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ABSTRACT

Fundamentals of major electronic equipments on board ships are presented in this text prepared for naval officers in general. Basic radio principles are discussed in connection with various types of transmitters, receivers, antennas, couplers, transfer panels, remote-control units, frequency standard equipments, teletypewriters, and facsimile installations. Theoretical and practical analyses are made of radar and sonar equipments to show their capabilities and limitations. On the subject of electronic navigation, loran, shoran, omega, tacan, and satellite and ships' inertial navigation systems are presented. Also included are descriptions of digital computers, gun and missile weapon systems, direction finders, closed-circuit television sets, electronic countermeasures, communication console equipments, underwater telephones, intrared and meteorological setups, carrier control approach systems, radiac instruments, and target control installations. Illustrations for explanation purposes and a glossary of general terms are included. (CC)

SHIPBOARD ELECTRONIC EQUIPMENTS

Prepared by

BUREAU OF NAVAL PERSONNEL

NAVPERS 10794-C

PREFACE

This text has been prepared to furnish naval officers who are not electronic specialists with an overview (1) of the fundamental concepts of major electronic equipments on board ships of the U.S. Navy, and (2) of the capabilities and limitations of the more common equipments installed in the categories of communications, radar, sonar, and navigational aids.

In view of the objectives of the text, technical details of circuits and of components of equipments have been kept to a minimum. Overall technical aspects of the systems have been covered in sufficient detail, however, so that students can acquire familiarity with the purposes, functions, and types of equipment.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

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

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

WE SERVE WITH HONOR

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

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

Our responsibilities sober us; our adversities strengthen us.

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

THE FUTURE OF THE NAVY

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

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

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

Never have our opportunities and our responsibilities been greater.

CONTENTS

CHAPTER 1

NOMENCLATURE AND GLOSSARY

As in any technical or specialist field, many of the special words, phrases, terms, and symbols used in electronics are unfamiliar to the average person. To assist you in following the material presented in the ensuing chapters, this chapter is devoted to a description of equipment indentification systems (nomenclature designations) and to a glossary of common electronic terms and symbols.

JOINT ELECTRONIC TYPE DESIGNATION SYSTEM

Electronic equipments and units are identified in the Joint Electronics Type Designation System (AN System) which is administered under the authority of the Armed Forces Supply Support Center.

The Electronic Type Designator System for electronic equipment is intended to:

1. Be logical in principle so that the nomenclature type numbers will be understood readily, and the operation of the armed services supply services will be facilitated.
2. Be flexible and sufficiently broad in scope to cover present types of equipment, as well as new types and uses of equipment that will be developed in the future.
3. Avoid conflict with nomenclature assigned at present to the equipment used by the Armed Services.
4. Furnish adequate identification on name plate with or without the name part of the nomenclature.
5. Provide a ready means of identifying equipment in correspondence and other types of communications.

The system is so designed that its indicators reveal at a glance many details that pertain to the item. For example, it tells whether the item is a SET or a UNIT, and such other information as where it is used, what type equipment it is, and what it is used for.

AN nomenclature consists of an approved name followed by the type number. For a complete set, the type number will consist of three indicator letters and an assigned number.

Using this system of identification, the installation type, the type of equipment, and the purpose of each equipment and unit can be readily determined. The derivation and meaning of the nomenclature for a representative equipment (Communications Central AN/SRC-16) is delineated in figure 1-1.

In the three letter group (fig. 1-1A and B) the first letter "S," designates the type of installation, i.e., "Water Surface (See table 1-1.)" The second letter "R" designates the type of equipment, in this case "Radio." The third letter "C" defines the purpose of the equipment as "Communications."

The number (type number) immediately following the three letter group identifies a particular equipment and includes all of its modifications as discussed below. The meaning of any three letter group can be similarly interpreted by referring to Table 1-1.

A modification letter is used to identify a set that has been modified, but which still retains the basic design and is functionally and electrically (power source is the same) interchangeable with the unmodified set (fig. 1-1A). When the AN/SRC-16 is modified, it becomes the AN/SRC-16A; the "A" indicates the first modification. The next modification would be the AN/SRC-16B, and so on.

The parenthesis ( ) as shown in figure 1-1A is used with the type number assignment to provide a broader identification than that provided by a type number alone. A series of sets or units may be identified by the use of one or more letters and/or numbers in the

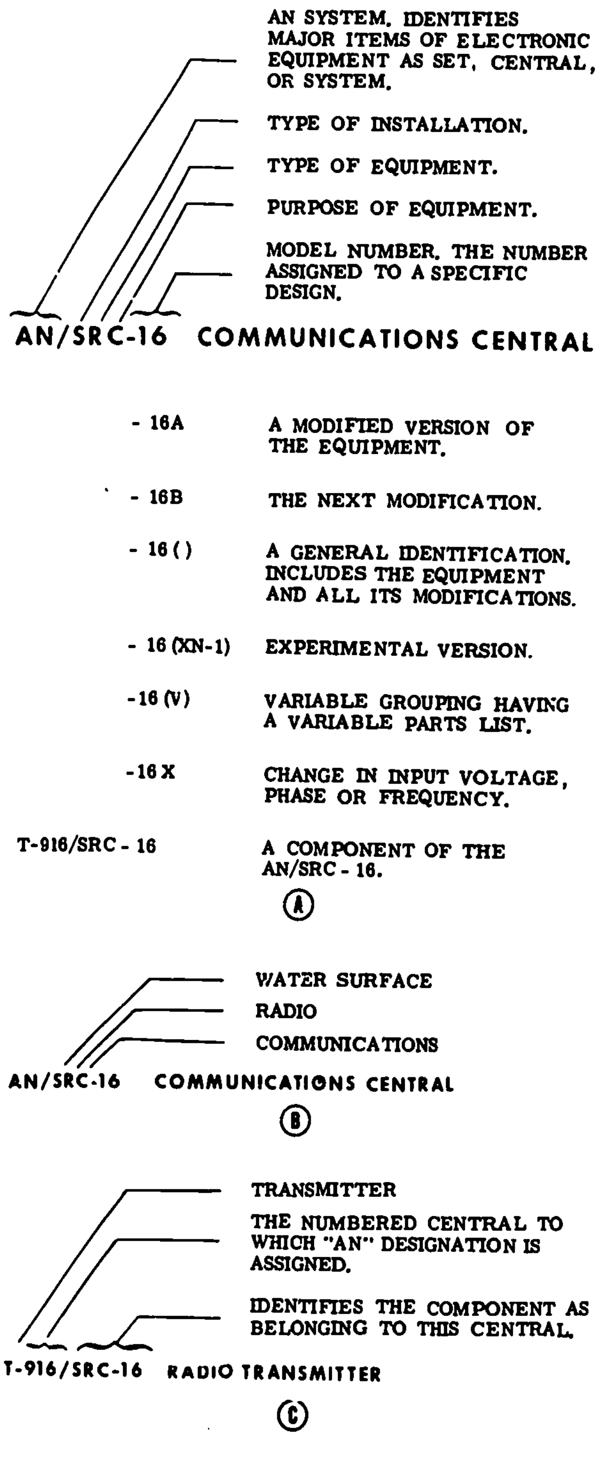

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Figure 1-1.—Joint Electronic Type Designation System for nomenclature AN/SRC-16 Communications Central.

parenthesis after the identifying number. For example, the AN/SRC-16 (XN-1) designates an experimental or special model. If the same basic design of an equipment is kept, but the input power is changed from 110 volts to 220 volts, the letter "X" is added to the nomenclature so that it becomes the AN/SRC-16X. The second power input change would be identified by the letter "Y". The letter (V) within the parenthesis is used to identify systems with varying parts lists. It indicates that a set utilizes or can utilize a variable grouping or selection of units thereby making possible optional installations.

The letter (T) is used for training sets. It is used in conjunction with the other indicators to show that it is a training set for a specific equipment. Likewise, it may be used to indicate a trainer for a special family of equipment. For example, the first training set for the AN/SRC-16 would be the AN/SRC-16T1.

COMPONENT IDENTIFICATION

So far, consideration has been given only to the indicators used in set nomenclature. Now, let's examine the indicators for major components of a set.

Components are identified by means of indicating letters, which tell the type of component it is; a number, which identifies the particular component; and, finally, the designation of the equipment of which it is a part or with which it is used.

The transmitter for the AN/SRC-16 for example, would be identified as shown in (fig. 1-1C).

A modification letter identifies a component that has been modified but still retains the basic design and is interchangeable physically, electrically, and mechanically with the modified item. Thus, the T-916(A)/SRC-16 would be a modified version of the T-916/SRC-16.

Components that are part of or used with two or more sets are identified in the usual way, except that only those indicators that are appropriate and without a set model number appear after the slant bar.

RADIO OPERATING POSITIONS AND REMOTES

Table 1-2 shows the alphabet for radio operating positions and remotes.

Table 1-1.—Table of Equipment Indicator Letters.

FIRST LETTER (DESIGNED INSTALLATION CLASSES)	SECOND LETTER (TYPE OF EQUIPMENT)	THIRD LETTER (PURPOSE)
A - Piloted aircraft	A - Invisible light, heat radiation	A - Auxiliary assemblies (not complete operating sets used with or part of two or more sets or sets series)
B - Underwater mobile, submarine	B - Pigeon (do not use)	B - Bombing
C - Air transportable (inactivated, do not use)	C - Carrier	C - Communications (receiving and transmitting)
D - Pilotless carrier	D - Radiac	D - Direction finder, reconnaissance, and/or surveillance
F - Fixed ground	E - Nupac	E - Ejection and/or release
G - General ground use	*F - Photographic	G - Fire-control, or searchlight directing
K - Amphibious	G - Telegraph or teletype	H - Recording and/or reproducing (graphic, meteorological and sound)
M - Ground, mobile	I - Interphone and public address	K - Computing
P - Portable	J - Electromechanical or inertial wire covered	L - Searchlight control (inactivated, use G)
S - Water surface	K - Telemetering	M - Maintenance and/or test assemblies (including tools)
T - Ground, transportable	L - Countermeasures	N - Navigational aids (including altimeters, beacons, compasses, racons, depth, sounding, approach, and landing)
U - General utility	M - Meteorological	P - Reproducing (inactivated, use H)
V - Ground, vehicular	N - Sound in air	Q - Special, or combination of purposes
W - Water surface and underwater combination	P - Radar	R - Receiving, passive detecting
	Q - Sonar and underwater sound	S - Detecting and/or range and bearing, search
	R - Radio	T - Transmitting
	S - Special types, magnetic, etc., or combinations of types	W - Automatic flight or remote control
	T - Telephone (wire)	X - Identification and recognition
	V - Visual and visible light	
	W - Armament (peculiar to armament, not otherwise covered)	
	X - Facsimile or television	
	Y - Data processing	

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Table 1-2.—Alphabet for Radio Operating Positions and Remotes.

Radio		Radio	
Alphabet	Position & Remotes	Alphabet	Position & Remotes
A	Audio	N	Channel
C	Control	O	Operating
D	Data	P	Position
E	Emergency	Q	Secure
F	Facsimile	R	Remote
G	Telegraph	S	Station
H	Radiophone	T	Teletype
J	Panel	U	Unit
L	Local	V	Supervisor
M	Monitor	X	Extension

Examples of position designations are:

LOP: Local Operating Position
LTP: Local Teletype Position
RHS: Remote Radiophone Station
RDP: Remote Data Position

GLOSSARY OF COMMON ELECTRONIC TERMS

You doubtless are familiar with some of the terms listed in this glossary. It is not expected, however, that you will know all of the terms used with operational electronics. Accordingly, a study of these terms should contribute to a better understanding of the information contained in this text.

3-M: Maintenance and Material Management. A planned maintenance system concept and application.

ACCELEROMETER: An inertial device. An instrument for sensing a change in velocity such as the increase in the speed of an object.

ADP: Automatic data processing: (See below)

AEW: Airborne early warning. A planned radar system between surface ship and aircraft for long-range detection and identification used near the periphery of a defended area.

AF: Audiofrequency. (See below)

AFTSRATT: Audiofrequency tone shift radioteletype. A radioteletype tone-modulated system similar to the familiar AM radio method of broadcasting. It replaces the term frequency shift keying.

ALIGN: To adjust the tuned circuits of a transmitter or receiver for proper signal response.

ALPHA PARTICLES: Positively charged particles (helium nucleus) having great ionizing power but very little penetrating power, and are dangerous to living tissue.

AM: Amplitude modulation: (See below)

AMBIENT NOISE: The overall noise energy from all environmental sources. In sonar it is the background noise inherent in the sea and collectively designated ambient noise.

AM COMPATABLE: Used in conjunction with SSB (single side band) where the amplitude modulated carrier wave and either the upper side band or the lower side band carries the intelligence.

AMMETER: An instrument for measuring the electron flow in amperes.

AMPERE: The basic unit of current flow; a current of 1 ampere will flow through a conductor having a resistance of 1 ohm when a potential of 1 volt is applied.

AMPLIFICATION: The process of increasing the strength (voltage, current, or power of a signal).

AMPLIFICATION FACTOR (μ): The ratio of a small change in plate voltage to a small change in grid voltage, with all other electrode voltage constant, required to produce the same small change in plate current.

AMPLIFIER: A device for increasing the signal voltage, current, or power without appreciably altering its quality; generally made up of an electron tube or transistor and an associated circuit called a stage. The amplifier may contain several stages in order to obtain a desired gain.

AMPLITUDE DISTORTION: The undesired change of a waveshape so that it no longer is proportional to its original form.

AMPLITUDE MODULATION: Changing the amplitude of a radiofrequency carrier wave in accordance with the variations of an audiofrequency wave.

ANALOG COMPUTER: A computer which solves problems by translating physical conditions such as flow, temperature, pressure, or voltage into electrical equivalent circuits and producing numbers as outputs.

ANODE: A positive electrode; the plate of a vacuum tube.

ANTENNA: Also aerial. A conductor or system of conductors that radiates or intercepts energy in the form of electromagnetic waves.

ANTENNA REFLECTOR: That portion of a directional antenna array which changes the direction of radiant energy behind the array and increases it in the forward direction.

ANTIJAMMING: A function of a radar set to reduce or eliminate enemy jamming of electromagnetic waves which are hindering the usefullness of specific segments of the radio spectrum.

ARRAY: Radio:-A combination of antenna elements arranged to reinforce the performance of the other and used where signal gain by direction is required. Computer:-A series of items arranged in a meaningful pattern.

ASW: Antisubmarine warfare.

ATTENUATION: The reduction in strength of a signal. The amount of attenuation is usually expressed in decibels.

AUDIO COMPONENT: That portion of any wave or signal whose frequencies are within the audio range.

AUDIOFREQUENCY: A frequency that can be detected as a sound by the human ear. The range of audiofrequencies extends from 20 to 20,000 hertz.

AUTOMATIC DATA PROCESSING: The processing of data automatically by means of a machine in which the internal interacting assemblies of procedures, processes, and methods perform a complex series of computer operations.

AUTOMATIC DIRECTION FINDER: An automatic radio compass which automatically aims a directional antenna to show the direction of location of a transmitter.

AUTOMATIC GAIN CONTROL: A method of automatically regulating the gain of a receiver so that the output tends to remain constant though the incoming signal may vary in strength.

AZIMUTH: An angle measured clockwise from true north. Azimuth and bearing are usually used synonymously. (See bearing)

BALANCED CIRCUIT: A divided circuit in which both sides are electrically equal.

BAND: The radio frequencies existing between two definite limits and used for a definite purpose. Example: Standard broadcast band extending from 550 to 1600 kHz.

BANDPASS FILTER: A circuit designed to pass currents of frequencies within a definite frequency band with nearly equal response, and to reduce substantially the amplitude of currents of all frequencies outside that band.

BAND SPREAD: Any method of spreading tuning over a greater range to facilitate tuning in a crowded band of frequencies.

BANDWIDTH: The total frequency width of a channel or band of frequencies.

BATHYTHERMOGRAPH: A recording thermometer for obtaining a permanent graphical record of water temperature in degrees fahrenheit at different water depths in feet as it is lowered or dropped into the ocean.

