CHAPTER 5

ELECTRONIC INSTALLATIONS

The purpose of this chapter is to give the prospective ET 3 an over all view of the equipments that he may be called upon to service as he becomes more familiar with electronic equipment.

Electronic equipment is rapidly being improved, and therefore much of the equipment discussed in the following paragraphs will eventually become obsolete. However, equipments are not replaced suddenly just as soon as new equipments are designed. Before large numbers of new equipment are installed, extensive tests and evaluations must be made; this takes time. Therefore, although a piece of equipment may be on the way out, it may still be used on certain ships for a considerable length of time.

Methods of installing electronic equipment (and the reasons why certain equipments are installed as they are) are important to the ET and are also included.

COMMUNICATION EQUIPMENT

Naval communications may be grouped into three categories as follows:

1. Electrical communications—which includes radiotelegraph (CW), radiotelephone (voice radio), teletypewriter, and facsimile.
2. Visual communications—which includes flaghoists, visible and invisible flashing light, and semaphore.
3. Sound communications—which includes amplified voice, whistles, sirens, bells, and sonar.

As an ET you will be concerned with the equipment used for electrical communications.

RADIO EQUIPMENT

Radio equipment may be classified in a general way as transmitters and receivers, the principles of which are discussed in Basic Electronics, NavPers 10087-A. Both transmitters and receivers are classified according to the frequency range that they cover, or the power output in the case of the transmitter.

There are no standard transmitters used aboard ship in the VLF band. The shore transmitters for this band are of special design and have power outputs ranging from 300kw to one million watts. Receivers that operate in the VLF band are installed aboard surface ships and submarines primarily to receive the radioteletype and CW fleet broadcasts from the VLF shore station transmitters. Communication in the VLF band is advantageous for surface ships and submarines operating in the arctic regions due to its reliability during electrical storms. It is particularly useful for submarine communications as the signals may be received while submerged. There are many shipboard transmitters and receivers used in the LF through the UHF bands.

Radio wave emissions (transmissions) have been classified by international agreement according to the type of modulation used (table 5-1).

Review of Modulation

Modulation is the process of varying either the amplitude or frequency of the r-f output of a transmitter at an audio rate. With amplitude modulation the strength (amplitude) of the r-f energy is made to vary in accordance with the audio signal amplitude variations. Modulating an r-f carrier with a single audio frequency of sine wave form produces three waves. These include the r-f (carrier), the sum of the carrier and the audio frequency (upper sideband) and the difference in the carrier and the audio frequency (lower sideband). When the amplitude of the r-f carrier is carried to zero during one half the modulating cycle and twice the unmodulated value during the other half cycle the modulation is said to be 100 percent. For this condition the sidebands contain the maximum permissible amount of power (one-half the carrier power). Modulation in excess of 100 percent causes distortion and loss of sideband power.

Single Sideband

Single sideband (SSB) communication systems have become increasingly important in Navy applications.

Table 5-1.—Classification of Radio Emissions.

Symbol	Type of transmission
	Amplitude modulated
A0	Continuous wave, no modulation.
A1	Continuous-wave telegraphy. On-off keying.
A2	Telegraphy by keying of a modulated emission.
A3	Telephony. Double sideband, full carrier.
A3a	Telephony. Single sideband, reduced carrier.
A3b	Telephony. Two independent sidebands with reduced carrier.
A4	Facsimile.
A5	Television.
A9	Composite transmissions and cases not covered by above classifications of emissions.
A9a	Composite transmissions, reduced carrier.
	Frequency (or phase) modulated
F0	Absence of modulation.
F1	Telegraphy by frequency shift keying, with no modulation.
F2	Telegraphy by keying of a modulating audio frequency. Also by keying of modulated emission.
F3	Telephony.
F4	Facsimile.
F5	Television.
F9	Composite transmissions and cases not covered by above classification of emissions.
	Pulse modulated
P0	Absence of modulation intended to carry information (such as radar).
P1	Telegraphy. No modulation of audio frequency.
P2d	Telegraphy by keying an audio frequency which modulates the pulse in its amplitude.
P2e	Telegraphy by keying an audio frequency which modulates the pulse in its width.
P2f	Telegraphy by keying an audio frequency which modulates the pulse in its phase (or position).
P3d	Telephony. Amplitude modulated.
P3e	Telephony. Width modulated.
P3f	Telephony. Phase (or position) modulated.
P9	Composite transmissions and cases not covered by above classification of emissions.

In order to understand what is meant by SSB transmission, you should review the pages of Basic Electronics, NavPers 10087 (revised) which discuss conventional amplitude modulation.

A receiver tuned to a conventional AM signal having upper and lower sidebands will detect the intelligence in the sidebands by heterodyning the carrier with the upper and lower sidebands to yield the audio modulating signal. The only function of the carrier is to provide this heterodyning process at the second detector. If the carrier were absent the signal could be recovered at the second detector by reinjecting the carrier derived from a local oscillator at the receiver provided its phase were the same as that of the carrier at the transmitter. By using this method the power in the transmitted carrier can be saved since it is not radiated from the transmitting antenna.

SUPPRESSED CARRIER.—The r-f carrier may be eliminated by using a balanced modulator in one of the early r-f stages of the transmitter so that the sidebands are produced, but no pilot carrier will be present. A simplified circuit of a balanced modulator is shown in figure 5-1A.

The carrier is applied with the same magnitude and instantaneous polarity to both grids of the push-pull circuit, and is therefore canceled in the output. The modulating signal, however, produces opposite instantaneous polarities at the grids of tubes A and B; the sideband components are likewise of opposite phase and appear in the output. If only one sideband is to be transmitted, a suitable filter may be used to pass the desired sideband and suppress the other. That is, when speech is fed into the transmitter the carrier itself does not appear in the output. What appears at the output is sideband energy or "talk power."

TRANSMITTING SSB.—If one of the two sidebands is "filtered" or "phased out" before it reaches the transmitter power amplifier, the intelligence can be transmitted on the remaining sideband. All of the power is then transmitted in one sideband, rather than being divided between the carrier and the two sidebands as in conventional AM. For example, in AM (for 100 percent modulation), when the output power is 150 watts, 100 watts is contained in the carrier and 25 watts in each of the sidebands, or a total of 50 watts in both sidebands. In SSB, all of the power is put into one sideband.

Thus, theoretically, a radiated power of 50 watts at the transmitter employing SSB is equivalent to a radiated power of 150 watts at the transmitter when conventional AM is used. Equally important, the bandwidth required for a SSB voice circuit is approximately half that needed for conventional AM (see fig. 5-1B).

Receiving SSB.—The SSB receiver must have rigid frequency stability, much more so than when conventional AM is used. The SSB receiving station has the problem of furnishing an artificial carrier, because the SSB signal does not have a carrier against which the sideband

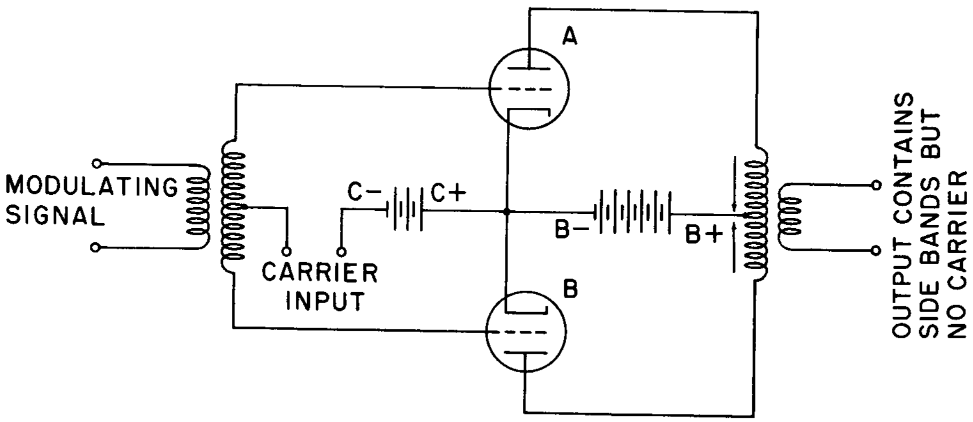

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Figure 5-1A.—Balanced modulator.

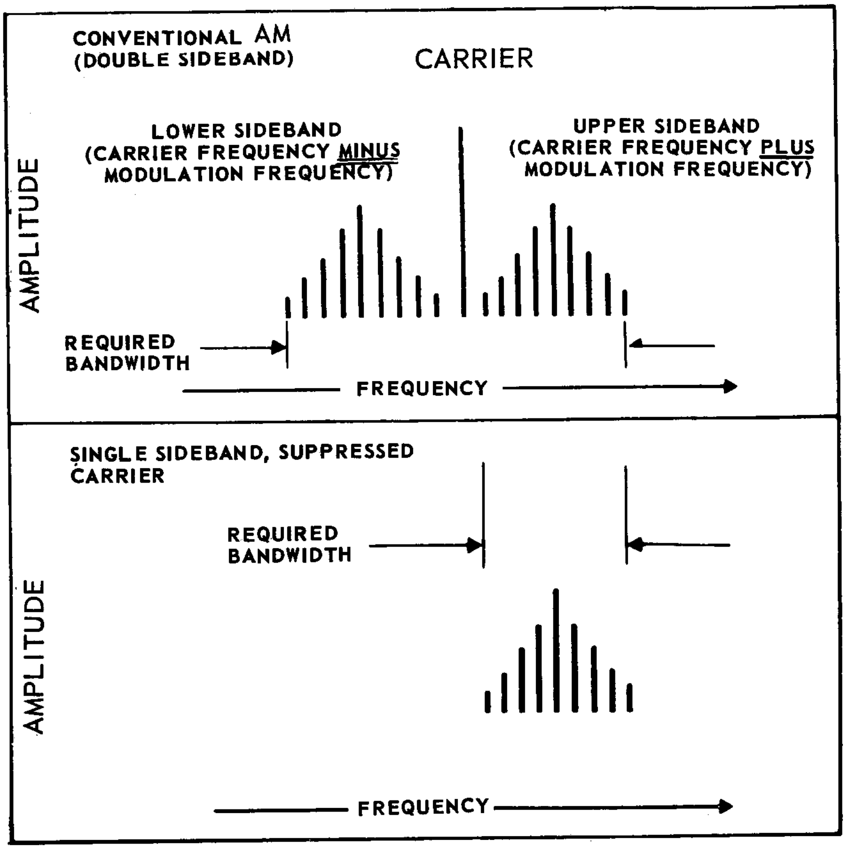

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Figure 5-1B.—Comparison of DSB and SSB bandwidths.

signals can be heterodyned in the receiver (during the demodulation process) to produce useful audio signals.

Normally, the artificial carrier is furnished by a beat-frequency oscillator in the receiver. This method of carrier reinsertion is not to be confused with those commercial SSB transmitters that transmit a residual (not totally suppressed) carrier signal, so that automatic frequency-control equipment may be used. Such is the type used in the Navy's fixed shore installations.

It is necessary that the SSB transmitter have the same high order of stability as the receiver. The transmitter and receiver must not drift apart more than a very few cycles for quality voice reception.

ADVANTAGES OF SSB.—In conventional AM, if the sidebands are not received in the proper phase (due largely to multipath skywave propagation conditions), the signal is fuzzy, distorted, and sometimes quite loud. However, with the suppressed-carrier type of SSB, this problem is greatly reduced.

There is, as has been stated, an increase in effective power because all of the power goes into the single sideband, which carries the useful voice intelligence. The power gain in the SSB system is from 6 to 9 db over the equivalent conventional AM system. The SSB transmitter provides about 6 db of gain, and about 3 db of gain results from the narrow-band, single-sideband receiver.

Essentially the number of available channels is doubled when SSB is used. Doubling the number of channels in the 2 to 30 mc range is especially important in fleet communications.

In some voice conventional AM communications systems the carrier remains on the air during periods when modulation is absent. If one station transmits while another (having nearly the same carrier frequency) is on, the result is interference (squeals).

In SSB, with voice break-in, as soon as the individual stops speaking into the microphone, "talk power" in the sideband leaves the air so that interference is reduced. A ship may enter the network as soon as the "talk power" leaves the air. Even when two stations transmit at the same time, a receiving station can read through the interfering station the same way you are able to choose one conversation from several going on around a conference table.

A brief discussion of radio equipment in use aboard Navy ships follows.

Transmitters

The TBL (7 to 13) operates in the 175-kc to 600-kc (LF-MF) range and also in the 2-mc to 18.1-mc (MF-HF) range; it is capable of A1, or A3 emission at 200, 100, and 50 watts, respectively. The standard installation includes speech input equipment and one or more remote radiophone units.

The TBK (7 to 20) operates in the 2-mc to 18.1-mc (MF-HF) range. The output is 500 watts on A1 only.

The AN/SRT (14, 15, 16 series) operates in the 0.3-mc to 26-mc (MF-HF) range on A1, A3, F1, and F4 emissions at 100 or 500 watts, and is described in chapter 9 of this training course.

The AN/URC 32 is a manually operated radio communications transceiver for operation in the 2 to 30 mc (high frequency) range with a transmitting peak envelope power (pep) of 500 watts except on A9a emission. Emission types include A1, A3a&b, A9, A9a and F1 (table 5-1). Additional information on this radio set is given in chapter 9 of this training course.

The TED series operates in the 225-mc to 400-mc (VHF-UHF) range on A2 or A3 emissions.

Additional transmitters presently in use are listed in table 5-2.

Receivers

The AN/SRR (11, 12, and 13) operates in the 14 kc to 32 mc (VLF-LF-MF-HF-VHF) range. The sets are designed for general application

Table 5-2—Radio Transmitters.

Model	Frequency Range	Emission	Power Output	Intended Use
AN/WRT-1	300-1500 kc	A1, F1, A3	500 w	MF Shipboard communications
AN/WRT-2	2-30 mc	A1, A3, A3a A3b, F1	500-1000 (PEP) w	HF Shipboard communications
AN/URT-17	2-32 mc	A1, A2, A3 A3a&b, F1, F4	750-1000 w	HF Ship and Shore Communications
AN/URC-7 Transmitter-Receiver	2-7 mc	A3	25 w	MF Ship and Shore Communications
AN/URT-7	115-156 mc	A2, A3	30 w	VHF Ship and Shore Communications
AN/GRC-27 Transmitter-Receiver	225-400 mc	A2, A3	100 w	UHF Ship and Shore Communications

in all types of ships. Circuits are provided for the reception of four classes of emission—A1, A2, A3, and F1 in the appropriate bands. These receivers are described in chapter 9 as examples of common operating adjustments of electronic equipments.

The AN/URR (13 and 35) operates between 225 mc and 400 mc (portions of the VHF/UHF bands). The sets are designed to receive A2 and A3 transmissions on ships or at naval air and shore radio stations.

The AN/URR-27 performs essentially the same functions, except that it covers only a portion (150 mc to 190 mc) of the VHF band.

The RBA, RBB, and RBC receivers, although being replaced by the AN/SRR-11, 12, and 13, are still in use aboard some ships. The RBO, the standard shipboard entertainment receiver, is being replaced by the AN/URR-22. The AN/URR-22 can also be used as an emergency communication receiver for CW and MCW signals. It covers the frequency range of 540 kc to 18.6 mc in four frequency bands.

Receiver R-390/URR is a modern receiver for both shipboard and shore station use covering frequencies from 0.5 mc through 32 mc. It can receive A1, A2, A3, and F1 emissions, used in conjunction with converter CV-5911/URR, A3a and A3b (SSB) signals may be received.

The AN/WRR-2 is a modern receiver for shipboard and shore station use. Frequencies from 2 to 32 mc are covered for A1, A2, A3, A9, F1, and F4 emissions.

RADIO TELETYPE TERMINAL EQUIPMENT

A brief description of radio teletype systems is necessary before a description of the individual components can have any real meaning. More of the details are given in chapter 10 of this training course.

The Navy uses two radio teletype systems afloat. One, the TONE-MODULATED system for short-range operations, is similar to the familiar AM radio. The other, the CARRIER FREQUENCY-SHIFT system for long-range operations, is similar to standard FM radio.

Tone-Modulated System

The tone-modulated system is illustrated in figure 5-1C. The teleprinter (TTY) sends out a signal consisting of direct-current, on-and-off pulses. An "on" or "current" interval is called a MARK or MARKING impulse. An "off" or "no-current" interval is called a SPACE or SPACING impulse.

The marks and spaces, designated as M and S in figure 5-2, are generated in various code groups of five units each. The group shown in figure 5-2 is for the letter "H."

A knowledge of the specific groupings is incidental to a basic understanding of the operation of the radio teletype system. The important thing to know is that the succession of direct-current "marks" and "spaces" in fixed-timed intervals conveys both intelligence and synchronization from one teleprinter to another.

To transmit messages by the tone-modulated system (fig 5-1C (1)), a teleprinter, a tone terminal, and a transmitter are needed. The teleprinter sends out a direct-current signal of marks and spaces, and the signal is changed to either of two audio tones in the tone terminal. The tones may be 500 cycles for a space and 700 cycles for a mark. The transmitter impresses the audio tones on the carrier and sends out an amplitude or tone-modulated carrier wave.

To receive messages with the tone-modulated system (fig 5-1C (2)), a radio receiver, a tone converter, and a teleprinter are needed. The tone-modulated carrier wave enters the receiver, which extracts the signal intelligence and sends the audio tones to the tone converter. The converter changes the audio tones into direct-current mark and space pulses for the teleprinter.

In practice, the same tone terminal is used for both the sending and the receiving circuits because it contains both a transmit "keyer" unit and a receiver "converter" unit.

Frequency-Shift System

The frequency-shift system is illustrated in figure 5-3. At the transmitting end of this system (fig. 5-3, A) are a teleprinter; a frequency-shift keyer unit, which is built into the newer transmitters; and a transmitter (XMIT). In some older systems, the keyer unit is a separate piece of equipment.

When the teleprinter is operated, the direct-current teleprinter mark and space signals are changed by the keyer unit into frequency-shift intervals. The frequency-shift intervals are transmitted as carrier frequency-shift (CFS) signals. The carrier shift is very small compared with the frequency of the carrier; it may be of the order of 850 cycles.

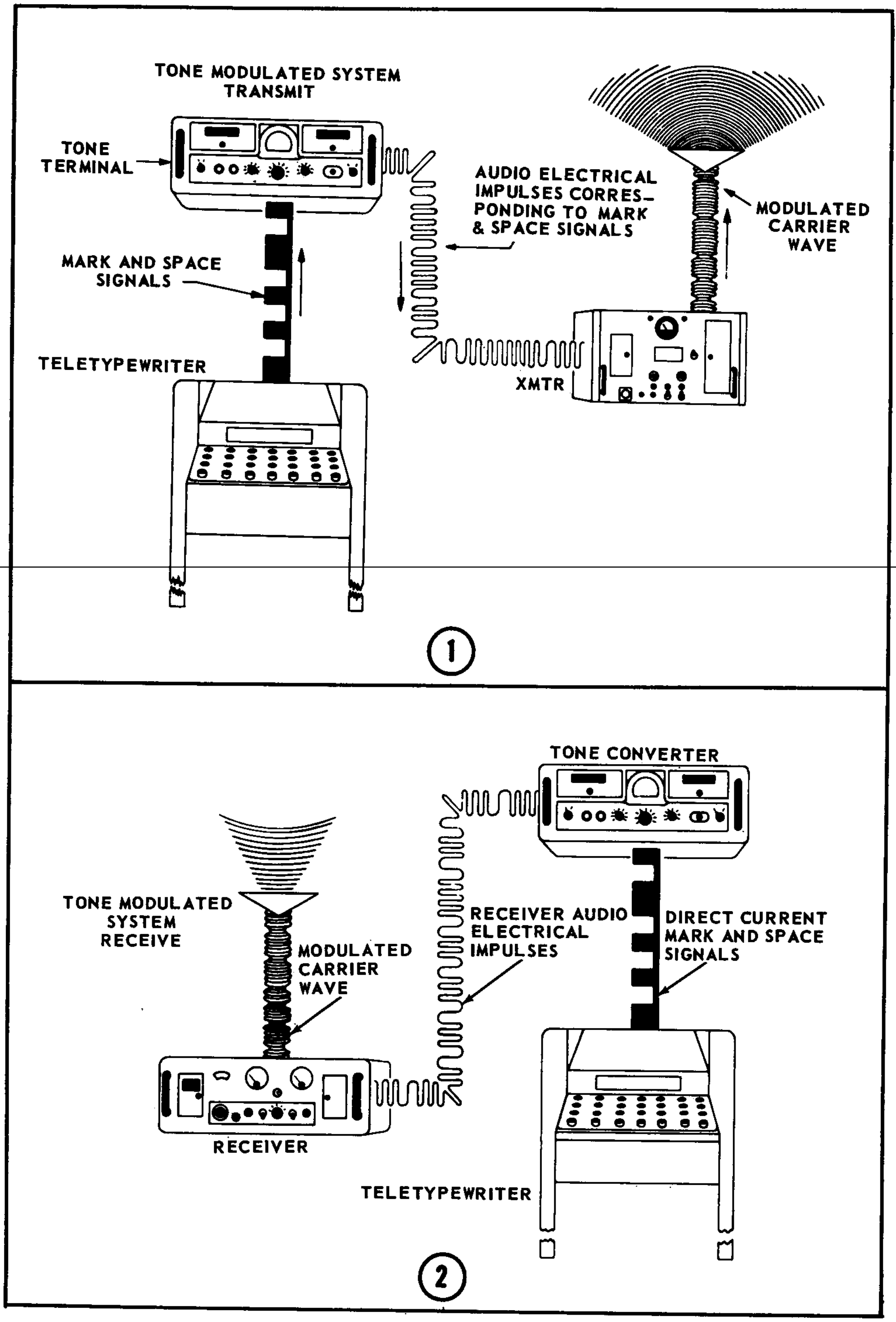

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Figure 5-1C.—Tone-modulated system.

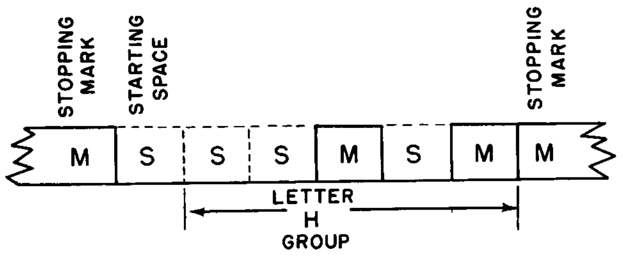

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Figure 5-2.—Teletype code group.

On the receiving side of this system (fig. 5-3, B) are a receiver, a frequency-shift converter, and a teleprinter. When the carrier frequency-shift signal enters the receiver, it is detected and changed into a corresponding frequency-shifted audio signal. The audio output of the receiver is fed to the converter, which changes the frequency-shifted audio signal into the direct-current mark and space teletype signals. The tone converter in the tone-modulated system is similar to the carrier frequency-shift converter in the frequency-shift system.

Basic Radio Teletype System

When the carrier frequency-shift system (long range) is combined with the tone-modulated system (short range), several more pieces of equipment are needed—a TELETYPE PANEL, a POWER SUPPLY, a SWITCHING CONTROL, a TRANSMITTER SWITCHBOARD, and a RECEIVER SWITCHBOARD, as illustrated in figure 5-4.

The teletype panel is capable of handling six channels, or "loops." The power supply furnishes the direct "looping" current for all teletype direct-current signals. Located at the teleprinter is the switching control, which is used to select the desired system. The transmitter and receiver switchboards are used to join the radio teletype systems with other communication systems on board ship.

As has been stated, the tone-modulated system and the carrier-frequency-shift system are combined to form one teletype system in shipboard communications. The tone-modulated system is used only for short-range, or "line-of-sight," communications in the UHF band. Manmade and atmospheric static and signal fading are not major problems in this band, and no special equipment to counteract these effects is needed.

The frequency-shift system, used in the LF to HF bands, is the best way to send the rapidly keyed signals of the teletypewriter over long distances. Fading and interference are sometimes major problems in these bands.

Because a single r-f carrier usually does not fade simultaneously in areas separated by more than one wavelength, and because fading of carriers of different frequencies usually does not occur simultaneously at the same point, the Navy has taken advantage of this situation by the use of two methods of DIVERSITY RECEPTION (fig. 5-5).

In SPACE DIVERSITY (fig. 5-5A) reception one signal is transmitted, and this signal is received by two receivers. Antennas for these receivers are separated by a distance greater than one wavelength. The outputs of the receivers are fed into two frequency-shift converters and then into a COMPARATOR, which selects the best signal for the teletypewriters.

In FREQUENCY DIVERSITY reception (fig. 5-5B), two or more identical signals are transmitted on different frequencies. Two receivers, tow converters, and a COMPARATOR are used, as in space diversity. The receiving antennas are not separated.

For the tone-modulation system (higher frequencies), the transmitter may be the TED and the receiver may be the AN/URR-35; for the carrier frequency-shift system (lower frequencies), the transmitter may be the AN/SRT-14, and the receiver may be the AN/SRR-11, 12, 13 system.

A basic teletype system employing diversity reception is illustrated in figure 5-6.

Frequency Division Multiplexing

To a great extent, the maximum permissible number of intelligible transmissions taking place in the radio spectrum per unit of time is being increased through the use of multiplexing. Multiplexing involves the transmission of several intelligible signals during the same period of time normally required for the transmission of a single signal. Either of two methods of multiplexing may be used. These are time-division and frequency-division multiplexing, respectively.

