFF or FLI decoder, it is passed to a single-swing blocking oscillator composed of V-121A, V-109B, and T-101 in Figure 8. Also connected in the blocking oscillator timing circuit is a two-section delay line Z-101B which operates in conjunction with K-101B to determine the length of the pulse generated in the blocking oscillator when operating in NORMAL condition. The length of the pulse may be either 1 microsecond or 2.5 microseconds depending upon the action of K-101B. This is the method used to generate slow coding in the equipment. K-101B is actuated from the keyer assembly which consists of several cams (one for each letter available in the system) rotated by a d-c motor at exactly the same speed. Actually all cams are being continuously rotated but switch action and energy for the relay K-101B can only be obtained from any three at a time. Thus three code letters are available for use on any airborne transpondor. When multiple pulses, such as PI or EMER, are to be generated, a form of regenerative feedback is employed whereby a portion of the output pulses are fed back through a 7.6-microsecond delay line into the input of the blocking oscillator. The basic requirements are an initial pulse to kick the blocking oscillator and an enabling gate to hold the feedback circuit open just long enough to permit the required number of pulses to be generated, the gate length being 12 microseconds in PI operation and from 28 to 35 microseconds in EMER operation. The reason for requiring two gate lengths for EMER is, as mentioned previously, that only the last pulse of the series (fifth pulse) is slow coded during EMER reply generation. This pulse is not coded from narrow to wide but coded on and off corresponding to dots and dashes in the Morse code, with the pulse width

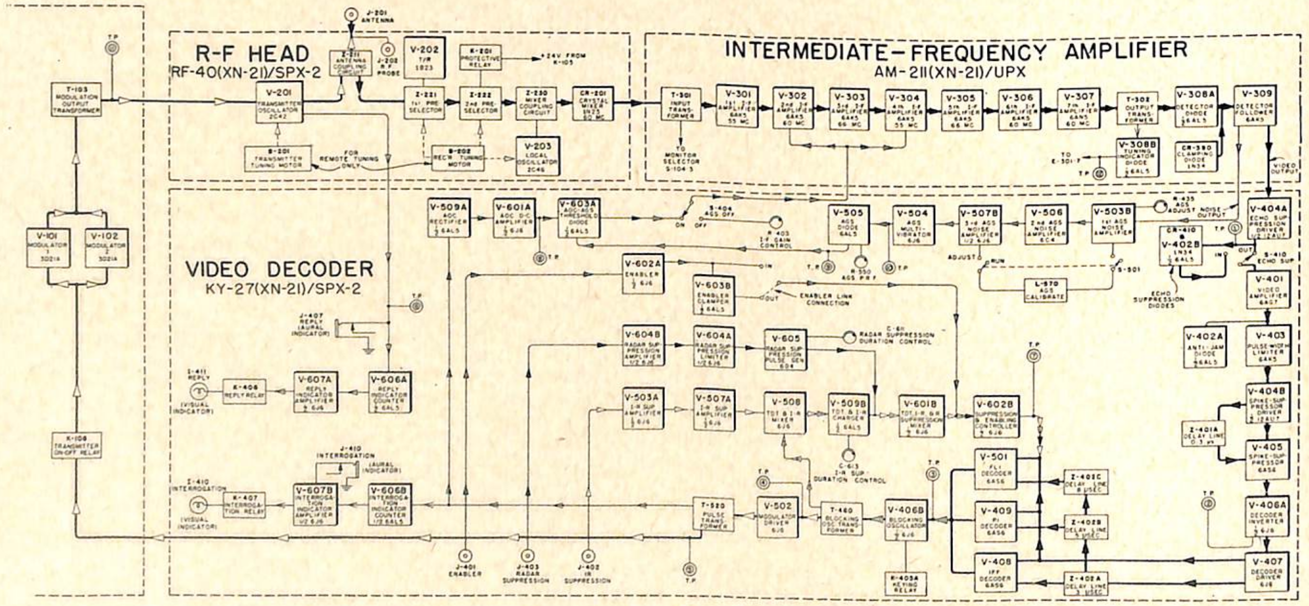


FIGURE 9. Functional stage-by-stage block diagram of the Surface Transpondor AN/SPX–2.

remaining at 1 microsecond. Thus the fifth pulse is required only when a keying cycle is being transmitted and relays are arranged to automatically increase the gate from 28 to 35 microseconds during these keying periods.

After the reply pulses are generated and slow coded they are delivered to the driver, V–110 in Figure 8, through a driver transformer to the modulators and thence to the transmitter oscillator. The transmitter oscillator is essentially a grounded-grid equivalent of a tuned-grid, tuned-plate oscillator, whose only plate supply is the modulation pulse. Tuning of the resonant circuit is accomplished by a detent tuning mechanism identical to those utilized in the shipboard and airborne interrogator-responsors. The r-f energy generated in the transmitter oscillator circuit is fed to the antenna via the antenna coupling link and a coaxial cable.

The shipboard transpondor AN/SPX–2 operates on the same basic principles as the airborne transpondor AN/APX–6 with a few minor modifications in circuitry. As can be seen from Figure 9 the paired pulses are received by the antenna and passed through the r-f head which includes the local oscillator, crystal mixer and associated circuits. The output of the crystal mixer is passed through the i-f amplifier and video detector to the video decoder amplifier stages which operate in the same manner as the corresponding circuits in the AN/APX–6. It is at this point that the similarity of operation between the two equipments varies. In the AN/APX–6, it will be remembered, there were facilities for generating paired PI and multiple EMER replies where such replies were required. In the AN/SPX–2 no facilities are provided for generating any multiple pulse replies regardless of the mode of interrogation. The output of the three decoders, IFF, PI, and FLI are in the form of single pulse replies which trigger a blocking oscillator. The blocking oscillator generates the corresponding reply pulse for the pair of interrogation pulses received. This reply pulse may be keyed from "narrow" (1 microsecond) to "wide" (2.5 microseconds) by the keyer unit to facilitate Morse-coding the replies which are generated in the blocking oscillator. The output of the blocking oscillator is amplified in a modulator driver, then delivered to the modulator circuit for additional amplification. The output of the modulator is used to drive the transmitter oscillator into oscillation during the length of time this pulse is present. The action of the oscillator is similar to that in the AN/APX–6. The bursts of r-f energy generated in the oscillator are delivered through the coaxial cable to the AS–177 antenna for radiation.

Numerous subsidiary and control circuits are provided with the AN/SPX–2 to assist in the correct operation of the unit at all times. These circuits (with front panel control, if provided) are listed below with a brief description of the function they perform in the overall operation of the equipment.

Receiver channel and transmitter channel selector switch which may be operated manually (local control) or automatically (remote control).

Rotary monitor selector switch, which permits eleven voltage and current measurements at important test points in the transpondor to be made and registered on an indicating milliammeter.

Radio-frequency adjustments for both the transmitter and receiver channels. These are front panel adjustments and in effect tune the channels by varying the position of the detents in the individual channels.

R-F probe jack which provides a convenient point for testing the transpondors transmitted pulses, with attenuation through the probe at 20 db.

Protection against cw jamming signals is provided in the i-f amplifier by a beat-note detector in the grid circuit of the detector follower, and by back-bias circuits in the fifth, sixth, and seventh i-f amplifier stages.

R-F pulse signals received as the result of reflections from nearby objects are, to a large extent, prevented from triggering the transpondor by the inclusion of an *echo suppression circuit* which may be disabled by a front panel control, if necessary.

A pulse-width limiting circuit to prevent extremely wide pulses (over three microseconds in duration) from triggering the transpondor.

Suppression circuits are provided to prevent the transpondor from being triggered by interrogator-responsors or radar transmitters in the immediate vicinity. The I-R suppression circuit operates on the principle of disabling the transpondor for a period of either 225 or 500 microseconds after each I-R transmission. The radar suppression circuit disables the transpondor for a period of 15 ± 5 microseconds after each radar pulse.

A "transmitter dead time" circuit is included in the equipment to render the unit insensitive for an interval of 225 or 500 microseconds after each actuation of the reply pulse generator, thereby limiting the maximum reply rate at either 4450 or 2200 pps, respectively. The transmitter dead time circuit primarily performs the following functions: 1—Prevents the transpondor from triggering itself with its own transmitted pulses (a condition known as "ring around"). 2—Prevents the FLI decoder from being falsely triggered by eight-microsecond paired pulse PI replies from an airborne transpondor that is being challenged (from a greater distance than the present transpondor) by an I-R within the service range of both transpondors. This condition is also known as "ring around", and 3—Prevents paired-pulse echoes of direct-path interrogations from triggering the transpondor when such echoes arrive much later than the direct-path pair and cannot be attenuated by the echo-suppression circuit.

BUREAU OF SHIPS
CONTRIBUTIONS TO NAVIGATION

In leading off the Navy's presentation to the Eastern Regional Meeting of the Institute of Navigation in Washington on the 9th of February, Secretary of the Navy Francis P. Matthews stressed the role of electronics in modern navigation. After demonstrating the relationship of "Navy" and "Navigation" all the way from the very word roots themselves, Mr. Matthews outlined the new and surpassingly difficult navigational requirements imposed by present methods of Naval warfare, in all of the three areas of conflict, under, on and above the sea. He pointed to the field of electronics as the particular one showing promise of fulfilling these requirements.

The meeting, a 2-day symposium entitled "The Federal Government and Navigation," was devoted chiefly to presentations by U. S. agencies concerned with navigation, including the Departments of Defense, Commerce, and State, the U. S. Coastguard, the U. S. Maritime Commission, and the Federal Communications Commission. The government-industry Radio Technical Commissions for Aeronautics and Marine Services were represented as well.

Navy speakers accompanying the Secretary, three of whom are shown with him in the group photograph, were Cdr. J. T. Moynahan, USN, Director of the Division of Air Navigation of the Hydrographic Office; Mr. G. M. Clemence, Director of the Nautical Almanac Office of the Naval Observatory; Cdr. James H. Cruse, USN, Air Branch of the Office of Naval Research; Cdr. B. L. Bailey, USN, Deputy Director of the Electronics Division Bureau of Aeronautics; and Capt. A. L. Becker, USN, Assistant Chief of the Bureau of Ships for Electronics.

Captain Becker, representing the Bureau of Ships and speaking on the Bureau's contributions to navigation, categorized the Bureau's technical interest in navigation as universal, since the Bureau must design, develop, procure, install and maintain equipment to aid in sub-surface, surface and air navigation. He gave highlights on the Bureau of Ships equipment programs in these three fields.

Underwater Navigation

Navigation underwater not only is part of one of our most pressing military problems, but also poses some of our most difficult technical problems. Sonar, the greatest tool available to us in the undersea field, has navigation applications typified by echo-sounding equipment, bathythermographs for ocean water condition surveys, and the Sofar project.

Echo-sounding equipment is a major requirement for navigating by observation of changes in the ocean floor. On the other hand, the very same equipment gives accurate soundings for navigational charts.

The bathythermographs furnished by the Bureau to the fleet provide temperature and pressure data recordings by which maximum effective use of sonar can be obtained, at least on an empirical basis pending perfection of understanding of the principles and phenomena of underwater sound propagation, as effected by various ocean conditions. Simultaneously, the Navy's collection of recordings from a large portion of the earth's water area should constitute a significant contribution to scientific advancement of the art.

A three-station Sofar net has been established in the Pacific, and is under evaluation. In its primary rescue application, this system makes possible the use of signals originating from small underwater explosions at the proper depth to determine the geographical location of the source, by timing the signal arrivals at the sound receiving stations constituting the net. Accuracy is within several miles at ranges of several thousand miles.

Surface Navigation

Improvements in aid to surface navigation have continued at a fast pace in spite of the great age of the problem. This is because of the tremendous economic, strategic and tactical value of the expeditious movement of ships, coupled with applicability of electronic devices and techniques to improvement of old systems and development of new.

From the early part of the inter-bellum period, when the old grand-dad of surface electronics aids, the shore-based radio direction finder sets, started in operation, new aids have appeared in rapid succession. Some are very well-known, for instance, manual and automatic direction finding for headings and fixes by triangulation; medium frequency loran; mechanical dead reckoning aids; and surface-search radar, shipboard in the Navy's application, as well as in the merchant marine, and recently adapted for shore use in aiding harbor movements.

Others not so often mentioned, but well worthy of mention, include reduction of time inaccuracies by provision of radio equipments which will in effect remote accurate time standards, as maintained in Washington, to key radio stations throughout the world for re-broadcast; evolution of a practical application to all-weather celestial navigation out of the infra-red program; increased dependable radio coverage of the globe at very low frequencies; and application of servo mechanisms to compass repeating, resulting in increased accuracy, efficiency and economy.

NAVY PARTICIPATES IN NAVIGATION SYMPOSIUM. Secretary of the Navy, Hon. Francis P. Matthews, led the Dept. of the Navy delegation to the Eastern Regional Meeting of the Institute of Navigation in Washington on 9 February 1950. Left to right, Rear Admiral Alfred M. Pride, USN, Chief of the Bureau of Aeronautics, who arranged the Navy's program; Mr. Matthews; Rear Admiral Leo Otis Colbert, Director, U. S. Coast and Geodetic Survey, and Vice President of the Institute of Navigation; Cdr. James H. Cruse, USN, Air Branch, Office of Naval Research; Capt. A. L. Becker, USN, Assistant Chief of the Bureau of Ships for Electronics; and Cdr. J. T. Moynahan, USN, Director, Division of Air Navigation, Hydrographic Office.

Support of Air Navigation

Because it has the assigned responsibility for surface-based electronic equipment both afloat and ashore, the Bureau provides all surface components for electronic air navigational aid sustems. New aircraft speeds and accompanying airframe design changes make greater demands for increased capabilities of the surface components.

Tactical requirements for increased radar detection range on smaller air targets and for continuous and more nearly up-to-the-second plots are making available radar and plotting equipment which are readily convertible to meet the modern demands for air surveillance radar and associated plots for use in air traffic control.

Secondary radar for use in data transmission, as visualized by the Air Navigation Development Board in implementing the common system of air navigation proposed by the Radio Technical Commission for Aeronautics, can be evolved out of other developments in which the Bureau of Ships Electronics Divisions have had a leading role.

Ground-controlled-approach equipment, itself undergoing improvement, is the springboard for carrier-controlled-approach, now under development. In this field another new feature is planned to provide for beacon reception, lengthening range and adding identification and altitude information.

Radar beacons, proved out in World War II, are now receiving the attention needed to improve their reliability and transponding capacity.

Convenience and speed in use of surface based radio direction finder equipments will be promoted by new design, to improve present location service extended to aviators without need for special electronic units in the aircraft. This will be done for future u-h-f as well as present v-h-f communication channels. The record of aircraft "saves" by enlargement of GCA range through use of surface based direction finders is already impressive.

In aerology, electronic contributions are mounting. To ceilometers, radar for tracking weather fronts and ordinary radiosonde equipment, is now being added the receptor for automatically tracking balloon-borne transmitters, and recording continuous meteorological data coordinated with position data of the balloon.