BEACON: Compared to a lighthouse. A radio or radar signal station which provides navigation and interrogation information for ships and aircraft.

BEARING: The angular position of an object with respect to a reference point or line. If the reference point is true north, the bearing is the true bearing; if the reference is NOT true north, the bearing is a relative bearing. (See azimuth)

BEAT FREQUENCY: One of the two additional frequencies obtained when signals of two different frequencies are combined. Their values are equal to the sum and difference, respectively, of the original frequencies.

BEAT FREQUENCY OSCILLATOR: An oscillator in which an audible beat frequency is obtained by mixing or beating together two radiofrequencies. The BFO is used for continuous wave (CW) reception in superheterodyne receivers, or as an instrument for test purposes.

BEAT NOTE: The audiofrequency produced by beating together two different frequencies.

BETA PARTICLES: High speed electrons that will travel several feet in air and are dangerous to living tissue.

BIAS: The DC voltage or current applied to a circuit to establish the desired electrical operating point.

BIASING RESISTOR: A resistor used to provide the voltage drop for a required bias.

BILLBOARD or BEDSPRING ARRAY: A broadside radar antenna array consisting of stacked dipoles in front of a large flat sheet-metal untuned reflector.

BIT: Binary digit: A single electrical pulse, a character, or unit of information used as the basic intelligence in a binary system.

BLEEDER: A resistance connected in parallel with a power-supply output to protect equipment from excessive voltages if the load is removed or substantially reduced; to improve the voltage regulation, and to drain the charge remaining in the filter capacitors when the unit is turned off.

BOTTOM BOUNCE: That form of sonar sound transmission in which sound rays strike the ocean bottom in deep water at steep angles and are reflected back to the surface and returned, which allows the obtaining of target information at long distances.

BREAKDOWN VOLTAGE: The voltage at which an insulator or dielectric ruptures; or the voltage at which ionization and conduction begin in a gas or vapor tube.

BT: Bathythermograph (see above).

BUFFER: Isolated circuitry inserted between two noncompatible circuits to make them compatible with each other. Also a storage device used to allow for differences in rates of data flow when transmitting information from one computer device to another.

BYPASS CAPACITOR: A capacitor used to provide an alternating current path of comparatively low impedance around a circuit element.

CAPACITOR: Two electrodes or sets of electrodes in the form of plates, separated from each other by an insulating material called the dielectric. The capacitor has the property of storing electrical energy in an electrostatic field between the electrode plates.

CARRIER: The frequency of an unmodulated RF transmitted wave. The RF component of a transmitted wave upon which an audio signal or other form of intelligence can be impressed.

CATHODE FOLLOWER: A vacuum-tube circuit in which the input signal is applied between the control grid and ground, and the output is taken from the cathode and ground. A cathode follower has a high input impedance and a low output impedance.

CCA: Carrier control approach. Provides a radar system for guiding aircraft to safe deck landings during night flying or under conditions approaching zero visibility.

CCM: Counter countermeasures. Measures taken to reduce the effect of enemy jamming on our own electronic equipment.

CATHODE: The electrode in a vacuum tube that provides electron emission.

CAVITATION: The separation between the ship's propeller blades and the surrounding water caused by the propeller turning so rapidly that the water does not have time to close in behind the blades thus producing a stream of bubbles. The abrupt collapse of the bubbles causes the acoustic signal known as cavitation. Sonar can often determine the class of ships by their cavitation.

CHANNEL: A narrow band of frequencies including the assigned carrier frequency, within which a radio or TV station is required to keep its signals within.

CHONOMETER: A time piece with a nearly constant rate having extremely great accuracy.

CLOSED CIRCUIT TELEVISION: The application of television where reception is confined locally and not for broadcasting. The receivers are connected to the television camera by coaxial cables. The system is used chiefly aboard ship for pilot's landing aid television (PLAT) system and crew entertainment.

COAXIAL CABLE: A transmission line consisting of one conductor, usually a small copper tube or wire, within and insulated from another conductor of larger diameter, usually copper tubing braid. The outer conductor may or may not be grounded. Radiation from this type of line is practically zero. Coaxial cable sometimes is called concentric line.

CODE: A system of dots and dashes for transmission of messages.

CONDUCTANCE: The ability of a material to conduct or carry an electric current. It is the reciprocal (opposite) of the resistance of the material and is expressed in mhos.

CONTINUOUS WAVES: Radio waves that maintain a constant amplitude and a constant frequency.

CONVERGENCE ZONE: That region in the deep ocean where sound transmissions directed downward refract from the depths and arrive at the surface in successive intervals of 30 to 35 miles. This sound channel can permit ships to detect targets at long distances.

CONVERSION: A term applied to the section(s) of a superheterodyne receiver that converts the desired incoming RF signals to desired IF values to lower the frequency. This may be accomplished in ONE, TWO, or THREE stages known as SINGLE, DOUBLE, or TRIPLE conversion (sometimes referred to as stages in DETECTION, or HETERODYNING).

COUNTERMEASURES: (see ECM)

COUNTERPOISE: A conductor or system of conductors used as a substitute for ground in an antenna system.

CROSS MODULATION: A type of crosstalk in which the modulated carrier frequency being received is interfered with by an adjacent modulated carrier, so that the modulated signals of both are heard at the same time.

CROSSTALK: Refers to an unwanted signal which may appear on one channel due to the recording on the adjacent channel, or to an undesired coupling with another communication channel.

CRT: Cathode-ray tube. An electron-beam tube in which the beam can be focused to a small cross section on a phosphorescent screen and varied in position and intensity to produce a visible pattern.

CRYPTOGRAPH: The art of writing in secret code. Rendering a plain text unintelligible to those who are not informed of the code.

CRYSTAL: A natural substance as quartz or tourmaline capable of producing a voltage when under stress or pressure, or producing pressure when under an applied voltage. Under stress, it has the property of responding only to a given frequency when cut to a given thickness. It is therefore valuable for transmitters or oscillators whose frequencies range between 500 kHz and 10 MHz.

CRYSTAL CONTROL: Control of the frequency of an oscillator by means of a specially designed and cut crystal.

CRYSTAL OSCILLATOR: An oscillator circuit in which a crystal is used to control the frequency and to reduce frequency instability to a minimum.

CURIE: The basic unit to describe the intensity of radioactivity in a sample of material.

CURRENT: The flow of free electrons, expressed in amperes.

CURSOR: A clear or amber-colored filter placed over an electronic marker, available on a radar or control indicator screen and manipulated to determine accurately the bearing of a target.

CW: Continuous wave (see above).

CYCLE: One complete positive alteration and one complete negative alteration of an alternating current or voltage.

DASH: Drome Antisubmarine helicopter. An unmanned remote-controlled helicopter used in dangerous areas for spotting targets with TV camera and other detection devices. The helicopter is capable of carrying two ASW torpedoes.

DB: Decibels. The unit for measuring the relative loudness of sounds. The unit is a value that expresses the comparison of sounds of two different levels.

DEAD RECKONING ANALYZER: The dead reckoning analyzer receives the ship's speed in knots from the pit log, and the ship's course input from the master gyro. These two inputs are combined to determine and indicate the total distance traveled and also the overall distances in a north-south and east-west direction traveled by the ship from any starting point.

DEMODULATION: The process of extracting the intelligence from the RF carrier, with which the carrier has been modulated.

DETECTOR CIRCUIT: The portion of a receiver that recovers the audible signal from the modulated RF carrier wave.

DEVIATION: A term used in frequency modulation to indicate the amount (of frequency) by which the carrier or resting frequency increases or decreases when modulated. It usually is expressed in kilohertz.

DEVIATION RATIO: A term used in frequency modulation to indicate the ratio of the maximum amount of deviation of a fully modulated carrier to the highest audiofrequency being transmitted.

DIELECTRIC: An insulator. A term applied to the insulating material between the plates of a capacitor.

DIGITAL COMPUTER: A type of calculating machine that operates with numbers expressed directly as digits, generally using binary or decimal notation to solve extremely complex and involved mathematical problems.

DIGITAL DATA TRANSMISSIONS: The RF transmission of data from a computer in serial or parallel format of binary numbers. The radiofrequency transmission is usually by a series of pulse code modulations.

DIODE: A two-electrode vacuum tube containing a cathode and a plate.

DIPOLE ANTENNA: A center-fed one-half wave antenna.

DISTORTION: Distortion is said to exist when an output waveform is not a true reproduction of the input waveform. Distortion may consist of irregularities in amplitude, frequency, or phase.

DOPPLER EFFECT: The change in frequency of sound, radio, or light waves reaching an observer, due to the difference in relative motion of the source or observer, or both. It is the change in a received frequency because of relative motion between transmitter and receiver.

DOSIMETER: A device that measures radiation dosage.

DRIVER: An amplifier used to excite the final power amplifier stage of a transmitter or receiver.

DUPLEXER: An electronic switching device which makes possible the use of one antenna for both transmitting and receiving.

EAM: Electrical accounting machine. The set of conventional punchcard equipment including sorters, collators, and tabulators.

ECM: Electronic countermeasures. Active-use of transmitting equipment that may jam the enemy transmissions. Passive-use of receiver equipment to intercept enemy radar or radio transmissions.

EDP: Electronic data processing. Processing performed largely by equipment using electronic circuitry for storing and manipulating data. It is the interacting assembly of methods, procedures, and electronic equipment.

EFFICIENCY: The ratio of output to input power, generally expressed as percentage.

ELECTRIC FIELD: A region in space in which electrified bodies are subjected to forces acting upon them by virtue of their electrification.

ELECTRODE: A terminal at which electricity passes from one medium into another.

ELECTROLYTE: A water solution of a substance which is capable of conducting electricity. An electrolyte may be in the form of either a liquid or a paste.

ELECTROMAGNETIC WAVE: A wave of electromagnetic radiation, characterized by variations of electric and magnetic fields.

ELECTRON: The most elementary charge of electricity. It is always negative.

ELECTRON EMISSION: The liberation of electrons from a body into space under the influence of heat, light, impact, chemical disintegration, or a potential difference.

ELECTROSTATIC FIELD: The field of influence between two charged bodies.

ELECTROSTRICTION: That property of certain ceramic materials which after having a permanent operating bias established causes these materials to vary slightly in length when they are placed in an electric field.

EMF: Electromotive force. An electrical force that produces an electrical current in a closed circuit. Has the same meaning as voltage, potential difference, electrical pressure.

EMO: Electronic material officer.

EXCITER: (see transmitter).

FACSIMILE: Transmitting photographs, drawings, handwriting, or printed matter over an electronic communications system.

FADING: Variations in the strength of a radio signal at the point of reception.

FAIL SAFE: A control so designed that a control circuit malfunction cannot cause a dangerous condition under any circumstance.

FARAD: The unit of capacitance.

FATHOMETER: An instrument aboard ship for determining depth of water by measuring the time that it takes the generated sound emissions to reach bottom and return as an echo.

FEEDBACK: A transfer of energy from the output circuit of a device back to its input.

FIDELITY: The degree of accuracy with which a system, or portion of a system, reproduces in its output the signal impressed on its input.

FIELD: The space containing electric or magnetic lines of force.

FILTER: A combination of resistances, inductances, and capacitances, or any one or two of these, which allows the comparatively free flow of certain frequencies or of direct current while blocking the passage of other frequencies. An example is the filter used in a power supply, which allows the direct current to pass, but filters out the AC component.

FIX: A determination of navigational position usually the intersection of several lines-of-position or bearing lines.

FLIP FLOP: A bistable multivibrator. Frequently used in computer applications as counters.

FM: Frequency modulated (see below).

FREE ELECTRONS: Electrons that are not bound to a particular atom, but move about continuously among the many atoms of a substance.

FREQUENCY: The number of hertz (cycles per second) of an alternating current.

FREQUENCY DIVERSITY: A method by which two or more transmitters will transmit simultaneously at two or more distinct frequency bands, and the reception is a single signal selected from a plurality of signals. This method reduces the effects of fading. It gives a greater effective range and reduces the susceptibility to jamming.

FREQUENCY DIVISION MULTIPLEXING: A process for the transmission of two or more channels over a common path by using a different frequency band for each channel. (See MULTIPLEXING.)

FREQUENCY DOUBLER: An electronic circuit in which the output is tuned to twice the frequency of the input.

FREQUENCY DRIFT: Change in a frequency from its basic wavelength caused by temperature or component variations in the frequency-determining elements.

FREQUENCY METER: A meter calibrated to measure frequency.

FREQUENCY MODULATION: The process of varying the frequency of an RF carrier wave in accordance with the frequency of an audio signal. The amplitude of the modulated wave stays essentially constant.

FREQUENCY MULTIPLIER: A frequency device used to multiply an original frequency by an integral value.

FREQUENCY STABILITY: The ability of an oscillator to maintain its operation at a constant frequency.

FREQUENCY STANDARD: A stable low frequency oscillator used for frequency calibrations. It usually generates a fundamental frequency of 50 to 100 kilohertz with a high degree of accuracy and the harmonics of this fundamental are used to provide reference points for checking (50 or 100 kilohertz apart) throughout the radio spectrum.

FULL-WAVE RECTIFIER CIRCUIT: A circuit which utilizes both the positive and the negative alterations of an alternating current to produce a direct current.

GAIN: The ratio of the output power, voltage, or current to the input power, voltage, or current.

GAMMA RADIATION: High energy short-wave length electromagnetic radiation with tremendous penetrating power, and is dangerous to living tissue.

GCA: Ground control approach. A talk-down method for landing an aircraft.

GHz: Giga hertz. Having a value of 1 billion hertz.

GIGA: A prefix indicating the value of one billion (1,000,000,000).

GRAZING ANGLE: The angle that the sound ray path forms with the reflecting surface; usually applies to sound rays reflected from the ocean bottom.

GROUND: A metallic connection with the earth to establish a common connecting point. Also, a common return to a point of zero potential.

GROUND PLANE ANTENNA: A vertical radio antenna combined with a turnstile element to lower the angle of radiation, and having a concentric base support and center conductor that together serve to place the antenna at ground potential even though it may be located several wavelengths above ground.

GROUNDWAVE: That portion of the transmitted radio wave that travels near the surface of the earth.

HAND KEY: A switch used in communications to provide a mode of operation in which transmission is usually coded.

HARMONIC: An integral multiple of a fundamental frequency. (The second harmonic is twice the frequency of the fundamental or first harmonic.)

HEMISPHERICAL SCAN: Scanning one of two equal parts of a sphere. Essentially a radio or radar scan of horizon-to-90 degree overhead, through 360° azimuth radiation pattern or sonar scan of horizon-to-90° ocean bottom, through 360° azimuth radiation pattern.

HENRY: The basic unit of inductance.

HERTZ: A new term used for frequency measurement replacing the old term cycles per second.

HETERODYNE: To mix two alternating currents of different frequencies in the same circuit; they are alternately additive and substractive, thus producing two beat frequencies, which are the sum of and difference between the two original frequencies.

HIGH FIDELITY: The ability to reproduce all audiofrequencies between 50 and 16,000 hertz without serious distortion.

HIGH-LEVEL MODULATION: Modulation produced at a point in a system where the power level approximates that at the output of the system. Also called plate modulation.

HYDROPHONE: An acoustic device that receives and converts underwater sound energy into electrical energy.

HYPERBOLA: In a flat plane, is the locus of a point which moves so that the difference between the distances from two fixed points (called the foci) is constant.

HYPERBOLOID OF REVOLUTION: The surface traced by a hyperbola rotating about one of its axes.

Hz: Hertz. Replaces the old abbreviation cps.

ICW: Interrupted continuous wave. Used for morse code transmission.

IF: Intermediate frequency. (see below).

IFF: Identification friend or foe. A challenge and an automatic response system developed for use with radar equipment. A coded challenging transmission, when received by a friendly craft will automatically transmit a coded identification signal.

IMPEDANCE: The total opposition to current flow in an AC circuit.

IMPULSE: Any force acting over a comparatively short period of time. An example would be a momentary rise in voltage.