Frequency-division multiplexing is the older of the two methods of multiplexing. In this

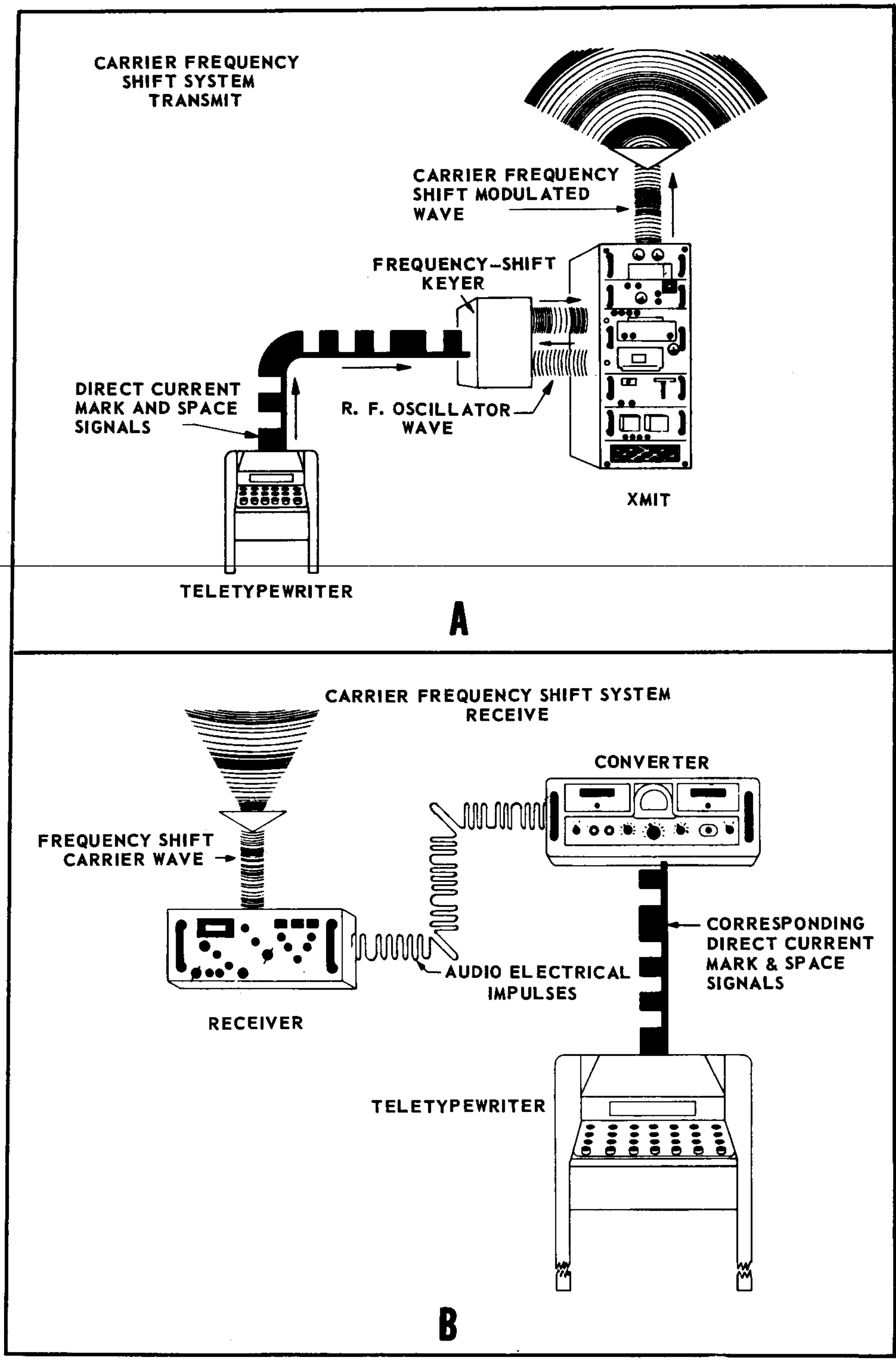

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Figure 5-3.—Frequency-shift system.

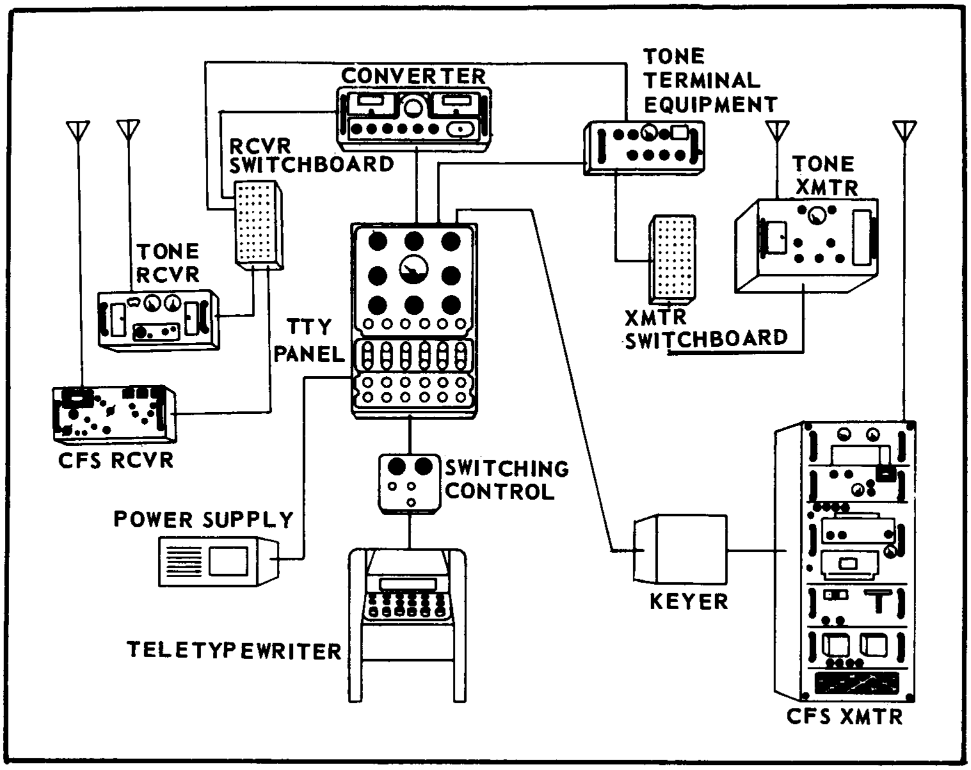

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Figure 5-4.—Basic radio teletype system.

system, different subcarrier frequencies are modulated by the signals of different channels, transmitted over the same cable (in the case of cable transmission) or on the same radio frequency carrier (in the case of radio transmission), then separated by filters before being demodulated. The total bandwidth, required for a frequency-division multiplexing system is the sum of the bandwidths of the individual channels, plus the sum of the necessary guard-band frequencies between channels.

Teletype Terminal Equipment
AN/UCC-1

The AN/UCC-1 is a modular terminal for frequency shift carrier telegraph communication employing a frequency division multiplex system over single-sideband radio circuits, voice-frequency wirelines, microwave circuits, or other transmission systems. The equipment provides a total of 16 narrow-band channels, or 8 narrow-band and 4 wide-band channels, within the nominal 300 cps to 3300 cps frequency band. For space diversity operation, 16 transmitter channels and 32 receiver channels are available. A multiplexer-demultiplexer provides translation of a composite signal between this band and the nominal 3300 to 6300 cps frequency band so that 32 narrow-band channels or 16 narrow-band and 9 wide-band channels are available for communication over a 6 kc single-sideband radio circuit. The terminal is all solid state design, with plug-in modules.

The AN/UCC-1 is compatible in operation and can replace the AN/FGC-29, AN/FGC-60 and AN/FGC-61. Reduced size and weight make it suitable for installation on most surface ships.

Time-Division Multiplexing

Time-division multiplexing is the transmission of the intelligence of several teletypewriter circuits on a time-sharing basis in a character-by-character sequence (fig. 5-7).

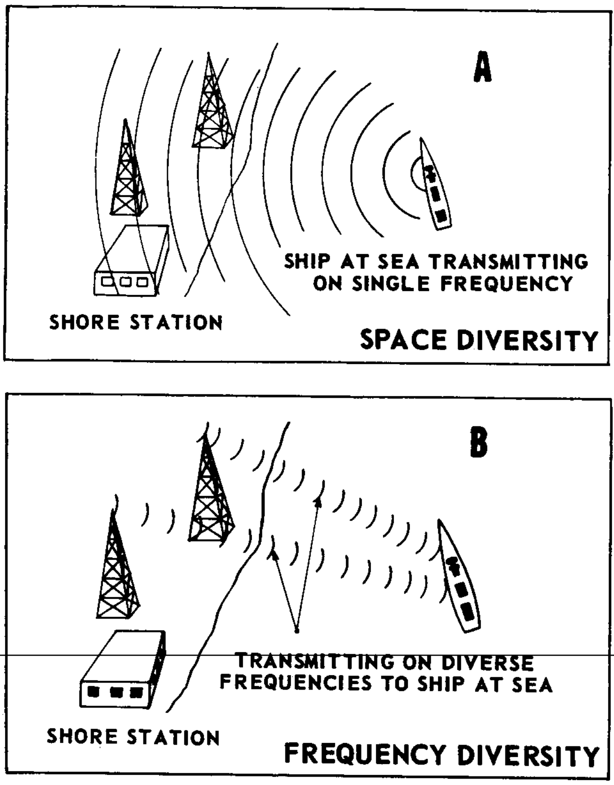

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Figure 5-5.—Diversity reception.

Information is fed into the multiplex equipment simultaneously from four teletypewriters. The same information is then transmitted from one multiplex equipment to the other in a time sequence with one character from each channel at a time. The receiving multiplex equipment then distributes the information to the proper teletypewriter circuits at telegraph speed.

Four characters are therefore transmitted over a single circuit during the time ordinarily required by one.

FACSIMILE EQUIPMENT

Facsimile equipment is used to transmit still images over an electrical communications system. The images, called pictures or copy in facsimile terminology, may be weather maps, photographs, sketches, typewritten or printed text, or handwriting. The still image serving as the facsimile copy or picture cannot be transmitted instantly in its entirety. Three distinct operations are performed. These are (1) scanning, (2) transmitting, and (3) recording.

Principle Of Operation

The SCANNING operation is that of subdividing the picture in an orderly manner into a large number of elemental segments. This process is accomplished in the facsimile transmitter (fig. 5-8) by a scanning drum and photocell arrangement.

The picture to be transmitted is mounted on a cylindrical scanning drum, which revolves at a speed of 1 revolution per second and travels along a lead screw at the rate of 12.5 inches in 20 minutes. (The lead screw has 96 threads per inch.) Light from an exciter lamp illuminates a small segment of the moving picture and is reflected by the picture through an aperture to a photocell. During the transmission of a complete picture, the light traverses every segment of the picture as the drum slowly spirals past the fixed lighted area.

At any instant, the amount of light reflected back to the photocell is a measure of the lightness or darkness of the tiny segment of the picture that is being scanned. The photocell transforms the varying amounts of light into varying electrical signals.

The fork oscillator unit develops an output voltage (MODULATION VOLTAGE) that is applied across the bridge modulator. The frequency of this voltage is 1800 cycles. When the bridge is balanced (photocell dark), the output voltage is zero. When the amount of light falling on the photocell varies, the resistance of the cell varies. This action unbalances the bridge and produces and output voltage that varies in amplitude with the variations in light. Thus, the 1800-cycle voltage is amplitude modulated in the bridge modulator.

The modulated signal is amplified in the voltage amplifier, the proper level is established in the gain control, and the signal is further amplified in the power amplifier before going to the radio circuits.

The fork oscillator unit, besides furnishing the carrier signal to the photocell bridge modulator, also supplies an 1800-cycle signal to the amplifier for the exciter lamp. This output keeps the exciter lamp at constant brilliancy. The fork oscillator output also supplies an 1800-cycle output to the synchronous motor amplifier. The output of the amplifier is used to operate the synchronous motor that drives the scanning drum at constant speed.

Electrical signals RECEIVED by the facsimile receiver (fig. 5-9) are amplified and

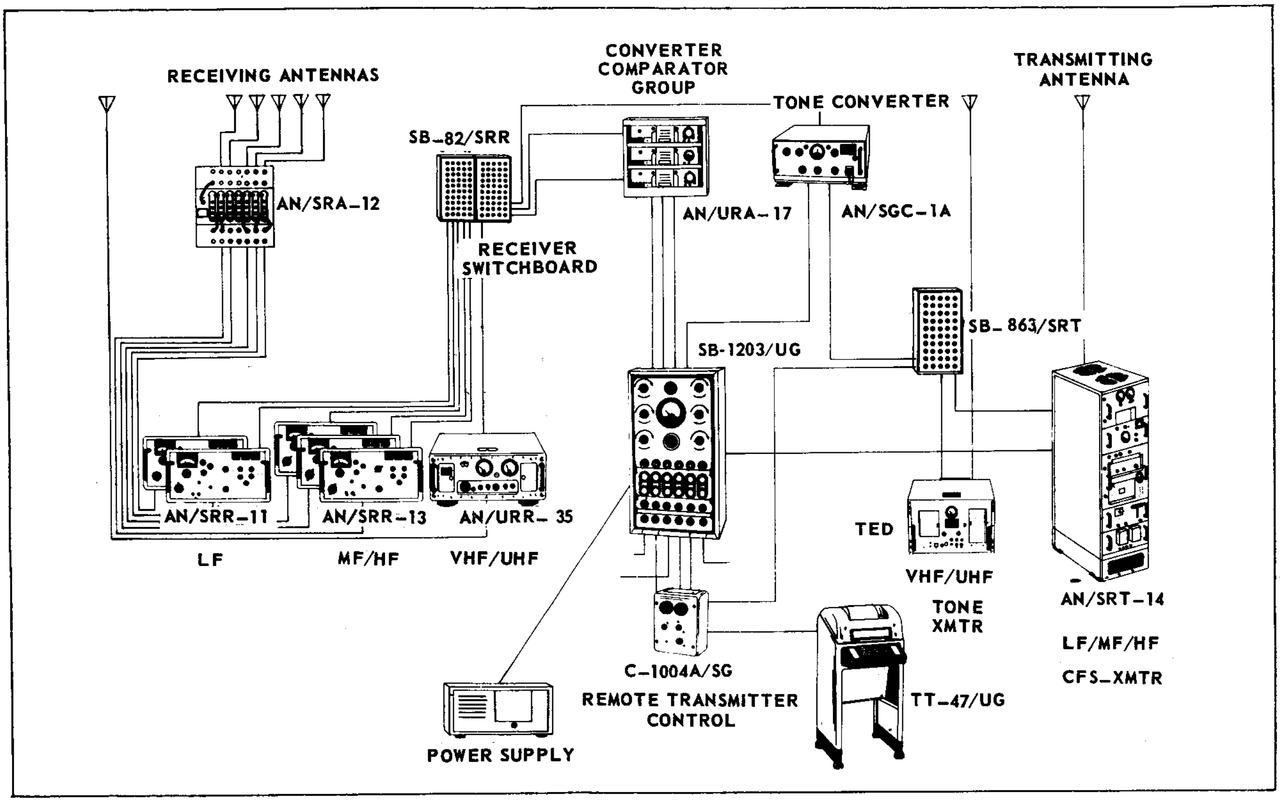

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Figure 5-6.—Teletype system employing diversity reception.

serve to actuate a recording mechanism that makes a permanent recording (segment by segment) on recording paper on a receiver drum similar to the one in the facsimile transmitter. The receiver drum rotates synchronously with the transmiter drum. This action continues until the complete original picture is reproduced in its entirety. The recording mechanism may reproduce photographically with a modulated light source shining on photographic paper or film; or, the recording mechanism may reproduce directly by burning a white protective coating from specially prepared black recording paper.

Synchronization is obtained by driving both receiving and transmitting drums with synchronous motors operating at exactly the same speed.

Framing (orienting) the receiver drum with respect to the transmitter drum is accomplished by transmitting a series of phasing pulses just before a picture transmission is to begin. The pulses operate a clutch mechanism that starts the scanning drum in the receiver so that it is properly phased with respect to the starting position of the scanning drum in the transmitter.

A start motor mechanically coupled to the synchronous motor serves to increase the synchronous motor speed above synchronism during the starting period after which it coasts down to synchronous speed when operating on 1800-cycle power.

The facsimile signal from the radio receiver circuit (fig. 5-9) is attenuated at the gain control, then amplified in the voltage and power amplifiers. The power amplifier output drives either the recording lamp for photographic recording, or the recording stylus for direct recording.

Another circuit from the power amplifier transmits phasing pulses to the phase amplifier, which operates the phase magnet and clutch during the phasing process just before each picture transmission.

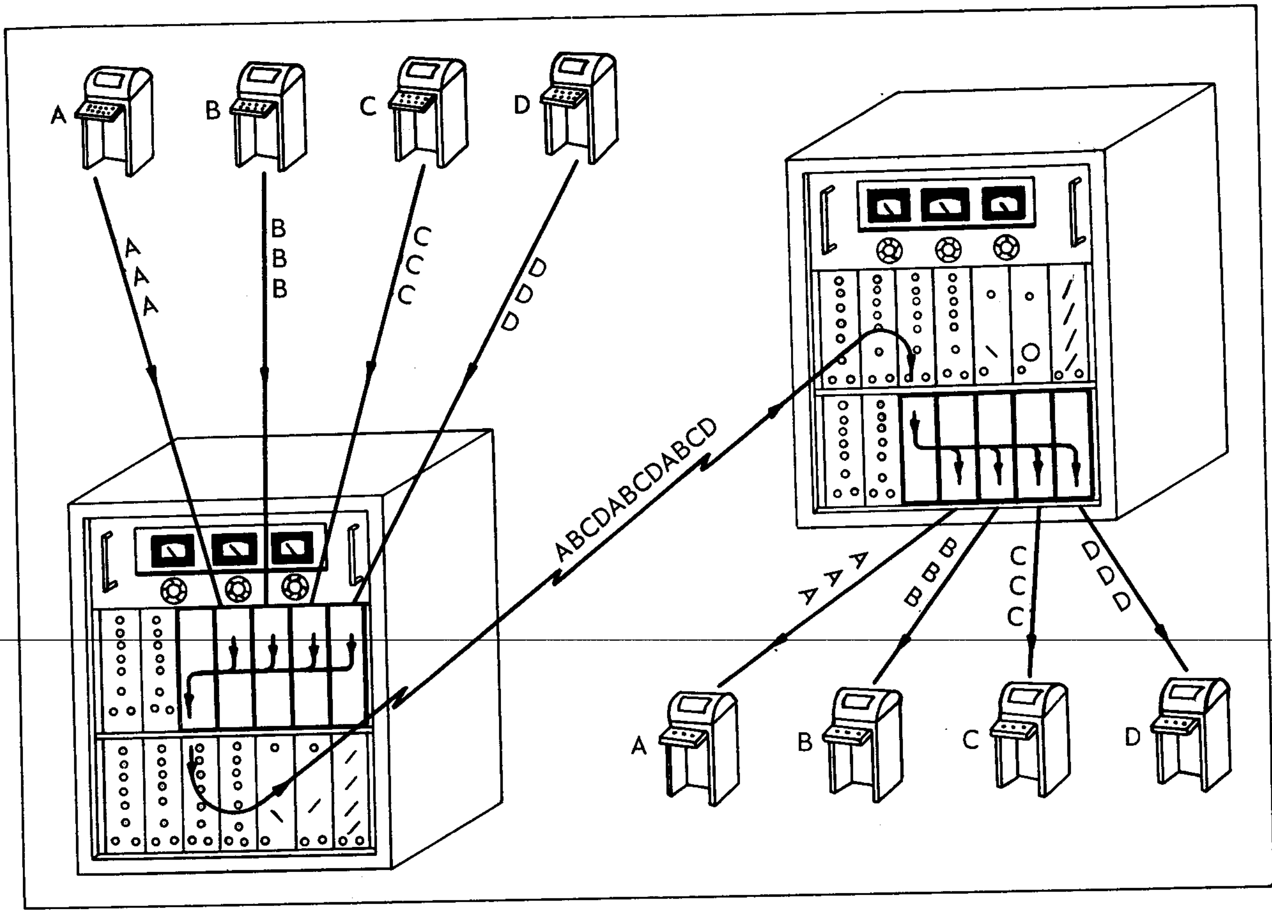

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Figure 5-7.—Time-division multiplex.

The fork oscillator serves a single purpose on receiving. It generates an 1800-cycle signal, which is amplified to operate the synchronous motor at the same speed as the motor in the transmitting transceiver.

Basic Shipboard System

Present radio facsimile transmission is accomplished by the carrier frequency shift method (with a 400-cycle shift), which uses a standard radio transmitter and receiver.

Radio facsimile terminal equipment (fig. 5-10) at the TRANSMITTER consists basically of a facsimile transceiver TT-41( )/TXC-1B, which generates an 1800 cycle amplitude modulated tone frequency in accordance with the black, white, and contrasting shades of the picture that is being scanned. The audio signal is fed to a keyer adapter, KY-44(A)/FX, where it is converted to a d-c voltage. This voltage is used to control the output of the frequency shift keyer, KY-75/SRT. The output of the keyer frequency modulates the r-f carrier of a c-w transmitter.

Radio modulator MD168/UX is used between a TT-41(B)/TXC-1B transceiver and an A-3 equipped transmitter. The modulator converts the 1800-cycle, a-m signal from the facsimile transceiver to constant amplitude (frequency modulated or frequency shift) which varies at frequencies between 1500 and 2300 cycles. This frequency variation is suitable for connection to an A-3 radio transmitter. This method is known as audio frequency shift (AFC) transmission.

To RECEIVE either carrier frequency shift or audio frequency shift, the AN/SRR 11-13A series receiver is used with a CV-172( )/U

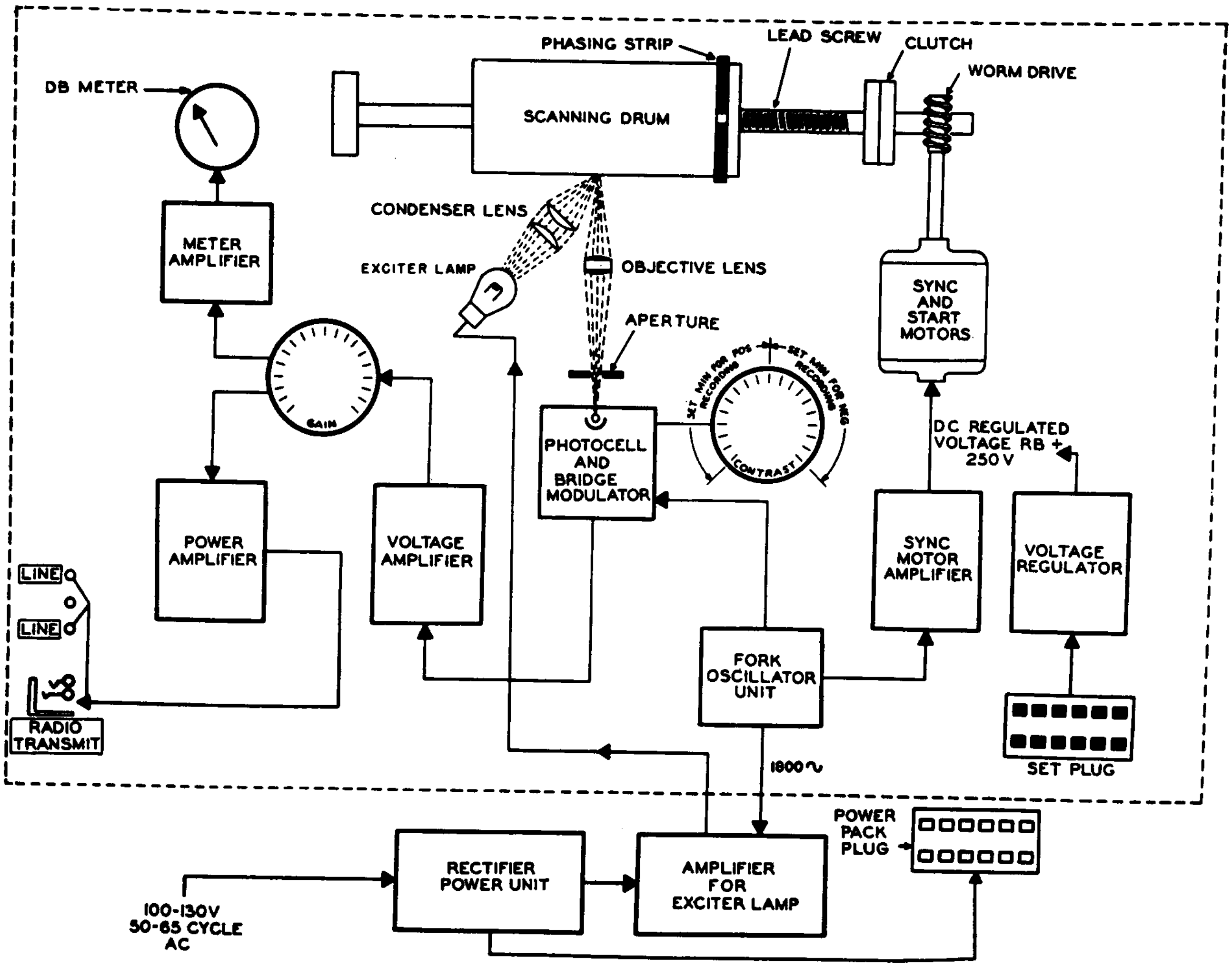

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Figure 5-8.—Facsimile transceiver-transmitting block diagram.

frequency-shift converter. The CV-172( )/U frequency-shift converter changes the audio output (varying between 1500 and 1800 cycles) from the receiver back to an 1800-cycle, a-m signal suitable for operation of a facsimile recorder RD-92(A)/UX.

The facsimile signal is fed to or from the transceiver by way of a receiver switchboard similar to SB-82/SRR used in the teletype system illustrated in figure 5-6.

NAVIGATIONAL EQUIPMENT

Navigation equipments include a variety of electronic gear, each serving one or more specific purposes. Included among these equipments are radio direction finders, radio compass equipments, radio and radar beacons, loran (LOng RAnge Navigation), and others. Only brief descriptions of the various equipments are given in this chapter. A more detailed treatment of these equipments is included in the ET 2 training course.