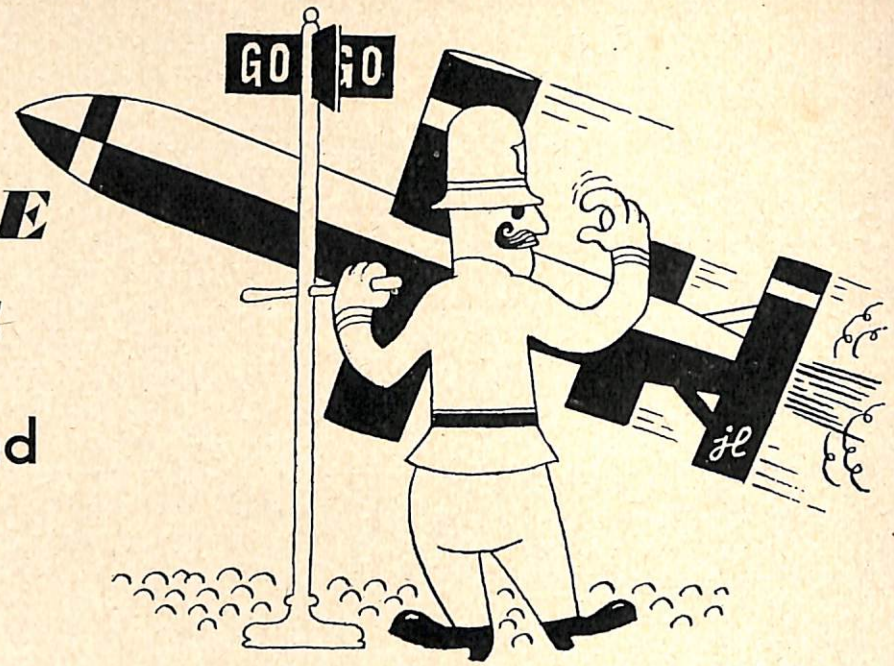
Navigators will share with other users of electronic equipments in the profits from the across-the-board electronics improvement projects undertaken by the Bureau. For instance, the design of components so as to require only operator-type maintenance in the field, coupled with parts standardization, will increase equipment reliability with ultimate actual saving in space and funds.

Because of the three-way application of the work of the Electronics Divisions of the Bureau of Ships to navigation, under, on, and above the sea, a very large proportion of the Divisions' effort is chargeable against navigation. Thus the reciprocal interests of the Bureau of Ships organization and the members of the Institute of Navigation are many.

The Institute of Navigation was founded in 1945, as a scientific and engineering society devoted to the advancement of air and surface navigation and its related arts and sciences. Besides publishing the quarterly "Navigation," it holds national, regional and sectional meetings to bring together navigators, educators, manufacturers, aviators, mariners, scientists, technicians, students, and other civil and military individuals and organizations on a professional footing to discuss matters of common interest.

MISSILE GUIDANCE RADARS

AN/MPQ-5 and AN/SPQ-2



This is the second in a series of two CONFIDENTIAL *articles on the progress being made in the field of guided missile control. This is a brief technical discussion of the individual components of the subject equipment. The information is from a report prepared by the Equipment Research Branch of the Naval Research Laboratory.*

System Integration

The fundamental principles of operation of the radar portion of the system are basically the same as those of any pulse radar system. Pulses of radio-frequency energy are radiated from a highly directional antenna. Upon striking an object, some of the radiated energy is reflected back to the source of the pulses. The elapsed time between the transmission of the pulse and the return of the echo is a measure of the distance or range of the reflecting object. The angular position of the object is commonly determined by means of the directional antenna.

The Lark SP–1M radar performs three operations not included in the ordinary search radar system. 1—The automatic tracking in train, elevation, and range of a missile or target. 2—The provision of a radar beam containing intelligence which may be used to guide a missile along the beam. 3—The simultaneous and independent automatic tracking in range of two "targets" which are not too widely separated in train or elevation. The latter function is made possible by almost complete duality in receiving, indicating, and range tracking circuits. Since the duality does not extend to the antenna, dual train and elevation tracking is not possible. However, a means is provided for continuously monitoring (within limits) the displacement from the radar beam of the second object being tracked in range. These three functions will be discussed briefly in the following paragraphs, before signal tracing explanations are presented.

Automatic tracking of a target in train and elevation is accomplished as follows: The radiated beam is caused to describe a conical scan which results in amplitude modulation of the echo pulses received from any target which is displaced from the scan axis. The resulting amplitude modulated video pulses from the receiver, after selection by the range gate and clamping for the entire repetition period at nearly peak level, are supplied to coordinate detectors. In the coordinate detectors separate comparison of the clamped video with each phase of a two-phase reference voltage takes place, and two d-c error voltages are developed—one for each phase of the reference voltage. One of these d-c voltages is a function of the train component of target displacement, the other of the elevation component. The magnitude of the error voltage is a function of the magnitude of the target displacement and the polarity represents the sense or direction of the displacement. These voltages, through amplifiers and an amplidyne drive, are used to control the movement of the antenna in train and elevation. The antenna is driven in such a direction as to reduce the error voltages to zero. Since this process is continuous, the antenna automatically aligns itself so that the scan axis passes through the target (provided the antenna is initially aligned so that the target is within the beam). The target may be any object which produces a reflection or it may be a missile which contains a receiver and transmitter to produce a beacon signal. The frequency of the beacon signal must be different from, but near, the frequency of the radar transmitter.

Automatic range tracking is accomplished by using a servo-controlled delay circuit to produce a range gate. The time delay between the gate and the transmitter pulse is proportional to the range of the target. The range gate, which is of very short duration (1 microsecond) compared to the total repetition period, controls or gates one output of the receiver so that only the signal occurring during the gate is passed. The gated output of the receiver (in addition to its use in the train and elevation tracking circuits) is applied to a range detector which develops an error voltage which is proportional to the time difference between the target signal and the gate. The error voltage, after amplification, drives a servo motor which, by varying the gate delay, reduces the error voltage to zero.

Missile guidance along the radar beam is accomplished by placing a receiver connected to a coordinate detector in a missile and using the error voltages developed to control flaps on the missile so as to move it to the center of the beam. The beam may be held stationary or it may be moved to maneuver the missile in any desired manner within the ability of the missile to respond. Because of the fact that the radar can simultaneously and independently track in range two targets it may be used equally well for command guidance. That is, a target and a missile may be tracked and the collision path of the missile determined by use of a computer at the radar; command signals are then sent by means of the radar beam to place the missile on the desired collision course.

Dual Channel Functions

Examination of Figure 1 will show an almost complete duality of the target and missile channels as traced from the duplexer in the transmitter. There are two exceptions: 1—The PPI unit gives a presentation of the output of the target receivers only; 2—The target coordinate detector is used to supply automatic drive to the antenna from either the target or missile receiver. That is, if a missile beacon is being tracked automatically, the output of the missile receiver can be supplied through the target coordinate detector to the antenna drive system.

Timing System

The Target Range Unit is the heart of the entire radar system. The unit performs three fundamental functions: 1—It develops the pulse which keys the transmitter. 2—It supplies gates or gate triggers to various portions of the system to permit or to prevent signals from passing through at a given time. 3—It supplies pulses to initiate sweep circuits throughout the equipment. In addition the range unit contains components of the range servo system.

The range unit contains a crystal oscillator having a frequency of 164.0 kilocycles or a period of approximately 6.1 microseconds. Although the reasons for this will not be discussed here, this frequency leads to a slight, constant percentage error in the indicated range but has the advantage that it may be readily checked against the standard frequency transmission of radio station WWV of the National Bureau of Standards. The output of the crystal oscillator is shaped into pulses and divided down to the mean pulse repetition rate of 576 pps in a series of blocking oscillators. The blocking oscillators are of the coincidence type and maintain the output in rigid phase synchronization with the original 164-kc signal. A blocking oscillator also effects the 24-cps pulse-time modulation of the repetition rate. Truly sinusoidal pulse-time modulation of the repetition rate is, of course, incompatible with the synchronization of the output pulses with the crystal oscillator, for the synchronization requires that the output pulse move along the time axis in discrete steps which are integral multiples of 6.1 microseconds. This fact is of no practical consequence because of the great disparity of the frequencies involved.

The repetition rate of 576 pps gives a maximum range of about 140 miles without pulse time modulation. The crystal oscillator, through the frequency dividers and through fixed and variable delay circuits, controls and synchronizes the timing of the entire system. Important functions of the output of this section of the range unit are: Modulator trigger, range gate trigger (delayed by servo-controlled variable-delay circuits), and indicator triggers bearing various time relationships to the modulator trigger. Functions of the modulator and indicator trigger or keyer pulses are conventional. The delayed pulses, through the gating circuits (which are physically located in the receiver unit), perform more diverse functions: 1—Control initiation of the range or "R" sweep. 2—Initiate the range gate for range tracking. 3—Control the gating of receiver i-f and video stages for elimination of unwanted signals and noise. 4—Control the full-repetition-period clamping of gated video signals which are used to develop the 24-cycle voltage for train and elevation tracking and to develop the automatic gain control voltage.

The timing circuits of the Missile Range Unit duplicate in every way those of the Target Range Unit, except that usually this unit is slave to the target unit crystal. The modulator trigger output of this unit is not used.

Radar System

The input pulse to the Hydrogen Thyratron Modulator is fed into a pulse shaper amplifier and is then used to trigger the hydrogen thyratron tubes. The triggered tubes discharge an artificial transmission line developing large amplitude negative pulses. These pulses are used to key the transmitter.

The Lark SP–1M transmitter consists of a magnetron coupled to the antenna by means of waveguide. The plate of the magnetron is grounded, and the tube is made to oscillate by driving the cathode negative with the large negative pulses of voltage developed in the modulator. The power output of the tube is limited by the amount of power the plate is capable of dissipating as heat. By reducing the length of time that the tube oscillates, the peak power can be increased. The peak power output of the magnetron exceeds 500 kilowatts but the duration of each pulse is approximately one microsecond.

In common with most radar systems, the Lark SP–1M uses the same antenna structure for both transmission and reception. To protect the receiver from overload during a transmission pulse, a duplexer is used. The action of this duplexer is conventional and no further explanation is deemed necessary.

The power traveling through the waveguide past the duplexer strikes a dipole antenna and reflector at the end of the waveguide. The energy is radiated from this antenna to the surface of a metal parabolic reflector. The resulting transmitted energy is a beam which is highly directional but much too wide for accurate target location. Accuracy of target location is greatly improved during actual target tracking by nutating the waveguide feed and dipole antenna in front of the parabolic reflector. In this motion, the dipole antenna describes a small circle about the focus of the paraboloid reflector (without changing its angle of polarization) and, in consequence, the radiated beam describes a cone about the axis of the reflector which remains fixed relative to the nutation. This is shown diagramatically in Figure 2. The axis of the reflector passes through the center of the circle in Figure 2. This line is also the axis of rotation of the radiated beam or lobe. A target anywhere along this line will reflect the same amount of energy, regardless of the instantaneous position of the lobe. If the target moves from the center toward T in the diagram, more energy will be reflected when the beam position is near T than when it is near T + 180 degrees. The result is amplitude modulation of the reflected signal at the frequency of nutation. The magnitude of the resulting modulation will depend upon how far the target has moved from the center of the circle. A target at T will, of course, produce a modulation of the same magnitude as it would at T + 180 degrees, but the phase of the modulation would be reversed. Similarly, targets located at other points on the circle will produce modulation proportionately displaced in phase from that produced at T. If, therefore, the position of the nutator is known at the instant the modulation reaches its maximum, then the direction of target displacement can be determined. This is accomplished as follows: The motor which drives the nutator at 24 cycles per second also drives a two-phase generator, the output of which—also at 24 cycles per second—bears a fixed phase relationship to the instantaneous position of the nutator. Thus each point in a cycle of the generator output voltage corresponds to an instantaneous position of the radar beam in space. For example, position T on Figure 2 may correspond to zero generator voltage (of one phase). Then T + 90 degrees may be the peak positive voltage, and T + 270 degrees would be the peak negative voltage. This 24-cycle reference voltage is supplied through an amplifier to the target coordinate detectors where, as will be explained later, d-c error voltages for driving the antenna are developed by comparison of the reference voltage with the amplitude modulated echo pulses received from the target. The 24-cycle reference voltage is also supplied through a phase shifter and amplifier to the range unit for frequency modulation of the repetition rate and to telemetering equipment.

Local Oscillator Preamplifier and Receiver

The reflected signal from a target is received by the antenna and is passed through the duplexer and local oscillator preamplifier into the target receiver. The target receiver is tuned to the radar frequency by changing the local oscillator frequency to obtain the desired intermediate frequency. The oscillator is of the reflex klystron type. Coarse tuning is accomplished by varying the voltage on the klystron repeller plate. Automatic frequency control is accomplished in the receiver by beating the transmitted signal with the local oscillator signal. The output is applied to an i-f amplifier which in turn supplies the input signal to a discriminator. The output of the discriminator controls the voltage applied to the repeller plate of the local oscillator klystron so that the required intermediate frequency is produced.

Following the crystal mixer and oscillator are a number of intermediate-frequency amplifier stages arranged to amplify in two channels. One of these channels is ungated and the other is gated by the gate received from the range unit so that only the signal occurring during the gate is amplified. Each i-f channel feeds a second detector which is followed by video amplifiers and cathode followers as necessary. Outputs from the target receiver are sent to the target range detector (gated), the PPI unit (ungated), the target indicator scope (ungated), the remote range indicator (ungated), and the target coordinate detector (gated). The range gate, properly shaped and delayed, is supplied to the range detector and target coordinate detector and to the indicators. Automatic gain control of several of the i-f and one of the video stages is provided, utilizing a voltage produced from the gated video signal in the coordinate detector unit. If missile-channel tracking of the antenna in train and elevation is used, the target receiver output

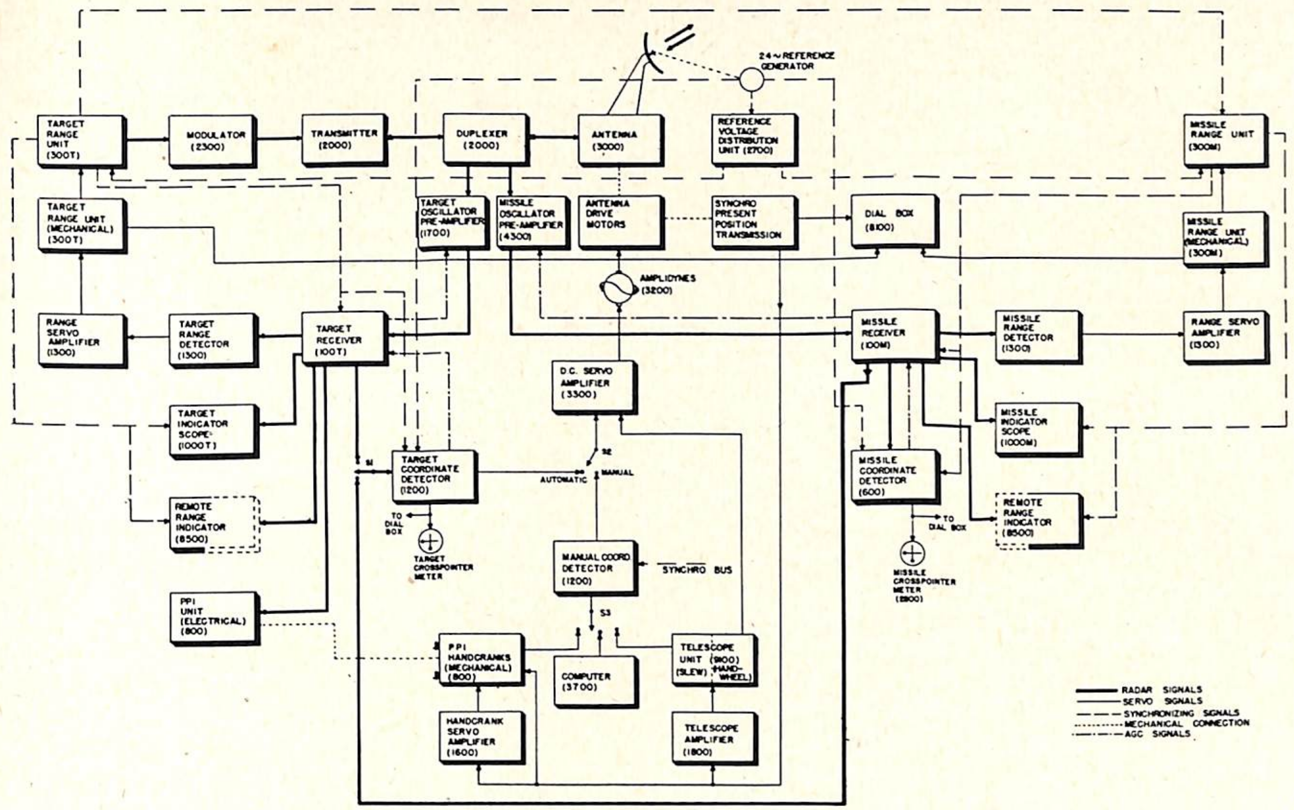


FIGURE 1—A detailed block diagram of the Lark SP–1M Guided Missile Control System.

to the target coordinate detector is switched to the missile coordinate detector and the target detector receives its input from the missile receiver. The AGC connections are also reversed, although for the sake of simplicity this is not shown on Figure 1. The "target" detector thus controls the antenna at all times, even when missile channel tracking is employed.