INERTIAL NAVIGATION: Dead reckoning performed automatically by a device which gives a continuous indication of position by combining vectors for speed, direction, and other factors since leaving a starting point.

IN PHASE: Applied to the condition that exists when two waves of the same frequency pass through their maximum and minimum values like polarity at the same instant.

INPUT-OUTPUT EQUIPMENT: A device which provides the means of communication between the computer and external equipment. The device accepts new data, sends it into the computer for processing, receives the results, and transforms the data into usable form.

INSTANTANEOUS VALUE: The magnitude at any particular instant when a value is continually varying with respect to time.

INTELLIGENCE: The message or information conveyed, as by a modulated radio wave.

INTENSITY: The relative strength of electric, magnetic, or vibrational energy.

INTERFACE: A concept involving the specification of the interconnection between two equipments or systems. The specifications include the type, quantity, and function of signals to be interchanged via those circuits.

INTERMEDIATE FREQUENCY: The fixed frequency to which all RF carrier waves are converted in a superheterodyne receiver.

INTERNATIONAL MORSE CODE: The universal code used for radio telegraphy. It differs from the American Morse Code used for wire telegraphy, in the spacing and letter codes.

ISB: Independent sidebands (two) (see SIDEBANDS).

ISOTHERM: Having no temperature changes in water from surface to varying depths.

ION: An atom that has lost or gained one or more electrons and is therefore positively or negatively charged.

IONIZATION: The breaking up of atoms into ions.

IONOSPHERE: Highly ionized layers of atmosphere from between 40 and 350 miles above the surface of the earth.

KHz: Kilohertz. Having a value of one thousand (1,000 or 10^3) hertz.

KILO: A prefix meaning one thousand.

KLYSTRON TUBES: A velocity-modulated thermionic tube for microwave operation.

LEAKAGE: The electrical loss due to poor insulation.

LINEAR: The relationship of two related quantities such that a change in one will result in the exact proportional change in the other. A system in which the output varies in direct proportion to the input.

LOCAL-REMOTE CONTROL: A switch usually mounted on an instrument control panel of a unit and permits the operation of the system locally (near the panel) or remotely (at some distant place).

LOF: Line of fire. A straight line joining missile or gun and point of impact (or burst) of the missile or projectile.

LONG RANGE: A radio distance of over 1,500 miles.

LOOP ANTENNA: One or more complete turns of wire used with a radio receiver. Also used with direction-finding equipment.

LORAN: Long range navigation. An electronic navigational system with high frequency receivers and scope indicators in which mathematical hyperbolic lines of position are determined by measuring the difference in the time of reception of synchronized pulse signals.

LOS: Line of sight. The straight-line distance from ship to horizon. Represents radio and radar VHF and UHF transmission range limits under normal conditions.

LOUDSPEAKER: A device that converts AF electrical energy to sound energy.

LOW-LEVEL MODULATION: Modulation produced at a point in a system where the power level is low compared with the power level at the output of the system.

LSB: Lower sideband. (See SIDEBANDS.)

MAGNETIC FIELD: The region in space in which a magnetic force exists, caused by a permanent magnetic, or as a result of current flowing in a conductor.

MAGNETIC HEAD: A transducer in a tape recorder which converts the electrical signals into magnetic fields for establishing the magnetic pattern on the tape.

MAGNETOSTRICTION: That property of certain ferro type materials which causes them to vary slightly in length when they are in an alternating magnetic field.

MAGNETRON: A special microwave oscillator tube which produces an AC output for radio and radar high power transmitters.

MARK AND SPACE: Pertaining to telegraph communications in which the marking intervals are the intervals which correspond to one condition or position of transmission, usually a closed condition. Spacings are the intervals which correspond to another condition of the transmission. usually an open condition.

MATCHED IMPEDANCE: The condition which exists when two coupled circuits are so adjusted that their impedances are equal.

MCW: Modulated continuous wave. A form of transmission in which the carrier wave is modulated by a constant AF tone.

MEG OR MEGA: A prefix indicating one million.

MHO: The unit of conductance.

MHz: Megahertz. Having a value of 1,000,000 or 10^6 hertz.

MICROPHONE: A device for converting sound energy into AF electrical energy.

MICROSECOND: Abbreviated (μ sec). A time measurement having a value of one millionth (.000001 or 10^{-6}) of a second.

MILLISECOND: Abbreviated (m sec). A time measurement having a value of one thousandth (.001 or 10^{-3}) of a second.

MTI: Moving target indicator. A radar system providing improved target discrimination against clutter from sea or shore return. Detects moving targets in the presence of obscuring echos which otherwise would be obscured.

MK: MARK. A designation followed by a serial number to identify equipment of a particular military design (usually ordnance). This MARK number is further extended by a MOD number(s) when equipment of this design has been modified.

MODULATED CARRIER: An RF carrier whose amplitude or frequency has been varied in accordance with the intelligence to be conveyed.

MODULATION: The process of varying the amplitude or the frequency of a carrier signal (RF output of the transmitter) at the rate of an audio signal. The modulating signal may be an audiofrequency signal, video signal (as in television), or even electrical pulses or tones.

MODULATOR: That part of a transmitter that supplies the modulating signal to the modulated circuit, where it can act upon the carrier wave.

MODULE: A technique of compact packaging electronic circuitry and components of an individual subsystem to be used in combination with other packaged subsystems to form a complete electronic system. This is a great aid in diagnostic maintenance of the equipment.

MULTICOUPLER: An antenna permitting simultaneous operation of several transmitters and/or receivers from the same antenna.

MULTIPLEXING: A system to increase the message-handling capacity of RF channels by simultaneous transmission of two or more signals using a common carrier wave.

NAUTICAL MILE: Equals 6,080 feet. An electromagnetic signal will travel a nautical mile in 6.18 microseconds.

NETWORK: Any electrical circuit containing two or more interconnected elements.

NIXIE TUBE: A radio tube capable of forming the ten different numerals (zero through nine) for digital readouts.

NTDS: Naval tactical data system. An automatic data processing system for combat ships within a fleet task force. The network is basically ship and airborne data links in communications and weapons systems.

OFF-LINE EQUIPMENT: Peripheral computer equipment which can operate independently of the main computer for such operations as transcribing punchcard information to magnetic tape, or magnetic tape to printed form.

OHM: The unit of electrical resistance.

OHM'S LAW: A fundamental law of electricity. It expresses the definite relationship existing between the voltage E, the current I, and the resistance R, the common form for which is $E = IR$.

OMNIDIRECTIONAL: Going out in all directions as the radiation pattern of a single dipole antenna.

ON-LINE EQUIPMENT: Main computer equipment, due to configuration or design, that requires the use of the central processing unit of the computer.

OPEN CIRCUIT: A circuit which does not provide a complete path for the flow of current.

OSCILLATOR: A generator of radiofrequency waves.

OSCILLOSCOPE: An instrument for showing visually on a cathode ray tube representations of the waveforms encountered in electrical circuits.

OUTPUT: The energy delivered by a device or circuit such as a radio receiver or transmitter.

OVERLOAD: A load greater than the rated load of an electrical device.

OVERMODULATION: More than 100 percent modulation. In amplitude modulation, over modulation produces positive peaks of more than twice the carrier's original amplitude, and brings about complete stoppage of the carrier on negative peaks, thus causing distortion.

PA: Power amplifier. The last stage of RF amplification in a transmitter or other appropriate equipment.

PARABOLIC REFLECTOR: A dish reflector whose section is a parabola and capable of reflecting waves in parallel when a radiated wave source is placed at its focus.

PASSIVE: Involves the natural radiation or reflection of energy given off by an object. Passive electronic equipments are designed for detection of objects.

PATCH CORDS: A cord equipped with plugs at each end for receiving jacks and used to connect transmitter and receiver transfer panels to remote control points located throughout the ship.

PATCH PANEL: A board where circuits are terminated in jacks for temporary connections to electric cords for communications.

PEAK VALUE: The maximum instantaneous value of a varying current, voltage, or power. It is equal to 1.414 times the effective value of a sine wave.

PERCENTAGE OF MODULATION: A measure of the degree of change in a carrier wave caused by the modulating signal, expressed as a percentage.

PERIPHERAL EQUIPMENT: Either on-line or off-line auxiliary equipment supporting the operations but is not a part of the computer itself. These machines may consist of card readers, cardpunches, magnetic tape feeds, and high speed printers.

PHASE DIFFERENCE: The time in electrical degrees by which one wave leads or lags another.

PIEZOELECTRIC EFFECT: Effect of producing a voltage by placing a stress, either by compression, expansion, or twisting, on a crystal and, conversely, producing a stress in a crystal by applying a voltage to it.

PIPS: Popular term for bright spots on a CRT display such as a radar or sonar screen.

PLATE: The principal electrode in a tube to which the electron stream is attracted. See Anode.

POTENTIOMETER: A variable voltage divider. A resistor that has a variable contact arm so that any portion of the potential applied between its ends may be obtained.

POWER: The rate of doing work or the rate of expending energy. The unit of electrical power is the watt.

POWER TUBE: A vacuum tube designed to handle a greater amount of power than the ordinary voltage-amplifying tube.

PPI: Planned position indicator. A type of radar or sonar scope display in which a sweep rotates radically across the screen to indicate position of targets simultaneously through 360 degrees.

PRECESSION: Change in the direction of the axis-of-rotation of a spinning body as a gyroscope, when acted upon by a torque.

PRINTED CIRCUIT BOARD: An insulating board method of connecting electrical circuits on a plane surface with conductive and resistive materials.

PROGRAM: A complete plan for the solution of a problem, including the complete sequence of machine instructions and routines necessary to solve the problem by an electronic computer.

PULSATING CURRENT: A direct current which periodically increases and decreases in value.

PULSE: A momentary sharp surge of electrical voltage or current.

PULSE-DOPPLER: Combines the best features of continuous wave and pulse radar. The pulse-doppler method is used principally to obtain information about a target by using high frequency continuous waves in the form of short burst or pulses.

PULSE DURATION: The time interval between the points on the leading and trailing edges at which the instantaneous values bears a specific relation to the peak pulse amplitude.

PULSE INTERVAL: The time interval between the leading edges of successive pulses in a sequence characterized by uniform spacing.

PULSE LENGTH: Same as Pulse Duration.

PULSE MODULATION: The forming of very short bursts of a carrier wave separated by relatively long periods during which no carrier wave is transmitted.

PULSE REPETITION RATE: The rate at which the recurring pulses are transmitted, usually expressed in pulses per second.

PULSE SEPARATION: The time interval between the trailing edge of one pulse and the leading edge of the next pulse.

PULSE SPACING: Same as PULSE INTERVAL.

PULSE TRAIN: A group of related pulses, constituting a series.

PULSE WIDTH: Same as PULSE DURATION.

RAD: An unit of absorbed dosage of nuclear radiation.

RADAR: Radio detection and ranging. A radio echo device for detecting and tracking ships and aircraft and other material targets.

RADIO: The science of communication in which radiofrequency waves are used to carry intelligence through space. A general term denoting radio waves transmission and reception, exclusive of specialized systems such as facsimile of television, and radar which employ radio principles but are commonly known by other terms.

RADIOACTIVITY: The emission by the unstable nucleus of particles or by electromagnetic waves as alpha, beta, or gamma radiation.

RADIO CHANNEL: A band of adjacent frequencies of a width sufficient to permit its use for radio communication.

RADIO DIRECTION FINDER: A receiver and a rotatable loop antenna used principally to locate personnel afloat on life rafts and life boats equipped with radio transmitters.

RADIOFACSIMILE: The transmission of still images (weather maps, photographs, sketches, typewritten pages, etc.) over a radiofrequency channel.

RADIOFREQUENCY: Any frequency of electrical energy capable of radiating great distances into space. Basically, these frequencies occupy the frequency spectrum between audio sound and infrared light.

RADIOSONDE: An instrument carried aloft by an unmanned balloon and equipped with elements for determining temperature, pressure, and relative humidity at regular intervals during the ascent by automatically transmitting the measurements back to earth by radio for recording. A parachute lowers the equipment earthward when the balloon bursts.

RADIOTELEPHONY: Two-way voice communications conducted by means of radiofrequency waves.

RADIOTELETYPE: The transmission of messages from a teletypewriter or coded tape over a radiofrequency channel by means of coded combinations of mark and space impulses.

RADIO CHANNEL: A band of adjacent frequencies of a width sufficient to permit radio communication. Channel width depends on the type of transmission and the tolerance for the frequency of emission.

RADIO WAVES: The electromagnetic radiations caused by oscillation of electric charges capable of traveling through space at the speed of light.

RCVR: An abbreviation for receiver.

RDT: Rotating directional transmission. Equipment used in radar and sonar to concentrate the total power into a directional transmission beam that covers a narrow sector as it rotates 360 degrees in azimuth.

REAL TIME: Computer operation with regard to the time interval between the inquiry for information and the delivery of information to and from the computer (virtually zero time).

REFLECTION: The turning back of a radio wave from the surface of the earth or the ionosphere.

REFRACTION: The bending or change in the direction of a wave in passing from one medium into another. This effect will turn a radio wave back to earth if the angle of attack is not too great, and it will bend a sound wave in sonar ranging as the wave passes from one layer of water to another.

RELATIVE BEARING: A bearing taken when the heading of a ship serves as the reference line.

REPEATERS: Radar or sonar indicators.

REPERFORATOR: A machine that automatically punches or perforates tape to record the message being sent or received by the radio teletype machine. May be used to perforate tapes for original outgoing messages or for taping incoming messages for later retransmission.

RESONANCE: The condition existing in a circuit when the values of inductance, capacitance, and the applied frequency are such that the inductive reactance and capacitive reactance cancel each other.

RESTING FREQUENCY: The initial frequency of the carrier wave of an FM transmitter before modulation. Also called the center frequency.

REVERBERATION: A succession of echos caused by reflections of sounds. In the ocean it is caused by irregularities in the ocean bottom surface, and suspended matter (as fish). Under these conditions an emitted pulse may be received as a muffed echo due to sound interference.

RFCSRATT: Radio frequency carrier shift radioteletype. A radioteletype frequency shift system similar to the familiar FM radio method of broadcasting. It replaces the term frequency shift keying.

RHEOSTAT: A variable resistor, usually associated with power devices.

RHI: Range-height indicators. Indicators used as radar repeater equipments for height-finding radar systems.

ROENTGEN: A unit of exposure dosage of nuclear radiation.

ROUTINE: A set of coded instructions arranged in proper sequence to direct the computer to perform a desired operation or sequence of operations.

SAM: Surface-to-air missile.

SCD: Ship's center display. A sonar CRT presentation display where the electron beam begins an expanding spiral sweep at the center of the indicator tube.

SELECTIVITY: The relative ability of a receiver to select a particular frequency and to reject all others.

SENSITIVITY: The relative ability of a receiver to amplify small signal voltages.

SHIELDING: A metallic covering used to prevent magnetic or electrostatic coupling between adjacent circuits.

SHORAN: Short range navigation. A very accurate short range navigational aid used to determine position. Ship or aircraft radar signals automatically trigger off two fixed transmitters ashore for range comparison and determination.

SHORT WAVE: Refers to radio operation on frequencies higher than those used at the present time for commercial broadcasting. The range of frequencies extend from 1500 kilohertz to 30,000 kilohertz.

SHUNT: Parallel. A parallel resistor placed in an ammeter to increase its range.

SIDEBAND POWER: The power contained in the sidebands. It is to this power that a receiver responds, not to the carrier power, when receiving a modulated wave.

SIDEBANDS: Two bands of frequencies, one above and one below the carrier frequency, produced as a result of modulation of a carrier. The upper sideband contains the frequencies that are the sums of the carrier and modulated frequencies. The lower sideband contains the difference of these frequencies.

SIF: Selective identification feature. Makes the system of identifying friendly units much more secure and more positive. An added improvement to the MARK X IFF system.

SILENT TUNING: A method of switching a low power continuous wave signal into a dummy load for tuning and silencing a possible radiating transmitter antenna against detection during a period of silence. The system is kept continuously tuned for maximum output at all times.