RADIO DIRECTION FINDERS

The RDF (for strictly navigational use) finds little shipboard application today, although it is used in air navigation. Other devices, however, are very rapidly replacing the RDF, even in aircraft.

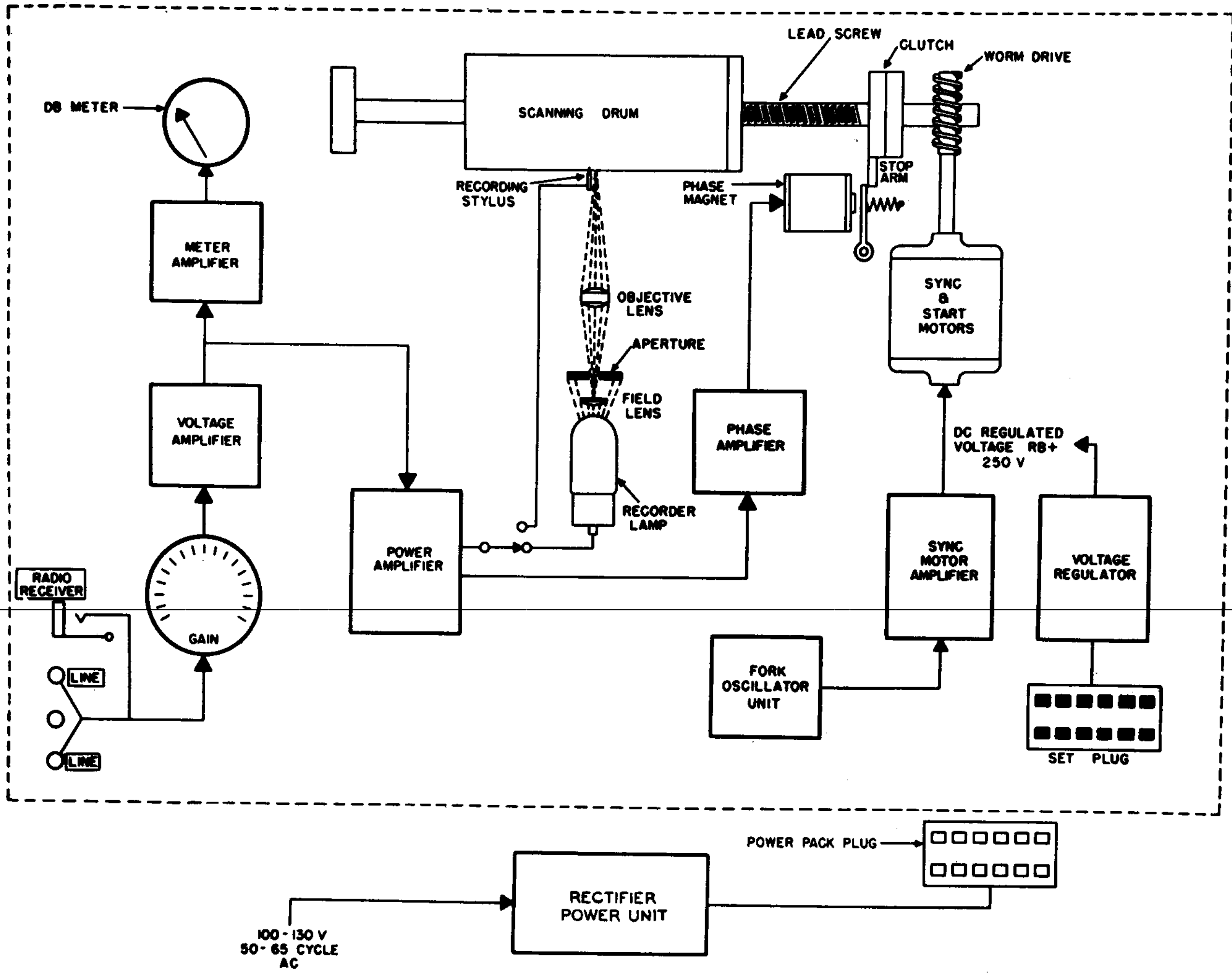

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Figure 5-9.—Facsimile transceiver-receiving block diagram.

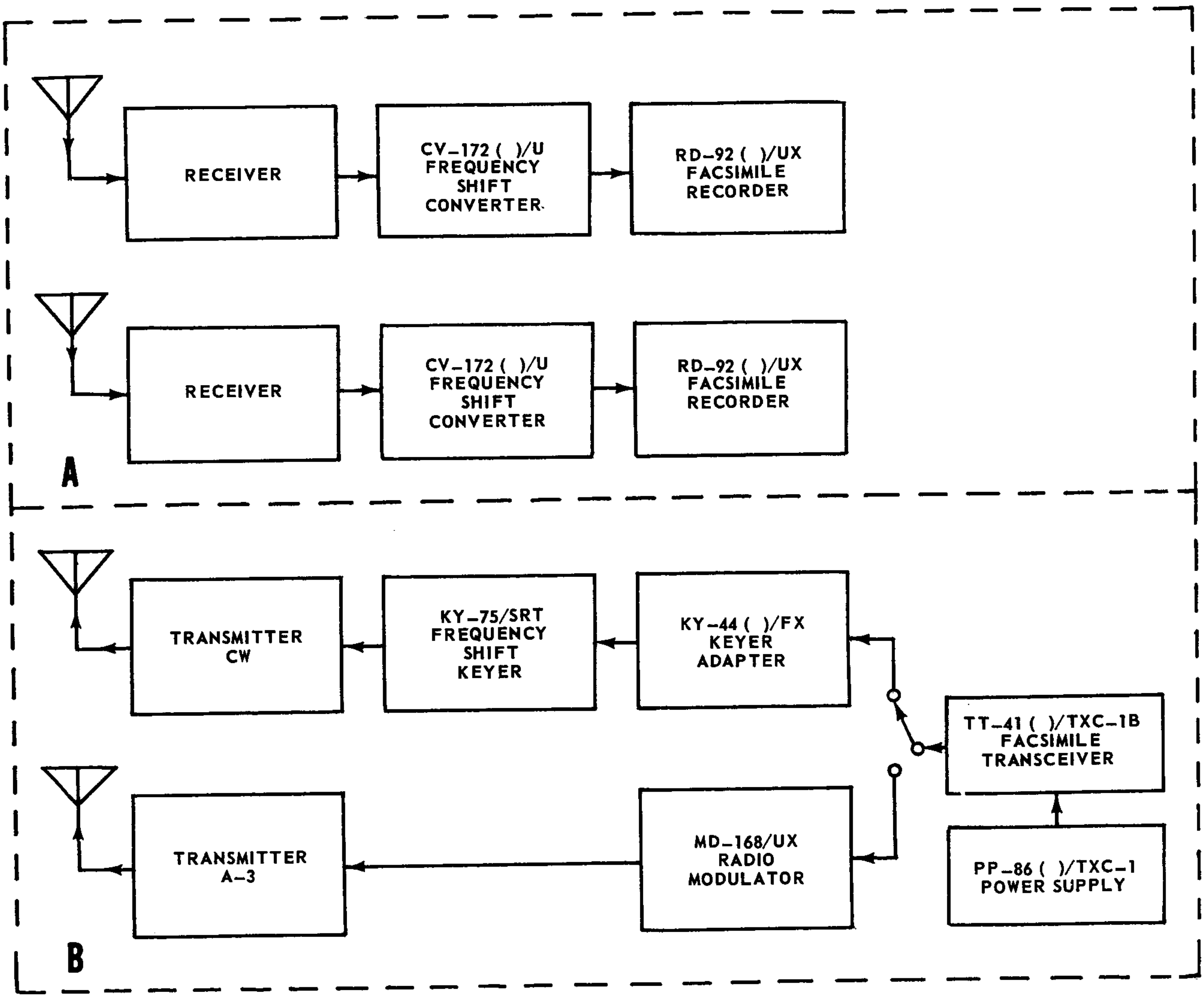
One of the uses of RDF today is in the location of personnel afloat in liferafts or lifeboats having a radio transmitter on which ships or planes can take bearings.

The radio direction finder is a sensitive receiver to which a directional (loop) antenna is connected. Range information is not obtained with just one bearing alone. By taking bearings on at least two transmitters a position can be obtained.

Many older shipboard direction finders operated in the low-and medium-frequency bands because in these frequency ranges the bearing accuracy was increased. However, many of the newer special-purpose RDF equipments operate in the VHF, UHF, and SHF bands. One of the uses of these equipments is to enable the operator to obtain bearings on intercepted radio and radar signals of unknown origin.

RADIO COMPASS EQUIPMENT

Radio compass equipment finds its greatest present-day usage in aircraft. With a network of radio beacons covering much of the earth's surface, the radio compass is essentially a radio direction finder that automatically indicates the plane's bearing at all times and thus helps the pilot to maintain his course and to locate his position. Where the beamed energy



70.14

Figure 5-10.—Radio Facsimile terminal equipment.

from the beacons cross, it is possible for the pilot or navigator to fix his position with considerable accuracy.

Ground-station radio beacons transmit either continuously or at automatically scheduled times; the pilot tunes his compass receiver to the frequency of the stations listed in the area through which he is passing. Indicators automatically show relative bearing information with respect to the station being received.

SECTOR BEACONS

In military applications, aircraft are guided to carriers and shore bases by means of homing beacons located on the carrier or base. The sector beacon is a special type of homing beacon. It transmits a directional beam from a rotating array that is coded differently in various sectors of its angular sweep.

Each sector has a different code letter so that a pilot can read the code to determine his approximate bearing with respect to the homing beacon.

Figure 5-11 illustrates the radiated signals that may originate in a beacon transmitting equipment. The combination of letters may be changed daily or hourly for purposes of security. The shaded areas in the pattern illustrate that the identification signal is transmitted at certain angular displacements rather than continuously.

TACAN

Tacan, an abbreviation of TACtical Air Navigation, is used by the U. S. Navy and the U. S. Air Force. It has replaced sector beacons discussed in the preceding section.

Tacan is an electronic navigation system which enables a pilot to instantaneously and continuously read the distance AND bearing of a fixed ground station or shipboard transmitter.

Tacan is a polar-coordinate system in which a ship or station installation of an AN/URN-3 (or the improved model, AN/SRN-6) transmitting set and an airborne AN/ARN-21 transmitter-receiver indicator gives bearing and distance information to a pilot (fig. 5-12).

In aircraft having the AN/ARN-21 the pilot can read on an azimuth indicator the position of the transmitting source in degrees of magnetic bearing from his aircraft. Also, the distance in nautical miles to the same reference point is registered as a numerical indication very similar to that of an automobile odometer (mileage indicator). In figure 5-12, the aircraft is 106 miles from the carrier and the ship is on a magnetic bearing of approximately 230° from the aircraft.

To provide a continuous navigation service through a large area, such as the continental United States, the system contains 126 selectable channels. As in television channel assignments, no two stations within interference distance of each other should be on the same channel.

The pilot can switch channels to select any tacan transmitter within maximum range that best suits his flight path.

To aid the pilot in his identification of a particular transmitter, the transmitter automatically transmits a three-letter tone signal in International Morse Code every 37.5 seconds. The aircraft receiver converts the signal to an audible tone that is heard in the pilot's headset.

Two frequencies are employed, as indicated in figure 5-13. One frequency (Y) is used for transmissions to the aircraft and another frequency (X) is used for transmission from the aircraft. The surface-to-air frequency carries bearing and range intelligence as well as

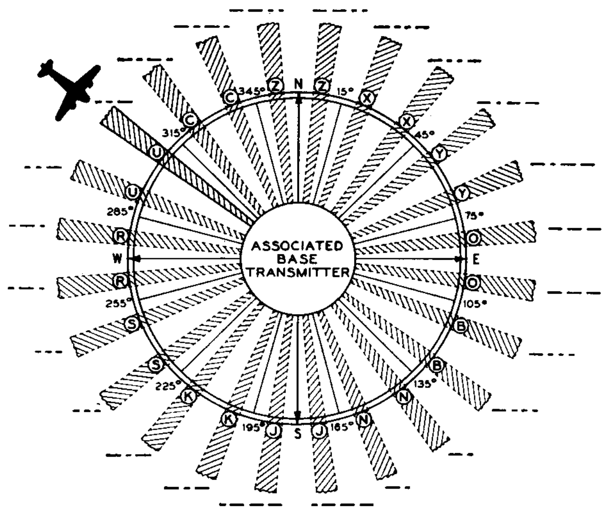


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Figure 5-11.—Radiated signal sectors of the Beacon Transmitter.

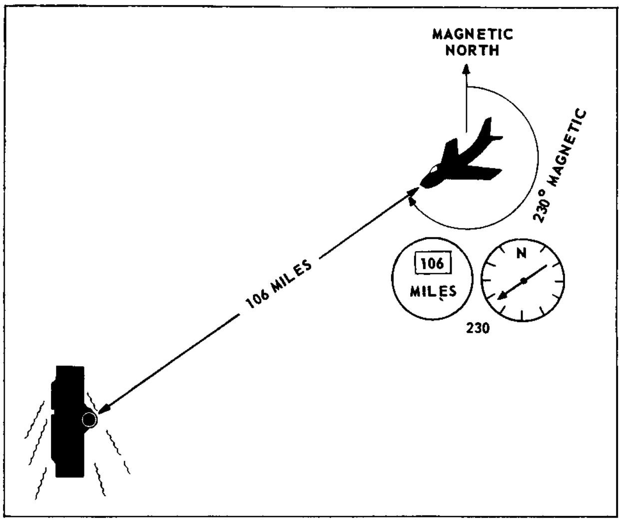

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Figure 5-12.—Polar coordinate presentation of tacan data.

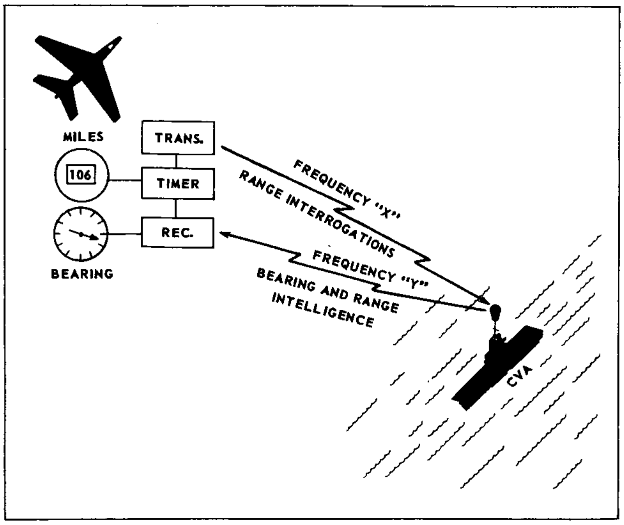

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Figure 5-13.—Dual-frequency transmission.

station-identification information. The transmission from the aircraft-to-surface unit is required to trigger the distance-measuring system.

When the pilot closes the proper switch on his set control, his receiver-transmitter radiates a series of range interrogation pulses (frequency X).

The interrogation pulses are detected by any ship or station that is operating on the same channel. The pulses cause the transmitter to radiate a response, which is a series of pulses on frequency Y.

When the reply signal is received in the aircraft, it is fed to range circuits that determine the time that has elapsed during the round-trip of the two signals. Other circuits convert the time difference to equivalent dial indication in miles. Bearing information is radiated continuously on frequency Y.

Radio set AN/SRN-6 is replacing the AN/URN-3 as TACAN radio sets on board ship. The AN/SRN-6 system (fig. 5-14) comprises three major groups: receiver-transmitter, antenna, and power supply assembly.

As many as 100 aircraft may simultaneously obtain navigational information in conjunction with a single installation of the AN/SRN-6. The set is capable of receiving on any one of 126 frequencies (channels) in the range of 1025 to 1150 mc. Transmission of information also takes place on 126 channel frequencies in the ranges of 962 to 1024 mc and 1151 to 1213 mc.

Two types of antennas are available for use. Each antenna operates on 63 channels, corresponding to low-band frequencies and high-band frequencies, respectively. Low-band installations transmit at frequencies between 962 and 1024 mc inclusive, and receive at frequencies between 1025 and 1087 mc. High-band installations transmit in the range of 1151 to 1213 mc, and receive in the range of 1088 to 1150 mc.

Two frequencies are used in each channel: one for receiving, and one for transmitting. The frequency used for receiving in low-band installations is 63 mc above the frequency used for transmitting in the same channel.

LORAN

The loran system was designed to provide a means of obtaining navigational fixes by using low-frequency radio signals. The word LORAN is a combination of the first letters of the words LOng RAnge Navigation. With loran, accurate fixes (locating one's position) can be obtained at much greater distances from transmitting stations than is possible with conventional radio direction finding. During the day, over sea water, fixes are possible up to 700 nautical miles from the loran transmitting stations. During the night when sky waves are utilized, satisfactory operation may be obtained up to 1400 miles.

A loran fix compares favorably in accuracy with a celestial fix and it has certain advantages. It may be used as well in a heavy fog as in clear weather, and the readings can be made rapidly at any time.

The principle of loran is based on the difference in time required for pulsed radio signals to arrive from a pair of synchronized transmitters. Loran transmitters are installed on shore several hundred miles apart. The principle of loran is illustrated in figure 5-15. If in part A, stations A and B are pulsed simultaneously, the two pulses arrive at any point on the center line at the same time. This is evident from the geometry of the figure; and an observer, with the proper receiving equipment, could tell if he was on this line.

Suppose, however, that an observer is located closer to station A than to station B. Then the pulse from station A will arrive at his location before the pulse from station B. Assume that the time difference is 800 μs, as shown in part B. There are many points at which the receiving

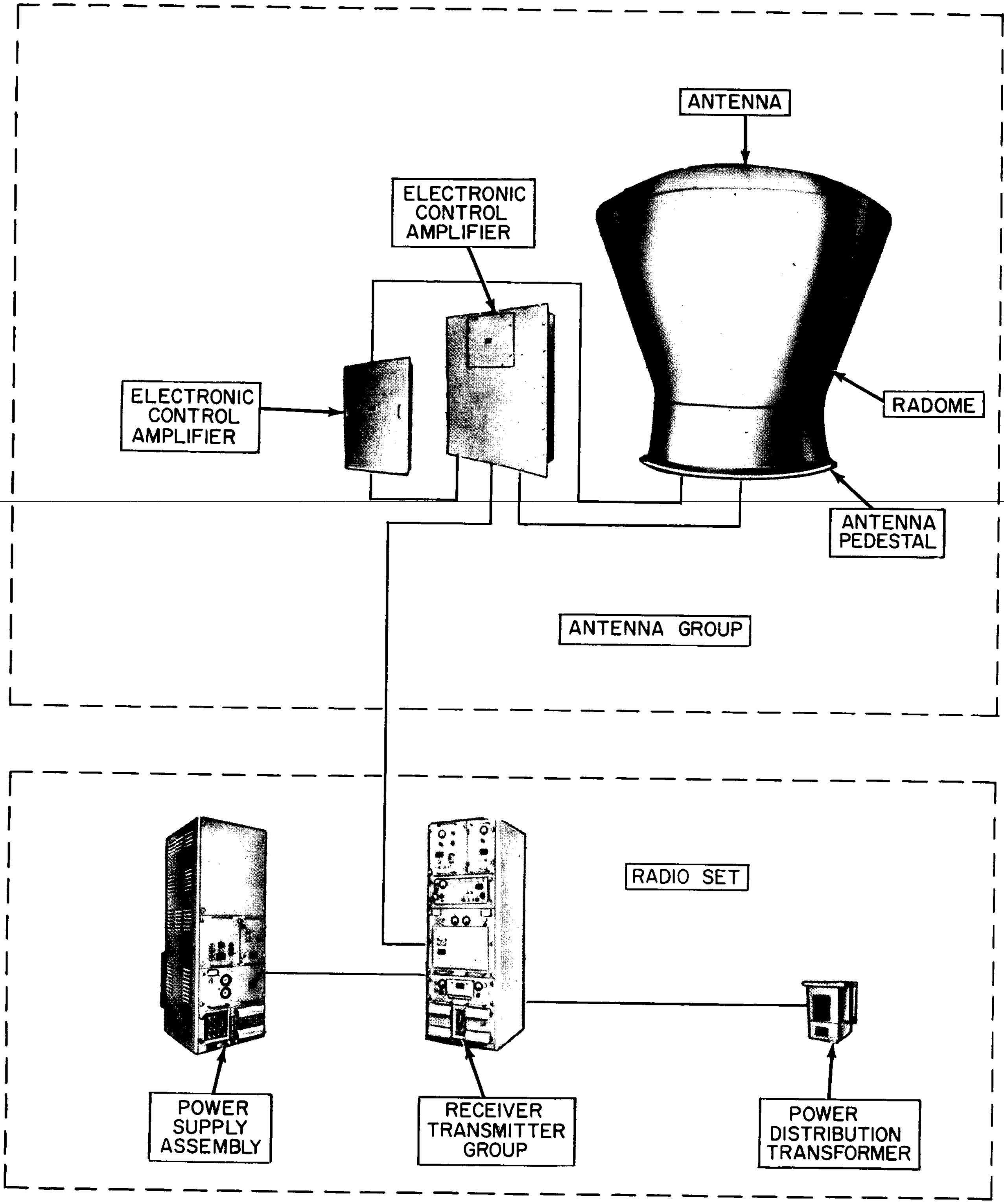

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Figure 5-14.—Shipboard radio beacon using radio set AN/SRN-6.

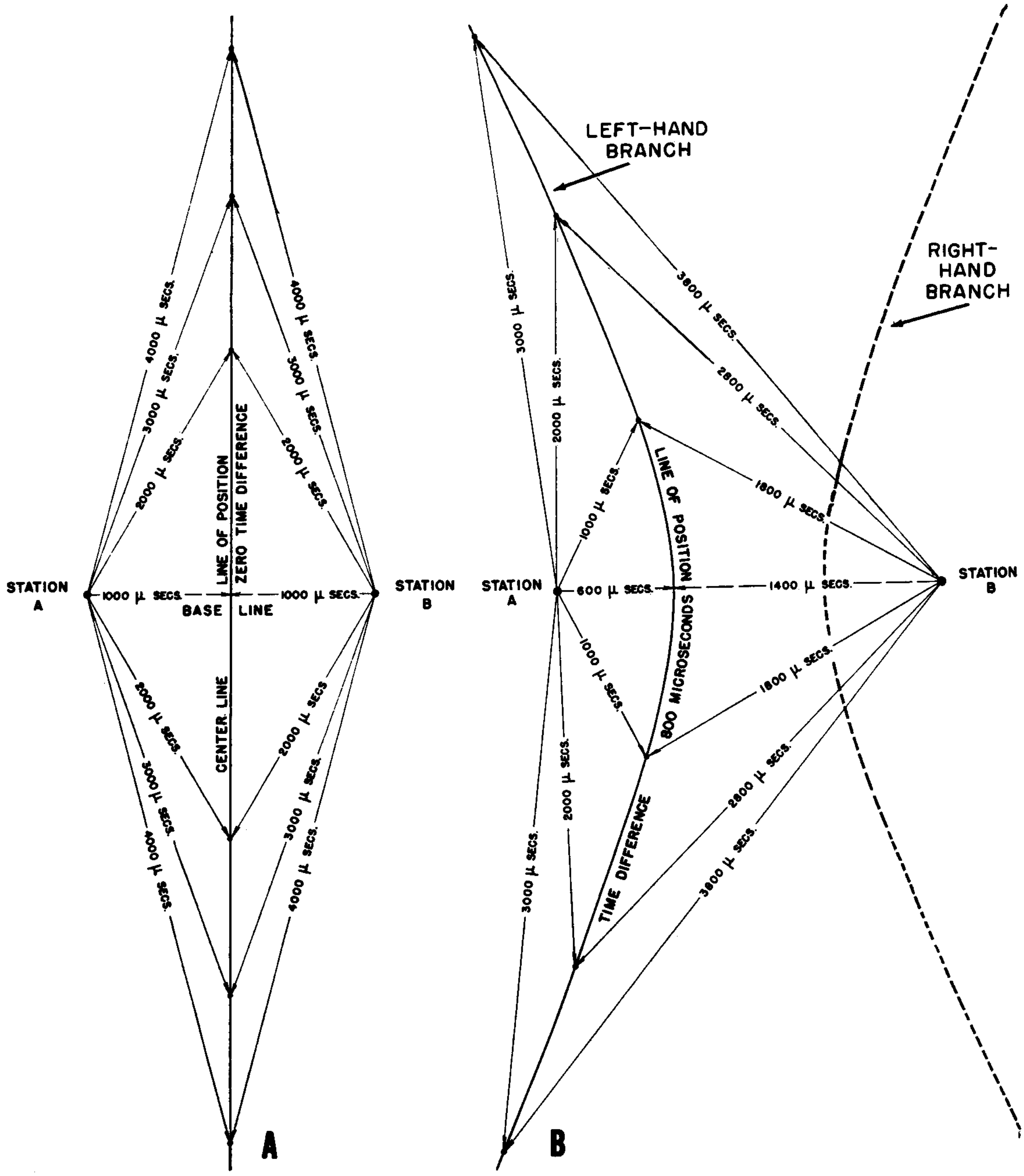

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Figure 5-15.—Principle of loran simplified.

equipment will indicate a time difference of 800 μs; these points lie on a hyperbola. Connecting the points where the time difference is the same forms a line of constant time difference, or hyperbolic line of position. This line (solid curved line) forms the LEFT BRANCH of the hyperbola. It is concave toward station A.

If the observer knows that he is closer to station A than station B and that the time difference is 800 μs, he still does not know this exact position on the hyperbolic line of position.