Target and Missile Indicator Scopes. The same type of indicator is used for both the target and missile channels. It consists of two oscilloscopes in each unit, one of which gives an A presentation and the other an R presentation. The A-type presentation is essentially a plot of target range against target amplitude (though not true target amplitude since AGC is used). In this type of presentation the entire range covered, from transmitter pulse to 100,000 yards is presented along the horizontal trace and the transmitter pulse and echo pulses are shown as vertical pips. The horizontal distance between the transmitter pulse and the echo pip is a measure of the range to the target. The A scope sweep is initiated by a trigger from the range unit. The output of the receiver produces the vertical deflection. The sweep trigger precedes the transmitter trigger by an amount sufficient to allow the transmitter pulse to be shown on the indicator screen.

The R-type presentation also shows range on the horizontal axis against target amplitude on the vertical. However, the R sweep displays only an expanded 2000-yard (12.2 microsecond) segment of the range covered by the A scope. The sweep trigger is derived from the delay circuits that determine the position of the range gate, as described above, and the sweep is therefore controlled by the range tracking circuits, manual or automatic. The sweep trigger is timed to occur about six microseconds before the range gate. Hence, the range gate, which is displayed on the R scope so as to produce a downward deflection or notch in the trace, always appears at about the center of the screen. The expanded R sweep facilitates precise ranging on target or missile echoes or the placing of a selected echo in the range gate for automatic tracking. These A and R indicators show range only and not train or elevation.

The function and operation of the remote range indicator will be discussed in connection with the data recording equipment. It is essentially an R presentation of both target and missile signals on a double-gun oscilloscope.

Another output of the receiver is applied to the PPI Unit, Unit 800. This unit is used to give an indication of bearing and range. A sweep starts from the center of the tube and progresses radially to the outside. It is then blanked out and the beam returned to the center to repeat the operation. A deflecting coil is rotated by a servo system so that any given position of the antenna in train corresponds to a particular angular position of the radial sweep. The intensity of the beam is varied in accordance with the strength of the reflected signal. Therefore, if the antenna is rotated continuously, a representation of the surroundings will be presented on the screen. All objects which produce reflections will show up as bright spots. The intensity of the spot will depend upon the strength of the reflected signal.

Range is represented by the distance from the center of the tube screen to the edge. The scale can be varied by changing the sweep time while keeping the sweep length constant. If the sweep time is reduced, the range is decreased. A system is provided for initiating the PPI sweep at the same time as the target R sweep. This condition is used for minute examination of the area surrounding a long range target and is called "delayed trigger" condition.

One limitation of the PPI is that it does not give an indication of elevation. If the elevation of the antenna is zero, the PPI gives a picture of all targets in a horizontal plane. If the elevation is not zero, targets will be shown which lie in a cone-shaped surface having an included angle of 180 degrees minus twice the elevation angle of the antenna.

Indicators

Handwheels and components of a servo system for control of the antenna in manual tracking and search are located in the PPI Unit. These portions of the PPI Unit will be described further on in this article.

Range Tracking System

The target range detector compares the gated output of the receiver with the range gate and develops a d-c signal proportional to the time displacement of the video from the gate. The polarity of the output signal indicates whether the video is early or late and the amplitude is proportional to the magnitude of the displacement. (The source of the range gate is the target range unit, via shaping and delay circuits in the receiver.) The d-c output of the target range detector is applied to a balanced modulator which produces a 60-cycle suppressed-carrier-type servo signal. This signal is amplified and used to operate the tracking motor of the target range unit. The motor shifts the position (in time) of the range gate to coincide with the position of the video and moves the range counter and dial. The range of the target, in yards, can be read from the counter and dial. Tachometer feedback around motor and amplifier is employed and means are provided for slewing and manual tracking in range. The range unit must, of course, be set to the approximate range of the target before automatic tracking can commence. This is done by positioning the video signal in the gate with the slew and manual controls as observed on the R scope of the target indicator unit, and then throwing a switch to the AUTOMATIC position.

Train and Elevation Tracking System

Target Coordinate—If the position of switch S1 (Figure 1) is correct, the target receiver will supply an input to the target coordinate detector. There is also a two-phase input from the 24-cycle reference generator which is operated by the antenna drive motor. The outputs obtained are two d-c voltages representing X and Y components. The polarity of the X and Y components shows the particular quadrant in which the target is located.

The component voltages are fed to a cross-pointer meter unit. This unit consists of two zero-center meters whose pointers, with zero deflection, are at right angles to each other and cross at the center of the face of the instrument. Within limits, the indications of the cross-pointer meter show the position of the target with respect to the axis of the transmitted beam. A similar meter is contained in the dial box.

Antenna Positioning—The train and elevation angles of the antenna are varied by means of d-c motors and gear trains. The advantage of using d-c motors is that the large amount of power required can easily be supplied by using amplidynes. The antenna can turn continuously in train but is limited to approximately 90 degrees in elevation. Limit switches are provided to prevent damage to the gear train or motor at maximum elevation.

The train and elevation motors require considerable power to move the antenna at the desired rate. Since vacuum tube amplifiers are not practicable for this purpose, amplidynes are used to supply the required d-c power. The amplidyne is a special type of motor generator whose d-c output power is a function of the field excitation and whose response to changes in field excitation is rapid. The source of power controlled is the a-c power used to drive the motor generator. Because of the method of connecting the field coils with respect to the armature, only a few watts applied to the field coils can control several hundred watts of d-c output power. The polarity of the output can be reversed by reversing the polarity of the voltage applied to the field.

A d-c amplifier is used to supply the d-c power required for the field coils of the amplidyne.

Automatic Tracking—When the output of the target coordinate detector is supplied through switch S2 to the d-c amplifier, the amplidynes and the antenna drive motors, the radar tracks the target automatically. Any misalignment of the beam and the target will set up error voltages which will drive the elevation or train motor in such a direction as to reduce the voltage to zero.

The one-microsecond range gate selects the target echo to be tracked in train and elevation as well as in range as previously described. When the range indicator is set to the approximate range of the target, the return

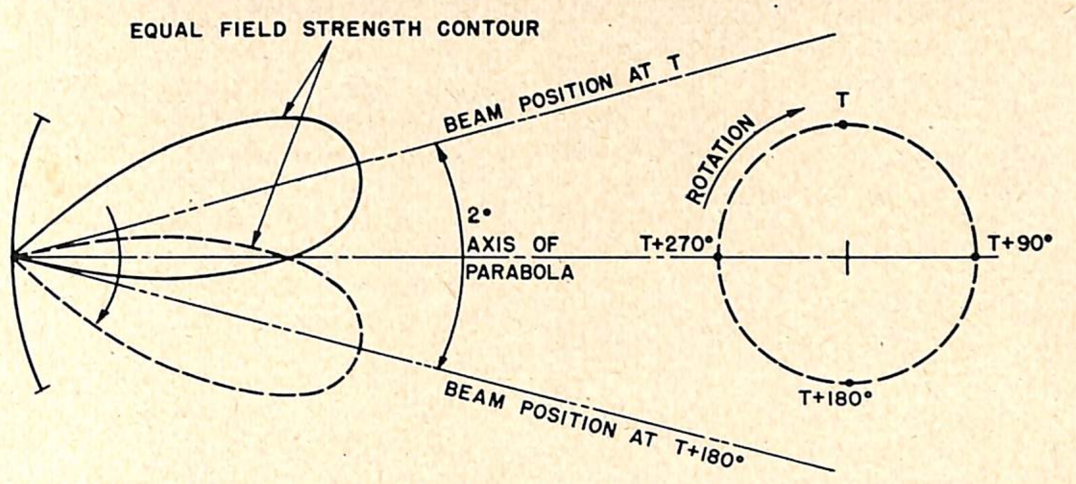


FIGURE 2—Idealized sketch of the Lark SP–1M Nutating Antenna, showing the cone about the axis of the reflector.

signal occurs simultaneously with the range gate and is applied to the coordinate detector to provide train and elevation error signals, while signals not occurring during the range gate are blocked and do not affect the automatic tracking circuits. If, however, two targets are within the gate, there is a possibility that the radar will track the one having the stronger echo.

The output of the missile receiver may be fed into the target coordinate detector through switch S1 on Figure 1, so that the radar may automatically track the missile. This operation is identical to that using the target channel except that the PPI does not properly display the tracked missile.

Manual Tracking—Telescope—When S3 on Figure 1 is at the telescope position, the antenna can be controlled from the telescope. Error signals developed by operating the slew sight or the telescope handwheels are applied through the manual coordinate detector, the servo amplifiers and amplidynes or through the servo amplifiers and the amplidynes to the antenna drive motors which move the antenna in such a direction as to reduce the error signal. The difference in voltages developed by synchro generators mechanically connected to the antenna drive motors and synchro control transformers connected to the telescope drive motors is applied through the telescope amplifier to drive the telescope until it points to the same angular position as the antenna. In this way if the crosshairs of the telescope are centered on the target, the center of the radar beam will also be on the target neglecting parallax. This method of operation is limited to relatively short distances because of the optical limitations of the telescope.

There are two methods of training the telescope on the target. One method is to use an open slew sight. The slew sight is connected to two potentiometers whose axes of rotation are mutually perpendicular. If the slew sight is held on the target, voltages are developed which are combined with the 60-cycle reference voltage in the manual detector to develop error voltages. These are applied through the servo amplifiers and amplidynes to drive the antenna in train or elevation until the error voltages are zero.

The second method of training the telescope is to use the handwheels on the side of the telescope column to develop error signals to bring the antenna on target. These handwheels turn tachometer generators which are connected in parallel with the train or elevation feedback tachometers on the antenna mount. The telescope handwheels thus provide direct position control of the antenna mount through the amplidyne drive system. The movement of the telescope itself is effected through synchro transmission from the antenna. The tachometers are shorted out when control from the telescope handwheels is not desired.

Manual Tracking—PPI—If switch S3 (Figure 1) is thrown to the PPI position, the antenna can be moved in train or elevation by use of the handwheels on the front of the PPI unit. The position of the target may be observed on the PPI screen or on the target or missile indicator scopes.

In this mode of operation the handcranks drive control transformers which develop voltages that are combined with the 60-cycle reference voltages in the manual detector to develop d-c error voltages for driving the antenna.

Handcrank Amplifiers and Telescope Amplifiers—When the antenna is tracking automatically or when it is rotating continuously, it is desirable that the handwheels on the PPI unit and the optics of the telescope unit follow the antenna. This is accomplished by the use of the synchro present position transmission as shown in Figure 1. Synchro generators, mechanically coupled to the antenna drive motors, are electrically connected to control transformers which are geared to the handcranks of the PPI unit and to the telescope column and elevation prism so that error voltages are developed if the handcranks and telescope are not aligned with the antenna. The error voltages are amplified and supplied to the motors which drive the handcranks and telescope. In this way the telescopes and handcranks are always kept in alignment with the antenna so that control may be rapidly transferred from automatic to manual or telescope without development of abnormally large error voltages.

Synchro Motors, Synchro Generators and Control Transformers—When a synchro motor is driven by a synchro generator, the rotors will be perfectly aligned if one assumes zero load on the motor. (This load includes all friction.) The position of zero angular error between generator and motor is also the position of zero torque. When the angular error is 90 degrees, the torque tending to reduce the error is at maximum. In any practical system there will be a load on the motor and hence an angular error. One method of reducing this error is to use a gear train so that several revolutions of the motor are required to give one revolution of the output shaft. The error is reduced in proportion to the gear ratio. A 36-speed synchro, for example, should have 1/36th the angular error of a 1-speed synchro, neglecting added friction and backlash in the gears. A 36-speed synchro has considerably greater torque for a small angular error, say 10, than a 1- or 2-speed synchro has for the same angular error. A serious defect is that the synchro motor can lock in at 36 different positions with respect to the output shaft. Thus the output information supplied from the motor can be greatly out of alignment with the input information unless the angular error is kept very small (less than approximately 10 degrees).

In the Lark SP–1M this problem is solved by using a built-in vacuum-tube voltmeter which constantly measures the error voltage. When the error voltage is large (corresponding to more than approximately 2.5 degrees), the 1-speed synchro is connected. When the error becomes smaller than 2.5 degrees, the plate current through the voltmeter tube changes so that the 36-speed synchro is switched in and the error is reduced to a few minutes of angle. Switching from 1-speed to 36-speed synchros at an error voltage corresponding to 2.5 degrees rather than 10 degrees removes the possibility of the system locking in 10 degrees out of alignment. The shift from 1-speed or 2-speed to 36-speed and back again is entirely a function of the magnitude of the error voltage.

A 1-speed synchro is used on the train motor and a 2-speed synchro is used on the elevation motor since the elevation travel of the antenna is only 90 degrees. The system can be locked in the 36-speed position if desired.

The range unit uses 1-speed and 100-speed synchros for coarse and fine range. The synchro generator and motor are fundamentally alike. They differ only in application. Because the synchro generator is always mechanically driven its bearings can have more friction than synchro motors. Further the generator does not require a damper to prevent oscillations. Synchros are built and tested. Those which have the lower friction bearings have dampers added and are used for motors, the others are used for generators.

Control transformers differ from synchros in that the output is a voltage whose amplitude and phase depends upon the rotor position and upon the voltages applied to the stator. The impedance of the stator and the rotor windings are high enough to be used with vacuum tube amplifiers. The rotor of a control transformer is always mechanically driven so dampers are never required.

Tachometer Feedback—Tachometer feedback, although not shown on the block diagram (Figure 1), is employed in all servos of the Lark SP–1M system. D-c tachometers are employed in the train and elevation antenna drive servos and in the range servo (although the latter uses an a-c motor and amplifier). A-c tachometers are used in the telescope and handcrank servos. The d-c tachometers coupled to the telescope handwheels are connected in parallel with the antenna tachometers and operate directly on the antenna drive servos. The feedback voltage developed by any of these tachometers is proportional to the velocity of the output member—the greater the velocity the greater the feedback voltage developed. Since the feedback voltage is applied so as to oppose the motion causing it, the effect is to make the system more responsive to sudden changes in velocity: for example, sudden removal of the input signal when the system is moving at constant velocity results, because of the inertia of the system, in full application of the feedback voltage to the input, bringing the system quickly to a stop. Conversely, if the system is at a standstill, sudden application of an input signal results in high starting torque, since the feedback voltage does not develop until the system gets under way. Tachometer feedback thus counteracts the inertia of elements and other system forces—usually of the motor and gearing—within its loop and outside its loop.