SINS: Ships inertial navigation system. A navigational aid first developed for submarines. This dead reckoning system is a self-contained guidance system which operates on an arrangement of three gyros and two accelerometers that automatically follow a preset course. Aircraft and missiles also use an inertial guidance system.

SKIP DISTANCE: The distance on the earth's surface between the points where a radio skywave is reflected successively between the earth and the ionosphere.

SKYWAVE: A radio wave which travels upward into the sky from a transmitter antenna and is, for the most part, bent back to earth by the ionosphere.

SOFTWARE: Pertains to the programs and routines used with computers. The totality of programs and routines used to extend the capabilities of computers. In contrast to HARDWARE which is the construction parts (mechanical, electrical, and electronic elements) of the computer.

SOLENOID: A multiturn coil of wire wound in a uniform layer or layers on a hollow cylindrical form.

SOLID STATE: The electronic components that convey or control electrons within solid materials.

SONAR: Sound navigation and ranging. Electronic equipment used for underwater detection of objects and range of these objects, also to determine the ocean profile and depths.

SPECTRUM: Arrangement of electromagnetic radiation energy wavelengths from the longest to the shortest radio waves.

STATIC: Any electrical disturbance caused by atmospheric conditions. Also a fixed, nonvarying condition, without motion.

SUBTRACK: The path traced on the earth by a satellite passing directly overhead.

SUPERHETERODYNE: A radio receiver which converts the carrier wave into a fixed intermediate lower radio frequency which is then highly amplified.

SURFACE WAVE: A radio wave which travels along the surface of the earth, bending with the earth's curvature.

SYNCHRONOUS: Happening at the same time; having the same period and phase.

TACAN: Tactical communication air navigation. An electronic polar coordinate system that enables an aircraft pilot to read continuously, the distance and bearing of a radio beacon transmitter onboard ship or on ground.

TCD: Target center display. A spiral sweep display in which the point of origin is moved, usually off the CRT tube, until a given target echo appears at the exact center of display.

THERMOCLINE: The layer in the sea where the temperature decreases continuously with depth. Usually the decrease (gradient) is greater than 2.7 degrees Fahrenheit per 165 feet in depth.

THYRATRON: A hot-cathode, gas-discharge tube in which one or more electrodes are used to control electrostatically the starting of an unidirectional flow of current.

TONE CONTROL: A method of emphasizing either low or high tones at will in an AF amplifier.

TONE MODULATION: A type of code-signal transmission obtained by causing the RF carrier amplitude to vary at a fixed audiofrequency.

TRANSCEIVER: Combination of radio transmitting and receiving equipment employing common circuit components in a common housing for portable or mobile use.

TRANSDUCER: A general term for any device that converts energy from one form to another, always retaining the characteristic amplitude variations of the energy being converted.

TRANSFORMER: A device composed of two or more coils, linked by magnetic lines of force, used to transfer energy from one circuit to another.

TRANSMISSIONS: Passage of radio waves in the space between transmitter and receiving station.

TRANSMITTER: A comprehensive term applied to all of the equipment used for generating and amplifying an RF carrier signal, modulating this carrier with intelligence, amplifying and feeding the modulated RF carrier to the antenna for transmission into space.

TRANSPONDER: An acoustic device that can be activated upon receipt of a sound or radio signal.

TRUE BEARING: A bearing given in relation to true geographic north which is a point on earth about which one end of the earth revolves on its axis. The axis of earth aligns with the north star. (It is not the earth's magnetic pole.)

TUNED CIRCUIT: A resonant circuit.

TUNING: The process of adjusting a radio circuit to resonance with the desired frequency.

UHF: Ultra high frequency. The spectrum range between 300 million hertz to 3000 million hertz.

ULTRASONICS: The field of science devoted to frequencies of sound above the human audio range, i.e., above 20 kHz.

UNIDIRECTIONAL: Flowing in one direction only. (Direct current is unidirectional.)

UT: Universal time. Greenwich mean time. The mean solar time from the meridian of Greenwich from which geographers and navigators count their longitude. It is adopted as the prime basis for standard time throughout the world.

USB: Upper sideband communications. (see SIDEBANDS).

VAC: Volts, AC. Abbreviation for alternating current voltage.

VACUUM-TUBE VOLTMETER (VTVM): A device which uses either the amplifier characteristic or the rectifier characteristic of a vacuum tube or both to measure either DC or AC voltages. Its input impedance is very high, and the current used to actuate the meter movement is not taken from the circuit being measured. It can be used to obtain accurate measurements in sensitive circuits.

VDS: Variable depth sonar. Equipment developed to minimize the thermal layers in the ocean by lowering the transducer to optimum depths when searching for targets.

VELOCITY: A rate of change of distance with respect to time in a given direction.

VHF: Very high frequency. The spectrum range from 30 million hertz to 300 million hertz.

VOLTAGE AMPLIFICATION: The process of amplifying a signal to produce a gain in voltage. The voltage gain of an amplifier is the ratio of its alternating-voltage output to its alternating-voltage input.

VOLUME: A term used to denote the sound intensity (amount of radio output) of a receiver or audio amplifier.

VOLUME CONTROL: A device for controlling the output volume.

WATT: The basic unit of electrical power.

WAVE: The progressive movement (propagation) either of sound or electromagnetic waves through a conducting medium, as rhythmical disturbances.

WAVEGUIDE: A hollow rectangular or round pipe (plumbing) used as a transmission line to guide electromagnetic waves.

WAVELENGTH: The distance in meters traveled by a wave during the time interval of one complete cycle. It is equal to the velocity divided by the frequency.

WAVE PROPAGATION: The radiation, as from an antenna, of RF energy into space, or of sound energy into a conducting medium.

WCS: Weapons control system. A group of interconnected and interrelated equipments that are used to control the delivery of effective gun and missile firing on selected targets.

WORD, COMPUTER: An ordered set of characters which occupies one storage location and is treated by the computer circuits as a unit and transferred as such. Ordinarily a word is treated by the control unit as an instruction, and by the arithmetic unit as a quantity. Word lengths may be fixed or variable depending on the particular computer.

XBT: Expendable bathythermograph. A non-reusable thermometer type instrument dropped into the ocean for measuring water temperature at different levels, and the associated shipboard equipment used for launching and recording the data automatically.

XMTR: Abbreviation for transmitter.

X RAY: Penetrating electromagnetic radiation. Non-nuclear in origin.

CHAPTER 2

RADIO

The word "radio" can be defined briefly as the transmission of signals through space by means of electromagnetic waves. Usually, the term is used in referring to the transmission of intelligence code and sound signals, although television (picture signals) and radar (pulse signals) also depend on electromagnetic waves.

Of the several methods of radio communications available, those utilized most commonly by the Navy are radiotelegraphy, radiotelephony, radioteletype, radiofacsimile, and digital data. These modes are defined as follows:

1. RADIOTELEGRAPHY: The transmission of intelligence coded radiofrequency waves in the form of short transmissions (dots) and long transmissions (dashes).
2. RADIOTELEPHONY: The transmission of sound intelligence (voice, music, or tones) by means of radiofrequency waves.
3. RADIOTELETYPE: The transmission of messages from a teletypewriter or coded tape over a radiofrequency channel by means of coded combinations of mark and space impulses.
4. RADIOFACSIMILE: The transmission of still images (weather maps, photographs, sketches, typewritten pages, and the like) over a radiofrequency channel.
5. DIGITAL DATA: The transmissions of data from a computer in serial or parallel format of binary numbers and zero. The radiofrequency transmission is usually by a series of pulse code modulations or sidetone modulations.

Radio equipment can be divided into two broad categories: transmitting equipment and receiving equipment. Both transmitting and receiving equipments consist basically of electronic power supplies, amplifiers, and oscillators.

A basic radio communication system may consist of only a transmitter and a receiver, which are connected by the medium through which the electromagnetic waves travel (fig. 2-1). The transmitter comprises an oscillator (which generates a basic radiofrequency), radiofrequency (RF) amplifiers, and the stages (if any) required to place the audio intelligence on the RF signal (modulator).

The electromagnetic variations are propagated through the medium (space) from the transmitting antenna to the receiving antenna.

The receiving antenna converts that portion of the transmitted electromagnetic energy received by the antenna into a flow of alternating radiofrequency currents. The receiver converts these current changes into the intelligence that is contained in the transmission.

FREQUENCY SPECTRUM

Radio transmitters operate on frequencies ranging from 10,000 hertz to several thousand megahertz. These frequencies are divided into eight bands as shown in table 2-1.

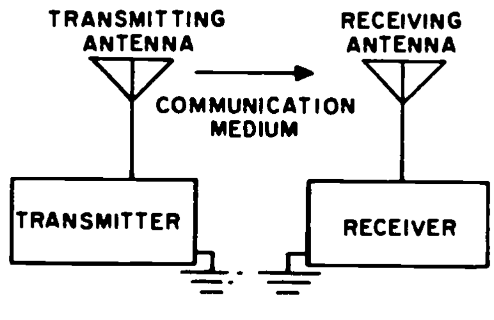

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Figure 2-1.—Basic radio communication system.

Table 2-1.—Bands of Frequencies

Abbreviation	Frequency band	Frequency range
VLF	Very low frequency	below 30 kHz
LF	Low frequency	30-300 kHz
MF	Medium frequency	300-3000 kHz
HF	High frequency	3000-30,000 kHz
VHF	Very high frequency	30-300 MHz
UHF	Ultrahigh frequency	300-3000 MHz
SHF	Superhigh frequency	3000-30,000 MHz
EHF	Extremely high frequency	30-300 GHz

Because the VLF and LF bands require great power and long antennas for efficient transmission, the Navy normally uses these bands mostly for shore station transmissions. (The antenna length varies inversely with frequency.)

Only the upper and lower ends of the MF band have naval use because of the commercial broadcast band extending from about 550 kHz to 1700 kHz.

Most shipboard radio communications are conducted in the HF band. Consequently, a large percentage of shipboard transmitters and receivers are designed to operate in this band. The HF band lends itself well for long-range communications.

A large portion of the lower end of the VHF band is assigned to the commercial television industry and is used by the Armed Forces only in special instances. The upper portion of the VHF band (225 MHz to 300 MHz) and the lower portion of the UHF band (300 MHz to 400 MHz) are used extensively by the Navy for their UHF communications. The frequencies above 400 MHz in the UHF band through the SHF and EHF bands are normally used for radar and special equipment.

ANTENNAS AND PROPAGATION

An antenna is a conductor or system of conductors that radiates or intercepts energy in the form of electromagnetic waves. In its elementary form, an antenna may be simply a length of elevated wire. For communication and radar work, however, other considerations make the design of an antenna system a more complex problem. For instance, the height of the radiator above ground, the conductivity of the earth below the radiator, and the shape and dimensions of an antenna all affect the radiated field pattern in space.

When RF current flows through a transmitting antenna, radio waves are radiated from the antenna in much the same way that waves travel on the surface of a pond into which a rock is thrown. Part of each radio wave moves outward in contact with the ground to form the groundwave, and the rest of the wave moves upward and outward to form the skywave. The ground and sky portions of the radio wave are responsible for two different methods of carrying signals from transmitter to receiver.

Commonly, the groundwave is considered to be made up of two parts: a surface wave and a direct wave. The surface wave travels along the surface of the earth, whereas the direct wave travels in the space immediately above the surface of the earth. The groundwave is used both for short-range communications at high frequencies with low power and for long-range communications at low frequencies with very high power.

That part of the radio wave that moves upward and outward, but is not in contact with the ground, is called the skywave. An ionized belt, found in the rarefied atmosphere approximately 40 to 350 miles above the earth, is known as the ionosphere. It refracts (bends) some of the energy of the skywave back toward the earth. A receiver in the vicinity of the returning skywave receives strong signals even though the receiver is several hundred miles beyond the range of the groundwave. The skywave is used for long-range, high-frequency, daylight communications. It also provides a means for long-range contacts at somewhat lower frequencies at night.

The direct wave is that portion of radiated energy which contains no sky or ground wave components. It attempts to travel in a straight line, however, it is refracted (bent) slightly downward due to atmospheric density. All

VHF and UHF communications are conducted via the direct wave.

CONTINUOUS-WAVE TRANSMITTER

One of the simplest types of radio transmitters is the continuous-wave (CW) transmitter (fig. 2-2). This CW transmitter is designed to send short or long pulse of RF energy to form the dots and dashes of the Morse code characters. Morse code transmission is also known as ICW (interrupt continuous wave).

A CW transmitter has four essential components: (1) a generator of RF oscillations, (2) a means of amplifying, and, if necessary, multiplying the frequencies of these oscillations, (3) a method of turning the RF output on and off (keying) in accordance with the code to be transmitted, and (4) a power supply to provide the operating potential to the various electron tubes and transistors. Although not actually a part of the transmitter, an antenna is required to radiate the keyed output of the transmitter.

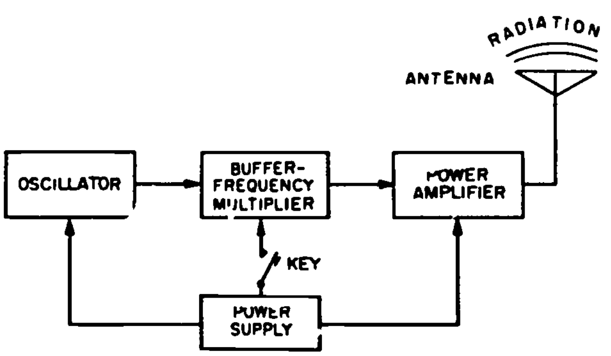
OSCILLATOR

The oscillator is the basic frequency determining element of the transmitter. It is here that the RF signal is generated. If the oscillator fails to function, no RF signals will be produced.

Frequently, the oscillator operates on a submultiple of the transmitter output frequency. When this occurs, a process called frequency multiplication is used to increase the transmitter frequency as desired. This action is particularly desirable when the output frequency is so high that stable oscillations are difficult to obtain.

Present-day transmitters may contain several oscillators to perform various functions. In general, only one of these is used to generate the basic transmitter radiofrequency. This oscillator usually is called the master oscillator (MO) to distinguish it from any other oscillator circuit in the transmitter.

Transmitters capable of transmitting over a wide frequency range normally have the total frequency coverage divided into separate bands. In such instances, the frequency-determining components in the oscillator (and other stages as necessary) are selected by means of a band switch.



20.201
Figure 2-2.—Continuous-wave transmitter.

BUFFER—FREQUENCY MULTIPLIER

The buffer stage is situated between the oscillator and subsequent stages to isolate the oscillator from load reflections. When the transmitter is keyed, the associated changes in the condition of the transmitter stages may cause undesired voltage or current reflections. If permitted to reach the oscillator, these reflections would cause the oscillator frequency to change.

As stated previously, the oscillator may be operated at a submultiple of the transmitter output frequency. With this mode of operation, the buffer stage usually performs the additional function of frequency multiplication in all but single sideband equipment.

POWER AMPLIFIER

The power amplifier (PA) is operated in such a manner that it greatly increases the magnitude of the RF current and voltage. The output from the PA is fed to the antenna via RF transformers and transmission lines. The PA is simply another RF amplifier. The last stage of RF amplification in a transmitter is usually referred to as the power amplifier.