Assume now that the observer is nearer station B than station A and that the time difference between the arrival of the two pulses is 800μs. The line of constant time difference is then the righthand branch of the hyperbola, and appears as the dotted curve in figure 5-15B. (Stations A and B are the foci of the hyperbola.) If the pulses from the transmitters are identical, the observer has no way of telling which pulse arrives first. He then cannot determine on which branch of the hyperbola he is located. This difficulty is overcome, and at the same time the measurement made by the observer is simplified by delaying the pulsing of one of the transmitters by an amount that is more than one half the pulse-recurrence interval from the other station. For example, the interval between a pulse from A and the next pulse from B is always made greater than the interval between the B pulse and the next A pulse. Thus the navigator can tell that the pulse followed by the longer interval is always from station A.

From the foregoing explanation it follows that many lines of position may be obtained. By selecting several time differences for a given pair of stations, the result is a family of hyperbolas like those shown in figure 5-16A. In this figure the pulses from both transmitters are identical and no time delay is introduced as indicated by zero on the center line.

In actual practice, one station of a loran pair (fig. 5-16B) is designated the master station. It establishes the Pulse Repetition Rate (PRR). The second, or slave station, receives the pulses of the master station and transmits its own pulses delayed in time but in synchronism with the master pulses. The time delay between the transmission of a pulse from the master station and the arrival of this pulse at the slave station depends chiefly upon the DISTANCE between the stations. This delay is caused by transit time.

After the pulse arrives at the slave station, there is a time delay of one-half the pulse-repetition period. This delay is necessary because of the two-trace method of cathode-ray-tube presentation at the loran indicator.

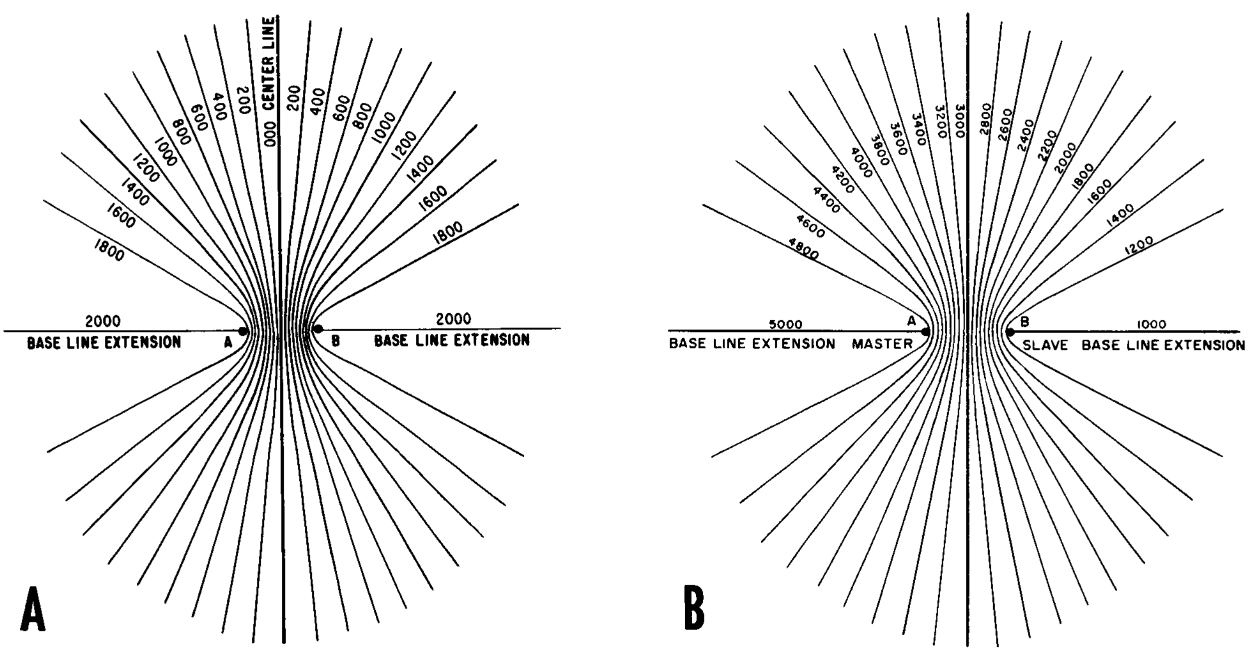

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Figure 5-16.—Lines of position.

In addition to these two delays, another delay, called the CODING DELAY, is added. The sum of the three delays is called the ABSOLUTE DELAY. The absolute delay is the time between the transmission of a pulse from the master station and the transmission of a pulse from the slave station. The absolute delay in figure 5-16, B, is 3000 μs, as indicated on the center line.

The PRR is different for different pairs of stations to enable the operator to identify the pair to which the receiver is tuned. There are four loran channels, numbered 1 through 4, corresponding to carrier frequencies of 1950, 1850, 1900, and 1750 kc, respectively. The BASIC PRR is either 25 cps (the LOW, or L, rate) or 33 1/3 cps (the HIGH, or H, rate). A third basic recurrence rate of 20 cps (the SPECIAL, or S, rate) is not in operational use, but is provided in new equipment to allow for expansion of the loran system.

The basic pulse recurrence rates are subdivided into SPECIFIC PRR. The specific low PRR is from 0 through 7, corresponding to 25 through 25 7/16 pulses per second in steps of 1/16 of a pulse per second. The specific high PRR is from 0 through 7, corresponding to 33 1/3 through 34 1/9 pulses per second in steps of 1/9 of a pulse per second.

To establish his position, the loran operator must have the proper loran charts, as well as the proper receiving equipment. A loran fix is the point of intersection of two lines of position. Two pairs of transmitting stations, or one master and two slave stations, are needed to establish the lines of position necessary for the fix. One pair of stations act as foci for one family of hyperbolas. The second pair of stations act as foci for another family of hyperbolas. As has been stated, a fix is the intersection of two hyperbolas, one from each family.

Figure 5-17 illustrates how a fix is obtained by using only one master and two slave stations. This is accomplished by causing the master station to transmit two distinct sets of pulses. The double-pulsed master station transmits one set of pulses at the PRR of the pulse transmitted by the first slave station and the other set of pulses at the PRR of the pulses from the second slave station.

Lines of position are identified by a letter and several numbers. The letter represents the basic PRR—Low (L), high (H), or special (S). The first number represents the channel (1 through 4), or carrier frequency; the second number denotes the specific PRR; and the last number is the time difference in microseconds. For example, 2L 6-2500 indicates channel 2, which is 1850 kc; a low basic PRR of 25 cps; a specific PRR of 6, corresponding to 25 6/16 cps; and a time difference of 2500 μs.

Loran charts for use aboard ships and aircraft are published by the U. S. Navy Oceanographic Office.

RADAR EQUIPMENT

Naval shipboard radar equipments are grouped into three general categories: search, fire control, and special. Search radars are further classified as surface search and air search. Fire control radars, integral parts of certain fire control systems, are used after targets have been located by search radars. Special radars are used for specific purposes such as recognition (IFF), ground-controlled and carrier-controlled approach, range rate, and height finding.

Radar operating principles are discussed in Basic Electronics, NavPers 10087 (revised). Representative radar sets and radar repeaters are listed below.

RADAR SETS

Radar Set AN/SPS-8B is a high-power, shipboard, height-finding radar system, designed for fighter aircraft direction. It presents target height, slant range, bearing, and beacon information on remote radar repeaters, Navy Model VK Plan Position Indicator (PPI), and Navy Model VL Range-Height Indicator (RHI).

Other height-finding radars that are either operational or being developed are AN/SPS-2, AN/SPS-13, AN/SPS-26, AN/SPS-34, AN/SPS-42, and AN/SPS-39A.

Table 5-3 presents information on operational search radars.

RADAR REPEATERS

In the early days of radar, indicators were a part of the console of the radar itself. However, with the increase in numbers and purposes of radar sets aboard ship remote indicators (radar repeaters) became necessary.

At the remote indicator, a selector switch permits the operator to select any one of the

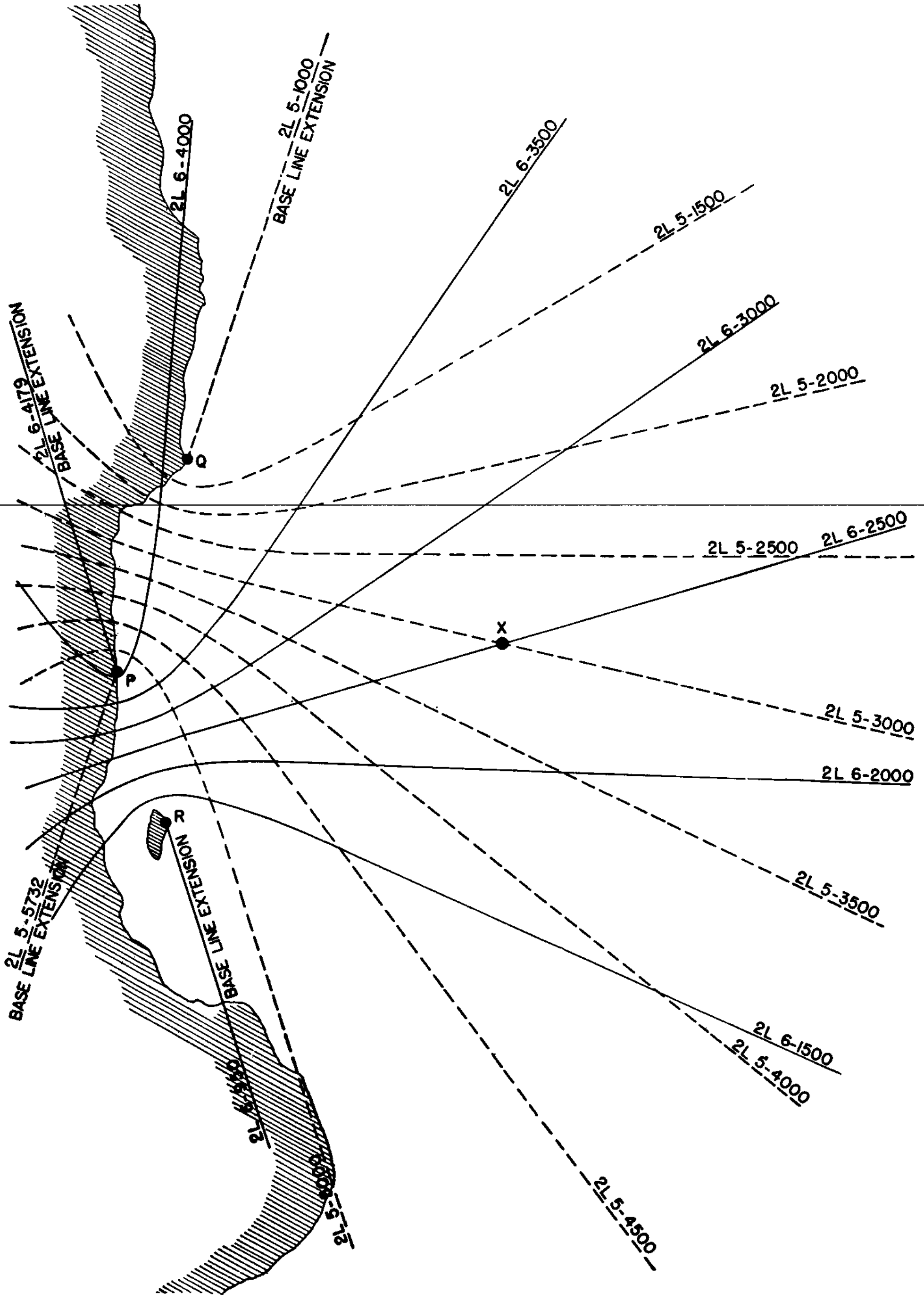

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Figure 5-17.—Obtaining a fix with one master and two slave stations.

Table 5-3.—Search Radars

Model	Type	Peak Power output	Use
AN/SPS-21	Surface Search	10 kw	Short range surface search on small craft, and as standby set on large ships.
AN/SPS-35	Surface Search	7 kw	Short range surface search—small craft.
AN/SPS-36	Surface Search	7-10 kw	Short range surface search—small craft.
AN/SPS-10	Surface Search	120-285 kw	Medium range surface search and limited air search—wide use on DDs and larger ships.
AN/SPS-12	Air Search	500 kw	Medium range air search—DDs and larger ships.
AN/SPS-28	Air Search	300 kw	Long range air search—DDs and larger ships.
AN/SPS-29	Air Search	750 kw	Long range air search—wide use on DDs and larger ships.
AN/SPS-37	Air Search	180 kw	Very long range air search—DDs and larger ships.

shipboard radar presentations for viewing. The output of the radar receiver is fed through an electronic network, which is separate from the main indicator circuit, and therefore the range scale used at the repeater does not have to be the same as that used at the main (console) indicator. A typical switching network is treated briefly in chapter 8 of this training course.

AN/SPA-8A Repeater

The AN/SPA-8A repeater may be used to display information from a variety of shipboard radars. When used with such radars, the PPI will be ship centered unless off-centering is introduced. Views of the top and front panels are shown in figure 5-18.

Provision is made on the indicator for an electronic cursor and range strobe. The electronic cursosr appears on the PPI as a sharp, bright line whose direction may be set by the BEARING CURSOR control. The range strobe is a bright spot that may be moved along the cursor by the RANGE STROBE control. Range and bearing may be read directly from counters. This information is made available in two synchro channels for transmission to remote points.

This repeater can be designed to be used as a part of the airborne early warning (AEW) system. This system extends the range of standard shipboard radar by carrying the search radar in a high-flying aircraft and relaying the radar information back to the ship for presentation on the ship's indicators.

Two indicators, one for tracking and one for use as a final indicator, may be used as a pair to display such relayed information. When used with the AEW system, the presentation on the tracking indicator will be AEW plane centered. The final (or repeat) indicator may present a display that is centered about the AEW plane, own ship, or any other point that is tracked on the tracking indicator. Ordinarily, in AEW applications, own ship will be tracked, thus causing an own-ship-centered display to appear on the final indicator, as illustrated in figure 5-19.

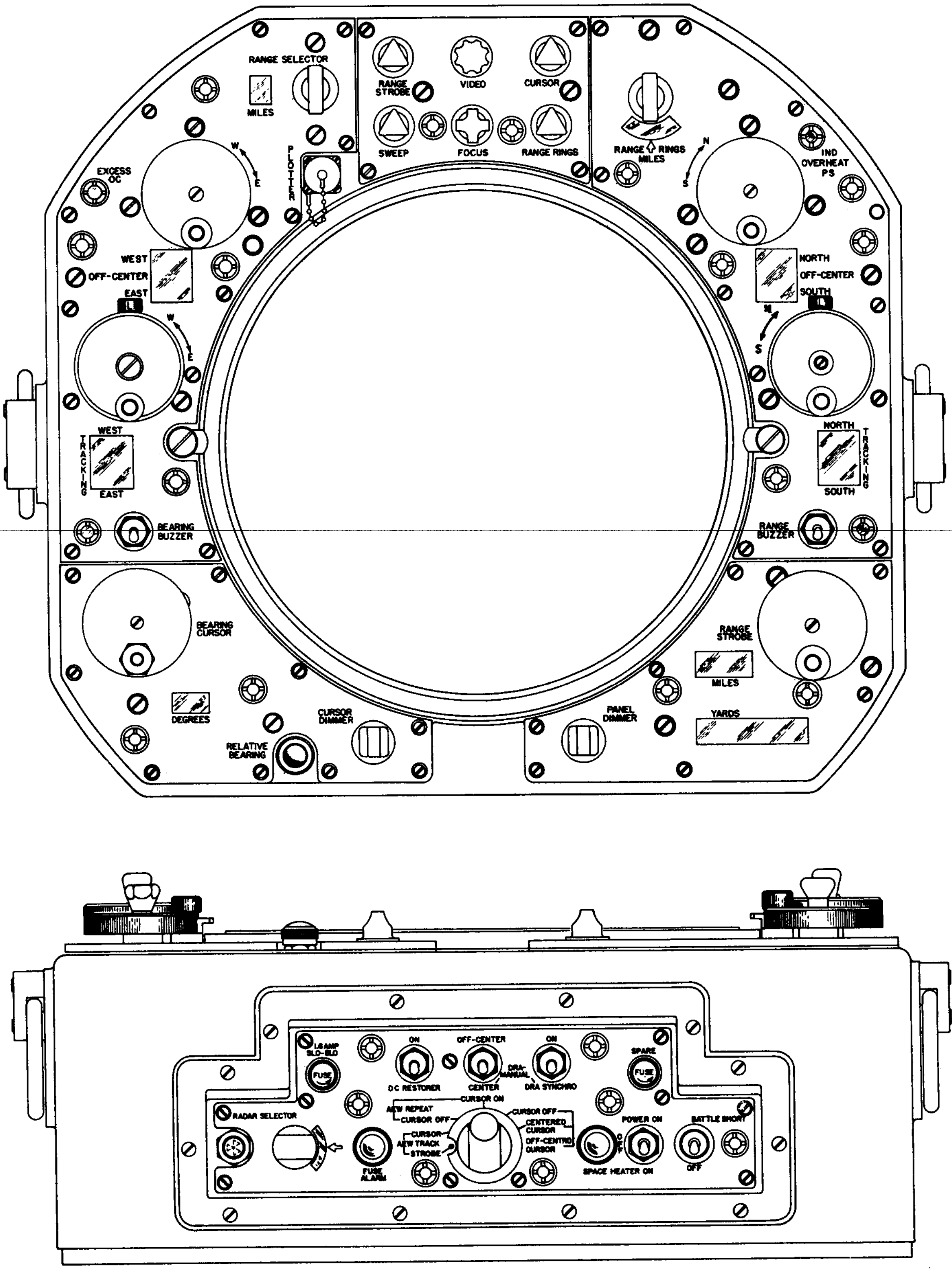

Figure 5-18.—Top and front panels of the AN/SPA-8A repeater.

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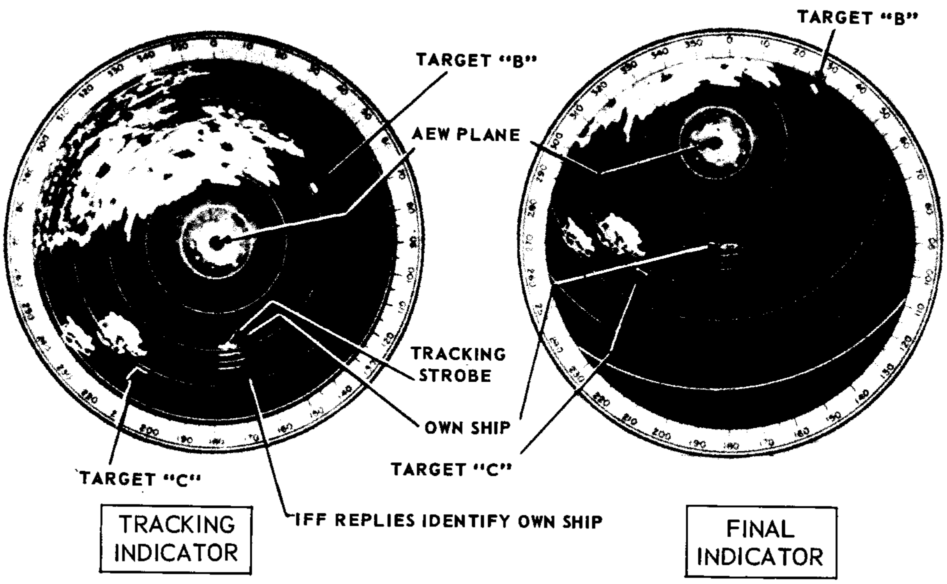

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Figure 5-19.—Ships presentation of AEW radar.

The display features may be listed as follows:

1. EXPANSION OF DISPLAY—The indicator is provided with a continuously variable sweep-speed control (rubber range control), permitting exact selection of the most useful range for any particular condition. It is often desirable to observe the radar display by the use of a short-range sweep. Close scrutiny of a target is permitted by expanding the display, and, if necessary, off-centering the display so as to keep the target on the screen. A fully expanded sweep yields a display in which the detail is limited by the radar, rather than by the PPI.

2. MANUAL OFF-CENTERING—The indicator is equipped with manual off-center controls, which permit displacement of the entire picture so that any target within a 250-mile range may be brought to the center (or any other region) of the display.

When using an expanded sweep, only a small portion of the area being searched by the radar is presented on the PPI. This small area may or may not include the particular desired target. To bring a desired target on the indicator, or to prevent the target from passing from view, manual off-centering may be introduced. By the use of both the expanded sweep and the manual off-centering, a remote target may be observed on a short-range display.

3. DRA OFF-CENTERING—The indicator has a synchro channel for receiving off-centering information from the ship's dead reckoning analyzer (DRA). This information is mechanically fed into the manual off-centering system of the indicator. DRA off-centering has the effect of cancelling the effects of own ship's motion, thereby presenting a stationary display. Such a display will show all targets, including own ship, moving in their true courses, and land masses will be fixed.

4. OFF-CENTER COUNTERS—There are two pairs of off-center counters (north-south and east-west) on the indicator. The counters show (in miles) how far the picture has been shifted from its centered position by the use of the off-center and the DRA.

5. TRACKING STROBE—When the AEW track strobe is used, a bright spot, known as the TRACKING STROBE, will appear on the display. This strobe may be moved about at will by means of the tracking controls, and may be caused to follow (track) any target that appears on the PPI. Synchro information regarding the position of this strobe can now be

furnished to remote points, specifically to a final (or repeat) indicator.

6. ELECTRONIC CURSOR—When the AEW track cursor is used, the origin of the bearing cursor on the indicator is not fixed at any point, but may be moved about so as to permit range and bearing to be taken between any two targets. When used in this manner, synchro data regarding the position of the origin of this roving cursor may be supplied to a final indicator just as though tracking were being performed with the tracking strobe. (Only one indicator at a time can be used for tracking.)

7. AEW OFF CENTERING—When an indicator is used as a final AEW repeater, a synchro channel is switched in for receiving off-center information from the tracking synchros of a tracking indicator. With such information, the location of the tracking strobe (or origin of the roving cursor) on a tracking indicator suitably wired to this indicator, will determine the location of the origin of the electronic cursor on the final indicator.

As many as five final indicators may be used with one tracking indicator without requiring auxiliary equipment.

AN/SPA-4A Repeater

The Range-Azimuth Indicator AN/SPA-4A (fig. 5-20) displays information supplied by ship's radar systems with pulse repetition rates between 60 and 3000 pulses per second. The information is displayed on a 10-inch cathode-ray tube PPI.

The PPI sweep is rotated in synchronism with the associated radar antenna by means of a servosystem. The cursor sweep can be rotated by a handcrank to any desired radial location. A spot of light (the range strobe), appearing on the cursor sweep may be superimposed on any target in the PPI display. The location of the range strobe may be changed by rotating either the range handcrank or the bearing handcrank or both.

The range and bearing of the range strobe (and hence the position of a particular target) is registered on mechanical counters. This information may also be repeated at remote points throughout the ship.

VK Repeater

The VK repeaters have been improved through a series of changes. The VK-5 functions as a standard PPI repeater, off-center PPI repeater, or expanded off-center PPI repeater. It may be used on shore, shipboard, or submarine. It presents AEW and DRA information and designates selected targets to remote PPI repeaters.

Target ranges may be estimated with fixed range markers or with a dial-controlled range ring. Target bearing may be measured on a dial around the rim of the PPI presentation with the aid of a mechanical cursor, or it may be measured with either a screen-centered, display-centered, or wandering electronic cursor.

Off-center presentation may be used to increase the effective screen area and to display targets from AEW aircraft or a DRA relay receiver. The start of the PPI sweep may be shifted off center in any direction by manual means to locate the observer's ship on the center of the PPI screen. After initial off-centering, displays are automatically off-centered in AEW or DRA operation.

VL Repeater

The VL-1 repeater is a remotely controlled range-height indicator designed to repeat information obtained from any standard Navy height finding radar system. The scope displays patterns within ranges of 20, 40, 70, and 140 miles (the ranges can be changed to 20, 40, 100, and 200 miles, if desired).

The screen display forms a roughly rectangular area, with the trace originating at the lower left-hand corner of the display. Targets appear as bright spots on the screen. Height is shown vertically, and range is shown horizontally.

In operation, four equally spaced electronic range marks appear on the screen as bright, curved lines (arcs of concentric circles) associated with each range. These lines appear on their respective ranges as 5-, 10-, 20-, and 50-mile range markers.

The height of a selected target is measured by means of a mechanically controlled electronic height marker appearing as an approximately horizontal line across the scope screen. The height line is raised or lowered by a handwheel until it intersects the bright spot representing the selected target. The height of the target, in feet, is then read from a height counter.