Computer Operation

Use of a computer makes it possible to synthesize any desired course and repeat it any desired number of times. If S2 is placed in MANUAL position and S3 in COMPUTER position, the antenna, and hence the radar beam, can be made to follow any desired straight line course within the response characteristics of the system. Any desired straight line course corresponding to an imaginary target can be set into the computer and a beam riding missile launched into the beam. By comparing the tracking camera record, the dial box record, and the computer course, the deviation of the missile from the theoretical course can be determined. This information, together with data which may be telemetered from the missile, makes possible a complete study of the performance of beam riding missiles. The theoretical course can be used to check the performance of the radar system itself and to compare its actual performance against that predicted by the design calculations.

Beacon Operation

Because of its small size and unfavorable aspect a missile produces an echo which is quite weak when moving away from the radar at a considerable distance. As an aid in tracking the missile, a receiver tuned to the radar frequency is installed in the missile. The output of this receiver is used to trigger a transmitter inside the missile which sends out a pulse that is picked up by the radar. The beacon transmitter is tuned to a frequency different from that of the radar transmitter and the signal is received at the radar by a separate receiving system (the missile receiver and related units). In this way a pulse striking the missile produces, in effect, a much stronger signal for use at the radar than would be possible from the reflection alone thus allowing the missile to be tracked to a greater distance. This arrangement also provides other advantages: (1) it permits automatic tracking of a missile as it leaves the launcher. Unless the missile is tracked automatically from the launcher, the early part of the flight record may be lost. Without a beacon the radar may get a stronger reflection from the launcher than from the missile and thus remain locked on the launcher. (2) Because of the greater strength of the beacon signal and because of its frequency there is much less probability of extraneous reflections from the ground or other sources causing the radar to lose the missile. The echo signal and the beacon signal may be received and observed directly or recorded simultaneously. By comparing the two signals an indication is obtained of the amount of noise developed in the beacon receiver and transmitter.

The receiver in the missile is connected to a coordinate detector which develops error voltages if the beam and missile are not aligned. The error voltages are used to control flaps on the missile so that it will follow the center of the beam where the error voltages are zero. If the beam is moved, error voltages will be developed and the missile will again align itself with the beam. In this way the beam can be held on a target and the missile will follow the beam to the target.

Data Recording Equipment

General—To make possible the use of the Lark SP–1M radar as a test instrument, a complete data recording system is included in the equipment. The data recording system is made up of six units. They are: the camera control unit, the antenna tracking cameras, the dial box, the remote range indicator, the time comparator, and the sound recorder.

Cameras—Correlation of the data requires that all cameras used operate at the same speed. This requirement is satisfied by driving a synchro generator with an a-c motor and using the output of the synchro generator to drive synchro motors which in turn drive the cameras. All of the cameras thus run in synchronism and the data obtained may be compared frame by frame. To provide a reference point for correlation at the beginning of each film, a small lamp is mounted inside each camera in such a way that it momentarily fogs the film when the camera start switch is thrown. A time delay relay extinguishes the lamps in all cameras simultaneously. All the motion-picture cameras normally operate at 10 frames per second and the continuous-strip camera used for the time comparator operates at an equivalent rate. This rate is chosen on the basis of missile flight time and the advantage of using 50-foot film magazines in the cameras. The cameras can be operated at 10, 20, or 30 frames per second by changing the gear ratio in the camera control unit.

Two 16-mm motion-picture tracking cameras are mounted on the antenna reflector. One has a 6-inch lens and the other a 21-inch telephoto lens. Both cameras have crosshairs which are photographed along with the target or missile. The cameras are aligned in such a way that when the object is in the center of the crosshairs it is also in the center of the radar beam.

Dial Box—A cross check on the antenna tracking cameras can be obtained by comparing the reading of the target and missile cross-pointer meters in the dial box with the antenna tracking film. These meters are in series with those in the output of the target and missile coordinate detector and indicate the position of the target or missile with respect to the center of the radar beam.

The dial box shows additional information. Dials mounted on synchro motor shafts give a continuous record of 2-speed and 36-speed antenna elevation and 1-speed and 36-speed antenna train angle. These synchros are controlled by other synchros mounted on the antenna elevation and train motors.

In the same way, other dials show coarse and fine range as transmitted by both the target and missile range units, so that the ranges of both the target and the missile are continuously recorded.

The range as supplied by the computer is recorded by two dials and their associated synchros. Additional spare dials and synchros are provided to display any additional information, if necessary.

The position of switches S1, S2, and S3 is recorded at all times by the use of indicator lights on the front of the dial box. When any of these switches is in any given position, the indicator light corresponding to this position is turned on.

A counter is provided on which the run number can be shown and photographed along with the other data.

Remote Range Indicator Unit, Unit 8500—The Remote Range Indicator Unit, Unit 8500, shows the position of the returned signal from either the target or missile in the range gate. Any interfering signal within the gate will be recorded. This information may be very useful in the interpretation of irregularities recorded on any other portion of the data recording equipment. The height of the pulse gives an indication of its strength. Four indicator lights are on the front of the remote range indicator. Two of them are used to show the position of switch S1 (Figure 1). The other two lights indicate whether the system is using the automatic target or the automatic missile range. A camera records the data shown by the remote range unit.

Time Comparator—A synchro motor is used to drive a commutator which supplies one pulse per revolution to the input of an amplifier. This pulse marks the opening of the camera shutters. The output of the amplifier is connected to a strobotron which flashes each time a pulse is applied to the amplifier input. The flash of light passes through a slit and produces a well-defined image on the film in the continuous strip camera. A duplicate amplifier and strobotron is connected to the output of receiver which picks up theodolite timing signals. Flashes from this source are photographed on the same film beside those derived from the commutator. This arrangement makes possible the correlation of the theodolite camera records and any of the radar records.

Sound Recorder—A sound recorder is connected to the communications equipment so that all communications by radio, telephone, or intercommunication system are recorded.

Type of Approach	Through January	To Date
Practice Landings	9,455	312,487
Landings Under Instrument Conditions	644	12,384

O.I.R. NEWSLETTER

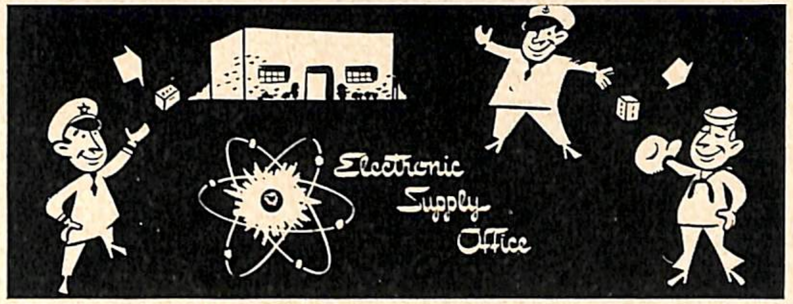
The Office of Industrial Relations, Navy Department, Washington, D. C. has recently inaugurated an informative monthly paper entitled "Newsletter," the first issue being dated January 1950. This series is being developed for the purpose of providing field activities with information about developments that influence Department of the Navy civilian personnel management, in the field and in overseas activities. Items included will be of interest to Commanding Officers of activities and key management officials as well as to staff members of civilian personnel offices. A major purpose of the Newsletter will be to serve as a medium for the exchange of ideas and successful experiences on a Navy-wide basis. Accordingly, all activities are invited and urged to submit, through activity channels, comments, suggestions, and news items which they believe will be of general benefit. Upon clearance through local activity channels, submissions should be forwarded to the Chief, Office of Industrial Relations, Code 235, Navy Department, Washington 25, D. C.

CORRECTIONS TO MARCH ELECTRON

On Page 6 of the March ELECTRON—under "Laboratories"—the Naval Research Laboratory, Bellevue, D. C. is under the direct control of ONR rather than BuShips. On Page 7—under "Laboratories"—the U. S. Navy Electronics Laboratory, San Diego, Calif., *was established in 1940, and is not a wartime founded institution.* On Page 10—under "Naval Shipyards"—"Senior Civilian Assistant" should be changed to read "Chief Civilian Assistant." The three general sections under the Electronics Officer are titled "Shore," "Ship," and "Services" rather than "Technical," "Inspection," and "Clerical." Subdivision of these three sections is a matter of local option at the different Naval shipyards.

TRAINING FILM . . .
"SOFAR IN SEARCH AND RESCUE"

See the new training film "Sofar in Search and Rescue", MN6600. This recently completed film, sponsored by the Bureau of Ships, explains how Sofar (SOund Fixing And Ranging) works to locate downed aircraft. The film was designed to acquaint electronics and aviation personnel, particularly, with the use of Sofar. 16mm prints may be borrowed from District Training Aids Section or Aviation Film Libraries.



E.S.O. MONTHLY COLUMN

Something New Has Been Added

Ahoy, Shipmates—Your editor of BUSHIPS ELECTRON has kindly offered the Electronic Supply Office a column in this publication whereby supply articles of interest to the technician may be discussed. Since furnishing technical personnel with the parts required to keep electronic equipment in good operating condition is our business, this medium of exchange on mutual problems should be helpful to more closely unite technical with supply.

The August 1949 issue of the ELECTRON was devoted to the Electronic Supply System and covered the overall objectives, mission, scope and problems of supply. As a major supply demand control point, we have not lost sight of our primary goal which is to get the material to you, the technician, when and where it is needed.

A tremendous amount of identification and catalogueing work, which will facilitate the requisitioning, stocking and supplying of parts, has been done—although much has yet to be accomplished in this field. The majority of the millions of parts in the Electronic Supply System have been converted to and binned under Standard Navy Stock Numbers at all supply activities. This number is used in the Electronic Maintenance Repair Parts Program, and will also appear in the new instruction book parts list. As a result, the use of Standard Navy Stock Numbers for requisitioning purposes, without the necessity of completing descriptions for items ordered, will facilitate the fulfillment of requests since no translation of technical descriptive data to stock numbers at supply activities is necessary before the item requested can be furnished.

Failure data which technicians submit to the Bureau of Ships on NavShips Form 383 will provide the Electronic Supply Office with a very valuable tool in predicting parts requirements. Also when the report states that defects are caused by improper packaging or handling, corrective action can be taken at the source of trouble. The Electronic Supply Office expects to have available soon detailed records of all shipboard and shore-based electronic installations, a complete listing of all parts used in each equipment, the number of times the same part is used in an equipment, and a report of all failures. Acquisition of this information will result in more intelligent and rapid supply support. Partial data of this sort has been available and utilized during the past year in order to distribute available materials as necessary and to help procure the right quantity when buying is necessary. The Electronic Supply Office, of course, maintains a record of the number of times a part is issued from stock, and the location and quantity of items in stock.

The technician who is the end user can do his part in helping to achieve a better Electronic Supply System for the Navy by carefully filling out NavShips 383 and submitting it to the Bureau of Ships each time a failure occurs.

Subsequent articles will appear in this column which will be of interest, as you will want to know something about such things as our procurement practices, catalogueing methods and our plans for standardization of stock—just to mention a few. The supply system is maintained for you; therefore, any recommendations or suggestions that will improve this service are most welcome. Answers to your questions on supply matters, when of interest to other personnel, will appear in this column.

Remember—you—have—no—cares—when—you—have—the—proper—spares.

Spare Parts Breakdown Lists

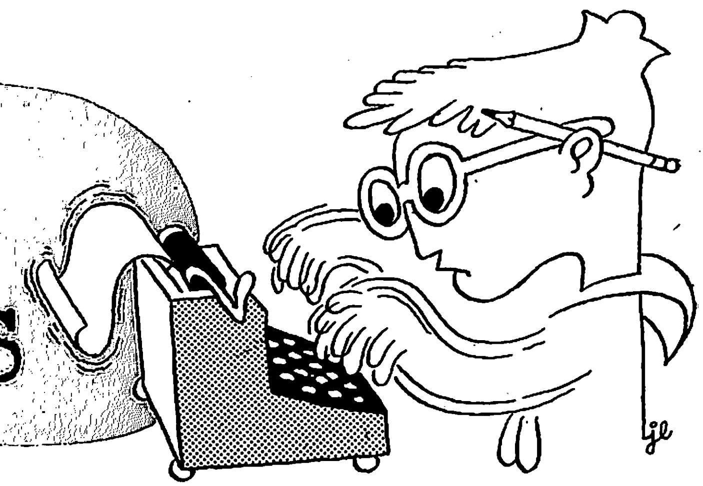
The publication of Spare Parts Breakdown Lists, which are developed by utilizing BuShips Electronic Maintenance Repair Parts Program information, is nearing completion. To date, 784 of these SPBL's have been distributed and comparatively few remain to be published.

(See "Breakdown Program" in the August 1949 issue of the ELECTRON.)

Electronics Catalogue

The BuShips Section, Part II (Electronics) of the Catalogue of Navy Material, which will cover electronic maintenance repair parts, is under contract. At present, compilation has been started on the variable, wire-wound resistor section which will contain approximately 2500 Standard Navy Stock Number items.

New Books



The BuShips Electron of September 1949 contained a list of all instruction books distributed from 1 September 1947 to 1 June 1949. The following pages list all instruction books distributed from 1 June 1949 to 1 January 1950. The key to the abbreviations appearing under *"Edition"* appears below.

Supplementary lists will be published in BuShips Electron at regular intervals, as additional instruction books are distributed.

In the September 1949 Electron NavShips 98113 and NavShips 98114 were listed as the short titles for AN/SPS-6 Field Change Bulletins Nos. 8 and 6 respectively. This is in error and should be corrected to Field Change Bulletins Nos. 3 and 9 respectively.