POWER SUPPLY

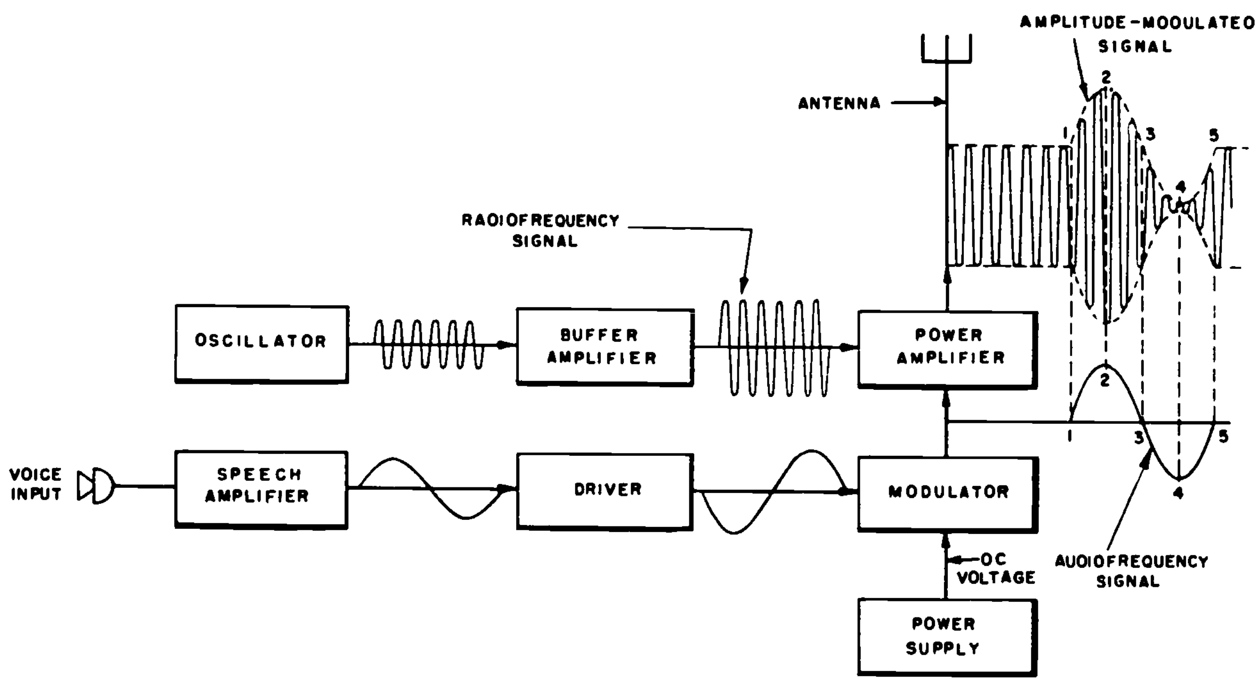
Transmitters (and many other types of electronic equipment) require DC voltages ranging from a minus hundreds of volts to plus thousands of volts. Additionally, they need AC voltages at smaller values than those available from the ship's normal power source. It is the function of the power supply to furnish these voltages at the necessary current ratings. Usually, this is accomplished through transformer-rectifier-filter action, with the ship's power as the source of supply.

VOICE MODULATION

Because it is impractical to transmit electromagnetic waves at sound frequencies (15 hertz to 20,000 hertz), the intelligence, by means of modulation, is impressed upon a higher frequency for transmission. Modulation is the process of varying the amplitude or the frequency of a carrier signal (RF output of the transmitter) at the rate of an audio signal. The composite wave thus contains radiofrequency and audiofrequency components. The audio portions of the modulation are removed before transmission leaving the audio effect (envelope) on the RF wave for transmission. A receiver that is within reception range and tuned to the carrier frequency accepts the transmitter signal and removes the audio component from the carrier. This process is called demodulation or detection. The audio signal is then fed to a loudspeaker or headset which reproduces the original sound.

AMPLITUDE MODULATION

Amplitude modulation (AM) is the process of combining audiofrequency and radiofrequency signals in a manner which causes the amplitude of the radiofrequency waves to vary at an audiofrequency rate. This process can be accomplished by removing the key and modifying the continuous-wave transmitter (fig. 2-2) so that the audio output from a microphone (and necessary amplifiers) is impressed on the carrier frequency. The required changes are incorporated in the block diagram of a basic AM radiotelephone transmitter, as shown in figure 2-3. The top row of blocks produces and amplifies the RF carrier frequency; the lower row produces and amplifies the audiofrequency. The speech amplifier driver, and modulator stages provide the voltage and power amplification required in the modulation process.



13.53

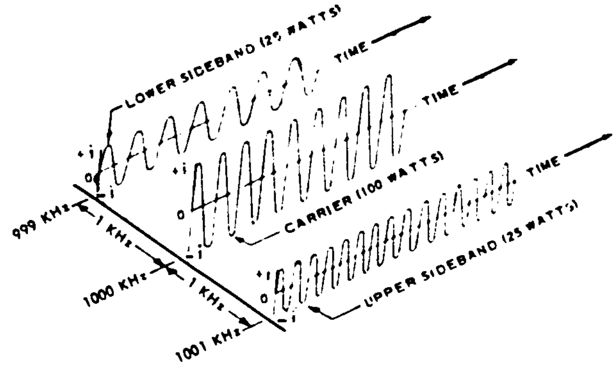
Figure 2-3.—An AM radiotelephone transmitter.

Assume that the modulating audio signal is of constant frequency. The audio voltage is fed into the RF power amplifier stage so that it alternately adds to and subtracts from the DC supply voltage in the amplifier. An increase in voltage in the PA increases the RF power output. Conversely, a decrease in voltage decreases the RF power. The presence of the audio voltage in series with the supply voltage causes the overall amplitude of the RF field at the antenna to increase gradually in strength during the time the audio voltage is increasing (from 1 to 2 on the waveforms, fig. 2-3). It also results in a decrease in strength during the time the audio output is decreasing (from 2 to 3). Similar variations in RF power output occur throughout each audio cycle. The waveform produced at the antenna thus contains the sum and difference frequencies combined with the carrier to produce a composite radio signal from which the audio may be extracted in a receiver.

Actually, the two frequencies introduced in the PA during the modulation process combine to produce two additional frequencies called sideband frequencies. The sideband frequencies are always related to the original two frequencies as sum and difference frequencies, respectively. The sum frequency, i.e., the sum of the RF carrier and audio-modulating frequencies, is called the upper sideband; the difference frequency is the lower sideband. At 100 percent modulation, one-sixth of the total power (RF plus audio power) appears in each of the sidebands.

The relationship of the carrier, audio, and sideband frequencies is illustrated in figure 2-4. Assume that the carrier frequency is 1000 kHz at 100 watts, and that the audio-modulating frequency is a single 1-kHz tone at 50 watts. Then, each of the sidebands is displaced 1000 hertz from the carrier frequency. The lower sideband is 1,000,000 hertz -1000 hertz = 999,000 hertz (or 999 kHz). The upper sideband is 1,000,000 hertz +1000 hertz = 1,001,000 Hz (or 1001 kHz). The power in each sideband (25 watts) is one-sixth the total transmitter output power (150 watts).

Note that the amplitude of each of the three frequencies is constant when considered alone. But, because these frequencies appear simultaneously at the output, they add to form one composite envelope (signal). This envelope is in the shape of the output waveform shown in figure 2-3.



20.184

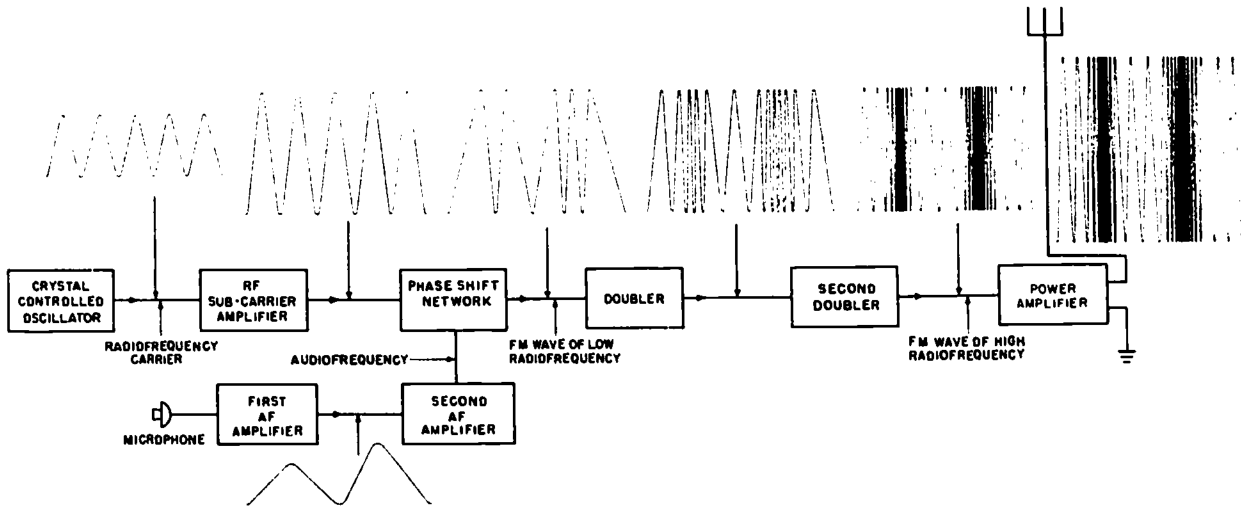
Figure 2-4.—Carrier wave and its sideband frequencies.

During modulation, the peak voltages and currents on the RF power amplifier stage are greater than values that occur when the stage is not modulated. To prevent damage to the equipment, a transmitter, designed to transmit both CW and radiotelephone signals, is provided with controls that reduce the transmitter power output for radiotelephone operation.

FREQUENCY MODULATION

Intelligence can be transmitted by varying the frequency of a carrier signal of constant amplitude. The carrier frequency can be varied a small amount on either side of its average or assigned frequency by means of the AF modulating signal. The amount the carrier is varied depends on the magnitude of the modulating signal. The rate with which the carrier is shifted depends on the frequency of the modulating signal. With or without modulation, the amplitude of the RF carrier remains substantially constant.

A block diagram of a representative FM transmitter, in which frequency modulation is accomplished by a phase-shift system, is shown in figure 2-5. The transmitter oscillator is maintained at a constant frequency by means of a quartz crystal. This constant-frequency signal passes through an amplifier that increases the amplitude of the RF subcarrier. The audio signal is applied to this carrier in a phase-shift network in such a manner as to cause the frequency of the carrier to shift according to the variations of the audio signal.



20.190

Figure 2-5.—Block diagram of FM transmitter and waveforms.

The FM output of the phase-shift network is fed into a series of frequency multipliers that raise the signal to the desired output frequency. Then the signal is amplified in the power amplifier and coupled to the antenna for radiation.

RECEIVERS

The modulated RF carrier wave produced at the transmitter travels through space as an electromagnetic wave. When the wave passes across a receiving antenna, it induces small RF voltages (and associated currents) in the antenna wire at the frequency of the transmitted signal. The signal voltage is coupled to the receiver input via an antenna coil or antenna transformer.

Electromagnetic energy is received from several transmitters simultaneously by the receiving antenna. The receiving circuits must select the desired transmitter signal from those present at the antenna and amplify this signal. The RF stages must isolate the internally generated frequencies within the receiver from the antenna which is necessary in observing radio silence. Further, the receiver must extract the audio component from the carrier frequency by a process called demodulation, or detection, and amplify the audio component to the proper magnitude to operate a loudspeaker or earphones.

TUNED RADIOFREQUENCY RECEIVER

The tuned radiofrequency (TRF) receiver is the forerunner of the modern military receiver. It is of the simplest design, and lends itself well for the purpose of explaining basic receiver principles. Although not used extensively in the Navy, it has advantages and may come back again due to improvements in solid state devices.

The TRF receiver (fig. 2-6) consists of one or more RF amplifier stages, a detector (demodulator) stage, one or more stages of audio amplification, a power supply, and a reproducer (usually loudspeaker or earphones). Waveforms that appear at the input and output of each stage are shown in the illustration.

Radiofrequency Stages

Radiofrequency stages of the receiver are designed to select and amplify the desired signal. The relative ability of a receiver to select a particular frequency and to reject all others is called the selectivity of the receiver. The relative ability of the receiver to amplify small signal voltages is called the sensitivity of the receiver. Both of these values can be improved within limits, by increasing the number of RF stages.

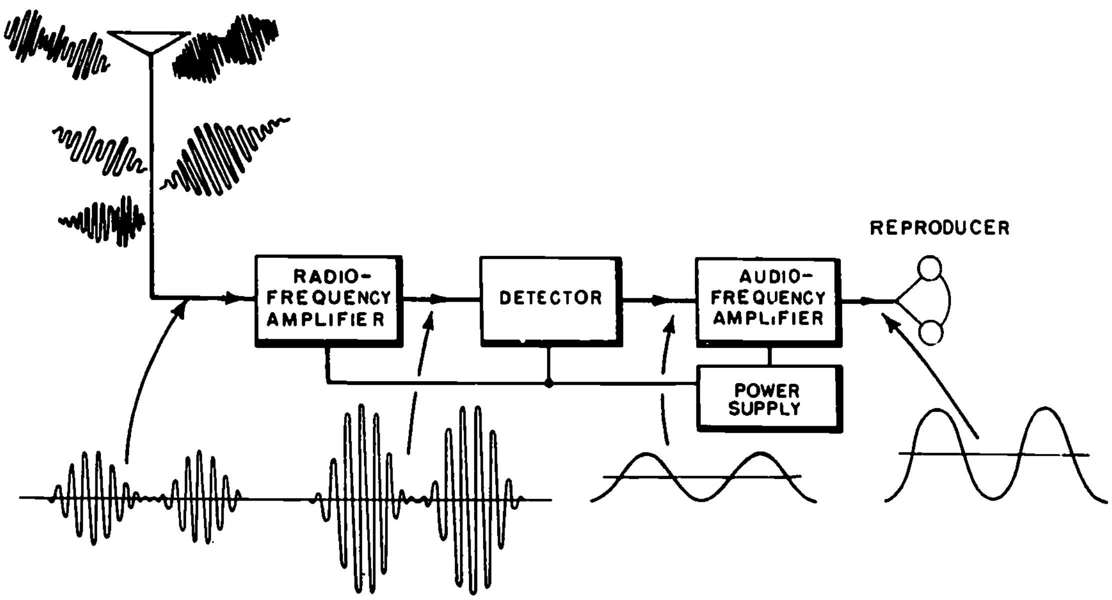


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Figure 2-6.—Block diagram of TRF receiver and waveforms.

Detector

In the detector stage, the intelligence component of the modulated wave is separated from the RF carrier. The separation process, called detection or demodulation, consists of rectifying the AM envelope and removing (filtering out) the RF carrier.

As seen earlier, amplitude modulation of an RF carrier with audio intelligence causes both the positive and the negative half cycles of RF to vary in amplitude. The resultant amplitude variations are a replica of the modulating audio signal. The detector stage accepts the RF amplitude variations at its input, and produces audio variations at its output.

Audio Amplifier

The function of the audiofrequency section of the receiver is to amplify the audio signal from the detector. In most instances, the amount of audio amplification necessary depends on the type of reproducer. If the reproducer is earphones, only one stage of amplification may be required.

Disadvantages of TRF Receiver

The principal disadvantages of the TRF receiver has been its inability to reject unwanted frequencies, and its inability to amplify desired frequencies uniformly. In other words, the selectivity and the sensitivity of the receiver are not uniform over its frequency range. As the TRF receiver is being tuned from the low-frequency end of its range towards the high-frequency end, the selectivity of the receiver will decrease; conversely, the sensitivity will increase. Solid state microminiature circuits are helping to minimize these disadvantages.

SUPERHETERODYNE (AM) RECEIVER

The superheterodyne receiver was developed to overcome the disadvantages of TRF receivers. The essential difference between the two types of receivers is in the amplifier stage(s) preceding the detector. Whereas the RF amplifier preceding the detector in the TRF receiver is tunable, the corresponding amplifier in the superheterodyne receiver is pretuned to one fixed frequency called the intermediate frequency (IF).

The intermediate frequency is obtained through the principle of frequency conversion by heterodyning a signal generated in a local oscillator of the receiver with the incoming signal in a mixer stage. Thus, an incoming signal is converted to the fixed intermediate frequency, and the IF amplifier operates with uniform selectivity and sensitivity over the entire tuning range of the receiver.

A block diagram of a representative superheterodyne receiver is shown in figure 2-7. Although not illustrated, a superheterodyne receiver may have more than one frequency converting stage and as many amplifiers as needed to obtain the desired power output.

Heterodyning

The intermediate frequency is produced by a process called heterodyning. This action takes place in the mixer, so called because it receives and combines (mixes) two frequencies. These two frequencies are the incoming signal from the RF amplifier, and a locally generated, unmodulated RF signal of constant amplitude from the local oscillator.