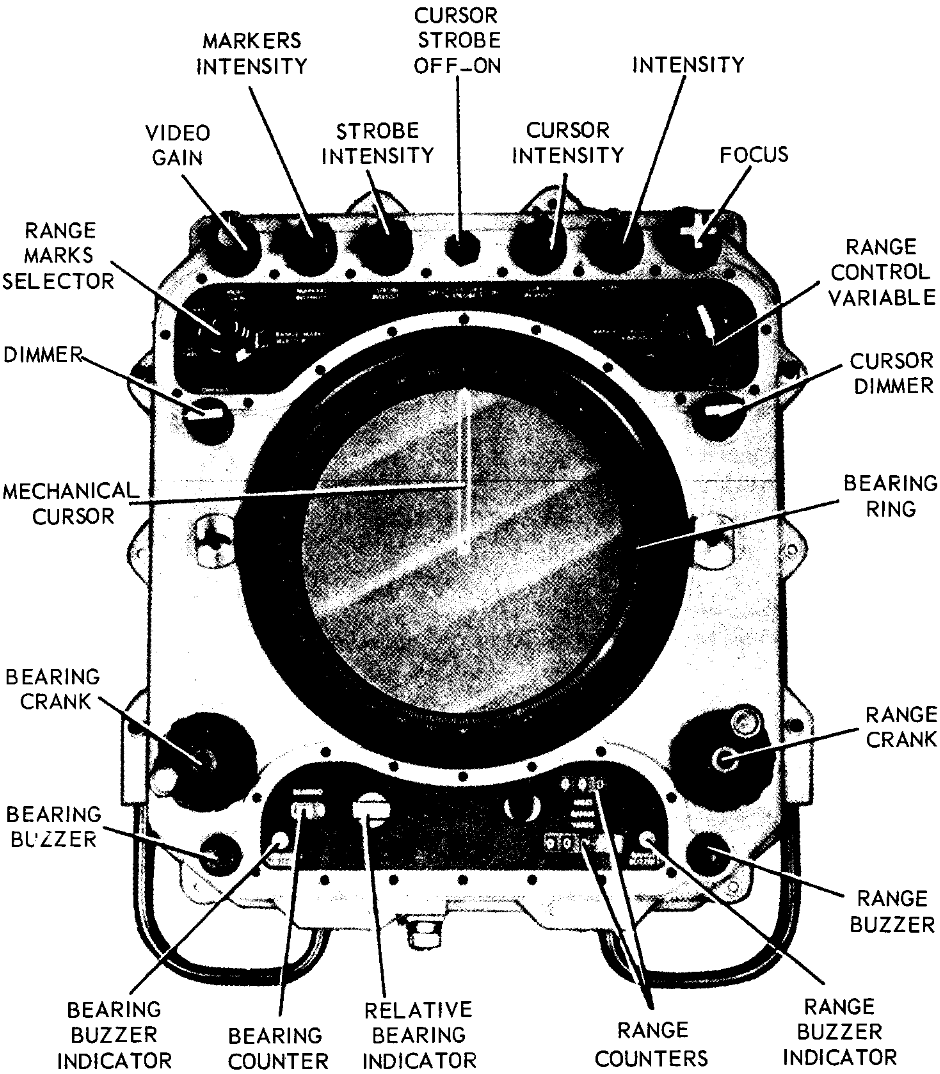

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Figure 5-20.—Radar repeater AN/SPA-4A.

IFF EQUIPMENT

An electronic system has been developed that permits a friendly craft to identify itself automatically before approaching near enough to threaten the security of other naval units This system is called identification, friend or foe, or IFF. It consists of a pair of special transmitter-receiver units. One set is aboard the friendly ship and the other is aboard the friendly unit (ship or aircraft). Because space and weight aboard aircraft are limited, the airborne system is smaller and lighter (and requires less power) than the shipboard transmitter-receiver. The airborne equipments are automatic and do not operate until triggered by a signal from a shipboard unit.

IFF systems are designated by MARK numbers. In order to avoid confusion between IFF systems and fire-control systems, the IFF mark number is a Roman numeral (Mark III); whereas, the fire control number is an Arabic numeral (Mark 29). The IFF system operates as follows: An air-search radar operator sees an unidentified target on his radar scope. He turns on the IFF transmitter-receiver, which transmits an INTERROGATING, or "asking," SIGNAL to the airborne transmitter-receiver. The interrogating signal is received by the airborne unit, which automatically transmits a characteristic signal called an IDENTIFICATION SIGNAL. The shipboard system receives the signal, amplifies it, and displays it on the radar scope, or on a separate indicator scope. When the radar operator sees the identifying signal and identifies it as the proper one, he knows that the aircraft is friendly.

However, if the aircraft does not reply when interrogated, or if it sends the wrong identifying signal, the ship must then assume that the target is an enemy, and defensive action must be taken. IFF equipments comprise (1) the interrogator-responsor, and (2) the identification set (transponder).

The interrogator-responsor performs two functions: transmits an interrogating signal, and receives the reply. The transponder also performs two functions: receives the interrogating signal, and replies automatically to the interrogating signal by transmitting an identifying signal. The two types of interrogation are DIRECT and INDIRECT. The interrogation is direct when the interrogating signal that triggers the transponder is a pulse from the radar equipment. The interrogation is indirect when the interrogating signal is a pulse from a separate recognition set operating at a different frequency from that of the master radar.

Early IFF systems used direct interrogation. However, direct interrogation proved unsatisfactory because the transponder was required to respond to radars that differed widely in frequency. Therefore, the later IFF systems make use of indirect interrogation within a special frequency band reserved for IFF operation.

ANTENNA STABILIZATION DATA EQUIPMENT

Stabilization Data Set AN/SSQ-14 is a vital link in establishing a stabilized antenna platform. It supplies a synchro signal indication of the angular displacement of the ship's deck with respect to the horizontal as the ship pitches and rolls. Two gyro units, one associated with pitch and the other with roll, are mounted on a horizontal platform with their output axes vertical. The outputs of these gyro units, with their associated servoloops, maintain this platform in a horizontal position. The pitch and roll angular correction is sent to the desired destination (the system that keeps the radar antenna stabilized, for example) by means of transmitting synchros geared to the pitch and roll axes of the stabilized platform.

Other equipments furnishing stabilization data (roll and pitch signals) are the AN/SSQ-4, Stable Elements Mk 8 Mods 2 and 4, and the Sperry Mk 19 gyrocompass.

COUNTERMEASURES

For the purpose of a brief description of countermeasures, this chapter treats the subjects under the two general headings; electronic countermeasures and nonelectronic countermeasures.

ELECTRONIC COUNTERMEASURES

Electronic countermeasures (ECM) may be classified as ACTIVE or PASSIVE. Passive ECM is the use of receiving equipment to intercept enemy radar or radio transmissions. Active ECM is the use of transmitting equipment that may be used to jam the enemy transmissions.

In order to use countermeasures most effectively against an enemy radar, as many as possible of the following characteristics should be known about the enemy radar facility: (1) the frequency, pulse width, pulse-repetition frequency, and peak power of the transmissions; (2) the receiver bandwidth and the time constants of the receiver coupling circuits; (3) antijamming features; (4) amount of shielding; (5) type of indicator; (6) antenna beamwidth; (7) types of scan; and (8) use of the radar.

Likewise, in order to use countermeasures most effectively against enemy communications systems, the following information is needed: (1) the frequency of transmissions, (2) type of modulation, and (3) receiver bandwidth.

Some of the foregoing information is obtained by analyzing the enemy transmission, and the other information may be obtained by examining captured equipment.

Special equipment has been developed for use in analyzing r-f transmissions. This equipment includes SEARCH RECEIVERS, which search the various frequency bands for the various types of emissions; PANORAMIC ADAPTERS, which measure the frequency, strength, and type of modulation of a transmission in a selected band of frequencies; and PULSE ANALYZERS, which measure the pulse rate and width. The pulse analyzer and the panoramic adapter are used with the search receiver.

NONELECTRIC COUNTERMEASURES

Units called CORNER REFLECTORS are used to present strong echoes to enemy radars. When suitably placed, they return strong echoes that appear to the enemy radar operator as a large naval force. Corner reflectors have other valuable uses also. For example, they can be used on liferafts to assist friendly search radar to locate them.

ROPE is the code name for long streamers of aluminum foil. This foil, cut in lengths of about 400 ft., is dropped by aircraft within range of an enemy radar. The twisting and turning of the foil as it falls presents many different effective lengths to the enemy radar. Some of these lengths are highly resonant at the frequency of the radar, and therefore appeared as strong target signals.

WINDOW is the code name for short strips of aluminum foil. The foil is cut to slightly different lengths so that it causes strong reflected signals at the frequency of the enemy radar. The strips are packaged and dropped over enemy territory. While fluttering to the ground, they present a multitude of targets to the enemy radars. Thus, enemy search and tracking radars follow the strong echoes presented by the window and find it difficult to track on the lesser echoes presented by the aircraft.

DECOYS consist of a wide variety of devices. Some of the most effective are balloons towing strips of aluminum foil. These strips, which vary in length, present strong reflections over a fairly wide band of frequencies. Other decoys are aircraft towing streamers of foil. Corner reflectors might also be considered decoys.

Antijamming measures, or counter-countermeasures (CCM), are used to reduce the effect of enemy jamming on our own equipment. In receivers some of the most important CCM devices are special filters that pass only the most important parts of echo signals, thus rejecting as much of the jamming signal as possible. In the transmitters, a great many radar equipments have tunable magnetrons whose frequency may be varied at intervals to prevent an enemy jamming transmitter from locking on the radar signal.

TIMING CIRCUITS

In many of the previously mentioned electronic installations aboard ship, timing circuits are an important part of the operation. For example, timing circuits are used in radar, loran, multiplex communications systems, closed circuit television, facsimile transmissions and electronic countermeasures. One application of timing circuits is that of multivibrators as electronic swiching devices (ring counters in multiplex system) and multi-signal inputs in cathode ray displays. An electronic switch enabling the simultaneous display of two waveforms on a cathode ray oscilloscope screen is described in Basic Electronics NP 10087 (revised). This circuit employs triode electron tubes that are periodically cut off so that a grid signal may not be transmitted. The signal is transmitted through the triode only during the period that the gating signal renders the tube in a conduction condition. This is a form of coincidence circuit that produces an output only when the gating signal on the cathode coincides in time with the input signal on the grid. Coincidence circuits are treated in more detail in advanced training courses.

EQUIPMENT INSTALLATION

The location of units of electronic equipment is normally governed by an installation plan. The installation is planned to ensure maximum efficiency of the electronic system as a whole—within the limitations imposed by a particular vessel.

The work of the ET is made easier when there is sufficient space to remove panels or chassis for adjustments and maintenance, and the electronic equipment spaces are well ventilated.

Equipments are installed on foundations or racks that are attached to the deck or bulkhead or a combination of both. Often it is necessary to make additional provisions for shock mounting the equipment. Adequate grounding should be made to the ship's structure according to the latest BuShips instruction.

EQUIPMENT FOUNDATIONS AND RACKS

Foundations and racks are constructed from appropriate metal shapes, and they are generally of all-welded construction. A rack using a combination of deck and bulkhead for support is illustrated in figure 5-21,A. A deck foundation is illustrated in part B.

Bulkheads that are inadequately stiffened or subjected to direct stresses and shocks caused by gun blasts, explosions, etc are not normally used to support electronic equipment containing vacuum tubes, relays, and geared mechanisms. Under these conditions these units are generally deck mounted or installed on suitable deck-mounted racks.

Adequate equipment-to-bulkhead clearance is necessary on all deck-mounted electronic equipment to provide space for shock-mount movement, ventilation, and servicing.

Tall and heavy units normally require that top foundations be used in addition to the regular deck foundations (fig. 5-22,A). A center-of-gravity mounting has four mounting points at diagonally opposite corners, and the plane of these points passes through or near the center of gravity of the unit, as illustrated in part B. When the equipment is low, a four-point bottom mounting (part C) may be adequate.

SHOCK MOUNTS

Shock mounts are used to protect equipment from the severe shock encountered in naval shipboard service. Most equipments are supplied with shock mounts by the manufacturer of the equipment, if required. There are several types of rubber shock mounts, but they all serve essentially the same function.

One type of shock mount, showing the method of grounding the equipment, is illustrated in figure 5-23.

In addition to the clearances required for the equipment, a clearance for the mount itself must be taken into consideration. The clearance in the direction perpendicular to the bolt axis should be at least equal to the thickness of the wall of rubber contained in the mount. Sufficient clearances around the equipment must be maintained so that motions due to shock do not cause the equipment to strike adjacent structures.

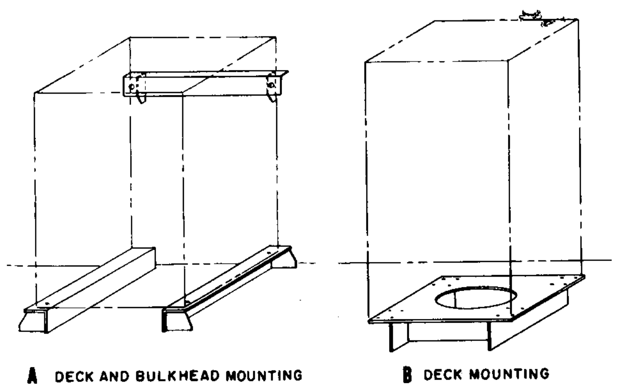

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Figure 5-21.—Deck and bulkhead foundations.

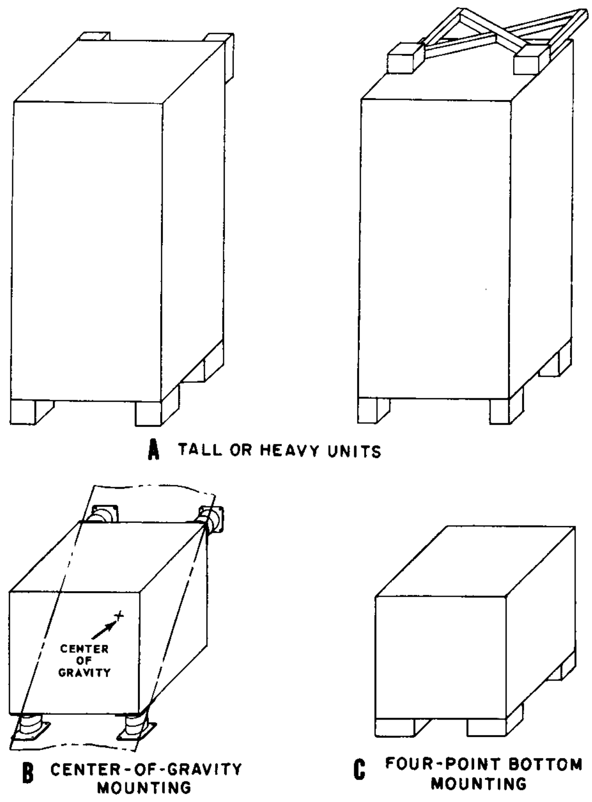

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Figure 5-22.—Unit installations.

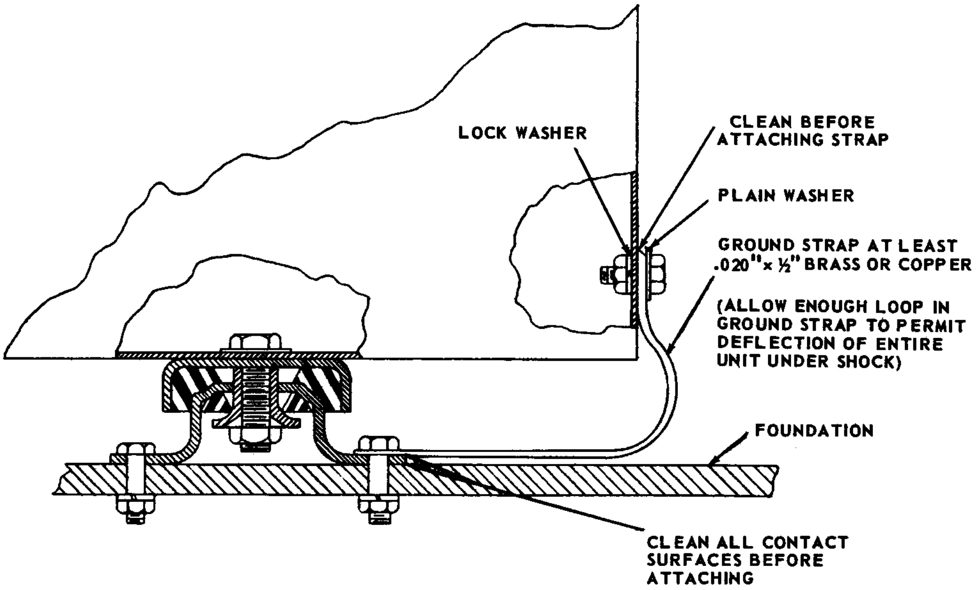

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Figure 5-23.—Shock mount and method of grounding the equipment.

GROUNDING ELECTRONIC EQUIPMENT

The proper grounding of electronic equipment is one of the most important steps in the installation procedure. During routine checks, tests should be made to ensure that all equipment is properly grounded.

All units of electronic equipment whose d-c resistance from case to ground exceeds 0.01 ohm (10 milliohms) are grounded by straps as follows:

1. On units requiring sound isolation, copper braid, not less than one-half inch wide is used.
2. On other units, not less than 0.020-inch by 1/2-inch sheet copper or brass is used.
3. The surfaces at the point of attachment of the straps are thoroughly cleaned to ensure metal-to-metal contact.
4. The straps are made as short as possible with only enough loop allowed to permit satisfactory deflection of shock or isolation mounts.
5. The strap connections are locked to prevent loosening from vibration.
6. Only one strap is used for each unit unless tests indicate more are needed.

Proper grounding is equally as important for shielded cables and other components as it is for electronic equipment.

TYPES OF CABLES

The various electrical and electronic systems aboard ship depend on power supplied by the ship's service generators. This power is distributed to the equipment by a system of cables. Power cables are normally installed by shipyard forces, but the ET should know the location and characteristics of the cabling, which supplies the electronics equipment.

He should become familiar with the current-carrying capacity of cables; their insulation strength; and their ability to withstand heat, cold, dryness, bending, crushing, vibration, twisting, and shock. Several types of cables are used in the applications under discussion, with design characteristics suited to their location and purpose.

Type SGA (Shipboard, General use, Armored) cables are designed to have a minimum diameter and weight consistent with service requirements in fixed wireways on naval ships. This type supersedes the older, widely used type HFA (Heat and Flame resistant, Armored) cable.

Type SSGA cable (fig. 5-24) consists of stranded copper conductors (in this case, only one conductor—indicated by the "S" before SGA) insulated with silicone rubber and glass fibers around which is placed an impervious sheath. The sheath is covered with braided metal armor, and then a coat of paint is applied.

The SGA cables are designated as follows: (1) SSGA, single conductor; (2) DSGA, twin (double) conductor; (3) TSGA, three conductor; and (4) FSGA, four conductor.

The HFA cables (also composed of stranded copper conductors) are designated as follows: (1) SHFA, single conductor; (2) DHFA, twin (double) conductor; (3) THFA, three conductor; (4) FHFA, four conductor; and (5) MHFA, multiconductor.

Twisted-pair telephone cables are designated as TTHFWA.

Many applications aboard ship require cables that can be bent and twisted again and again without damaging the conductor insulation or the protective covering. For such applications, flexible cables are used.

Flexible cables have synthetic rubber or synthetic resin insulation and a flexible sheath that is resistant to water, oil, heat, and flame. However, these cables are not as heat and flame resistant as armored HFA and SGA cables. Flexible cables for general use are designated by the letters, HOF—for example, DHOF, THOF, and FHOF. Flexible cables for limited use are designated by the letters COP—for example, DCOP, TCOP, and FCOP.

Other types of cables used in electronics work are:

1. DRHLA—Double conductor, radio, high-tension, lead armored.
2. FHFTA—Four conductor, heat and flame resistant, thin-walled armor.
3. MCSP—Multiple conductor, shielded, pressure resistant (submarine applications).
4. TTRSA—Twisted-pair telephone, radio shielded, armored (characteristic impedance approximately 76 ohms).

Designation of Conductor Size

Generally, when the size of the individual conductors contained in the cable is indicated in the cable designation, the numeral (or numerals) following the letter designation indicate the approximate cross-sectional area of the individual conductors in thousands of circular mils to the nearest thousands. For example, TSGA-60 is a 3-conductor armored cable for general shipboard use, with each conductor having a cross-sectional area of 60,090 circular mils. However, when the numerals immediately following the letter designation indicate the number of conductors comprising the cable, the size of the individual conductors may be indicated by additional numerals enclosed in parenthesis. For example, MDGA-19(6) is a 19-conductor electrical power cable for shipboard nonflexing service, with each conductor having a cross-sectional area of 6,512 circular mils.

Multiple-Conductor Designations

Multiple-conductor cable types and class designations are followed by a number that indicates the number of conductors. For example, MSCA-30 is a heat and flame resistant armored cable with 30 conductors.

For telephone cable, the number indicates twisted pairs. For example, TTHFWA-25 means that the cable contains 25 twisted pairs; TTRSA-4 means that the cable contains 4 pairs individually shielded.

Tagging Cables

Ship's cables are identified by metal tags (fig. 5-25) that give information about the cable. Permanently installed ships' cables are tagged as close as practicable to each point of connection, on both sides of decks, bulkheads, and other barriers. Cables located within a single compartment in such a manner that they can be readily traced are not tagged. Past practice was to use colored tags to classify vital, semivital, and nonvital cables. This practice

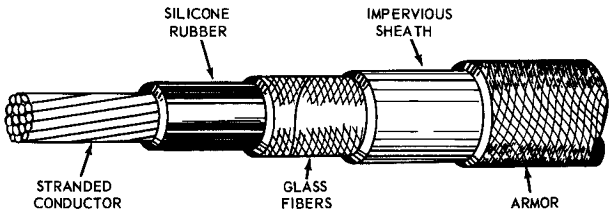

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Figure 5-24.—SSGA cable.

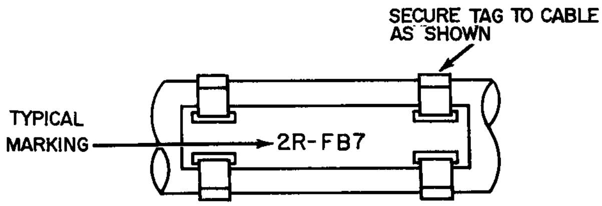

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Figure 5-25.—Cable tag.

has been discontinued, however colored tags will still be found on some ships.

Power and lighting cables are tagged as specified in article 60-270 of the Bureau of Ships Technical Manual. Cables between units of electronic equipment are tagged with electronics designations (table 5-4). For example, in figure 5-25, the 2R-ES indicates the second surface search radar circuit on the ship, R indicates electronics, ES indicates a surface-search radar circuit, and 7 indicates cable number 7 of the surface search radar. Electronics Information Bulletin #578 contains additional information concerning electronics designations.

SELECTION AND INSTALLATION OF POWER CABLES

The ET 3 will, in all probability, not be called upon to select and install power cables. However, he should have some knowledge of the power cables in the electronics spaces. There are at least five items that must be considered when power cables are installed. They are (1) the maximum connected load in amperes, (2) the possible added load due to future installations, (3) the demand factor (that is, the average demand in amperes over a 15-minute interval divided by the total connected load in amperes), (4) the cable service rating (the physical characteristics required for a given type of service), and (5) the maximum allowable voltage drop in the part of the circuit under consideration.

The current-carrying capacity and voltage-drop limitations determine the cable size for a particular application. The current capacity is dependent upon the type and size of the conductor, the permissible temperature rise, and the physical characteristics of the space in which the cable is installed. The allowable voltage drop depends on the type of load connected to the circuit.

All connections to cables are made in standard appliances and fittings; splice connections are not made. However, cable splices are permitted as an emergency repair (by ship's force), and on a limited basis (by repair activities) where it has been determined that time and replacement cost is excessive, and existing cable is in good condition. Cables entering watertight equipment are brought into the equipment through stuffing tubes. Stuffing tubes are also used where cables pass through decks and watertight bulkheads. Cables passing through decks are protected from mechanical injury by kick-pipes or riser boxes.

Table 5-4.—Electronics Circuit or System Designations.

Circuit or system designation	Circuit or system title
R-A	Meteorological
R-B	Beacons
R-C	Countermeasures
R-D	Data
R-E	Radar
R-F	Fire control radar
R-G	Electronic guidance remote control or remote telemetering.
R-H	CW passive tracking
R-I	IFF equipment
R-K	Precision timing
R-L	Automatic vectoring
R-M	Missile support
R-N	Infrared equipment
R-P	Special purpose
R-R	Radio communication
R-S	Sonar
R-T	Television

Two types of stuffing tubes are illustrated in figure 5-26. The type shown in part A is designed to be installed in the wall of an electrical appliance or fitting to permit the insertion of an electric cable. The cable is

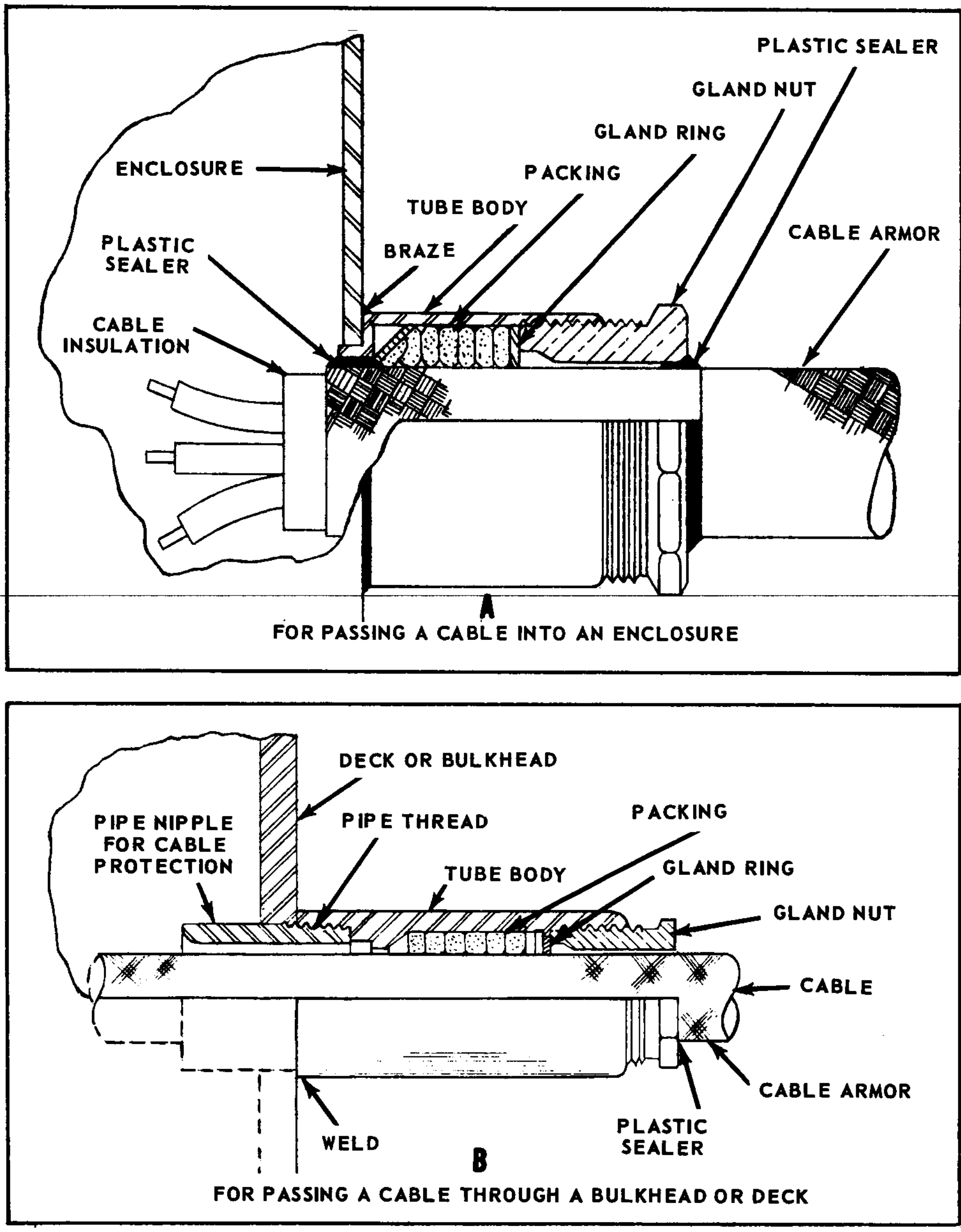

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Figure 5-26.—Types of stuffing tubes.

terminated in the appliance. The type shown in part B is designed to be installed in a deck, bulkhead, or hull to permit an electric cable to be passed through the structure. The cable is not terminated after passing through the tube but continues to some distant point.