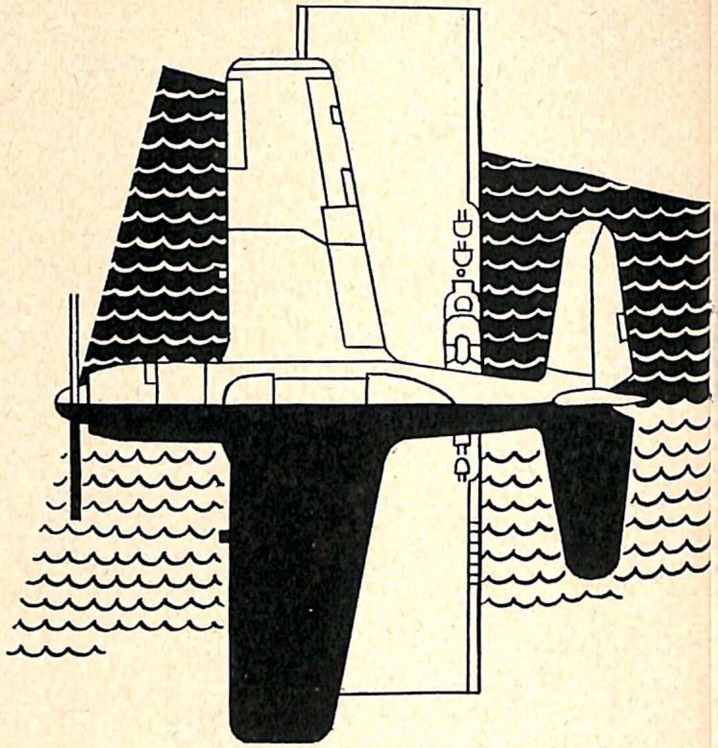
Model	*Short Title*	*Model*	*Edition*
C	Commercial Publication	MH	Maintenance Handbook
Ch.	Change	MI	Maintenance Instructions
CI	Complimentary Instructions	OH	Operators' Handbook
DB	Descriptive Booklet	P	Preliminary Instruction Book
F	Final Book	RS	Revision Sheets
FC	Field Change	S	Supplement
FCB	Field Change Bulletin	SP	Spare Parts Catalogue
IB	Instruction Book	T	Temporary
IH	Installation Handbook	TM	Technical Manual
IS	Instruction Sheets	*	Limited Quantities Only

Model	*Short Title*	*Edition*
AN/APN-63	NAVSHIPS 91,141	IB
AN/BQC-1	NAVSHIPS 91,178	F
AN/BQN-1	NAVSHIPS 91,179	F
AN/BQN-1	NAVSHIPS 91,179	Temp. Corr. T-1
AN/FGC-7	NAVSHIPS 91,247	IB
AN/FGC-9	NAVSHIPS 91,239	C
AN/FGC-10	NAVSHIPS 91,240	C
AN/FRT-4	NAVSHIPS 91,169	IB
AN/FRT-4	NAVSHIPS 91,169.1	IH
AN/FRT-4	NAVSHIPS 91,169.2	OH
AN/FRT-4	NAVSHIPS 91,169.3	MH
AN/FRT-4	NAVSHIPS 91,169.4	SP
AN/FRT-5	NAVSHIPS 91,183	F
AN/GPN-2	NAVSHIPS 98,145	FC #2
AN/MPN-1A	NAVSHIPS 98,111	FC #9
AN/MPN-1B	SHIPS 316A	Temp. Corr. T-3
AN/MPN-1B	SHIPS 316A	Temp. Corr. T-4
AN/PDR-2	NAVSHIPS 91,039(A)	F
AN/PDR-3A T-1	NAVSHIPS 91,133	Temp. Corr. T-1
AN/PRM-1	NAVSHIPS 91,255	IB
AN/PRM-1-(XN-5)	NAVSHIPS 91,208	F
AN/SPS-6	NAVSHIPS 98,146	FC #4
AN/SPS-6	NAVSHIPS 98,141	FC #5
AN/SPS-6	NAVSHIPS 98,147	FC #6
AN/SQN-1	NAVSHIPS 91,171	F
AN/SSQ-6	NAVSHIPS 91,234	F
AN/TIP	NAVSHIPS 91,168	F
AN/TIP-1	———	SIG M-8
AN/TPS-1B	NAVSHIPS 98,137	FC #1
AN/UQC-1	NAVSHIPS 91,180	Temp. Corr. T-1
AN/URM-6	NAVSHIPS 91,196	F
AN/UQC-1	NAVSHIPS 91,180	F
AN/URA-5	NAVSHIPS 91,225	F

Model	*Short Title*	*Edition*
AN/URD-2	NAVSHIPS 91,198	F
AN/URR-9	NAVSHIPS 91,021	F
AN/USM-3	SIG M-8	
BL-136/U	NAVSHIPS 91,244	C
C-492/SG	NAVSHIPS 91,108	F
CXJV	NAVSHIPS 91,176	F
*DU	NAVSHIPS 91,212	F
IM-3/PD	NAVSHIPS 91,032	F
IM-4/PD	NAVSHIPS 91,033(A)	IB
IM-5/PD	NAVSHIPS 91,034	F
IM-7A/PD	NAVSHIPS 91,227	IB
IM-11/UD	NAVSHIPS 91,036	IB
JT	NAVSHIPS 98,149	FC #7
KY-30/GRT	NAVSHIPS 91,232	IB
LAD	NAVSHIPS 95,622	F
LP-5	NAVSHIPS 900,425	F
LP-5	NAVSHIPS 900,425	Ch. 2
Mk 2 Mod 1B Gyrocompass	NAVSHIPS 91,140.4	Temp. Corr. T-1
Model 35 Grentz Ray Equipment	NAVSHIPS 91,251	C
MX-802 MRC	NAVSHIPS 91,280	IB
MX-802 MRC	NAVSHIPS 98,159	FC #1
MX-834/TPS-1B	NAVSHIPS 91,158	F
MX-834/TPS-1B	SIG M-8	
MX-904/U	NAVSHIPS 91,200	F
MX-906/U	NAVSHIPS 91,199	F
MX-907/U	NAVSHIPS 91,200	F
O-76/U	NAVSHIPS 91,124	Bulletin 1198
OAH-4	NAVSHIPS 91,147	F
OAP-1	NAVSHIPS 900,001-IB	F
OAV-1	NAVSHIPS 919.2	F
OC-1-2-3/S	NAVSHIPS 91,151	F
OCY-1	NAVSHIPS 91,011	F
OCY-1	NAVSHIPS 91,011	Vol. 3 Marines Final IB
OCZ-1	NAVSHIPS 91,215	F
OS-10/U	NAVSHIPS 91,204	F
PH-614/U	NAVSHIPS 91,038	F
PO & YQ	NAVSHIPS 900,602	Ch. 1
PO & YQ	NAVSHIPS 98,125	FC #2
PP-270/U	NAVSHIPS 91,139	F
PP-315/GGA-1	NAVSHIPS 91,243	C
PP-354/PD	NAVSHIPS 91,187A	F
PU-155A/SP	NAVSHIPS 91,197	IB
QHB-a	NAVSHIPS 91,125	F
Hydraulic Train Equipment for QLA/QLA-1	NAVSHIPS 91,149	F
RDP-a	NAVSHIPS 91,259	CI
Teletype Receiver-Projector	NAVSHIPS 91,220	F
REJ	NAVSHIPS 91,217	F
RG-8, 11, 17, 19/U	NAVSHIPS 900,520-IB	F
SG-1	NAVSHIPS 98,129	FC #6
SG-1	NAVSHIPS 98,105	FCB #62
SG-6	NAVSHIPS 98,155	FC #2
SG-22/U and PP-427/U	NAVSHIPS 91,170	IB
SG-25/U	NAVSHIPS 91,192	F
SIG M-8	I-95	
SO-1	NAVSHIPS 91,190	F
SO-4	NAVSHIPS 900,321(A)	F
SP-1M	NAVSHIPS 98,073	FCB #65

Model	*Short Title*	*Edition*
*SP-1M	NAVSHIPS 900,905	Maintenance Prints
SR-3	NAVSHIPS 98,133	FC #5
SR-3	NAVSHIPS 98,139	FC #6
SR-3	NAVSHIPS 98,127	FC #9
SR-3	NAVSHIPS 98,123	FCB #3
SR-6	NAVSHIPS 98,088	FC #2
SR-6	NAVSHIPS 98,143	FC #5
SR-6	NAVSHIPS 98,132	FC #10
SR-6	NAVSHIPS 98,128	FC #11
SV-3	NAVSHIPS 91,163	F
TCS-7/9/10/11/12	NAVSHIPS 900,291-IB	F
TD-26/U	NAVSHIPS 91,214	F
TDZ	NAVSHIPS 98,167	FC #1
TDZ	NAVSHIPS 98,168	FC #2
TDZ	NAVSHIPS 98,169	FC #3
TDZ	NAVSHIPS 98,170	FC #4
TDZ	NAVSHIPS 98,100	FC #5
TEG-1	NAVSHIPS 91,167	IB
TEG-1	NAVSHIPS 91,167.1	IH
TEG-1	NAVSHIPS 91,167.2	OH
TEG-1	NAVSHIPS 91,167.3	MH
TEG-1	NAVSHIPS 91,167.4	SP
TS-147A/UP	NAVSHIPS 91,104	F
TS-186A/UP	NAVSHIPS 91,025	F
TS-234/UP	NAVSHIPS 900,458(A)	F
TS-235/UG	NAVSHIPS 91,245	F
TS-275/UP	NAVSHIPS 900,825	Ch. 1
TS-295A/UP	NAVSHIPS 91,164	Ch. 1
TS-501/UP	NAVSHIPS 91,191	F
TS-545/UP	NAVSHIPS 91,213	F
TS-627/U	NONE	F
TS-657/FG	NAVSHIPS 91,210	F
TS-658/UG	NAVSHIPS 91,242	C
TT-44-FG	NAVSHIPS 91,238	C
TT-45/FG	NAVSHIPS 91,241	C
TT-67/UG	NAVSHIPS 91,245	F
UO	NAVSHIPS 95,355	F
VF	NAVSHIPS 900,858	F
VH	NAVSHIPS 900,984	Ch. 1
XD91GL	NAVSHIPS 95,449	Manual #59
X-VL	NAVSHIPS 91,075	F
YY-2	NAVSHIPS 91,282	C
A-30	NAVSHIPS 95,621	F
50AED	NAVSHIPS 95,620	F
165-A	NAVSHIPS 91,619	F
666H	AN 08-5QS-6	F
10306	NAVSHIPS 95,366	F
10345	NAVSHIPS 900,476-IB	F
23367	NAVSHIPS 900,297-IB	F
23551 & 23552	NAVSHIPS 91,189	F
35131	NAVSHIPS 91,144(A)	F
49131-C	NAVSHIPS 91,202	Diagrams and Parts List
50128A	NAVSHIPS 95,623	IB
60057	NAVSHIPS 95,413	F
60069-B	SHIPS 369	F
60094	NAVSHIPS 95,437	F
60175	NAVSHIPS 91,249	C
78270	NAVSHIPS 91,145(A)	F
211715	NAVSHIPS 91,216	F
Type H-21 Oscilloscope	NAVSHIPS 91,260	C
Type 511A and 511AD Oscilloscope	NAVSHIPS 91,273	F

Carrier Controlled Approach



by
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Bureau of Ships

Introduction

Before World War II drew to a close, it had become evident that Carrier Controlled Approach (CCA) was to become one of the most important functions aboard carriers for systematically landing planes returning from strikes, in damage status, or in maneuvers, during adverse weather conditions.

In the October 1945 issue of BuShips Electron certain fundamentals of CCA were outlined. At approximately that time the Navy adopted the already-existing ground controlled approach (GCA) for use aboard carriers, naming the revised system CCA. It is the purpose of this article to show the developments that have occurred between 1945 and the present time insofar as CCA is concerned. As a consequence, the following information is submitted in order that all hands may have an opportunity to know what the Bureau of Ships is contemplating for carrier controlled approach.

Procedure

Figure 1 illustrates the procedure presently under consideration for CCA landings. While it is not intended that these landings be executed under all conditions of weather nevertheless it seems logical to assume that such will eventually be the case. The following outline for CCA procedure is to be considered tentative insofar as the present state of the art is concerned:

The carrier controlled approach procedure is designed to position an aircraft in the landing attitude at such an altitude, airspeed and position relative to the carrier that a successful visual Landing-Signal-Officer directed landing may be made aboard, under ceiling and visibility conditions that would preclude contact carrier approaches. It is also designed to provide an evenly spaced flow of aircraft to the LSO. Because of the limitations imposed by present electronic equipment, aircraft instrumentation and personnel training, the following minimums are considered to be the best obtainable without undue risk to both the aircraft and the carrier:

1—Landing interval—60 to 90 seconds.
2—Ceiling—200 feet.
3—Visibility—500 yards.

The CCA pattern is diagrammed in Figure 1. Under contact conditions this pattern may be flown visually and will produce landing intervals comparable to the present standard contact procedure. The only difference between contact and instrument approaches will be the method of feeding aircraft into Point "B", the method of handling wave-offs and the degree of control exercised by the CCA controllers.

The aircraft is controlled to Point "A" by the Pick-up Controller, and from Point "A" to Point "B" by the Marshalling Controller.

The aircraft reaches Point "B" at an altitude of 750 feet and an airspeed of 150 knots and is turned over to one of the two Traffic Controllers. The Traffic Controller vectors the aircraft along the 215° relative bearing line to Point "C" where the aircraft is turned to reach Point "D", 2 miles 215° relative from a point 250 yards astern of the ship. During this turn, the landing check-off list is completed and speed is reduced to 90 knots and altitude to 500 feet at Point "D".

At Point "D", the aircraft is turned over to one of two Final Controllers. The Final Controller vectors the aircraft to make good a 350° track relative to the ship and to intersect the wake 250 yards astern. The aircraft descends at the rate of 300 feet per minute to 150 feet, reaching this altitude about 3/4 mile from the ship, and then further reduces to the approach speed and altitude. When the LSO sights the aircraft, he broadcasts "contact" and the approach is continued visually to a landing or wave-off. If the LSO does not contact at 500 yards, a wave-off to starboard is ordered by the Final Controller. If the pilot does not sight the LSO immediately after hearing "contact", an automatic starboard wave-off is taken.

It is intended through the use of AN/ARC–1 radio transmitters that each pilot have direct contact with a particular CCA operator. This means that when a pilot is at "B" he has a prearranged channel assigned to him, and when he continues to point "C" another channel is assigned to him. Thus, it is possible for one pilot to change channels four times in the prosecution of this pattern to homer. This procedure may be reversed so that the pilot remains on the channel and the operators in the CCA room change channels to agree with the pilot's single channel. The timing outlined in the foregoing may be increased as the occasion arises and as the LSO's wave-offs increase.

Attention is invited to the fact that all this is based on experience in the field (both reports and word of mouth), and recent conferences in the Bureau of Ships, and is intended for guidance purposes as no severe doctrine has been promulgated up to the present time. It is anticipated that until such time as the CV–34 installation is completed, final reports and decisions will not be made to revise this materially.

Background

The Bureau of Ships developed the first two CCA systems aboard the *USS Valley Forge* (*CV–45*) and the *USS Philippine Sea* (*CV–47*). Aboard these vessels the CCA space was located aft and partially below the flight deck only two or three steps from the Landing Signal Officer's space. At that time it was thought that this equipment should be located within walking and shouting distance of the Landing Signal Officer. The equipment within this space was the Model XSG–7 Traffic Control Radar, two Model AN/ARC–1 transmitter-receivers and the Models AN/SPN–2 and –3. The antenna for the XSG–7 was located on the port side of the stack. This equipment was used for marshalling, pick-up and traffic. The final approach was accomplished by employing the AN/SPN–2 and –3 radars.

Figure 2 illustrates graphically how the equipment was installed and shows the number of VJ repeaters and their positions in addition to a Model CXGH–2 Direction Finder (CV–47 only).

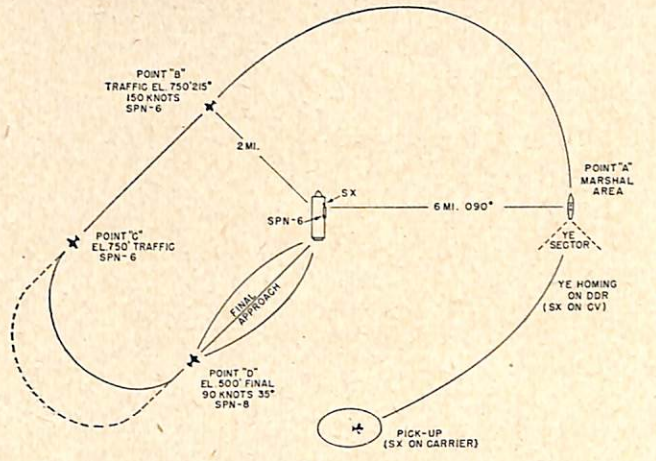


FIGURE 1

The antenna for the Model AN/SPN–2 was located directly aft at the same level as the CCA control room and just below the flight deck. This was considered to be the best location for this equipment, since it was used for the final approach.