The heterodyning action in the mixer (also called the first detector) produces four frequencies at the mixer output. These frequencies are (1) the incoming RF signal, (2) the local oscillator signal, (3) the sum of the incoming RF and local oscillator signals, and (4) the difference of these signals. Both the sum and difference frequencies contain the amplitude modulation. Usually, the difference-frequency is used as the intermediate frequency, although the sum-frequency can be used equally as well. A common intermediate frequency for communication receivers is 455 kHz.

SINGLE-SIDEBAND COMMUNICATIONS

As explained earlier, the intelligence of amplitude-modulated signals is contained in the sidebands, and for normal amplitude modulation, the intelligence in both sidebands is the same. Radio intelligence can be conveyed by removing the carrier and one sideband and transmitting only the remaining sideband if

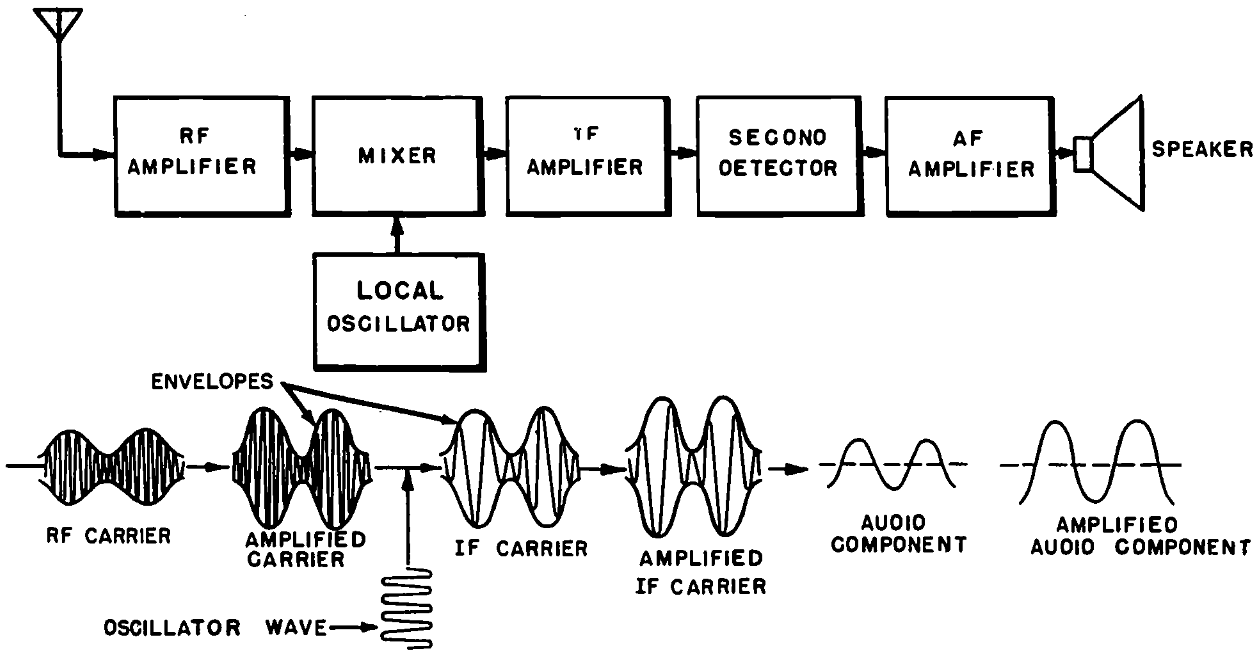

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Figure 2-7.—Block diagram of an AM superheterodyne receiver and waveforms.

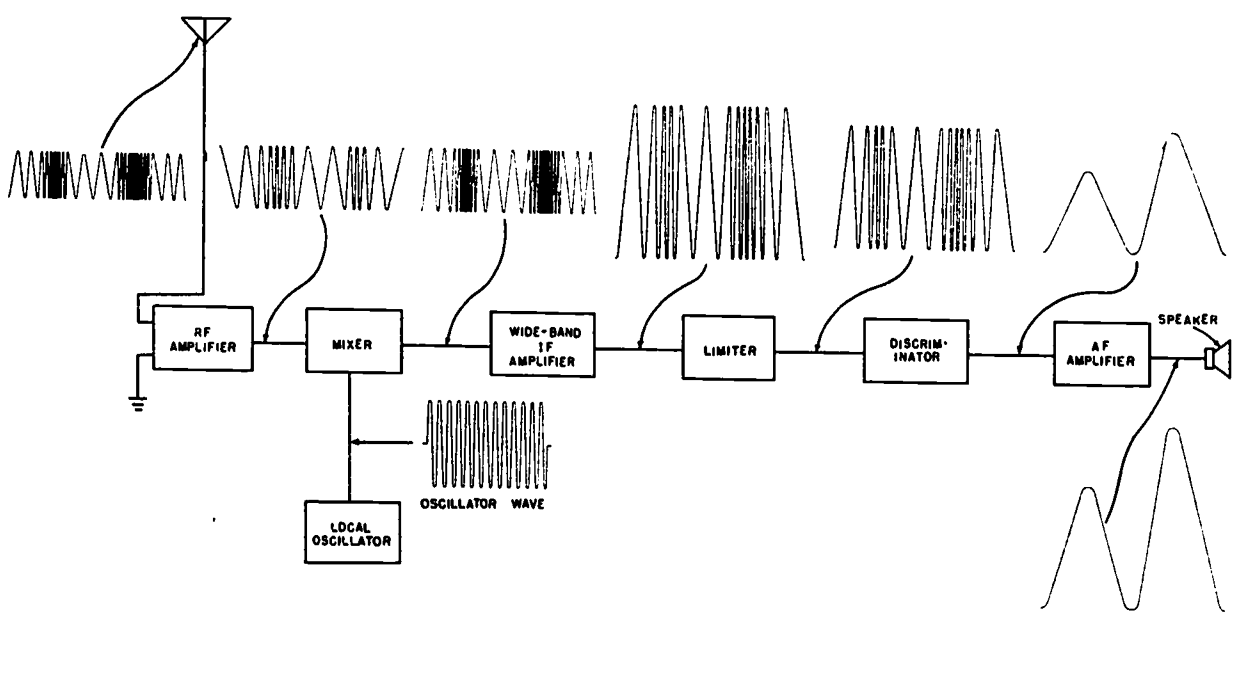
some method of carrier reinsertion is used at each receiving station. This type of communications is called single-sideband (SSB) communications---all transmitting power is concentrated in the one sideband. The RF carrier, which has been either partially or entirely suppressed at the transmitter, must be reinserted at the receiver to combine with the received single sideband. The result is a waveform identical to the one produced in the transmitter before suppression of the carrier and one sideband.

Single-sideband communications has several advantages over the conventional AM system. One of the major advantages is that all of the radiated power is utilized in conveying the intelligence, and no power is lost in transmitting the carrier or duplicate sideband. A second advantage is that the bandwidth necessary for single-sideband reception is narrower than that required to receive both sidebands for the same contained intelligence; therefore, more single-sideband channels can be accommodated in a given band of frequencies. Third, the AM signal is less affected by selective fading or by manmade interferences.

SUPERHETERODYNE (FM) RECEIVER

The function of a frequency modulated (FM) receiver is the same as an AM superheterodyne receiver. There are certain important differences in component construction and waveform design. Compare block diagrams (figs. 2-7 and 2-8). In both AM and FM sets the amplitude of the incoming signal is increased in the RF stages. The mixer combines the incoming RF with the local oscillator RF signals to produce the intermediate frequency which is then amplified by one or more IF amplifier stages. Note that the FM receiver has a wide-band IF amplifier. This is necessary, since the bandwidth requirements for any type of modulation is that it must be wide enough to receive and pass all the side-frequency components of the modulated signal without distortion.

Sidebands created by FM and phase-modulated (PM) systems differ from those of the AM system. They occur at integral multiples of the modulating frequency on either side of the carrier wave. Remember that the AM system consists of a single set of side frequencies for each radiofrequency signal that is modulated. An FM or phase-modulated



13.67

Figure 2-8.—Block diagram of FM receiver and waveforms.

signal inherently occupies a wider band than AM and the number of these extra sidebands that occur during FM transmission is related to the amplitudes and frequencies of the audio signal.

Now we begin to see a marked difference between the two receiver diagrams (figs. 2-7 and 2-8). While AM demodulation involves the detection of variations in the amplitude of the signal, FM demodulation is the process of detecting variations in the frequency of the signal. Thus, in AM superheterodyne receivers, the "detector" is designed to respond to amplitude variations of the signal and in FM receivers, a "discriminator" is designed to respond to frequency shift variations. A discriminator is preceded by a limiter, which limits all signals to the same amplitude level to minimize noise interference. The audiofrequency component is then removed by the discriminator. This audio signal is amplified in the AF amplifier and sent to the speaker.

Electrically, there are only two fundamental sections of the FM receiver which are different from the AM receiver; the discriminator (second detector) and the accompanying limiter.

Some Advantages of FM Receivers

In normal reception FM signals are totally absent of static while AM signals are subject to cracking noises and whistles. FM followed AM in development and had the advantage of operating at the higher frequency where spectrum is more plentiful. FM signals provide a much more realistic reproduction of sound because of an increased number of sidebands.

The major disadvantage of FM is the wide bandpass required to transmit the FM signals. Each station must be assigned a wide band in the frequency spectrum. During FM transmissions, the number of significant sidebands which must be transmitted in order to obtain the desired fidelity is equal to the deviation divided by the highest audiofrequency to be used. Thus, if the deviation is 40 kHz and the highest audiofrequency is 10 kHz, the number of significant sidebands is

$$\frac{40 \text{ kHz}}{10 \text{ kHz}} = 4$$

This number of sidebands exists on both sides of the rest frequency; thus, there are 8 significant sidebands. Because the audiofrequency is 10 kHz, and there are 8 sidebands, and bandwidth must accommodate an 80 kHz signal. This is considerably wider than the 10- to 15-kHz bandpass for AM transmitting stations.

Because of the wide bandwidth requirements, the Navy uses very little FM equipment. One type of FM equipment presently being used by the Navy is a series of walkie-talkie transceivers which provide voice communications for amphibious operations.

Frequency Conversion

Frequency conversion is accomplished by employing the heterodyne principle of beating two frequencies together to get an intermediate frequency. We have been studying this principle which is sometimes called single conversion.

'Some receivers use double or triple conversion, sometimes referred to as double or triple heterodyning or detection. These receivers are more selective since they suppress image signals in order to yield sharp signal discrimination. (The image frequency is an undesired modulated carrier frequency that differs from the frequency to which a superheterodyne receiver is tuned by twice the intermediate frequency.) Double and triple conversion receivers also have better adjacent channel selectivity than can be realized in single conversion sets.

MULTIPLEXING

Multiplexing techniques used in naval communications is becoming of vital interest to every naval officer. Today our frequency spectrum is becoming overcrowded. This situation is being alleviated by the simultaneous transmission of two or more signals using a common carrier wave or a single path in a telegraph system called multiplexing.

CLASSIFICATION OF RADIO EMISSIONS

Table 2-2 is a reference table pertaining to radio transmission. The three main classifications of radio emission are shown as amplitude modulation, frequency or phase modulation, and pulse modulation.

To better acquaint ourselves with radio emissions, let us consider a few combinations and representative examples in table 2-2. A1 refers to telegraphic communications by keying an

Table 2-2.—Classification of Radio Emissions.

Symbol	Type of transmission
	Amplitude modulated
A0	Continuous wave (CW) no modulation.
A1	Continuous-wave (CW) 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.
A3J	Telephony—Single sideband, suppressed carrier.
A4	Facsimile.
A5	Television.
A7	Telegraphy Multichannel Audiofrequency Tone Shift. (AFTSRATT).
A7B	Telegraphy Multichannel Audiofrequency Tone Shift. Two Independent Sidebands.
A7J	Telegraphy Multichannel Audiofrequency Tone Shift. Single Sideband Suppressed Carrier.
A9	Composite transmissions and cases not covered by above classifications of emissions.
A9A	Composite transmissions, reduced carrier.
A9B	Composite transmissions, two independent sidebands.
	Frequency (or phase) modulated
F0	Absence of modulation
F1	Telegraphy by Radio Frequency Carrier Shift. (RFCSRATT). No modulation.
F2	Telegraphy by keying of a modulating audiofrequency. 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 audiofrequency.
P2D	Telegraphy by keying an audiofrequency which modulates the pulse in its amplitude.
P2E	Telegraphy by keying an audiofrequency which modulates the pulse in its width.
P2F	Telegraphy by keying an audiofrequency 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.

Sampling of Transmitter Equipment

DESIGNATOR	TYPE OF EMISSION	SAMPLE EQUIPMENT
2.04A2	1020 Hz AFT Beacon	AN/WRT-1 (MF)
36F3	Telephony (FM)	AN/PRC-10 (VHF)

For further reference on radiofrequency emission, see JANAP 195.

unmodulated carrier wave (CW). A2 is also a form of telegraphy, but in this case, the transmitted signal is a keyed modulated carrier wave, generally referred to as MCW. In figure 2-9A and B, note that many more signal waves are involved in forming the DASH than in forming the DOT. This results from the time difference in the keying operation.

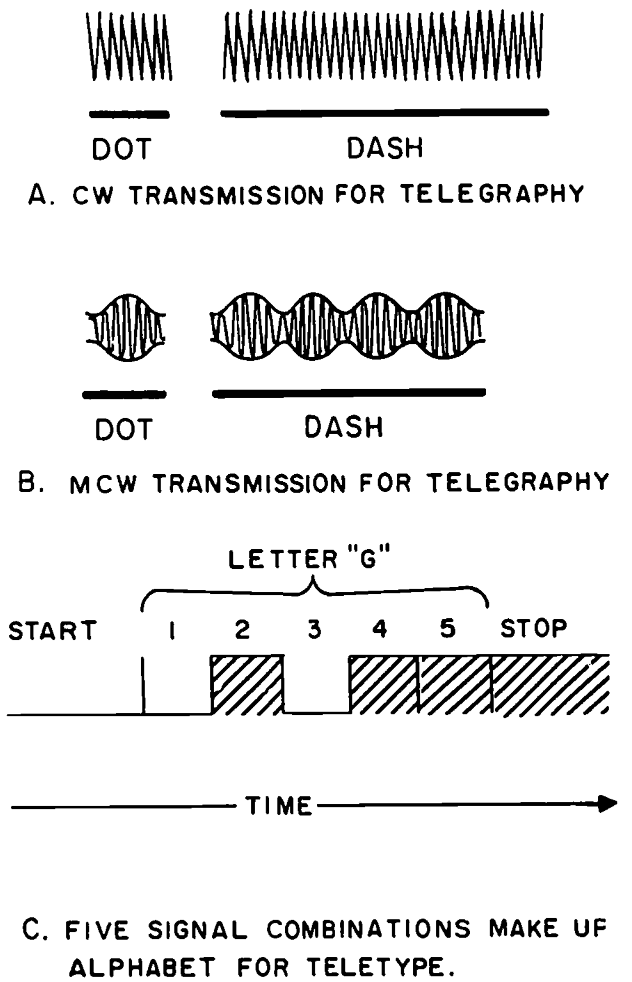


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Figure 2-9.—Representative types of special transmissions.

Various combinations of dots and dashes are used to form the alphabet by Morse code. The term "continuous wave" (CW) refers to the fact that the amplitude is continuous and does not vary. It does not refer to the interruption rate.

The advantage of CW over MCW is the narrow frequency band type of transmission involved for CW. CW is also advantageous for long range transmissions under severe noise conditions. Intelligence is easily encrypted for security using CW (A1) transmissions. A1 radio receivers, however, require a beat frequency oscillator (BFO) input to the IF stage to heterodyne with the continuous wave code so that audible tones can be reproduced at the second detector. This is not required for A2 reception since the incoming wave is modulated (MCW). A2 transmission is not often used for telegraphy, however, because a wider frequency band is required.