Both types of stuffing tubes are forms of packing glands and serve a common purpose in preventing the passage of liquids and gases at the point of cable entrance.

A kickpipe is a pipe used to pass cables through decks wherever cable protection from mechanical injury is needed. A kickpipe assembly is illustrated in figure 5-27. The minimum length of a kickpipe is nine inches and the maximum length depends on the requirements. If the length of the kickpipe is over twelve inches, the top is secured by a brace.

More recently, nylon stuffing tubes have been developed by the Bureau of Ships. These stuffing tubes are extremely durable and are used where practicable.

Specific information on the installation of stuffing tubes and kickpipes is included in chapter 8 of the Electronic Installation Practices Manual, NavShips 900,171.

CONSTRUCTION AND INSTALLATION OF R-F CABLES

R-f cables may look like power cables, but they require special handling and careful installation. These cables are vital to the proper operation of all electronic equipment and therefore must be installed and maintained with the greatest care.

Construction

Flexible radio-frequency transmission lines (coax) are two-conductor cables, one conductor of which is concentrically contained within the other, as illustrated in figure 5-28. Both conductors are essential for efficient operation of the transmission line. The proper connectors and terminations are also necessary for efficient operation of the line.

The inner conductor may be either solid or stranded and may be made of unplated copper, tinned copper, or silver-plated copper. Special alloys may be used for special cables.

The dielectric insulating material is usually polyethylene or teflon, although neoprene or other rubber-like materials are occasionally used for pulse cables. (Pulse cables carry d-c pulses that may have relatively high voltages during a relatively short pulse time.)

Braided copper is usually used for the outer conductor; it may be tinned, silver plated, or bare. The outer conductor is chosen to give the best electrical qualities consistent with maximum flexibility.

The protective insulating jacket is usually a synthetic plastic material (vinyl resin). Neoprene rubber is generally used on pulse cable; silicone rubber jackets are used for high-temperature applications.

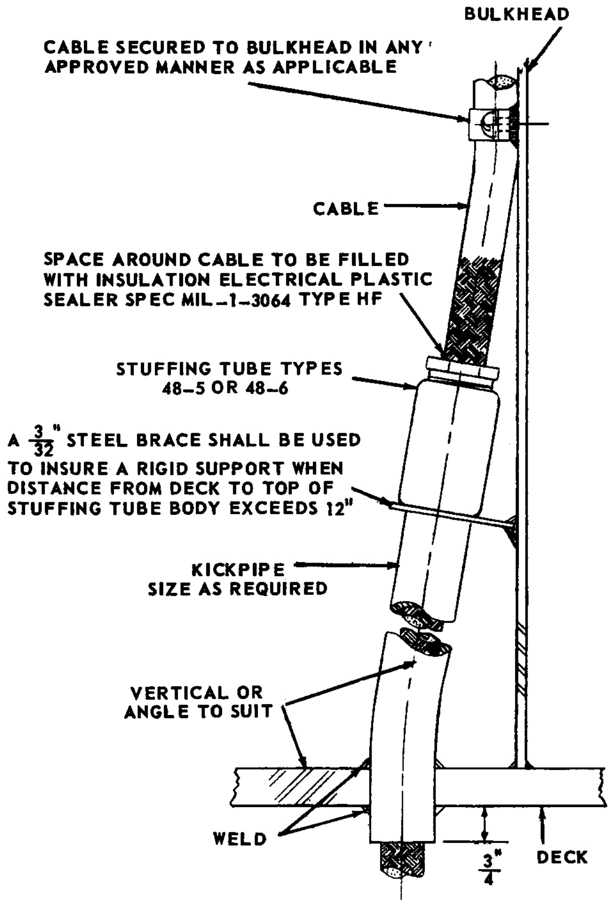

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Figure 5-27.—Kickpipe assembly.

Armor is needed for protection. It may be braided aluminum, or sometimes galvanized steel, similar to that used on power cables.

Polyethylene is a gray, translucent material. Although it is tough under general usage, it will flow when subjected to heavy pressure for a period of time. Two possible effects of bad installations are illustrated in figure 5-29.

Teflon is a white opaque plastic material. This material will withstand high temperatures and will remain flexible at relatively low temperatures. It has a peculiar quality in that nothing will stick to it and it is unaffected by the usual solvents.

Synthetic rubber (neoprene) is black and very flexible. It has high power loss at high frequencies and therefore is not used in cables carrying r-f energy. However, it is used for

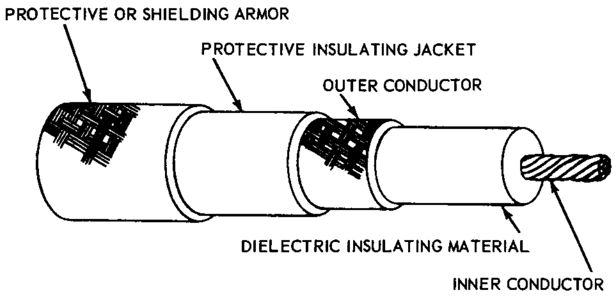

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Figure 5-28.—Construction of flexible r-f transmission line.

transmitting high-voltage d-c pulses. Because of its flexibility and ability to "stick" to metals, it forms very tightly around the conductors and minimizes corona (high-voltage breakdown of the air surrounding a conductor).

Location and Length of Cable Runs

When possible, cables are run along different well separated paths to reduce the probability of battle damage to several cables simultaneously. Wherever possible, high-temperature locations are avoided. Pulse cables are run separately, when possible, to reduce coupling and interference.

Because attenuation (power loss) in a line increases with its length, cables are kept as short as practicable, consistent with avoiding high-temperature locations, sharp bends, and strain on the cable.

If the equipment is shock mounted, enough slack in the cable is allowed to permit unrestricted motion of the equipment. The cable may be wrapped with friction tape for a distance of three or four inches from a point under the last cable clamp in the direction of the equipment. This eases the bending of the cable at the point and reduces the possibility of cable deformation because of constant vibration.

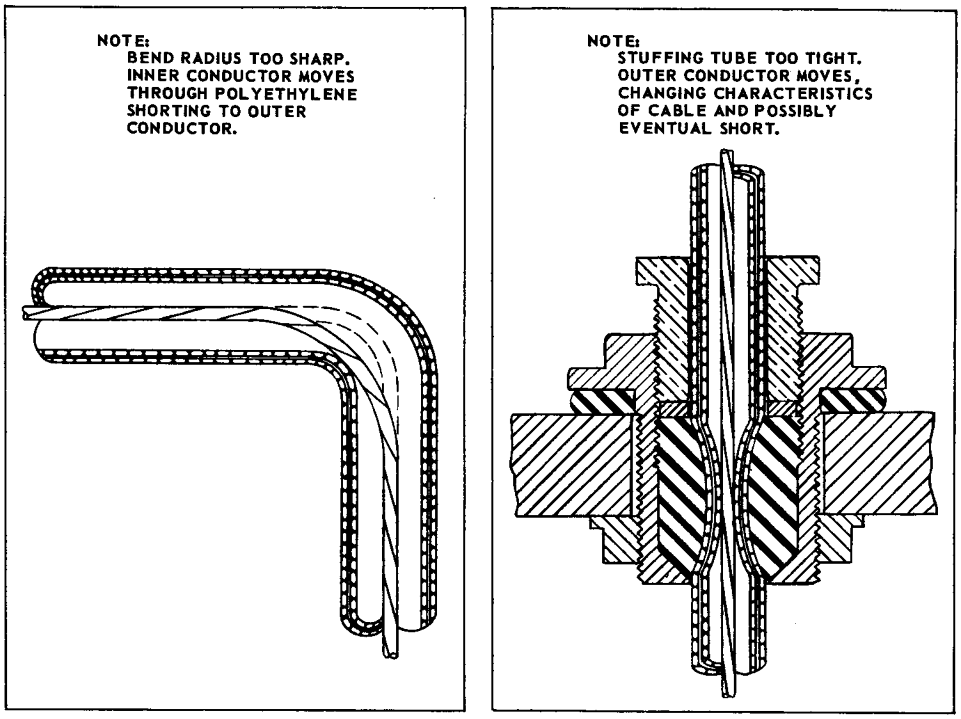

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Figure 5-29.—Effects of bad installations.

When cables are connected to equipment that slides out for maintenance, extra slack is provided.

Installing the Cables

Flexible cables are flexible only in the sense that they will assume a relatively long bend radius. They are not intended to be stretched, compressed, or twisted; and they are installed with this in mind. Bends are made as large as practicable, the minimum radius of bend being 10 times the diamater of the cable.

The number of connectors are generally kept to a minimum to reduce line losses and maintenance problems.

Fabricated straps are used for holding the cables. They are snug, but not too tight. Back straps (which keep the cable away from a surface) are used in making cable runs along masts or in compartments that are subject to sweating. In more recent installations semicontour straps and cable bands are used for certain applications.

The exact methods of installing cables are included in the Electronics Installation Practices Manual, NavShips 900,171.

In addition, the Cable Comparison Guide, NavShips 250-660-23, contains information pertaining to all types of electric shipboard cable.

RIGID R-F TRANSMISSION LINES

Rigid r-f transmission lines include waveguides (rigid and flexible), bead-supported coax (teflon and steatite), stub-supported coax, and pyrotenax cable.

Rigid waveguides may be round or rectangular in shape; however, the use of round waveguides is limited to special applications, such as rotating joints. Rectangular waveguides are widely used in radar applications. Waveguides are generally designated by size. Table 5-5 lists some of the more common sizes.

Flexible waveguides have greater power loss than rigid waveguides, and therefore the flexible type is seldom used except where there is considerable vibration.

Bead-supported coax was used on early radar equipment installations and is still necessary in certain types of installations.

Stub supported coax was more widely used on early radar equipment installations; and short runs are still found in late equipments, usually within the antenna pedestal.

Pyrotenax coax r-f cables have a solid copper inner conductor, a seamless copper outer conductor, and a tightly packed powdered magnesium oxide dielectric. They are fireproof and pressure proof, and are designed for installations where these properties are important.

The proper type and size of waveguide is determined by the equipment designer, and no change is made without the approval of the Bureau of Ships.

Many factors are considered when a waveguide is installed. However, two of the most important considerations are: (1) the range of the equipment depends on the height of the antenna and (2) a great deal of energy is lost when the length of the waveguide is increased by a small amount (over one-half of the power may be lost in a 50-ft run).

The method of installation is equally important. For example, sharp bends, dents, and foreign materials in the guide will cause serious attenuation of the signal.

From these considerations it may be seen that there is an optimum height beyond which additional waveguide length will defeat its own purpose.

Rigid r-f transmission lines are discussed in detail in chapter 11 EIPM-NavShips 900171.

Table 5-5.—Commonly Used Sizes Of Rigid Waveguides.

Size (inches)	Radar Band	Frequency Band
6 1/2 x 3 1/4	L	UHF
3 x 1 1/2	S	UHF/SHF
1 1/4 x 5/8	X	SHF
1 x 1/2	X (small)	SHF
5/8 x 5/16	K	SHF/EHF

ANTENNA SYSTEMS

One of the most important functions performed aboard ship is that of communicating with other ships or stations; and one of the most important links in a communication chain is the antenna system. The following paragraphs are included to give the prospective ET 3 information about shipboard antennas and antenna transmission lines.

Wire Antennas

The whip and dipole antenna assemblies are greatly supplementing the wire antenna for shipboard installations. The wire antenna is used on many installations, often as an emergency antenna, as well as for special fan antennas which have broad band characteristics.

Antenna wire is usually a stranded, bare, phosphor or silicon-bronze wire. For transmitting, a 5/16-inch diameter wire is commonly used; and a 1/8-inch diameter wire is commonly used for receiving. The wire is continuous from the entrance insulator to the far end. Good installation practice requires that it be free from splices, kinks, sharp bends, deformed spots, and broken strands. The length depends on the frequency that is being transmitted, the space that is available, and other considerations.

In addition to the necessary wire, an antenna installation requires such items as supporting insulators, turnbuckles, clamps, shackles, safety links, staples, and pad eyes.

A wire antenna installation is illustrated in figure 5-30. The methods of installing antennas are included in Shipboard Antenna Details, NavShips 900121 (revised).

Whip Antennas

Whip antennas give a neater topside appearance and on carriers they are a practical necessity as the hazard to aircraft is reduced by use of the tilting types. Whip antennas have become increasingly important to shipboard installations due to the use of antenna tuners and couplers. There are also special types of whip antennas, such as the dual-frequency discage, and the top-loaded stub discone which provide broad band characteristics for use with multicouplers.

Because whip antennas are essentially self-supporting, they may be installed in many locations aboard ship either horizontally or vertically. They may be deck mounted or mounted on brackets on the stacks, superstructure, etc. If

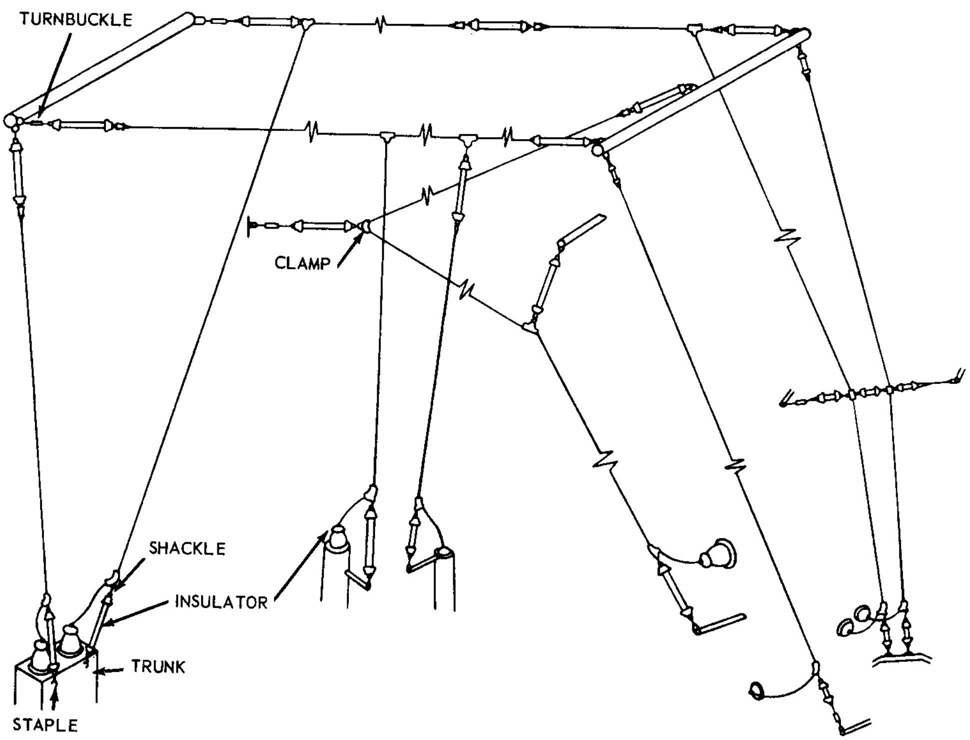

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Figure 5-30.—Wire antenna installations.

the stack is used, the outer casing will usually have to be reinforced to support the added weight and stress. When the whip antenna is installed on a stack, it is usually mounted near the top and approximately 24 inches away from the stack. In all installations of whip antennas, allowance is made for swaying of the whip. The whip is mounted in a clear space where it cannot strike other objects.

Whip antennas that are used for receiving only are mounted away from the transmitting antennas so that a minimum of energy from the transmitter will be picked up.

The preferred method of mounting whip antennas on shipboard is shown in figure 5-31.

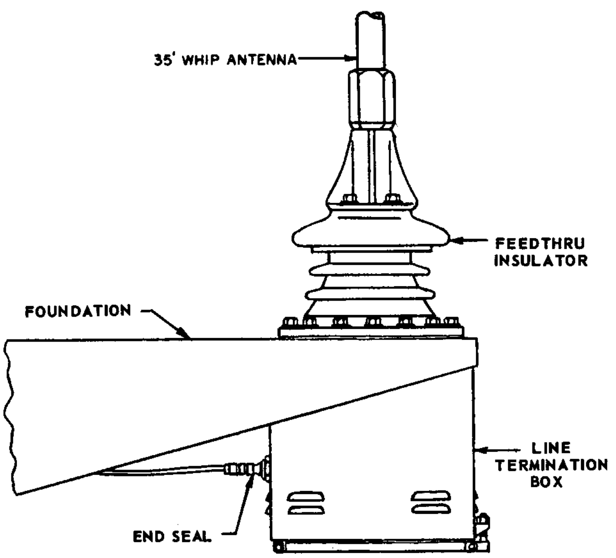
VHF and UHF Antennas

The physical size of antenna elements decreases as the frequency increases. Antennas that operate in the VHF (30-300 mc) and UHF (300-3000 mc) frequency ranges are relatively small in size. Because line-of-sight communication is used in the VHF-UHF ranges, high power is not necessary. Receiver signal strength then depends upon antenna height and the distance from the transmitter.

In these frequency ranges, it is important that both the transmitting and receiving antennas have the same polarization. The Navy employs vertical polarization in the VHF-UHF ranges.

Vertical conductors such as masts, rigging, and cables in the vicinity of UHF antennas will cause unwanted directivity. For this reason, these antennas are mounted as high and as much in the clear as possible.

Figure 5-32 shows two types of shipboard antennas operating in the VHF-UHF frequency range. Usually, either a vertical quarter-wave stub with a ground plane (part A) or a vertical half-wave dipole (part B) is used. The ground



F ure 5-31.—Method of mounting a whip antenna.

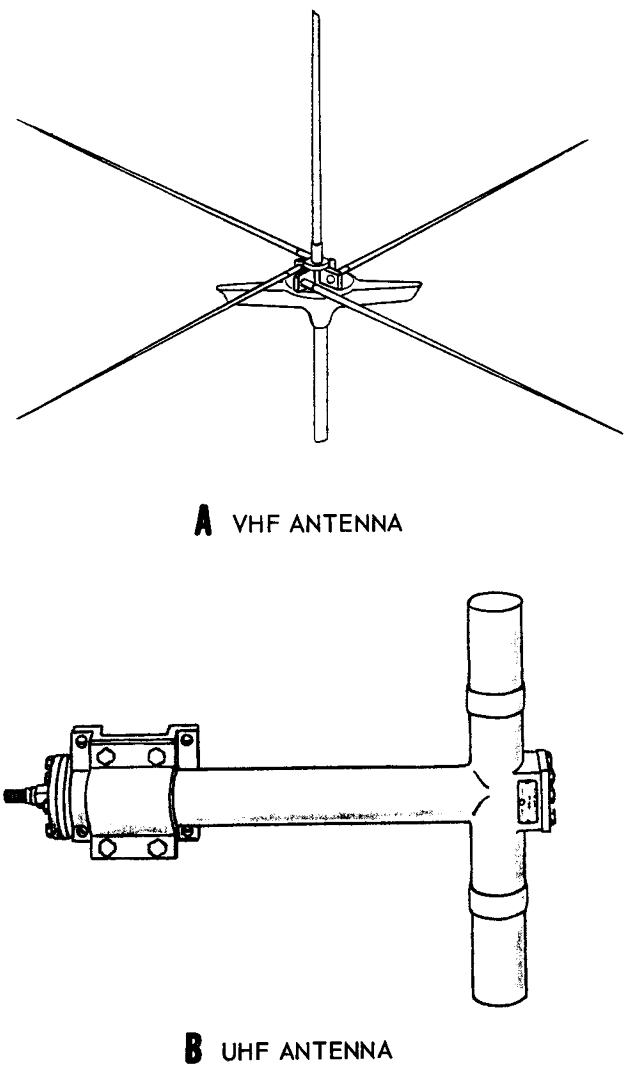


Figure 5-32.—Types of VHF and UHF shipboard antennas.

plane prevents the metallic support mast from acting as a radiating portion of the antenna. It establishes the ground level at the base of the antenna.

Microwave Antennas

Parabolic-shaped reflectors are generally used to direct microwaves in the desired direction and in the required pattern.

Figure 5-33 illustrates that the energy from a radiating element placed at the focal point of a parabolic reflecting surface will be reflected into a narrow beam. Two types of parabolic reflectors used for microwave operation are shown in figures 5-34 and 5-35. (Other types—for example, the parabolic cylinder and the paraboloid—are used in aircraft; the paraboloid is also used aboard ship in fire control radars.) These reflectors are usually fabricated from solid metal or metal screening. In most instances these reflectors are placed on rotatable mounts.

The transmission lines used at microwave frequencies are coaxial lines or waveguides, using either a front- or a rear-feed system. In a front-feed system the waveguide or coaxial line approaches the reflector from the front and directs the spray of r-f energy into the reflector. In a rear-feed system the coaxial line or waveguide projects through the reflector from the rear, and an additional parasitic reflector is placed in front of the radiating element to direct the energy back toward the parabolic reflector.

RECEIVING-ANTENNA DISTRIBUTION SYSTEMS

Various types of shipboard receiver-antenna distribution systems are in use. Some systems are for small vessels and special applications

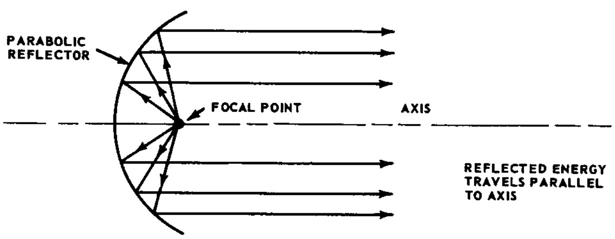


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Figure 5-33.—Principles of parabolic reflection.

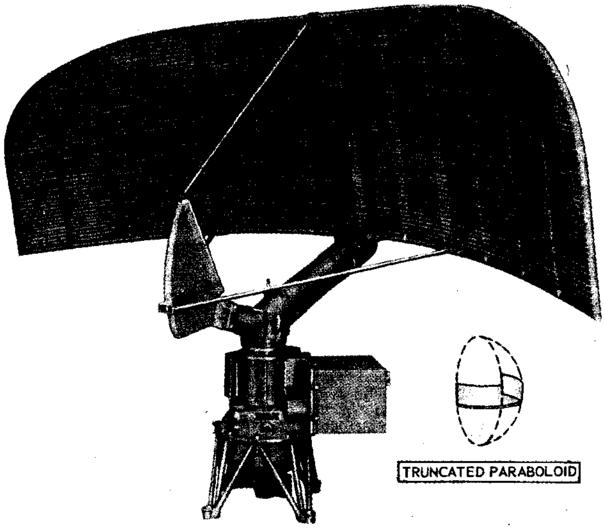

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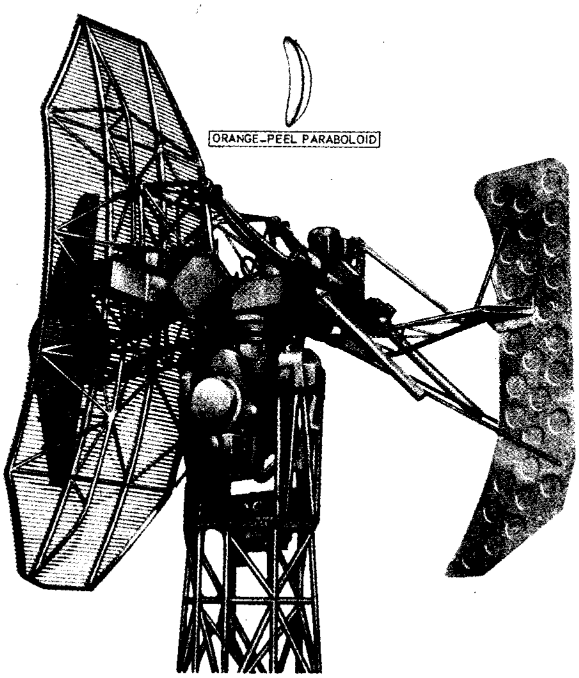
Figure 5-34.—Antenna installation utilizing the truncated paraboloid.



70.26

Figure 5-35.—Antenna installation utilizing the orange-peel paraboloid.

only. Antenna transfer panels or more recently filter assemblies (multicouplers) have replaced the older systems utilizing terminal boxes.