Present Practices

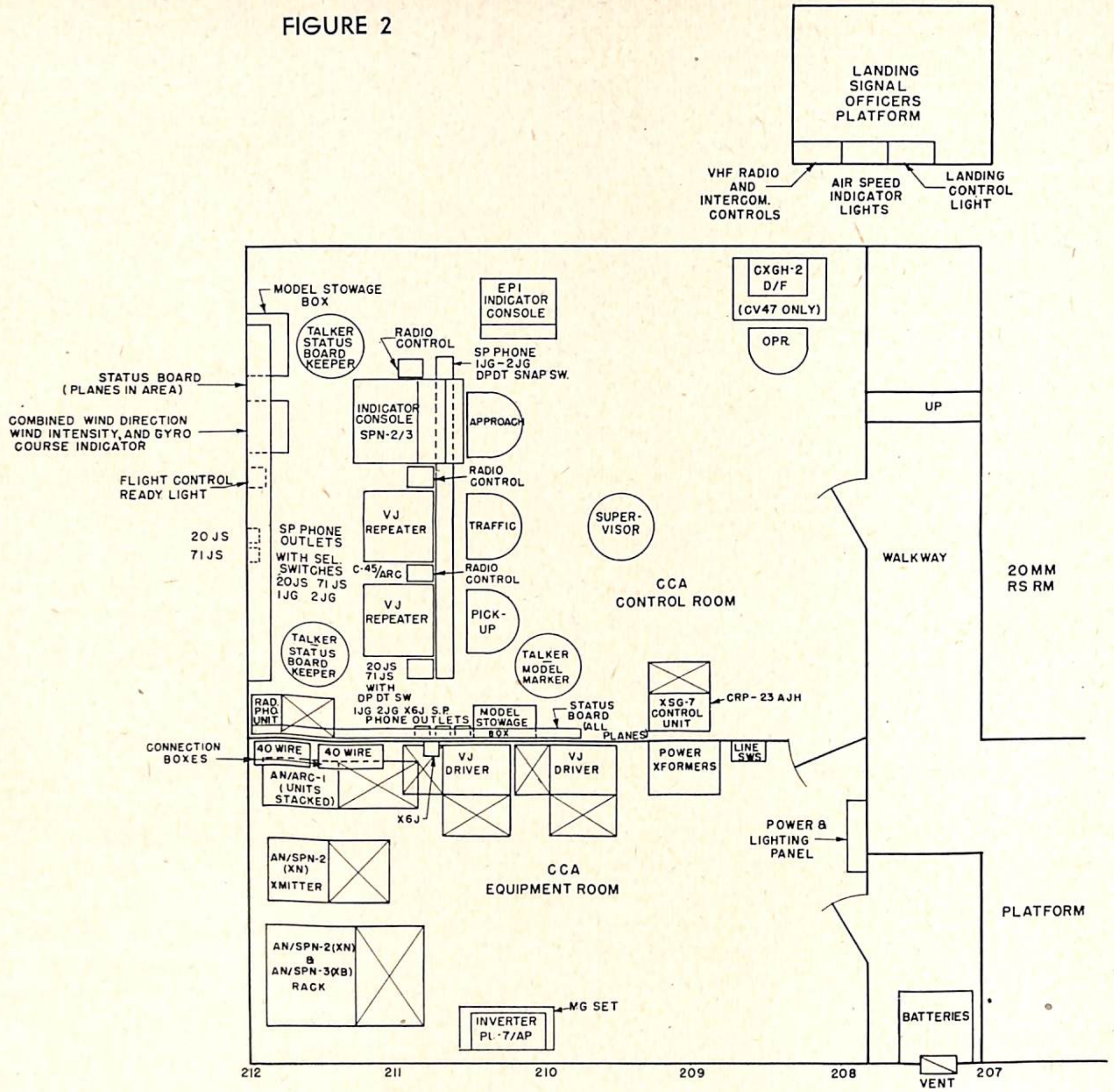
Based on operational developments and augmented by reports from ComOpDevFor in the further evaluation of the CCA system, the following was developed:

Figure 3 illustrates the contemplated CCA control room arrangement for the *USS Oriskany* (*CV–34*).

The space assigned for this function was determined to be the best under the circumstances. It was located in the vicinity of CIC but not inside it, thus eliminating mutual interference between the functions of CIC and CCA. However, it provided for physical supervision if it was considered eventually to be necessary. This space amidship was considered best because of the absence of vibration. The space allocated on the CV–45 and CV–47 was not free of excessive vibration. The problem of vibration is particularly important when operator surveillance of radar scopes is involved, or maintenance of equipment is paramount.

A room approximately 18' x 18' is considered to be the minimum working area required. As noted in Figure 2, this arrangement has been developed to illustrate the functional arrangement desired. To best simulate the conditions of descent and landing of planes for the two final operators at the Model AN/SPN–8, it is emphasized that these operators should be oriented to face toward the bow of the ship. Thus the pilot and CCA operators are "one." The LSO, in the event of a wave-off will have the means for indicating the proper circuit for selective over-ride. This over-ride will be provided on six channels. The LSO organi-

FIGURE 2



zation, it will be noted, has ultimate control on all six channels for conditions of descent.

The CCA control room in the CV–34 has been developed to provide for the following 13 personnel and control equipment:

- 1 Supervisor
- 1 Pick-up Controller
- 1 Marshall Controller
- 2 Traffic Controllers
- Approach Controllers (maybe 3)
- 6 Status Board Keepers and Directors
- 5 Model VK Radar Repeaters
- 3 AN/SPN–8 Indicators for Approach Controllers (3 needed for 2 controllers)
- 1 AN/SPN–6 General Control Unit (attached to VK)
- 7 C–45/ARC–1 Control Units with handsets and jacks (1 for each Controller and Supervisor)
- 7 51015 Chest Microphone Assemblies
- Type 23500 Radiophone Units
- 49274 Jackboxes with volume control (modified)
- 1 Wind Direction and Intensity Indicator
- 1 OSC Indicator (gyro repeater)
- 2 Flight Control Ready Light System Indicators
- 2 Air Status Boards
- 1 Mark 5 Edge-Lighted Status Board
- 1 AN/URD–2 Direction Finder
- Other miscellaneous equipments

The 5 Model VK Radar Repeaters will be used, one for the Supervisor, one for the Pick-up Controller, one for the Marshall Controller, and two for the Traffic Controllers.

Soundproofing and painting in accordance with the latest directives for CIC spaces is recommended. Sound powered telephone circuits have been provided.

The balance of the equipment may be located in this space, but it is recommended that it be located as close as practicable to the antennas. In the CV–34 it was located in the island tower, thus obtaining the shortest practicable run from the antenna to the transmitter. The equipment located in this space did not require operator surveillance and is listed as follows:

Model AN SPN–8 Precision Approach Radar:

- Transmitter—2 racks each
- Indicator—3 racks each
- 1 Stable Element (Westinghouse Mark VIII, Mod 2)

Model AN SPN–6 Traffic Control Radar:

- Transmitter-Receiver (SG–3)
- Modulator (SG–3)
- Voltage Regulator (SG–3)
- Power Transformer
- R-F Filter Unit (SG–3)
- Video Unit (SR–6)
- Antenna Control Unit
- Platform Control Unit
- Gyro Compass Synchro Amplifier
- Mk 8 Mod 4 Stable Element
- Mk 8 Mod 4 Control Panel
- Mk 8 Mod 4 Frequency Changer
- Range Indicator-IFF Coordinator

Interested activities can obtain the weights and dimensions of these equipments by requesting them from the Chief of the Bureau of Ships, Attention Code 981B, Washington 25, D. C.

Further developments not included above nor in Figure 3 will be the additional supervisor's communication console with a Model VK repeater adjacent, and sub-console units for the operators. It is anticipated that a new type electronic status board will be developed in time to augment the present boards in this space.

Conclusion

While the foregoing installation is considered ultimate at this time, nevertheless, as the state of the art progresses, newer equipments designed to handle additional traffic, wave-offs, etc., will be introduced.

Perhaps during conditions of clear weather, television will be employed to "see" the actual stacking of planes, one above the other, after wave-offs. The television camera equipment could be further developed to "see" within a ten-mile radius. If this is considered practicable, it would eliminate the need for cumbersome, heavy and elaborate radar antennas as presently designed. A maximum of four television cameras could be located at the corners and directly under the flight deck. This would obtain the necessary 360° coverage desired for optimum performance. The information obtained in this manner could be transmitted to the CCA control room and a clear visual presentation would be obtained, thus increasing the safe landing of planes returning from a strike or maneuvers.