In recent years, the Navy has vastly improved its radio teletype (RATT) capabilities with new equipment that uses two types of RATT emissions (FM and AM). Both require the use of two discrete radiofrequencies to produce one channel of radioteletype; one frequency for the MARK signal and the other for the SPACE signal (fig. 2-9C). The START signals are always SPACE, and the STOP signals are always MARK. Combinations of 5 marks and/or spaces make up the various letters of the code.

The AN/WRT-1 (mentioned as a sample equipment at the bottom of Table 2-2) is a medium frequency range AM transmitter. In this example it is being used as a 1020 Hz audiofrequency tone homing beacon. 2.04A2 indicates the Navy's assigned bandwidth and type of transmission; 2.04 designates the "necessary bandwidth" in kHz and A2 represents telegraphy by keying of amplitude modulated emission.

The AN/PRC-10, another sample equipment, is an FM transmitter operating in the very high frequency range. In the designator 36F3 the 36 indicates the Navy's assigned bandwidth for the transmitter (36 kHz) and F3 denotes frequency modulated telephony.

CHAPTER 3

RADIO EQUIPMENT

The equipments discussed and illustrated in this chapter are selected as representative of the many models and types of radio transmitters, receivers, and auxiliary equipments used in the fleet today. No attempt is made to cover all of the equipments in use.

Modern shipboard radio equipments must be rugged construction for long service life. This equipment must be capable of transmitting and receiving over a wide range of frequencies and distances, while operating in any one of several modes. Because of limited space aboard ships and of ship's motion on rough seas, compactness and ruggedness are among the factors considered in designing these equipments.

TRANSMITTERS, TRANSMITTER-RECEIVERS, AND TRANSCEIVERS

A transmitter-receiver comprises a separate transmitter and receiver mounted in the same rack or cabinet. The same antenna may be used for the transmitter-receiver arrangement. When so used, the capability for simultaneous operation of both the transmitting and receiving equipments does not exist. The equipments may be operated independently, using separate antennas.

A transceiver is a combined transmitter and receiver in one unit which uses switching arrangements in order to utilize parts of the same electronic circuitry for both transmitting and receiving. Hence, a transceiver cannot transmit and receive simultaneously.

MF, AND HF TRANSMITTERS

Transmitters operating in the medium- an high-frequency bands of the frequency spectrum are used chiefly for communication at medium and long ranges. Some transmitters in these bands, however, are designed for short-range communication. In most instances, short-range transmitters have a lower output power than those designed for communication at medium and long ranges.

In the following descriptions of specific equipment capabilities, the term "short range" (or "distance") means a measurement less than 200 miles; "medium range" is between 200 and 1500 miles; and "long range" exceeds 1500 miles. These values are approximates, because the range of a given equipment varies considerably according to terrain, atmospheric conditions, frequencies, and time of day, month, and year.

Some transmission equipment has a capability of radio teletype emission. The older equipment employed RFCSRATT (radiofrequency carrier shift radioteletype). The newer equipment has employed AFTSRATT (audiofrequency tone shift radioteletype). The old designation FSK (frequency shift keyer) is to be replaced with the above designators since it is more descriptive (reference JANAP 195H). This is covered more in detail in the next chapter on teletype equipment.

Transmitters AN/SRT-14, -15, and -16

Transmitting sets AN/SRT-14, -15, and -16 are a series of shipboard transmitters designed for medium- and long-range communications. The AN/SRT-14 (fig. 3-1A) is the basic transmitter in the series, with a power output of 100 watts. By adding a power booster to the basic transmitter, it becomes the AN/SRT-15 (fig. 3-1B). The AN/SRT-15 has an optional output power of either 100 or 500 watts. Transmitter set AN/SRT-16 (fig. 3-1C) consists of two AN/SRT-14 equipments plus the booster, furnishing two entirely independent transmitting channels of 100-watt output, with the 500-watt booster available for use with either channel when desired.

All three transmitters cover the frequency range 0.3 to 26 MHz, and may be used for CW, radiotelephone, radioteletype, and facsimile

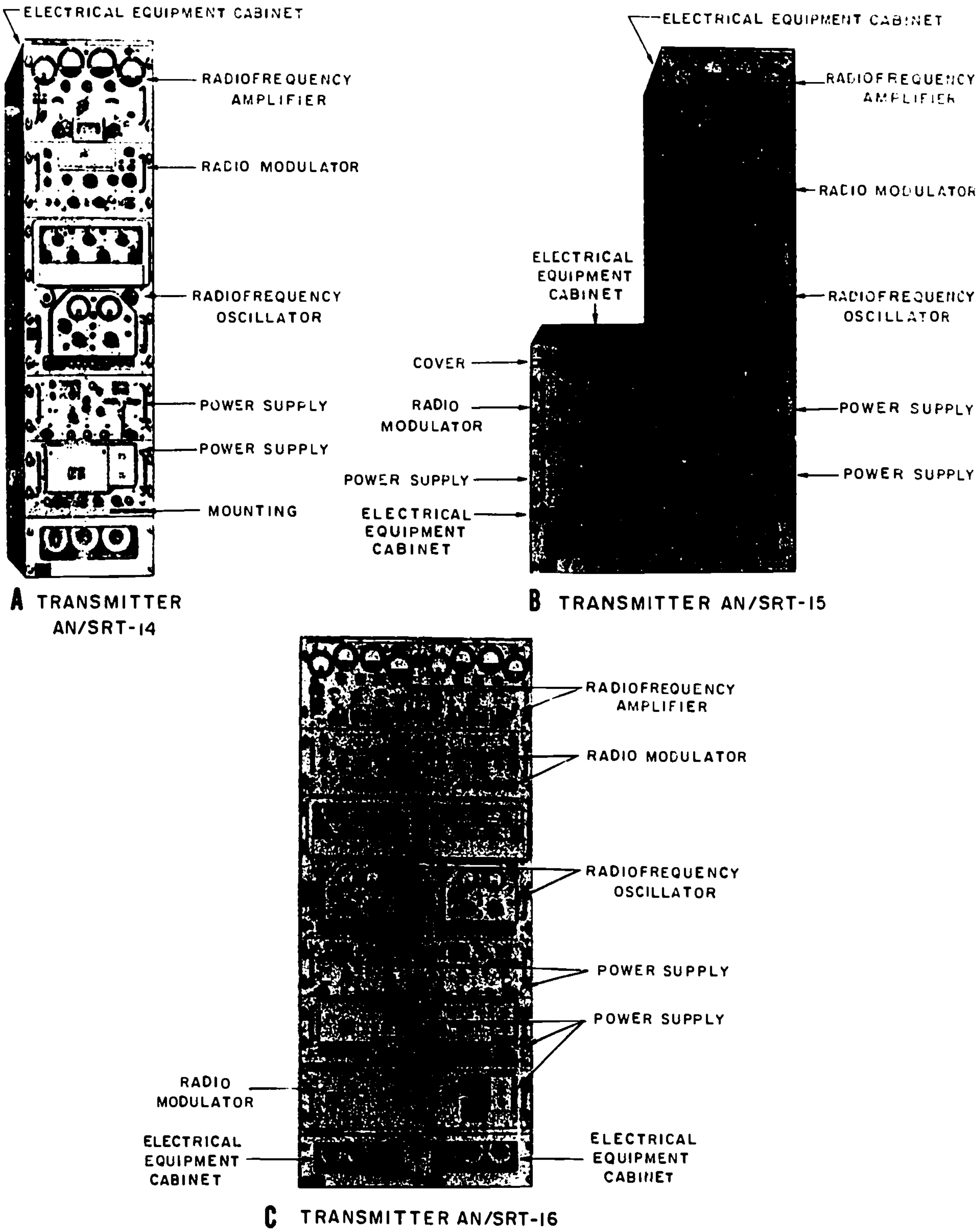

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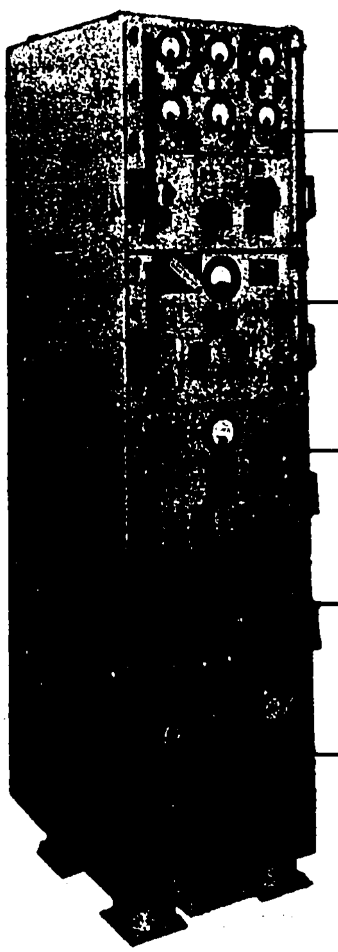
Figure 3-1.—Radio Transmitter AN/SRT-14, -15, -16.

transmissions. The 500-watt output pcwer, however, is available only when the AN/SRT-15 or the AN/SRT-16 is operating in the frequency range of 2 to 26 MHz; at frequencies below 2 MHz, output is limited to 100 watts.

Transmitter AN/WRT-1A

The AN/WRT (fig. 3-2) is a shipboard transmitter designed for operation in the frequency range 300 to 1500 kHZ. This equipment can transmit CW, RFCS, MCW and voice signals, but it has no SSB capability. When used for CW and RFCS transmissions, the transmitter has a power output of 500 watts. Voice operation, however, reduces the available power to approximately 125 watts.

Because of operating in the medium frequencies with a substantial power output, the AN/WRT-1A lends itself well for communicating over long distances during the hours of darkness. Its range is reduced to medium distances during daylight hours.



32.278(76)
Figure 3-2.—Radio Transmitter AN/WRT-1A.

Transmitter AN/WRT-2

Radio transmitter AN/WRT-2 (not illustrated) is similar in size and appearance to the AN/WRT-1A. It covers the frequency spectrum between 2 and 30 MHz, and has an average power output of 500 watts for CW, AFTS, and compatible AM modes of operation. When operating as a single-sideband transmitter, it produces 1000 watts. An additional feature of the AN/WRT-2 is that it provides independent sideband operation. This mode of operation permits simultaneous transmission of both sidebands, each one carrying separate intelligence.

Actual transmitter output values as gained from feedback from the fleet indicate that the power output levels are substantially lower than those cited above. Personnel must ensure that the transmitter is properly maintained and that optimum tuning exists for all operating modes. (Refer to Chapter 2, Table 2-2, "Classifications of Radio Emissions," for more detail on the modes of operation for the following radio sets.)

As indicated by its operating frequencies and power outputs, the AN/WRT-2 is used for medium- and long-range communications.

Transmitter-Receiver AN/SRC-23(V)

The AN/SRC-23(V) (fig. 3-3) is a single channel HF transmitter-receiver communications system which operates in the 2-30 MHz range. The transmitter-receiver is automatically tuned and capable of local or remote control in either simplex or duplex modes of operation for AM, CW, USB, LSB, ISB, AFTS, voice, or data. The equipment has a 1 KW power output; however, an alternate 5 KW RF power output may be obtained using a 5 KW linear power amplifier.

Designed especially for shipboard installations, this transmitter-receiver group may also be used for shore-base installations and consists of eight basic units located within a cabinet.

The front panel of the transmitter control unit (fig. 3-3) provides the controls for manually selecting the modes of operation for the transmitter and amplifier group.

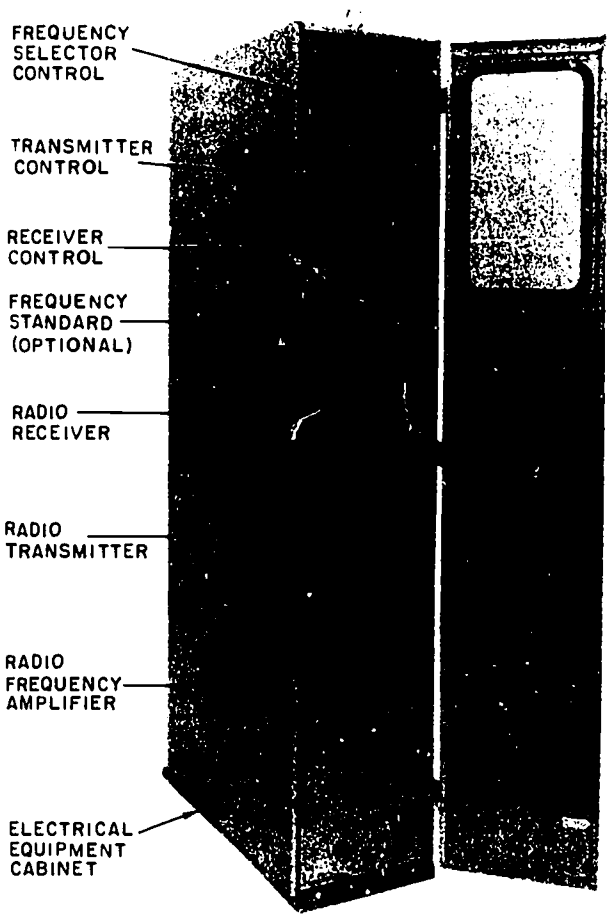


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Figure 3-3.—Radio-Transmitter-receiver AN/SRC-23(V).

The receiver control unit provides controls for operating the receiver.

The frequency selector control unit provides the selector switches for selecting the desired operating frequency for the transmitter and receiver units.

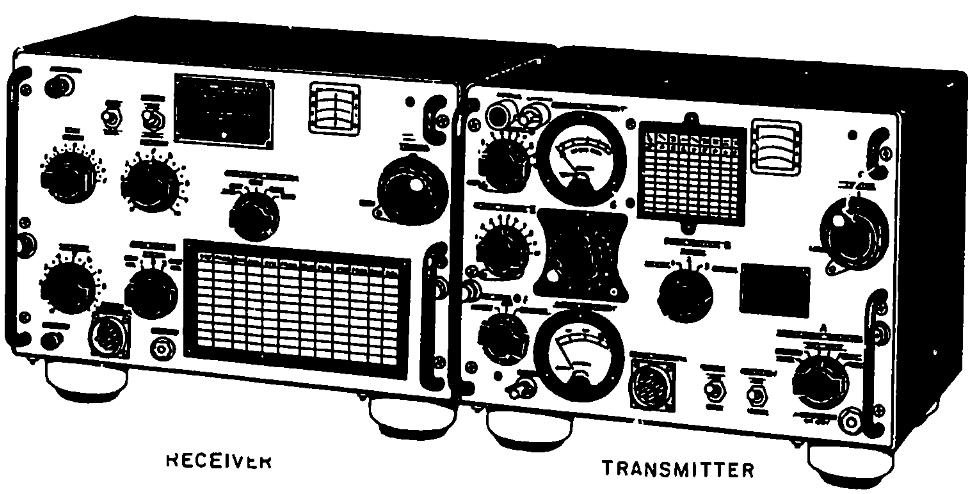
The radiofrequency amplifier unit receives the signal from the transmitter and amplifies it to 1,000 watts.

The frequency standard unit is optional equipment, which may be installed in the cabinet when external frequency standard equipment is not supplied. It provides an unmodulated 100-kHz output frequency used for calibrating the radio transmitter and receiver. In case of power failure, an internal 28 VDC battery in this unit will automatically supply power for two hours.

The electrical equipment cabinet provides mounting space for all of the functional units and other equipment, such as a heat exchanger and blower for cooling the system, patch terminal strips, thermal alarm indicators, a warning panel, primary power circuit breaker, and interconnection system components.

The equipment is completely transistorized except for the use of two electron tubes. A frequency-synthesizer provides transmitter-receiver frequencies separated at 500 hertz intervals across the band.

The AN/SRC-23(V) is a single-channel version of the four-channel service test NTDS (Naval Tactical Data System) AN/SRC-16, covered later in the chapter.