These transfer panels (fig. 5-36) provide means for operating as many as four radio receivers simultaneously into one antenna. At the transfer panel, each antenna is connected to a row of four jacks. One jack is connected directly to the antenna; the other three jacks are connected in parallel through 600-ohm decoupling resistors. The receivers connected to the three decoupled jacks will operate at a reduced efficiency.

Operation of many receivers from a single antenna is possible utilizing the antenna filter assembly (fig. 5-37). These systems are discussed in more detail in chapter 8.

TRANSMITTING ANTENNAS AND TRANSMISSION LINES

In general, radio transmitting and receiving antennas are similar except that in the case of transmitting antennas much larger amounts of r-f power are handled. Because transmitting antennas present a hazard to personnel, the transmitting antenna installation is planned with the safety of the personnel in mind. For the proper safety precautions to be taken when work is done on antennas or transmission lines, see chapter 2 of this training course. See also United States Navy Safety Precautions, OpNav 34P1, and chapter 67 of Bureau of Ships Manual. For additional information, see General Installation Specifications For Shipboard Radio Transmitting Antenna Systems, RE 66A430.

In shipboard radio transmitting systems, both openwire and whip antennas are used. In older ships the transmission line for the antenna consists of a copper bus enclosed in an antenna trunk for use with high-power transmitters. Coaxial cable may also be used for the transmission line between the transmitter and its antenna, and has become the preferred method of connecting an antenna to its transmitter.

The term "trunkline" is applied today to those coaxial cables which interconnect internal antenna panels.

It is necessary to minimize the power losses in the transmission line if most of the power from the transmitter is to be radiated from the antenna. Matched impedances are maintained as closely as practicable in the antenna system to avoid high voltage-standing-wave ratios. In

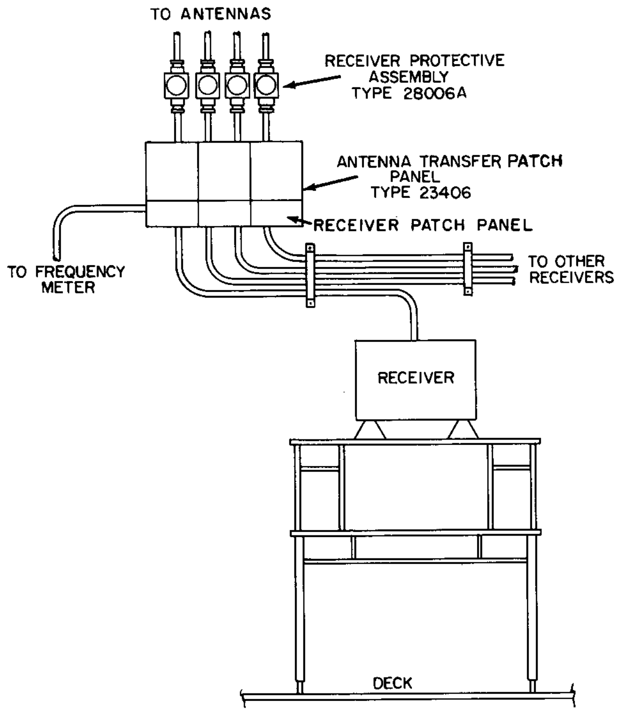


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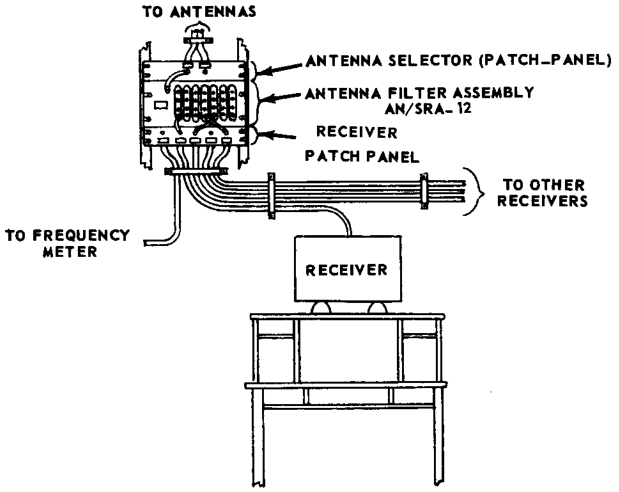
Figure 5-36.—Receiving antenna distribution system using transfer panel.



1.51.2
Figure 5-37.—Receiving antenna distribution system using filter assembly.

general, all r-f transmission lines should be as short as possible.

A transmitting wire antenna trunkline assembly that can still be found in older installations is illustrated in figure 5-38. The purpose of the trunk is to carry energy from the transmitter to the wire antenna with minimum loss, minimum interference, and maximum safety.

The disconnect switch has three positions: GROUND, CLOSED, and OPEN. The switch has a shield, or blanking-off plate, which is inserted into the trunk section of the switch between the switch mechanism and the bus leading to the transmitter. An interlock prevents the shield from being inserted into the slide except when the switch is in the GROUND position. This prevents closing the switch again before the shield has been removed.

The Transmitting Antenna Transfer Patch Panel (fig. 5-39) is manufactured in Shipyards and provides efficient use of transmitting antennas. It also provides protection to the associated transmitters. The antennas are permanently connected to the panel, either through HF multicouplers or directly, along with the transmitters. A patching facility provides combinations of antenna and transmitter connections. The connections are made in some panels at jacks which contain transmitter-enabling microswitches. If a coaxial connection is not fully completed at the patch panel, the transmitter concerned will not radiate because the microswitch has not operated. This prevents arcing at the coaxial plug and damage to the transmitter.

MULTICOUPLERS

Because of the increasing number of communications equipments required aboard naval vessels, it has bacome difficult to find suitable locations for the necessary additional antennas. One approach to the problem has been the use of multicouplers. These devices permit the simultaneous operation of a number of transmitters and/or receivers into a single antenna. Thus, the number of antennas can be reduced without sacrificing any of the required communications channels. This arrangement permits maximum use of the best available antenna locations and reduces the intercoupling between antennas.

Much research and development is being done on multicouplers, and various types have been designed to cover different frequency ranges and to operate with either receivers or transmitters or both. Filter-type multicouplers are described in detail in chapter 8 of this training course.

VHF-UHF Multicouplers

One type of VHF-UHF multicoupler (the CU-255/UR) is shown in figure 5-40. When six units are used (as shown), a system is provided for operating six transmitters (and/or receivers) into a single antenna. One coupler is required for each transmitter or receiver, or transmitter-receiver combination. The frequency range of this particular equipment is 230 to 390 mc.

These couplers can be tuned manually to any frequency in this range. When used with automatic tuning transmitter equipment they may be tuned automatically to any one of 10 preset channels in this band by dialing the desired channel locally on the transmitter or on a remote channel selector.

This coupler consists of two major components: the coupling cavity, or r-f section, and the automatic-drive mechanism.

The r-f section is essentially an impedance-matching device. It is capable of transforming antenna loads ranging from 50 to 125 ohms into 50 ohms at the r-f feedline terminal. This results in maximum power transfer to or from the antenna system.

Correct adjustment of the tuning controls is indicated by the meter on the front panel of the unit. This meter indicates the output from the reflectometer, which is a device for indicating the magnitude of the power reflected back from the coupling circuit. When the controls are adjusted so that the tuning indicator reads zero, the system impedances are properly matched and there is minimum reflected power in the system.

This multicoupler is designed to be mounted vertically on a bulkhead or other solid support on small ships. Space limitations, however, may dictate other arrangements. In some cases, the couplers may be mounted horizontally overhead. This position, however, is inconvenient from the point of view of tuning.

A typical TED-AN/URR-13/35 installation employing multicouplers (CU-332A/UR) is illustrated in figure 5-41. One coupler unit is required for each transmitter or receiver, or transmitter-receiver combination.

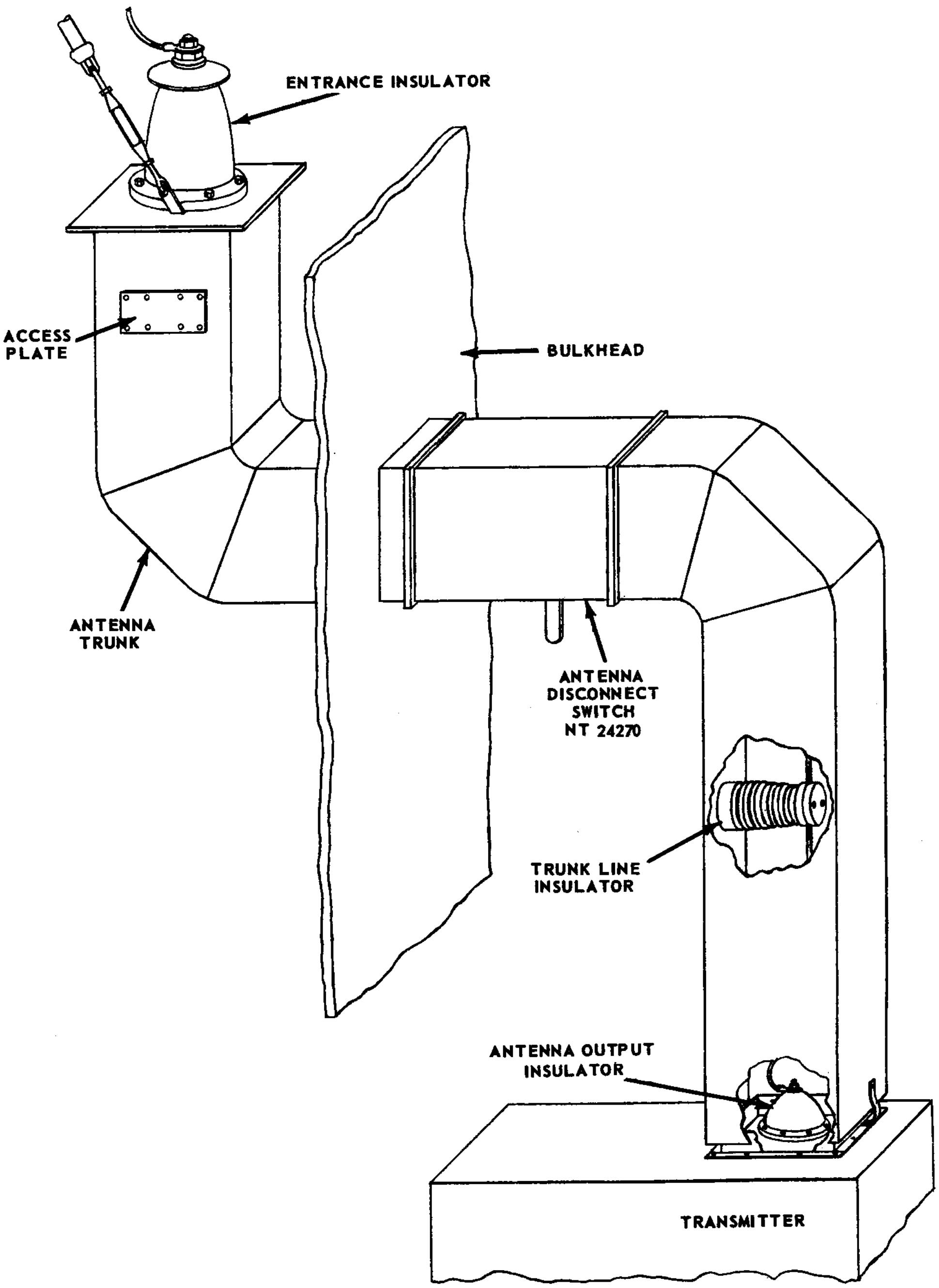


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Figure 5-38.—Transmitting wire antenna trunkline assembly.

The CU-332A/UR multicoupler is identical to the CU-255/UR multicoupler previously described except for the drive mechanism. The CU-332A/UR provides for manual tuning only; whereas, the other has both automatic and manual tuning.

The CU-332A/UR coupler is used with manually tuned UHF equipment, such as the Model

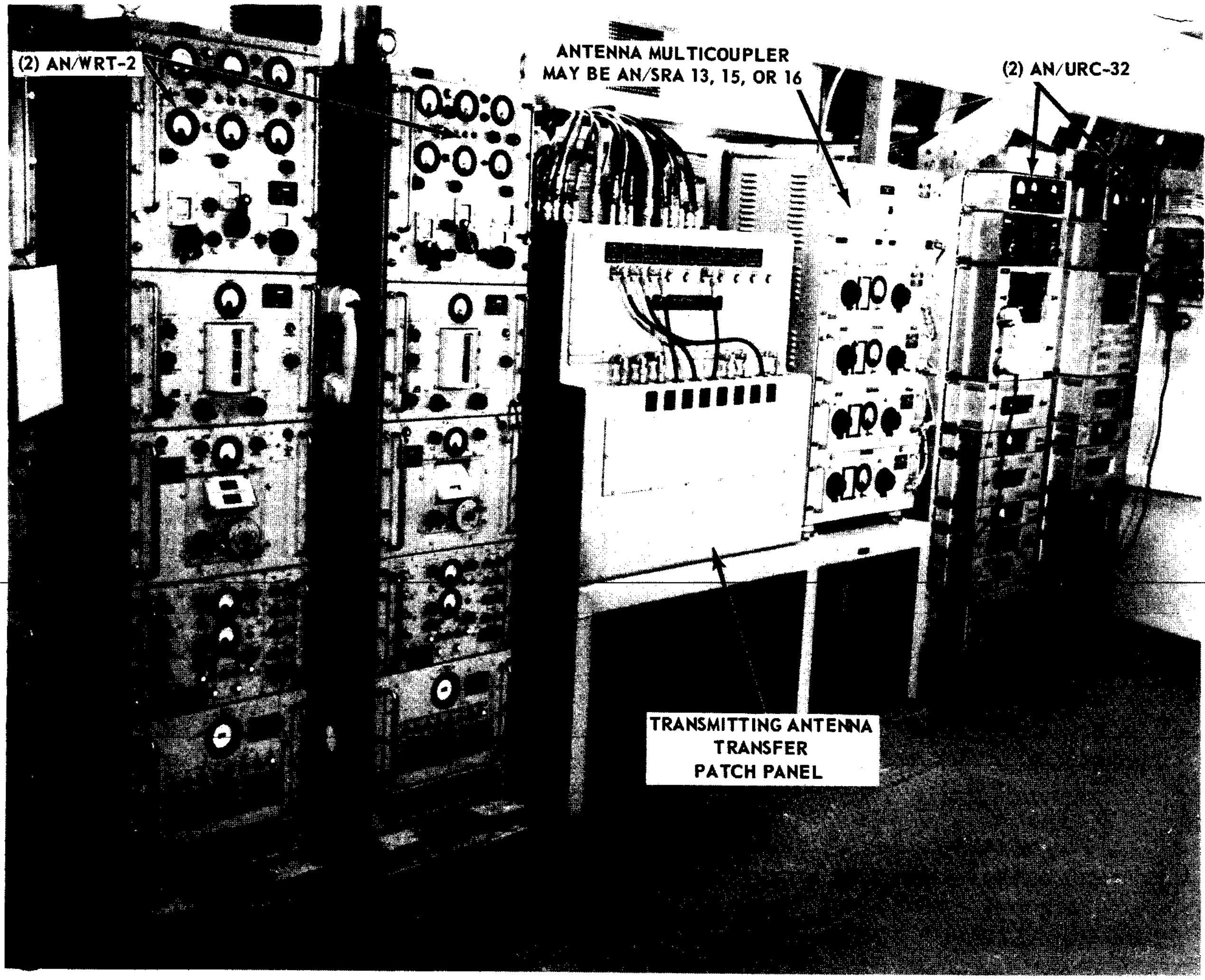

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Figure 5-39.—Transmitting antenna transfer patch panel and associated equipment.

TED transmitter and the AN/URR-13/35 receiver, or any other manually tuned equipment operating in the 230- to 390-mc frequency range.

HF Multicouplers

A system of h-f antenna couplers has been developed for simultaneously operating up to four transmitters into the same antenna in the frequency range of 2 to 26 mc. These antenna couplers are made up into four channel groups, each group operating in one of the following bands: 2-6 mc, 4-12 mc, 6-18 mc, and 9-26 mc. To obtain complete coverage from 2 to 26 mc, four coupler groups and four broad-band antennas are required.

The four types of h-f couplers are the AN/SRA-13, 14, 15, and 16. The AN/SRA-15 coupler (fig. 5-42) which is typical of this group of couplers, provides for the simultaneous operation of four 500 w. transmitting equipments into a single broad-band antenna.

It covers the frequency range from 6 to 18 mc and will operate into any antenna having a standing wave ratio (relative to 50 ohms) of 3 to 1 or better. The four transmitters connected

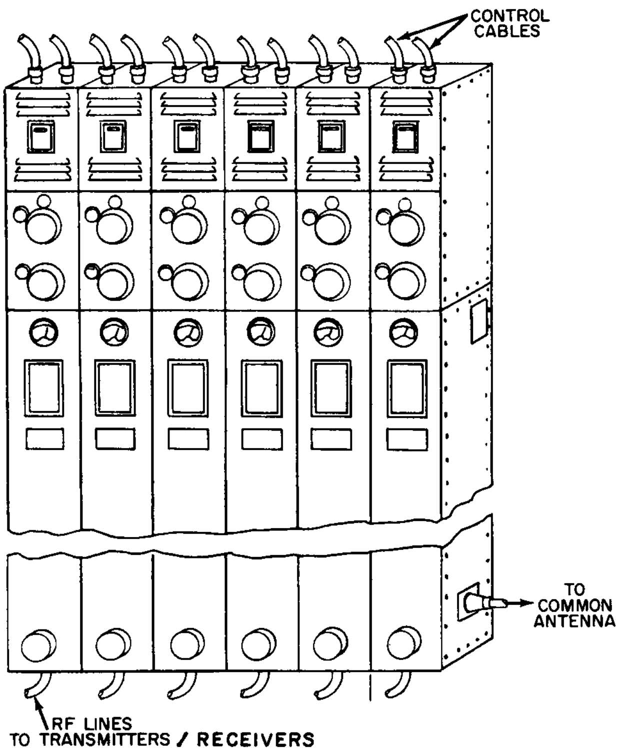

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Figure 5-40.—VHF-UHF multicoupler (CU-255/UR).

to this coupler may be operated anywhere in the frequency range from 6 to 18 mc provided there is sufficient separation between the operating frequencies.

FILTERS

Modern electronic receiving equipments are being made with greater sensitivities, and this has increased the problem of radio interference generated by electromechanical devices such as motors, generators, relays, etc. Likewise, the interactions between the various equipments can cause major interference problems.

Good installation practices will reduce or perhaps eliminate radio interference, but a filter may be needed to reduce certain types of interference to a tolerable level.

The major sources of radio interference are summarized as follows:

1. ATMOSPHERIC NOISE—caused by lightning. The reduction of this noise is accomplished by the use of noise limiters and f-m.

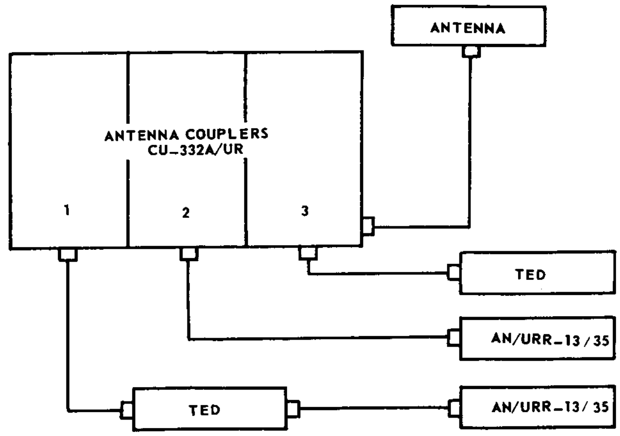

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Figure 5-41.—TED and AN/URR-13/35 installation employing a multicoupler.

2. PRECIPITATION STATIC—a problem chiefly in aircraft caused by static discharges and corona on snow, dust, rain, etc. It is identified by a frying sound. Special measures are needed for its reduction or elimination. On surface ships proper grounding of equipments and mast structures will generally reduce this type of disturbance.
3. BACKGROUND NOISE—due largely to shot effect (bombardment of the tube elements by irregularly spaced bunches of electrons), thermal noise (agitation of electrons in resistances because of heat), and microphonic noise (generally due to vibration of electron-tube elements).
4. COSMIC NOISE—the result of radiations from space. It is fast becoming a limiting factor in the design of more sensitive receivers.
5. MAN-MADE NOISE—may be generated by a variety of sources. These sources include rotating electrical machinery, ignition systems, relays, pulse-type equipment (for example, radars), interaction between equipments, diathermy, induction heating and welding equipment, hum pick-up at power or audio frequencies, and systems employing ionization of gas vapors.

Another type of interference that must be dealt with is that caused by operating several receivers from one antenna, as in MULTICOUPLER INSTALLATIONS. Various combinations of filters are used to feed the appropriate frequencies to the various receivers.

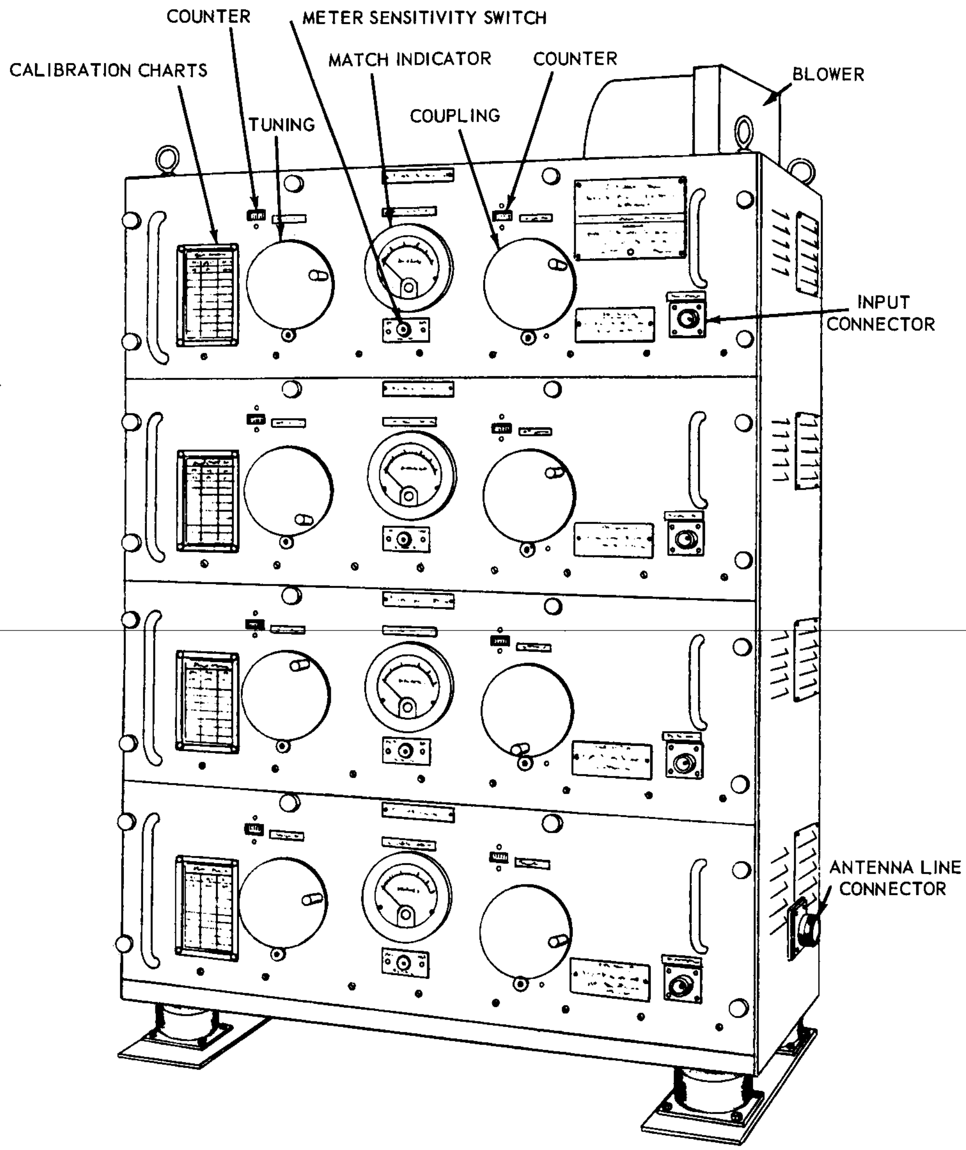

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Figure 5-42.—Antenna multicoupler AN/SRA-15.

Signal or noise interference may be transferred from one circuit to another by several means. They include:

1. CAPACITIVE or ELECTROSTATIC coupling in which one circuit is linked to another by means of a capacitance that is common to both. This is especially true at radio frequencies.

2. INDUCTIVE or ELECTROMAGNETIC coupling in which a conductor is present in the electromagnetic field set up by the noise interference. This type is the hardest to isolate.

3. DIRECT RADIATION, which involves essentially the same principle as radiation from a transmitting antenna to a receiving antenna.

4. CONDUCTION ALONG LINES, (conductive coupling) which is the tranfer of r-f energy along a conductor. It is this flow of signal or noise energy that is coupled by the methods

mentioned above and can be reduced or eliminated by the use of a filter or filter network at the noise source (fig. 5-43).

Types of Filters

ATTENUATION is the amount that the signal or noise voltage is reduced in a filter. It is measured in decibels (db). Decibels are discussed in Basic Electronics, NavPers 10087 (revised).

PASS BAND is the frequency range over which the filter passes signals with minimum attenuation (fig. 5-44).

STOP BAND is the frequency range over which the filter attenuates the applied signal.