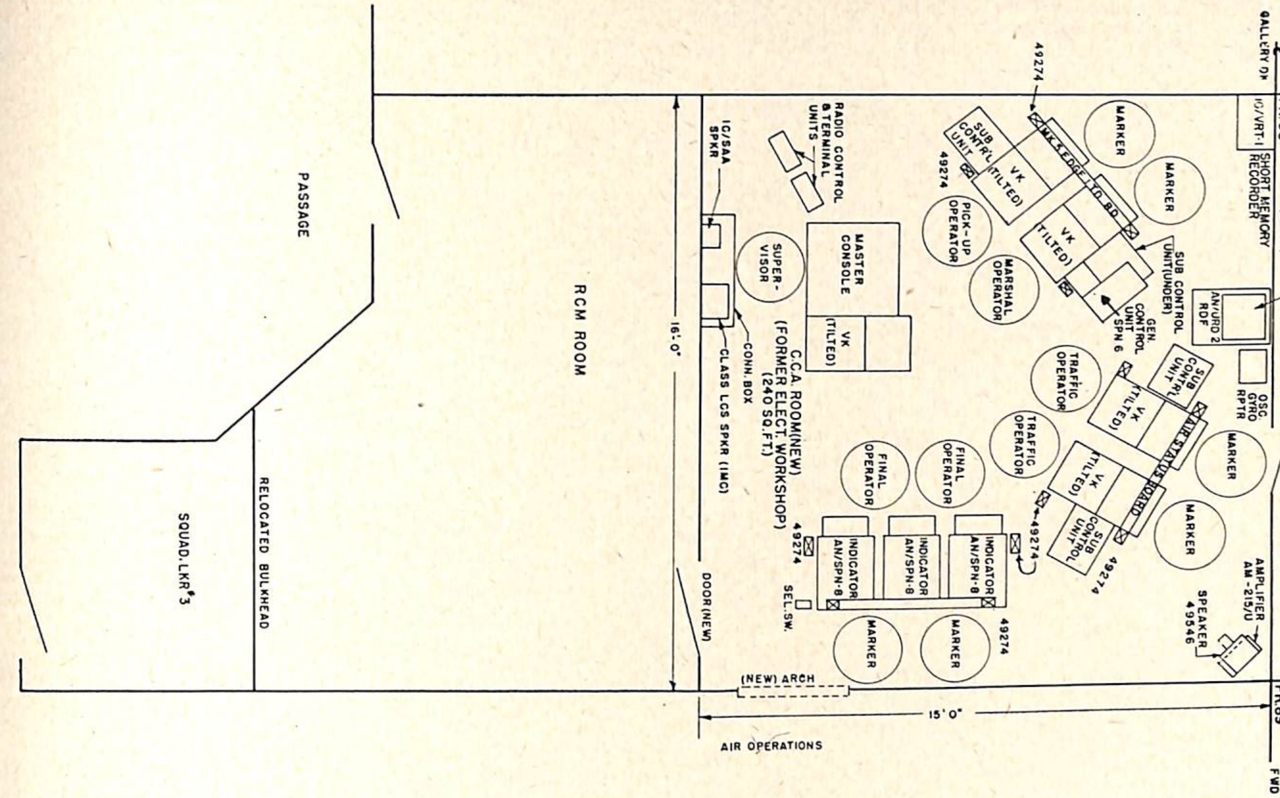


FIGURE 3

SUMMARY OF JOINT NOMENCLATURE SYSTEM ("AN" SYSTEM) FOR COMMUNICATION-ELECTRONIC EQUIPMENT

TABLE OF COMPONENT INDICATORS

COMP. IND.	FAMILY NAME	DEFINITION OF EXAMPLE (Not to be construed as limiting the application of the component indicator to those items)
AB	Supports, Antenna	Antenna mounts, mast bases, mast sections, towers, etc.
AM	Amplifiers	Power, audio, interphone, radio frequency, video, servo (nonrotating), etc.
AS	Antenna Assemblies	Complex: Arrays, parabolic type, masthead, etc.
AT	Antennae	Simple: Whip or telescopic, loop, dipole, reflector, also transducer, etc. (See H).
BA	Battery, primary type	B-batteries, battery packs, etc.
BB	Battery, secondary type	Storage batteries, battery packs, etc.
BZ	Signal Devices, Audible	Buzzers, gongs, horns, etc.
C	Control Articles	Control box, remote tuning control, etc.
CA	Commutator Assemblies, Sonar	Peculiar to Sonar equipment.
CB	Capacitor Bank	Used as a power supply.
CG	Cables and Transmission Line, R. F.	R. F. cables, wave guides, etc., with terminals.
CK	Crystal Kits	A kit of crystals with holders.
CM	Comparators	Analyzes or compares two or more input signals.
CN	Compensators	Electrical and/or mechanical compensating, regulating or attenuating apparatus.
CP	Computers	A mechanical and/or electronic mathematical calculating device.
CR	Crystals	Crystal in crystal holder.
CU	Coupling Devices	Impedance coupling devices, directional couplers, etc.
CV	Converters (electronic)	Electronic apparatus for changing the phase, frequency, or from one medium to another.
CW	Covers	Cover, bag, roll, cap, radome, nacelle, etc.
CX	Cords	Cord with terminals, also composite cables of R. F. and non-R. F. conductors.
CY	Cases	Rigid and semirigid structure for housing or carrying equipment.
DA	Antenna, Dummy	R. F. test loads.
DT	Detecting Heads	Magnetic pick-up device, search coil, hydrophone, etc.
DY	Dynamotors	Dynamotor power supply.
E	Hoist Assembly	Sonar hoist assembly, etc.
F	Filters	Band-pass noise, telephone, wave traps, etc.
FN	Furniture	Chairs, desks, tables, etc.
FR	Frequency Measuring Devices	Frequency meters, echo boxes, etc.
G	Generators	Electrical power generators without prime movers. (See PU & PD).
GO	Goniometers	Goniometers of all types.
GP	Ground Rods	Ground Rods, stakes, etc.
H	Head, Hand, and Chest Sets	Includes earphone.
HC	Crystal Holder	Crystal Holder less crystal.
HD	Air Conditioning Apparatus	Heating, cooling, dehumidifying, pressure, vacuum devices, etc.
ID	Indicating Devices	Calibrated dials and meters, indicating lights, etc. (See IP).
IL	Insulators	Strain, stand-off, feed-through, etc.
IM	Intensity Measuring Devices	Includes SWR gear, field intensity and noise meters, etc.
IP	Indicators, Cathode Ray Tube	Azimuth, Elevation, PPI, panoramic, etc.
J	Junction Devices	Junction, jack and terminal boxes, connector panels, etc.
KY	Keying Devices	Mechanical, electrical and electronic keyers, coders, interrupters, etc.
LC	Tools, Line Construction	Includes special apparatus such as cable plows, etc.
LS	Loudspeakers	Separately housed loudspeakers.
M	Microphones	Radio, telephone, throat, hand, etc.
MD	Modulators	Device for varying amplitude, frequency or phase.
ME	Meters, Portable	Multimeters, volt-ohm-milliammeters, vacuum tube voltmeters, power meters, etc.
MK	Maintenance Kits or Equipments	Radio, telephone, general utility, etc.
ML	Meteorological Devices	Barometer, hygrometer, thermometer, scales, etc.
MT	Mountings	Mountings, racks, frames, stands, etc.
MX	Miscellaneous	Equipment not otherwise classified. Do not use if better indicator is available.
O	Oscillators	Master frequency, blocking, multivibrators, etc. For test oscillators, see SG.
OA	Operating Assemblies	Assembly of operating units not otherwise covered.
OC	Oceanographic Devices	Bathythermographs, etc.
OS	Oscilloscope, Test	Test Oscilloscopes for general test purposes.
PD	Prime Drivers	Gasoline engines, electric motors, Diesel motors, etc.
PF	Fittings, Pole	Cable hanger, clamp, protectors, etc.
PG	Pigeon Articles	Container, loft, vest, etc.
PH	Photographic Articles	Camera, projector, sensitometer, etc.
PP	Power Supplies	Nonrotating machine type such as vibrator pack, rectifier, thermoelectric, etc.
PT	Plotting Equipments	Except meteorological. Boards, maps, plotting table, etc.
PU	Power Equipments	Rotating power equipment except dynamotors. Motor-generator, etc.
R	Receivers	Receivers, all types except telephone.
RD	Recorders and Reproducers	Tape, facsimile disc, magnetic, etc.
RE	Relay Assemblies	Electrical, electronic, etc.
RF	Radio Frequency Component	Composite component of R. F. circuits. Do not use if better indicator is available.
RG	Cables and Transmission Line Bulk R. F.	R. F. cable, wave guides, etc., without terminals.
RL	Reel Assemblies	Antenna, field wire, etc.
RP	Rope and Twine	Nonelectrical cord, etc.
RR	Reflectors	Target, confusion, etc. Except antenna reflectors. (See AT).
RT	Receiver and Transmitter	Radio and radar transceivers, composite transmitter and receiver, etc.
S	Shelters	House, tent, protective shelter, etc.
SA	Switching Devices	Manual, impact, motor driven, pressure operated, etc.
SB	Switchboards	Telephone, fire control, power, panel, etc.
SG	Generators, Signal	Includes test oscillators and noise generators. (See O.)
SM	Simulators	Flight, aircraft, target, signal, etc.
SN	Synchronizers	Equipment to coordinate two or more functions.
ST	Straps	Harness, straps, etc.
T	Transmitters	Transmitters, all types except telephone.
TA	Telephone Apparatus	Miscellaneous telephone equipment.
TD	Timing Devices	Mechanical and electronic timing devices, range device, multiplexers, electronic gates, etc
TF	Transformers	Transformers when used as separate items.
TG	Positioning Devices	Tilt and/or Train Assemblies.
TH	Telegraph Apparatus	Miscellaneous telegraph apparatus.
TK	Tool Kits or Equipments	Miscellaneous tool assemblies.
TL	Tools	All types except line construction. (See LC.)
TN	Tuning Units	Receiver, transmitter, antenna, etc.
TS	Test Equipment	Test and measuring equipment not otherwise included.
TT	Teletypewriter and Facsimile Apparatus.	Miscellaneous tape, teletype, facsimile equipment, etc.
TV	Tester, Tube	Vacuum tube tester.
U	Connectors, Audio and Power	Unions, plugs, sockets, adapters, etc.
UG	Connectors, R. F.	Unions, plugs, sockets, choke couplings, adapters, elbows, flanges, etc.
V	Vehicles	Carts, dollies, trucks, trailers, etc.
VS	Signaling Equipment, Visual	Flag sets, aerial panels, signal lamp equipment, etc.
WD	Cables, Two Conductor	Includes non-R. F. wire, cable and cordage in bulk.
WF	Cables, Four Conductor	Includes non-R. F. wire, cable and cordage in bulk.
WM	Cables, Multiple Conductor	Includes non-R. F. wire, cable and cordage in bulk.
WS	Cables, Single Conductor	Includes non-R. F. wire, cable and cordage in bulk.
WT	Cables, Three Conductor	Includes non-R. F. wire, cable and cordage in bulk.
ZM	Impedance Measuring Devices	Used for measuring Q, C, L, R or PF, etc.

TABLE OF SET OR EQUIPMENT INDICATOR LETTERS

INSTALLATION

- A—Airborne (installed and operated in aircraft)
- B—Underwater mobile, submarine
- C—Air transportable (Inactivated, do not use)
- D—Pilotless carrier
- F—Fixed
- G—Ground, general ground use (includes two or more ground installations)
- K—Amphibious
- M—Mobile (installed as operating unit in a vehicle which has no function other than transporting the equipment)
- P—Pack or portable (animal or man)
- S—Water surface craft
- T—Ground, transportable
- U—General utility (includes two or more general installation classes, airborne, shipboard and ground)
- V—Ground, vehicular (installed in vehicle designed for functions other than carrying electronic equipment, etc., such as tanks)

TYPE OF EQUIPMENT

- A—Invisible light, heat radiation
- B—Pigeon
- C—Carrier (wire)
- D—Radiac
- F—Photographic
- G—Telegraphic or teletype (wire)
- I—Interphone and public address
- K—Telemetering
- L—Countermeasures (inactivated do not use)
- M—Meteorological
- N—Sound in air
- P—Radar
- Q—Sonar and underwater sound
- R—Radio
- S—Special types, magnetic, etc. or combinations of types
- T—Telephone (wire)
- V—Visual and visible light
- X—Facsimile or television

PURPOSE

- A—Auxiliary assemblies (not complete operating sets)
- B—Bombing
- C—Communications (receiving and transmitting)
- D—Direction finder
- G—Gun or searchlight directing
- H—Recording (photographic, meteorological and sound)
- L—Searchlight control (inactivated use "G")
- M—Maintenance and test assemblies (including tools)
- N—Navigational aids (including altimeters, beacons, compasses, racons, depth sounding, approach and landing).
- P—Reproducing (photographic and sound)
- Q—Special or combination of types
- R—Receiving
- S—Detecting and/or range and bearing
- T—Transmitting
- W—Remote control
- X—Identification and recognition

EXAMPLES OF "AN" TYPE NUMBERS

TYPE NUMBER	INDICATES
AN/SRC-3( )	General reference set nomenclature for water surface craft radio communication set No. 3.
AN/SRC-3	Original procurement set nomenclature applied against AN/SRC-3( ).
AN/SRC-3A	Modification set nomenclature applied against AN/SRC-3.
AN/APQ-13-T1( )	General reference training set nomenclature for the AN/APQ-13 set.
AN/APQ-13-T1	Original procurement training set nomenclature applied against AN/APQ-13-T1( ).
AN/APQ-13-T1A	Modification training set nomenclature applied against AN/APQ-13-T1( ).
AN/UPT-T3( )	General reference training set nomenclature for general utility radar transmitting training set No. 3.
AN/UPT-T3	Original procurement training set nomenclature applied against AN/UPT-T3( ).
AN/UPT-T3A	Modification training set nomenclature applied against AN/UPT-T3.
T-51( )/ARQ-8	General reference component nomenclature for transmitter No. 51, part of or used with airborne radar special set No. 8.
T-51/ARQ-8	Original procurement component nomenclature applied against T-51( )/ARQ-8.
T-51A/ARQ-8	Modification component nomenclature applied against T-51/ARQ-8.
RD-31( )/U	General reference component nomenclature for recorder-reproducer No. 31 for general utility use, not part of a specific set.
RD-31/U	Original procurement component nomenclature applied against RD-31( )/U.
RD-31A/U	Modification component nomenclature applied against RD-31/U.

NOTES

1. This chart was formerly titled SUMMARY OF JOINT ARMY-NAVY NOMENCLATURE SYSTEM ("AN" SYSTEM) FOR COMMUNICATION AND ASSOCIATED EQUIPMENT.

2. The system indicator "AN" does not mean that the Army, Navy and Air Force use the equipment but simply that the type number was assigned in the "AN" system.

3. In the "AN" nomenclature system, nomenclature consists of a name followed by a type number. The type number will consist of indicator letters shown on this chart and an assigned number.

4. The type number of an independent component not part of or used with a specific set will consist of a component indicator, a number, the slant and such of the set or equipment indicator letters as apply. Example: SB-5/PT would be the type number of a portable telephone switchboard for independent use.

5. All requests for nomenclature assignments will be submitted on an approved form and in accordance with the joint Army-Navy Manual of Standard Descriptions (JANP109) or superseding Munitions Board Cataloging Agency publications.

MODIFICATION LETTERS

Component modification suffix letters will be assigned for each modification of a component when detail parts and subassemblies used therein are no longer interchangeable, but the component itself is interchangeable physically, electrically, and mechanically.

Set modification letters will be assigned for each modification not affecting interchangeability of the sets or equipment as a whole, except that in some special cases they will be assigned to indicate functional interchangeability and not necessarily complete electrical and mechanical interchangeability. Modification letters will only be assigned if the frequency coverage of the unmodified equipment is maintained.

The suffix letters, X, Y, and Z will be used only to designate a set or equipment modified by changing the input voltage phase or frequency. X will indicate the first change, Y the second, Z the third, XX the fourth, etc., and these letters will be in addition to other modification letters applicable.

ADDITIONAL INDICATORS

Experimental Sets. In order to identify a set or equipment of an experimental nature with the development organization concerned, the following indicators will be used within the parentheses:

- **XA**—Air Material Command, Hq., Dayton, Ohio.
- **XB**—Naval Research Lab. Wash. D. C.
- **XC**—Coles Signal Laboratory, Fort Monmouth, N. J.
- **XE**—Evans Signal Laboratory, Fort Monmouth, N. J.
- **XG**—U. S. N. Electronic Lab. San Diego, Calif.
- **XM**—Squier Signal Laboratory, Fort Monmouth, N. J.
- **XN**—Navy
- **XU**—U. S. N. Underwater Sound Lab. Fort Trumbull, New London, Conn.
- **XW**—Watson Laboratories, AMC, Redbank, N. J.

Example: Radio Set AN/ARC-3( ) might be assigned for a new airborne radio communication set under development. The cognizant development organization might then assign AN/ARC-3(XA-1), AN/ARC-3(XA-2), etc., type numbers to the various sets developed for test. When the set was considered satisfactory for use, the experimental indicator would be dropped and procurement nomenclature AN/ARC-3 would be assigned thereto.

Training Sets. A set or equipment designed for training purposes will be assigned type numbers as follows:

1. A set to train for a specific basic set will be assigned the basic set type number followed by a dash, the letter T, and a number. Example: Radio Training Set AN/ARC-6A-T1 would be the first training set for Radio Set AN/ARC-6A.
2. A set to train for general types of sets will be assigned the usual set indicator letters followed by a dash, the letter T, and a number. Example: Radio Training Set AN/ARC-T1 would be the first training set for general airborne radio communication sets.

Parentheses Indicator. A nomenclature assignment with parentheses, ( ) following the basic type number is made to identify an article generally, when a need exists for a more general identification than that provided by nomenclature assigned to specific designs of the article. Example: AN/GRC-5( ), AM-6( )/GRC-5, SB-9( )/GG. A specific design is identified by the plain basic type number, the basic type number with a suffix letter, or the basic type number with an experimental symbol in parentheses. Examples: AN/GRC-5, AN/GRC-5A, AN/GRC-5(XC-1), AM-6B/GRC-5, SB-9(XE-3)/GG.

NOMENCLATURE POLICY

1. AN Nomenclature will be assigned to:
   A. Complete sets of equipment and motor components of military design.
   B. Groups of articles of either commercial or military design which are grouped for a military purpose.
   C. Major articles of military design which are not part of or used with a set.
   D. Commercial articles when nomenclature will facilitate military identification and/or procedures.
2. AN Nomenclature will not be assigned to:
   A. Articles cataloged commercially except in accordance with Paragraph 1.D.
   B. Major components of military design for which other adequate means of identification are available.
   C. Small parts such as capacitors and resistors.
   D. Articles having other adequate identification in joint military specifications.
3. Nomenclature assignments will remain unchanged regardless of later changes in installation and/or application.

IMPORTANT.—All personnel are cautioned against originating or changing any part of any nomenclature assignment, including modification letters, without authorization.

RADAR EQUIPMENT

MARK 44 MOD 0

The Bureau of Ordnance, in its continuing research for improved fire control radar systems, has only recently completed a project which was established to consider the use of higher frequencies in fire control radar equipments.

The first task under this project was to study all available existing information on microwave propagation to permit selection of the optimum frequency, based on propagation and system considerations. General requirements had been established for the system which would permit a complete evaluation of the usefulness of the new frequency to the services. Equipment had been developed previously at a frequency of 24,000 Mc (1.25 cm). Tests of this equipment indicated that it was at the peak of the curve of attenuation due to water vapor and oxygen absorption and that backscattering, the masking of the target, caused serious difficulties in detecting and tracking targets. Although little experimental data was available for other frequencies in this region, theoretical studies indicated that a frequency slightly lower than 24,000 Mc was better in this respect and that the general requirements established could be satisfied with this frequency.

An experimental model of Radar Equipment Mark 44 Mod 0, completed by the Submarine Signal Company, Boston, Mass., early in 1949, is now undergoing operational evaluation. Early results of tests underway indicate that the frequency was well chosen. Development contracts awarded by other services for equipment in this band indicate general usage of the frequency in service in the near future.

In line with findings on frequency research, the radar was designed to operate on a fixed frequency less than 24,000 Mc. The equipment presents a system in which is combined the features of search and sector scan and automatic tracking for fire control, together with the provision of one-man control. The major operating units are shown in Figure 1. A stable element is used to provide roll stabilization for the antenna, shown in Figure 2. Two indicators are provided on the Control Indicator Unit. For search, a PPI presentation is utilized; and for fire control, either a precision "B" or double "L" presentation is provided for use in sector scanning or automatic tracking, respectively. These presentations are illustrated in Figures 3, 4, and 5.

The PPI is of conventional design with a few features added to facilitate more efficient operation of the system. Four ranges of 4,000, 8,000, 30,000, and 60,000 yards are provided with calibration marks of 1,000, 2,000, 5,000, and 10,000 yards, respectively. In addition, the PPI has a movable range mark which corresponds to the center of the mapped area on the B-scope. The range mark moves along the sweep line and is controlled by the manual range slewing control. The PPI is used for initial target detection and provides target acquisition for the fire control precision "B" presentation. This displays $\pm 1{,}000$ yards vertically about the indicated range mark and $\pm 6°$ horizontally about the antenna line of sight. The range and bearing manual slewing and tracking controls are operated to keep the target centered on the "B" scope.

In the case of low-flying planes or surface targets which subtend very small angles, a foot pedal can be used to switch into automatic tracking. The indication provided is a double "L" presentation in place of the "B" presentation. Trace separation gates permit an alternating display of the range marks (0 and ± 1000 yards of the precision range sweep) and target display. Meters on the auxiliary indicator unit provide an indication of the actual tracking errors. The automatic tracking system tracks the desired target in range and azimuth and presents continuous data to the computer.