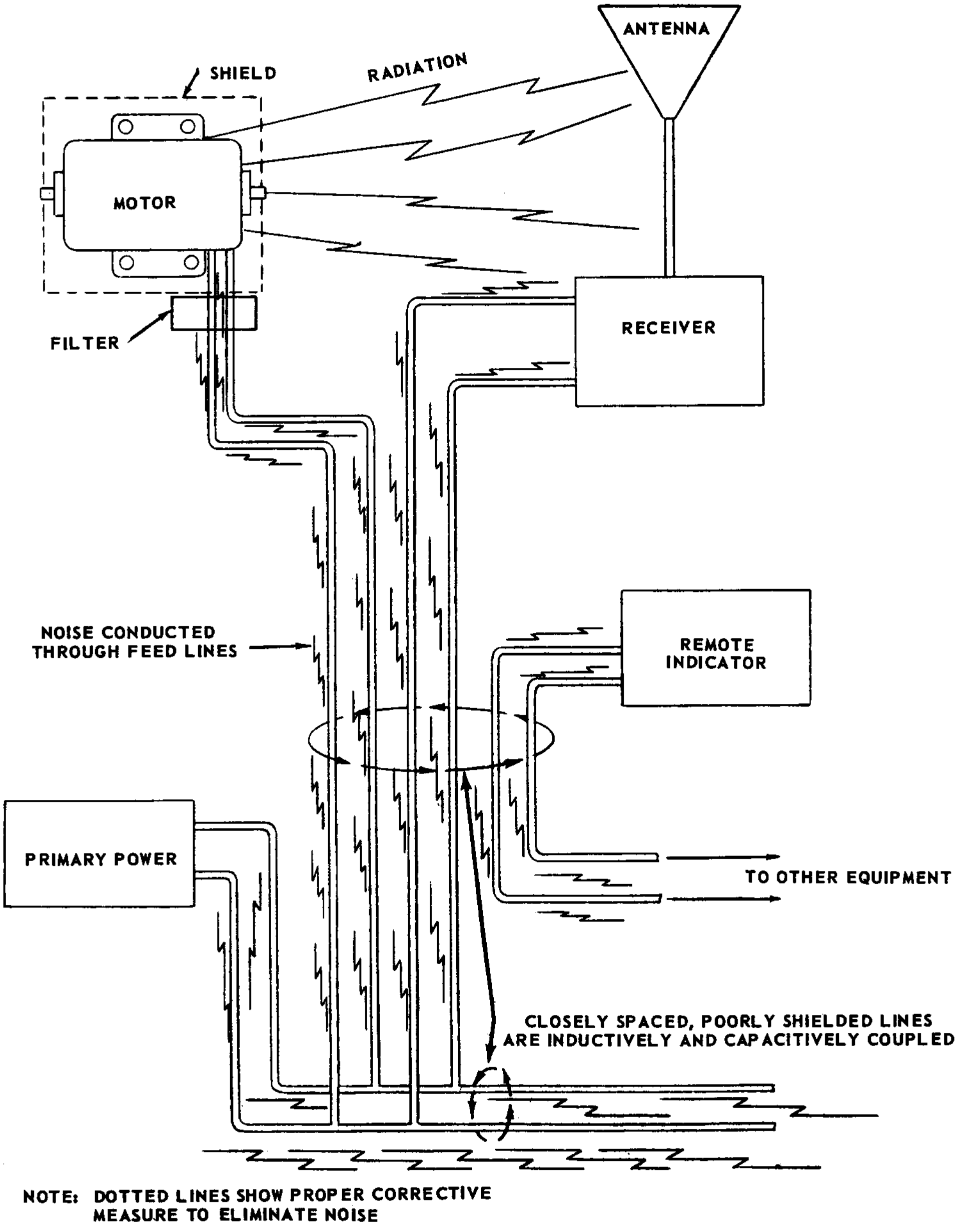

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Figure 5-43.—Radio noise coupling showing position of filter for noise elimination.

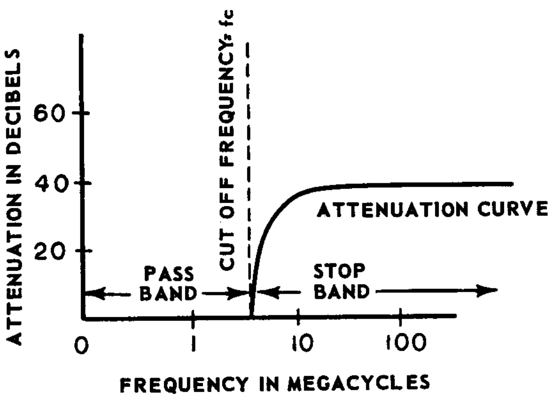

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Figure 5-44.—Illustration of the terms used in filters.

CUTOFF FREQUENCY is the frequency at which the filter changes from a pass-band to a stop-band filter or vice versa.

GROUND means the equipment frame, the chassis, shielding, filter housing, etc; it is an important part of the circuit.

LOW-PASS FILTER.—The low-pass filter passes all frequencies from zero frequency (fig. 5-45 A) (dc) up to the cutoff frequency (fc). All power lead filters fall in this class. For example, if it is desirable to pass 60-cycle power and to attenuate noise frequencies above (for example) 150 kc, a low-pass filter having a cutoff frequency of approximately 50 kc, may be used.

HIGH-PASS FILTER.—The high-pass filter attenuates all frequencies from zero frequency to the cutoff frequency and passes all frequencies above the cutoff frequency (fig. 5-45 B).

BAND-PASS FILTER.—This filter passes all frequencies within a specified range and attenuates all other frequencies (fig. 5-45C). Band-pass filters have special applications and are seldom used for noise elimination. One form of band-pass filter is the crystal filter used in communications receivers.

BAND ELIMINATION FILTER.—This filter attenuates a band of frequencies and passes all other frequencies (fig. 5-45D). It is most commonly used as a simple wave trap or absorption filter. Several wave traps are used in a television receiver.

Schematic diagrams of low-pass and high-pass filters are shown in figure 5-46.

Location and Installation of Filters

Filtering is done at the noise source whenever practicable. This eliminates or reduces interference caused by the noise source. It may be impracticable to filter at the source in the following cases:

1. When the source is an antenna that interferes with other antennas under operating conditions.
2. When the source feeds many multiconductor cables and a filter would be required on every cable.
3. When the source is poorly shielded.

Three types of power-line filters are shown in figure 5-47. Filters may be mounted on bulkheads or on equipments.

The method of mounting a filter so that a bulkhead, chassis, or equipment case acts as an isolating shield between the input and output of the filter is referred to as bulkhead mounting (fig. 5-48). Very often, filters that are to be used in a component piece of equipment are designed for this type of mounting. This same principle may be applied to filters enclosed in a box mounted on the side of the equipment. It does not lend itself to watertight installations because the space through which the leads pass into the equipment cannot be effectively sealed.

Filters mounted on machines or other noise sources are illustrated in figure 5-49.

A good r-f connection is exceedingly important in filter installations regardless of whether it is a joint, a grounding surface, or a shield contact. Clean continuous r-f surfaces must be maintained throughout the installation. This means that all painted surfaces, at the point where electrical connections are made, must be cleaned to the bare metal.

Low-pass filters are used on many radio receivers—for example, the AN/SRR 11, 12, 13 and the AN/URR-35 (fig. 5-50).

The schematic diagram of this filter is shown in figure 5-51. The filter allows the necessary connections into and out of the rear of the receiver, but eliminates unwanted signals from passing through the lines. There are three main circuits through the filter: the antenna lead the a-c power lead, and the audio output lead.

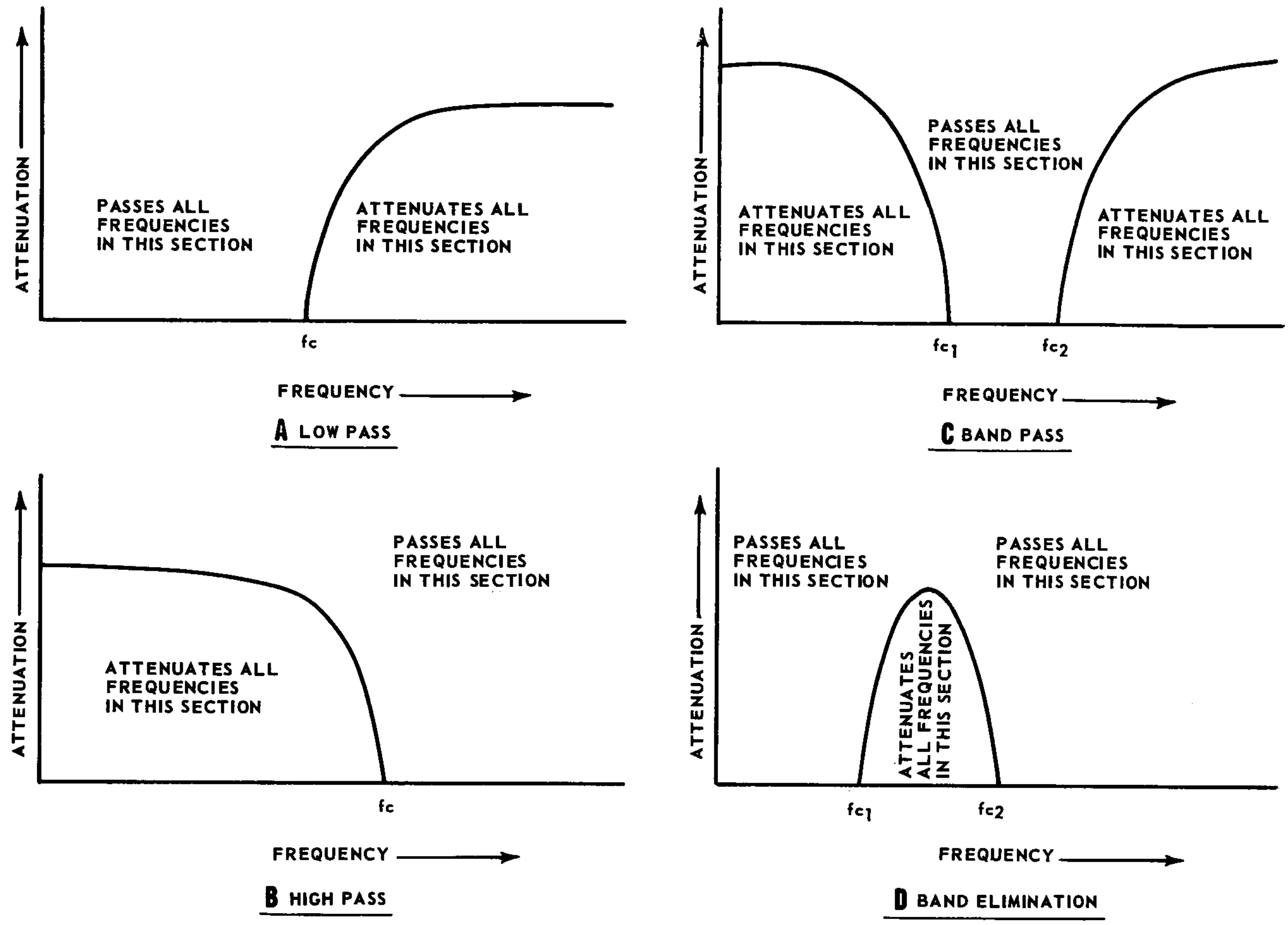

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Figure 5-45.—Filter response curves.

R-f signals from an antenna are brought through a coaxial lead and connected to the antenna jack. They pass through the low-pass filter to the r-f amplifier unit.

Power for the receiver is connected to the power jack. The two-section, r-f filter eliminates any r-f energy that may tend to come in through the power lines. After passing through the filter, the power is fed to the receiver through terminals 70 and 71.

The audio signal from the receiver output transformer is connected through terminals 68 and 69 to the low-pass filter. The audio signals then pass through the two-section filter to the audio output (to speakers, etc). The filter allows the audio signals to pass through, but prevents any feeding back of r-f signals through the audio lines from outside the receiver.

Chapter 21 of EIPM, NavShips 900,171, contains additional information concerning filters.

POWER SYSTEM FOR ELECTRONIC EQUIPMENT

The power distribution system connects the generators of electric power to the equipments that use it. Built into the system are devices that protect the generators, the equipments that use the power, and the system itself from certain types of damage.

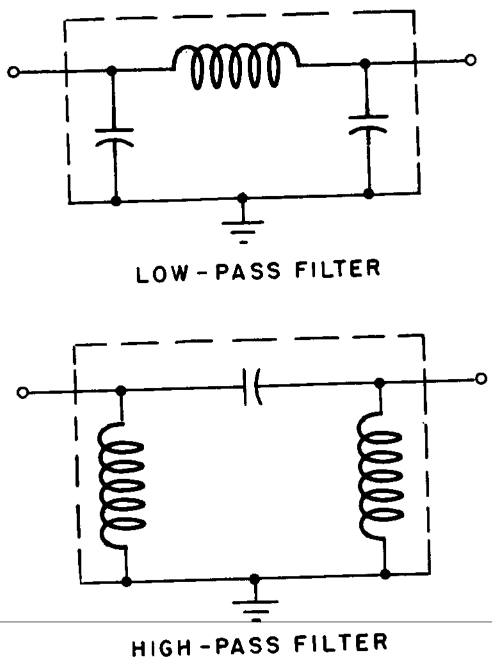

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Figure 5-46.—Low-pass and high-pass filters.

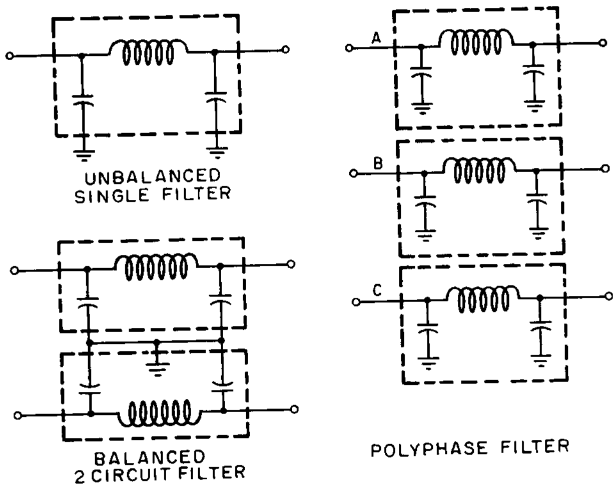

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Figure 5-47.—Types of power line filters.

A comprehensive distribution system includes the following:

1. SHIP'S SERVICE DISTRIBUTION SYSTEM includes the ship's service generators and the ship's service distribution system. It is the normal source of electric power.

2. EMERGENCY DISTRIBUTION SYSTEM includes at least one emergency generator and the emergency distribution system. An emergency system is installed on most ships to supply a limited amount of power for the operation of vital equipment when the ship's service system is incapacitated.

3. CASUALTY POWER DISTRIBUTION SYSTEM is installed on many ships to make temporary electrical connections if both the ship's service and the emergency distribution systems are damaged.

At least two independent sources of power are provided for selected vital loads (for example, steering, I. C. and F. C. switchboards, and ordnance equipment). This is done by means of a normal and an alternate ship's service feeder; or a normal ship's service feeder and an emergency feeder; or, in some cases, both normal and alternate ship's service feeders plus an emergency feeder.

Normal and alternate feeders run from different ship's service switchboards and are spaced as far apart as feasible to minimize the possibility that both will be damaged by a single hit.

Motor-Generator Sets

Motor-generator sets are used to change an available type of power to a desired type of power. The change may be from d-c to a-c, a-c to d-c, from one frequency to another, one voltage to another, or a combination of these.

Each motor-generator set consists of a driving motor and one, or sometimes two, generators. A coupling is provided to connect the motor and the generator mechanically together. In most motor-generator sets the stationary components of all the machines are rigidly coupled together on a mounting bed to maintain proper alignment (fig. 5-52).

In electronic applications, the motor-generator sets (when used) are usually designed to supply power to one particular equipment.

The Amplidyne

The amplidyne is a specially constructed d-c generator having a large ratio between

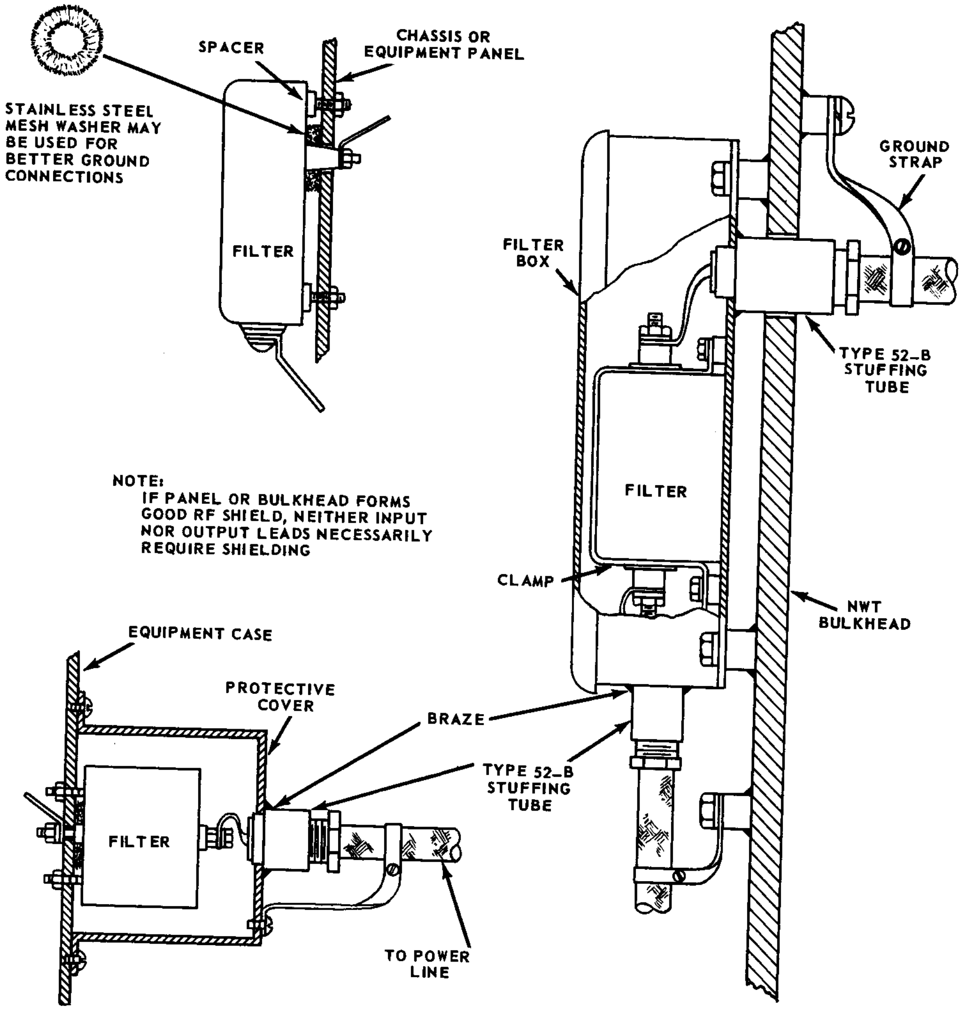

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Figure 5-48.—Installations using bulkhead mountings.

field excitation (control power) and output power. Special windings are utilized in such a way that any change in control field strength causes a corresponding change (greatly amplified) in the armature output. Amplidyne motor-generators are used extensively in servo-systems. A remote control signal is fed to the amplidyne control field and is amplified in the armature output. The output furnishes power to a d-c motor that may make a gun or antenna move in the direction and speed required by the remote signal. The amplidyne group used with the AN/SPS-8 radar is shown in figure 5-53.

Each of the five amplidyne motor generators weighs about 160 pounds. They are supplied with 450-volt, three-phase current. The top generator produces the 425-volt, d-c (B+) needed by the equipment; the others provide 250-volt, d-c power for the roll, pitch, scan, and train motors.

Amplidynes are also used as voltage regulators and exciters for a-c generators, and in turboelectric propulsion systems.

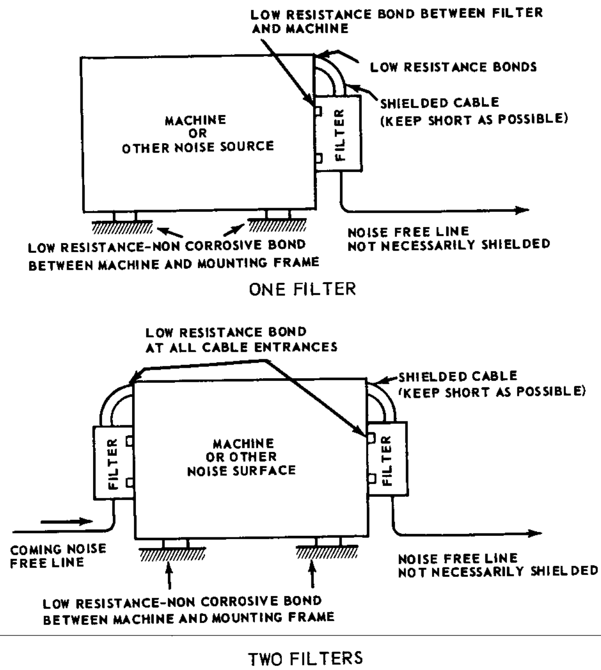

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Figure 5-49.—Low-pass filter on a machine or other noise sources.

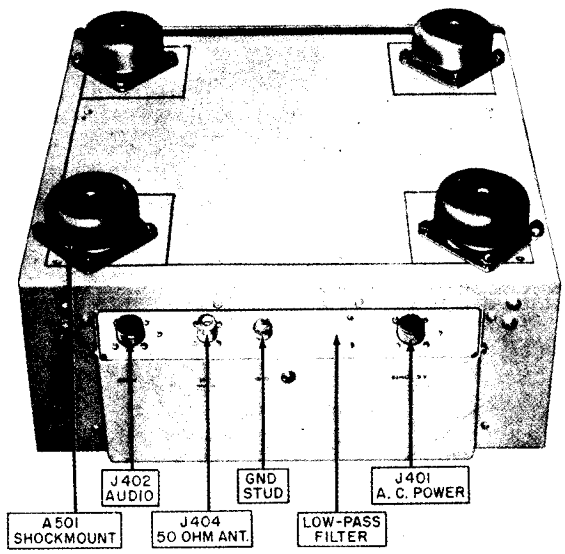

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Figure 5-50.—Low-pass filter used with the AN/URR-35 radio receiver.

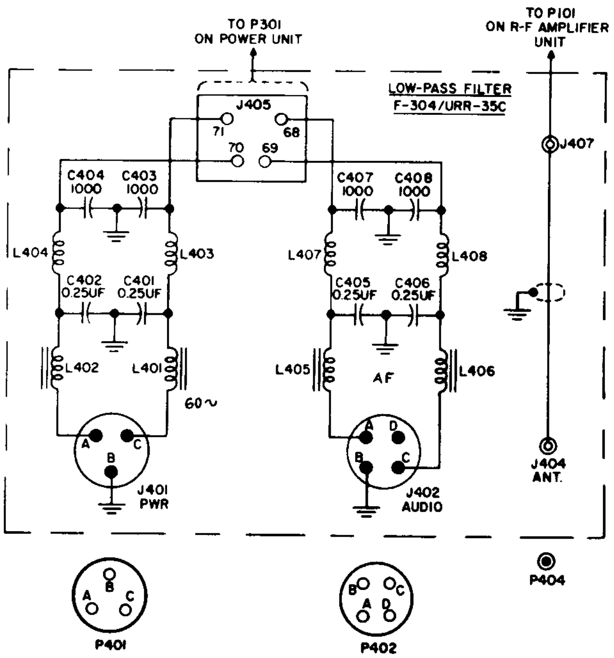

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Figure 5-51.—Schematic diagram of the low-pass filter used with the AN/URR-35 radio receiver.

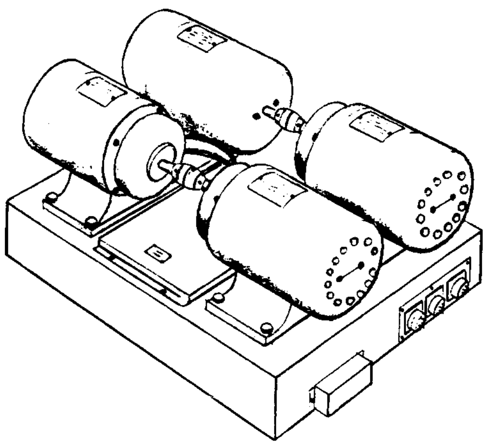

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Figure 5-52.—Motor-generator sets used for electronics equipment.

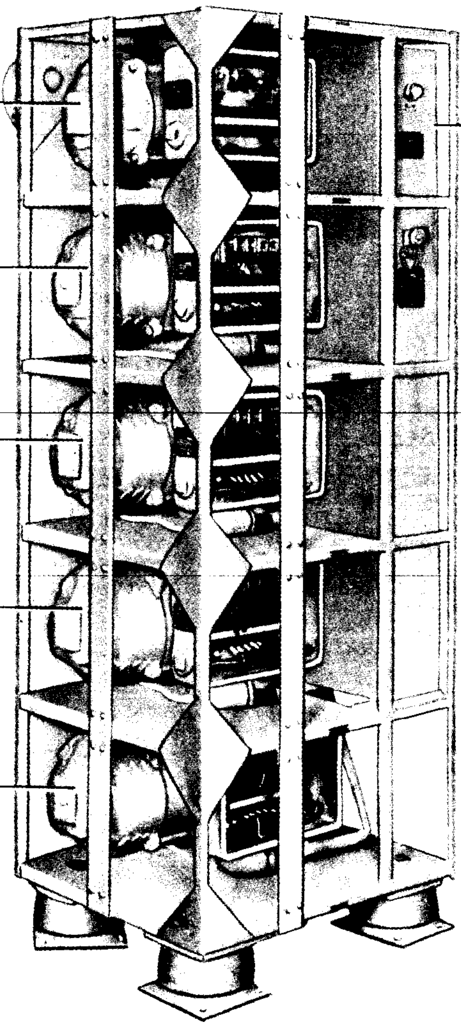

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Figure 5-53.—Motor-generator (amplidyne) group used with the AN/SPS-8 radar.