New features, notably "Look Around," "Organ Pipe" scanning, and new r-f components for this frequency are incorporated in the radar equipment. The "Look Around" button may be pushed at any time during quick 360° search in about two seconds with the antenna returning to its initial position. Since the target would probably be lost in returning to automatic tracking, the foot pedal is pressed to permit returning to sector scanning for target acquisition. A 37-section "Organ Pipe" waveguide maze utilizing a rotating dual horn was developed for sector scanning. It provides a linear sector scan of $\pm 6°$. All side lobes of the antenna beam are down 23 db or more. The sector scan can be

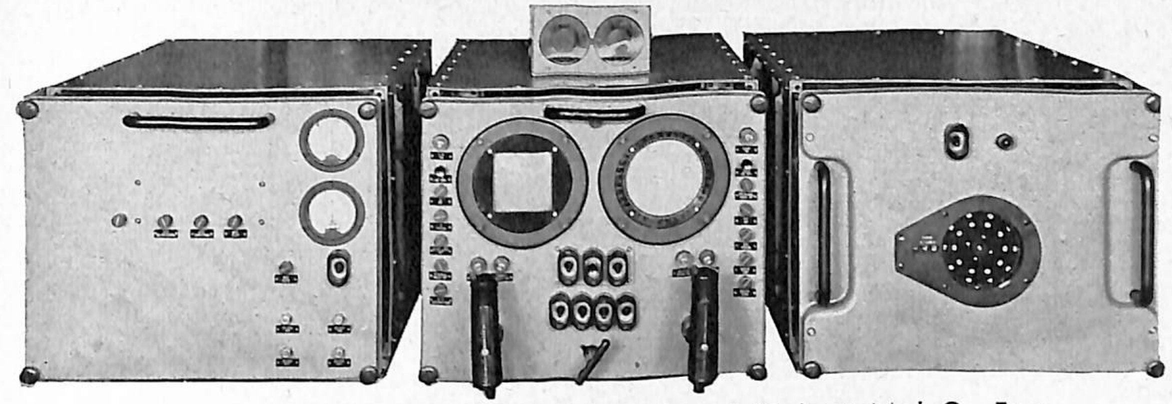


FIGURE 1—Operating units of Radar Equipment Mark 44 Mod O. From left to right—Auxiliary Indicator Unit, Control Indicator Unit, and Range Unit.

increased to a maximum range of $\pm 8°$ but the side lobes become objectionable. The r-f plumbing, including a balanced mixer and duplexer, was newly developed for this frequency.

Standard features incorporated in the equipment include slow and fast automatic-gain-control (AGC) circuits for controlling the i-f amplifier gain, an automatic-frequency-control (AFC) circuit to sample the transmitted signal and operate to center the i-f frequency on the receiver bandpass, a fast time constant (FTC) to increase the discernibility of a single radar echo in the midst of ground clutter or sea return, hybrid waveguide junctions to improve the signal-to-noise ratio, and a sensitivity time control (STC) for minimizing sea return and equalizing echoes from near and distant objects. An additional aid in minimizing sea return is the absence of any noticeable underlobes for the vertical beam pattern of the antenna.

The radar operating controls are arranged on the front panels of the units in a manner expected to provide greatest utility and most efficient operation by a single operator. As may be seen in the accompanying illustrations, indicators and controls normally associated with each other are located in such a position as to require a minimum of effort on the part of the operator to acquire and track targets. Six units of approximately the same over-all dimensions and the antenna with its associated waveguides, stable element and a Ward-Leonard motor-generator set comprise Radar Equipment Mark 44. These six units, including the three units required for operational control (Figure 1) are separately identified as the Auxiliary Indicator, Control Indicator, Range Unit, Modulator-Transmitter-Receiver Unit, Low Voltage Power Supply Unit, and Servo Unit. Over-all power requirement for the system is 3 kw.

The receiver has an over-all gain of 120 db, including a 3-db noise level. The i-f amplifier, centered at 30 Mc, has an over-all gain of 110 db and a bandwidth of 10 Mc at the half power points. The video bandwidth was also extended to 10 Mc to improve the fidelity of pulse reproduction. Additional general characteristics of the Mark 44 Mod 0 are as follows:

GENERAL OPERATION

Pulse repetition rate (variable)	1,000 $\pm$10% (0–60,000 yds) 3,600 $\pm$10% (0–30,000 yds)
Pulse width	0.8 μsecs. (1,000 pps) 0.2 μsecs. (3,600 pps)
Peak power output	50 kw.
Maximum measurable range	60,000 yards (search) 30,000 yards (fire control)
Minimum detectable range	190 yards.
Range slewing rate	2,000 yards per second.
Bearing slewing rate	180° per second.

FIGURE 2—Antenna for Radar Equipment Mark 44 Mod O.

SEARCH OPERATION

Plan position indicator	(1) 4,000 yards with 1,000-yard range marks. (2) 8,000 yards with 2,000-yard range marks. (3) 30,000 yards with 5,000-yard range marks. (4) 60,000 yards with 10,-000-yard range marks.
Beam width—horizontal	1.5°
vertical	9°
Range accuracy	±0.5% of range or 100 yds, whichever is greater
Bearing accuracy	±0.75°
Range resolution	1% of range sweep in use.
Bearing resolution	1.5°
Rotation rate	0 to 30 rpm.

FIRE CONTROL OPERATION

	Manual Tracking	Automatic Tracking
Presentation	Precision B	Precision L
Range	Any 2,000-yd interval from 0 to 30,000 yds.	Any 2,000-yd interval from 0 to 30,000 yds.
Bearing	12°	....
Range tracking rate	2,000 yds per second.	250 yds per second.
Bearing tracking rate	180° per second.	50° per second.
Beam width—horizontal	1.5°	1.15°
vertical	9°	9°
Beam Separation	....	0.6°
Range accuracy	±(15 yds 0.1%R) yds	±(15 yds 0.1%R) yds
Bearing accuracy	4½ minutes	4½ minutes
Range resolution	40 yds	40 yds
Bearing resolution	1.9°	1.9°
Width of range gates	100 yds	100 yds
Scan	Linear sector scan at 30 scans per second.	Sequential lobing at 300 lobes per second.

Radar Equipment Mark 44 is an experimental model, as stated previously, and is currently under test on a small boat operating in the Boston area. A proposal has been approved to install an X-band Pathfinder (a commercial equipment) on the same boat so that direct comparison can be made between the two bands of operation under various atmospheric conditions. After extensive tests have been completed, final reports will be submitted and decisions made regarding future work in the new frequency band by the Bureau of Ordnance—*Bulletin of Ordnance Information No. 2–49.*

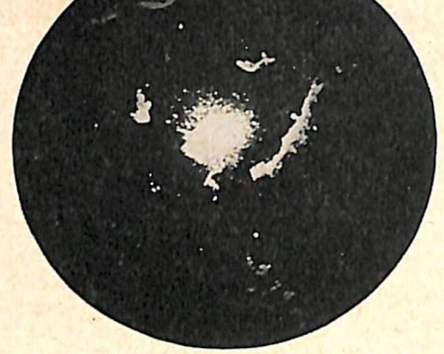


FIGURE 3—Typical PPI presentation of Mark 44 Mod O Radar showing outer Boston Harbor. Sea return to 1000 yards, wave height peak-to-trough approximately 3.5 feet, 4,000-yd. sweep.

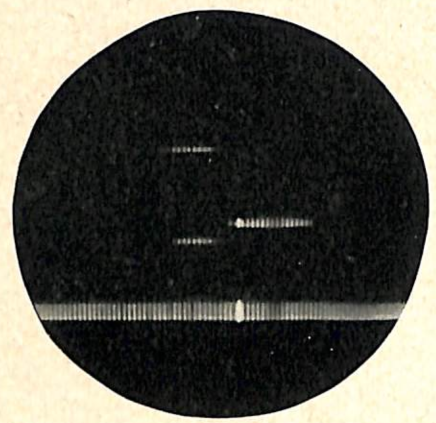


FIGURE 4—B-Scope presentation on Mark 44 Mod O Radar showing "main bang" and 65-foot launch (center target) towing special float target. Farthest target is "can" buoy.

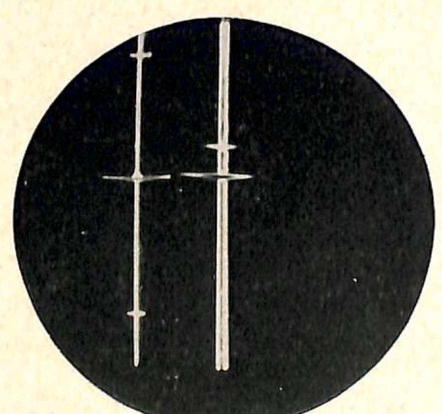
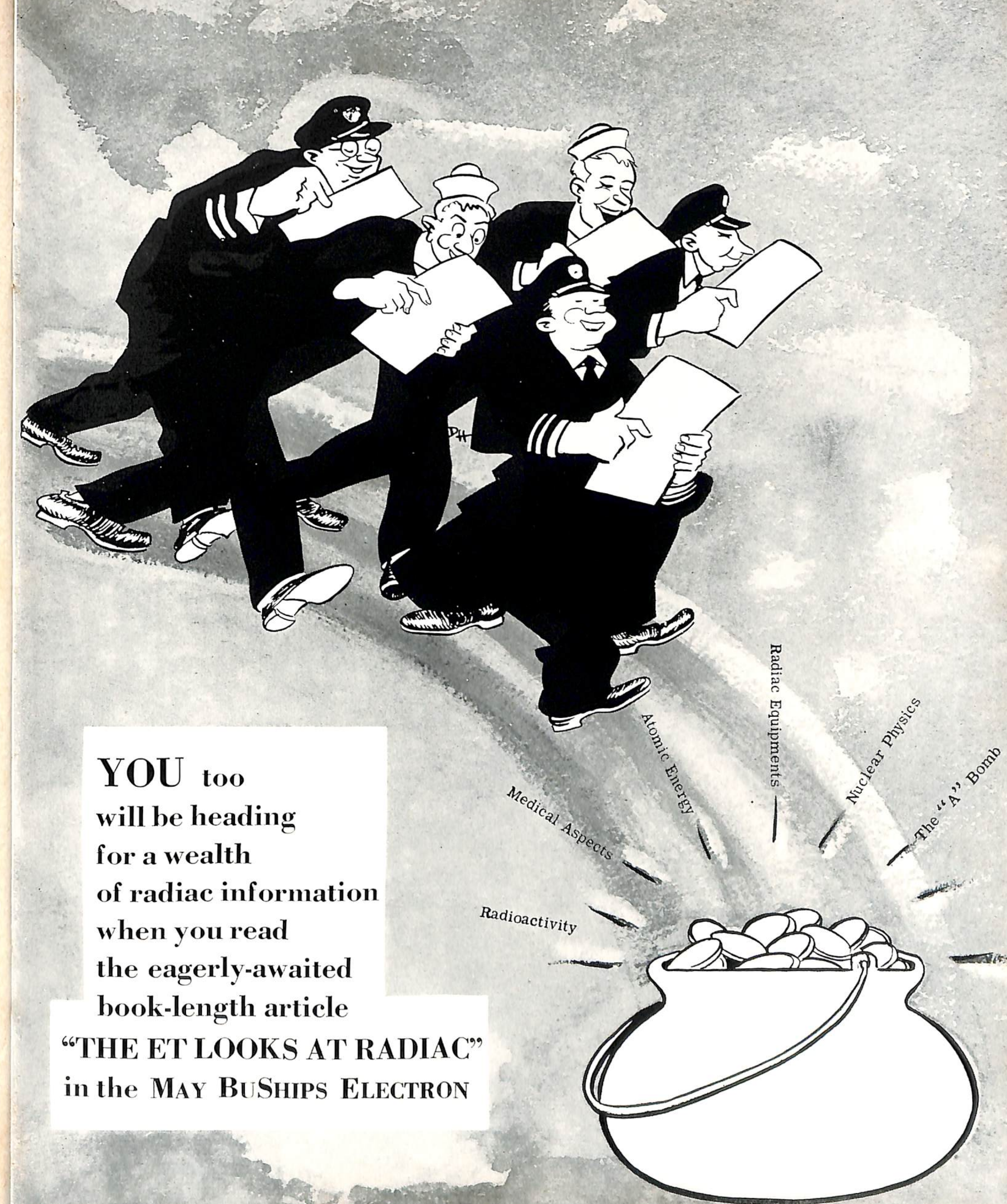


FIGURE 5—L-type presentation on Mark 44 Mod O Radar. Auto-tracking showing small boat gated at 3200 yards; buoy 200 yards beyond.



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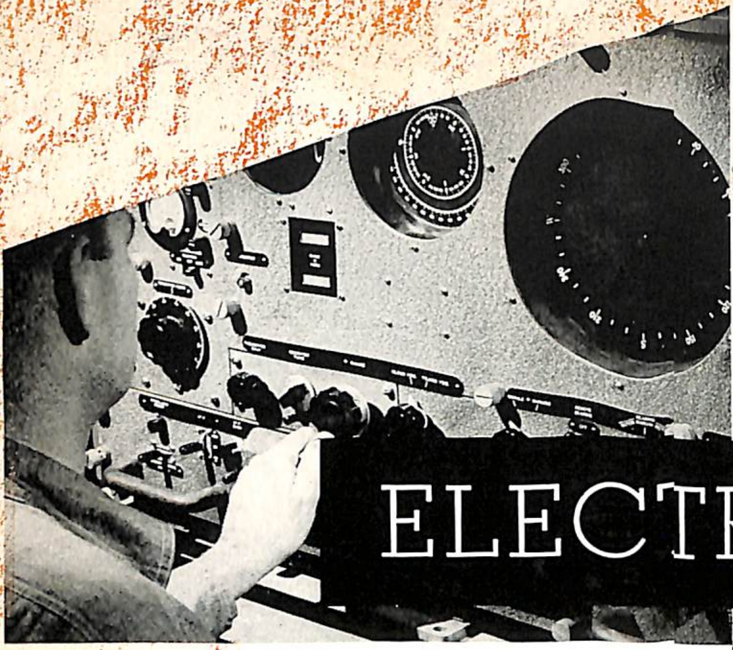

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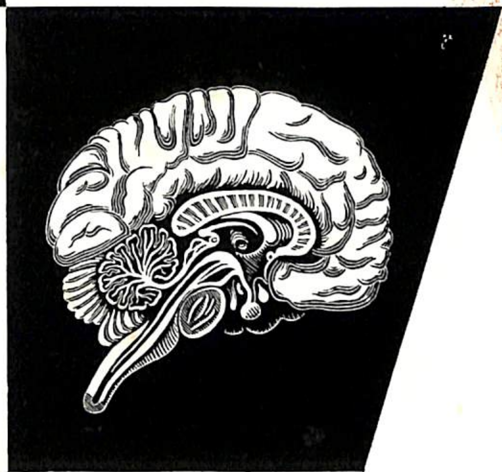

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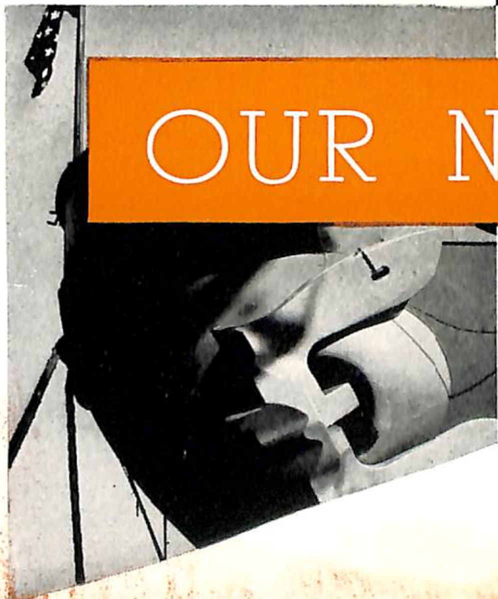

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