76.22
Figure 3-4.—Radio Transmitter-receiver Model TCS-( ).

Transmitter-Receiver Model TCS-( )

The model TCS-( ), (fig. 3-4) is a small transmitter-receiver that has been in use for many years for short-range communications. It has an output power of 10 watts for radiotelephone and 25 watts for CW. The TCS-( ) has a frequency range of 1.5 to 12 MHz. Its frequency-determining section may be either crystal-controlled or tuned by a continuously variable oscillator, whichever is more desirable. Transmitter and receiver use the same antenna, which is switched from receiver to transmitter by a relay when the transmitter is keyed. Although it is being replaced by the AN/URC-35, the TCS-( ) is still used aboard ships of many types.

Transmitter-Receiver AN/WRC-1 ( )

Another radio set that covers the frequency range 2 to 30 MHz is the AN/WRC-1( ) transmitter-receiver (fig. 3-5). It has a maximum power output of 100 watts, and is capable of transmission and reception on upper sideband, lower sideband, continuous wave, amplitude modulation, radioteletype, and independent sideband modes of operation.

An outstanding feature of the AN/WRC-1( ) is that it has an automatic antenna tuning system. This system automatically tunes the antenna to the transmitter's output frequency, thereby assuring maximum transfer of power at all times. Manual controls are provided for fine tuning for maximum power output.

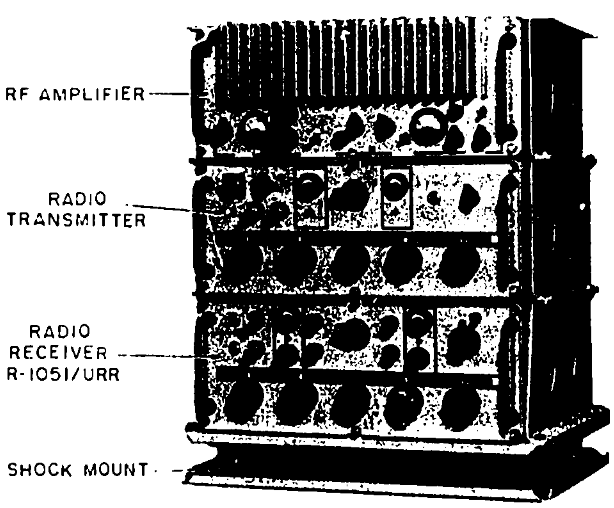
Transmitter AN/URT-24

When the receiver unit is removed from the AN/WRC-1( ) transmitter-receiver the remaining units form the AN/URT-24 transmitter. When used as an AN/URT-24, the top two units in figure 3-5 (RF amplifier and radio transmitter) are seated directly on the shock mount, thus eliminating the receiver unit.

The transmitter is used for short range communications.

Transmitter AN/URT-23(V)

The AN/URT-23(V) is a long and medium range transmitter which operates as a 1 KW single-sideband transmitter (fig. 3-6). The



76.61
Figure 3-5.—Radio Transmitter-receiver AN/WRC-1.

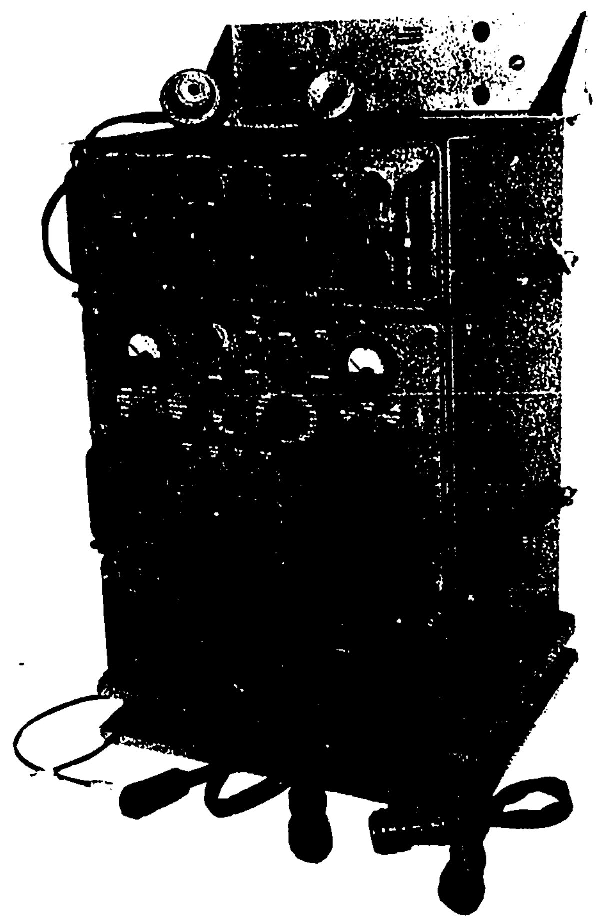


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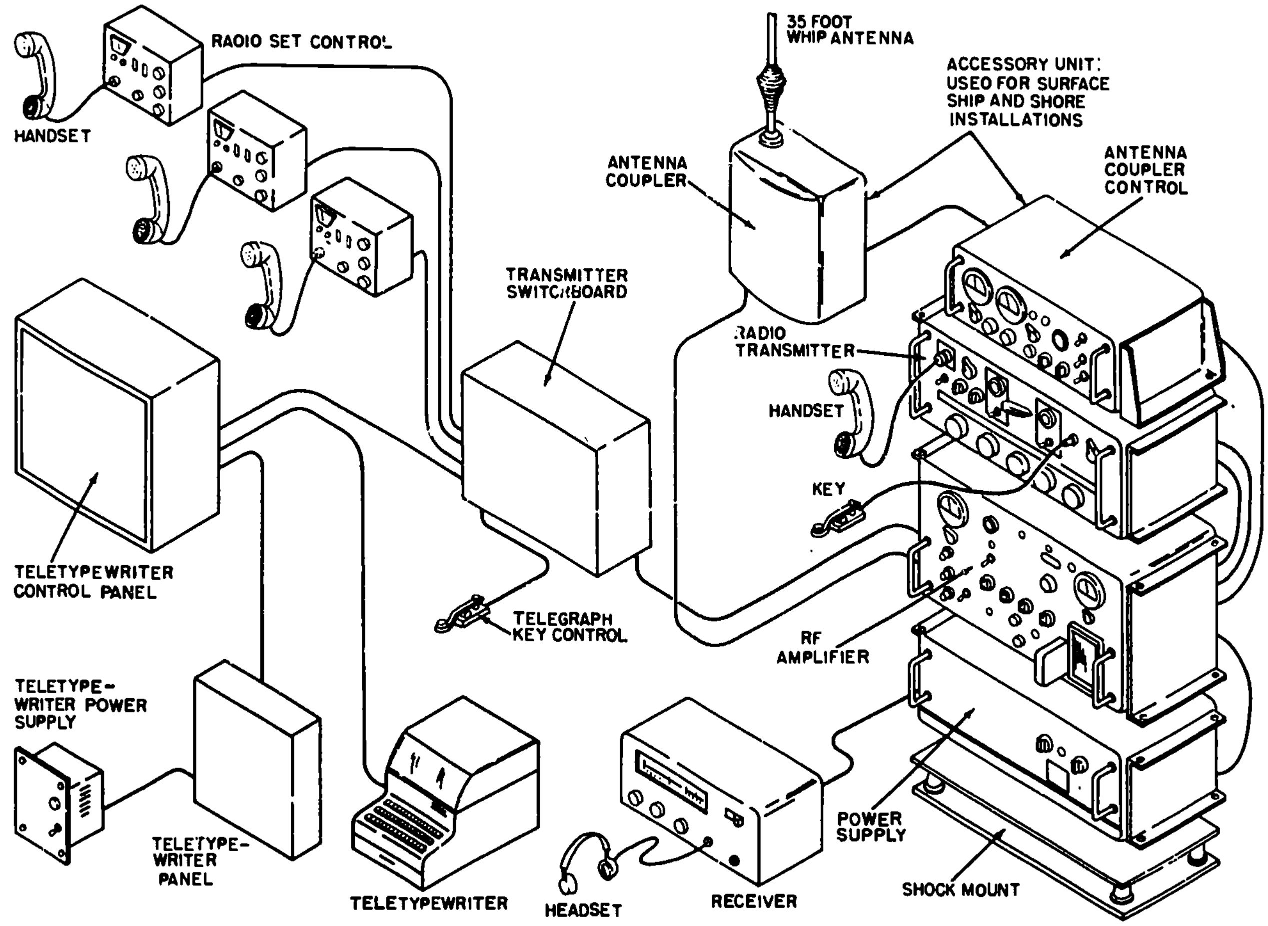
Figure 3-6.—Radio Transmitter AN/URT-23(V) (with 60 hertz power supply).



120.66
Figure 3-7.—A complete communications system for Radio Transmitter AN/URT-23(V).

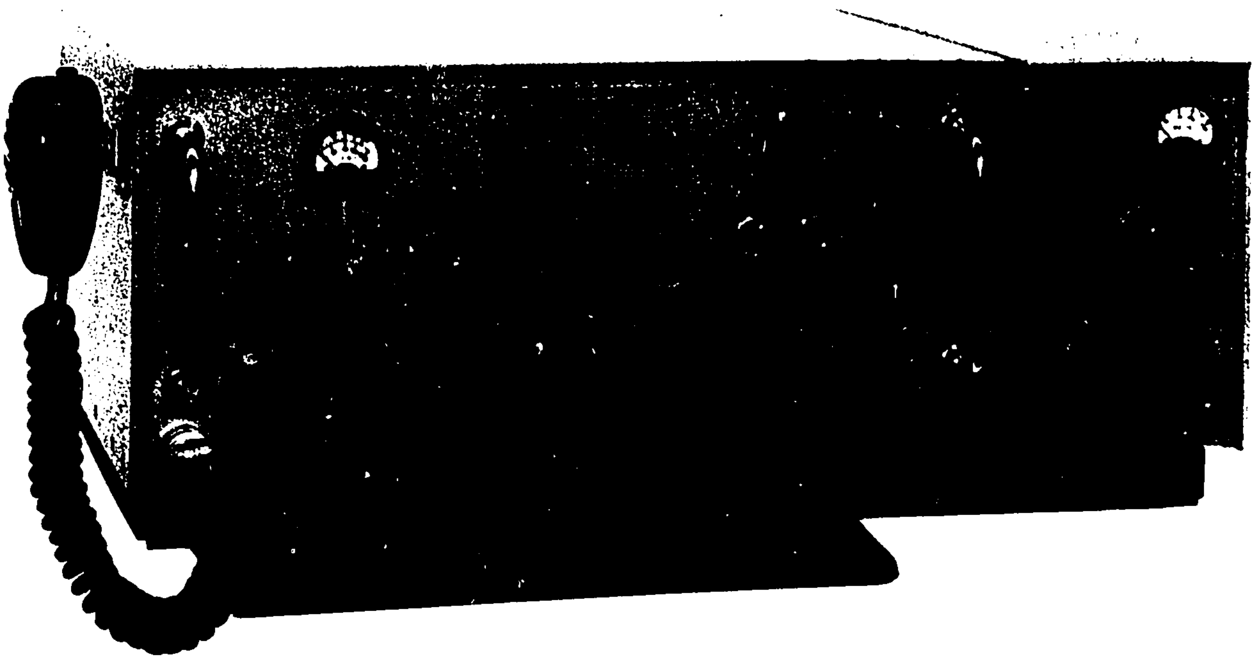
normal configuration provides voice, continuous wave, and radio teletypewriter transmissions in the 2-30 MHz frequency range. A frequency standard (either internal or external), with crystal-controlled synthesizers is used for frequency control. The transmitter is equipped to provide automatic (digital) tuning to the correct frequency within a frequency band. Two optional power supply equipments permit the use of any one of three, 3-phase primary power sources: 115 volts line-to-line 400 hertz or 208 or 440 volts line-to-line 60 hertz.

The major units of the AN/URT-23(V) may be stack or rack mounted for installation aboard ship or for shore installations to form a complete communications system as illustrated in figure 3-7.

Transceiver AN/URC-58(V)

The AN/URC-58(V) radio set (fig. 3-8) is a single sideband (SSB) transceiver for general-purpose voice and CW communications and may be used for ship and shore fixed installations, semiportable applications such as in vehicles, and amphibious landing craft, and for use aboard ship.

The radio set operates in the 2 to 15 MHz frequency range and provides transmission and reception on single sideband (selectable upper and lower sideband), CW and AM (compatible) signals. This equipment operates from a nominal primary power input of 115/230 volts, 50 to 60 hertz, single phase and either 12 or 24 VDC power, providing a power output of



120.67

Figure 3-8.—Radio Transceiver AN/URC-58(V).

100 watts. Audio and keying facilities are provided for both local and remote operation. The transceiver is a triple-conversion superheterodyne receiver and transmitter tunable over the entire frequency range in 1 kHz increments.

Transceiver AN/URC-32B

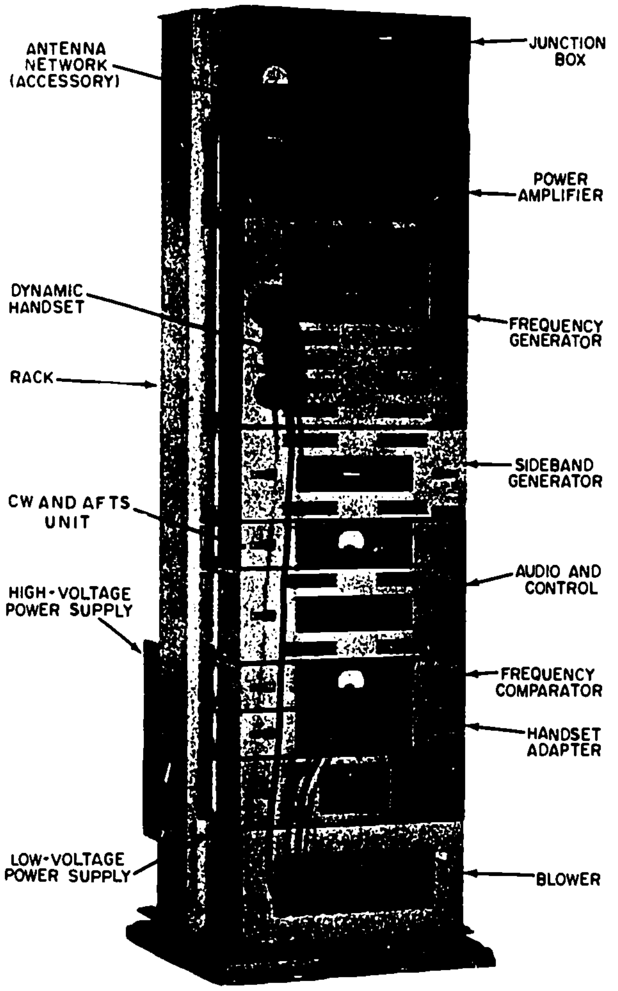
Radio Transceiver AN/URC-32B (fig. 3-9) is a manually operated radio communication equipment for operating in the 2 to 30 MHz (high-frequency) range. With a power output of 500 watts, this transceiver is capable of transmitting signals over long distances. It is designed for single-sideband transmission and reception on upper sideband, lower sideband, or the two independent sidebands simultaneously, with separate AF and IF channels for each sideband. In addition to SSB operation, provisions are included for compatible AM (carrier plus upper sideband), CW, or tone-shift keying (AFTS). The AFTS mode of operation is used for sending radioteletype (RATT) and facsimile (FAX) signals.

The frequency range of 2 to 30 MHz is covered in four bands. The desired operating frequency in kHz is tunable in 100 Hz increments on a direct-reading frequency counter. Frequency accuracy and stability are controlled by a self-contained frequency standard. Provisions are also made for using an external frequency standard.

Because of its versatility and power, the AN/URC-32B is installed on most Navy ships having a requirement for communicating over long distances. It is being replaced by the AN/URT-23.

Transceiver AN/URC-35

Designed primarily for mobile operations, the AN/URC-35 (fig. 3-10) has continuous wave transmitting capabilities, but is used chiefly for voice communications over short and medium distances. These portable sets are found aboard vehicular and small surface craft, and aboard regular Navy ships for emergency use.



32.135

Figure 3-9.—Radio Transceiver AN/URC-32B.

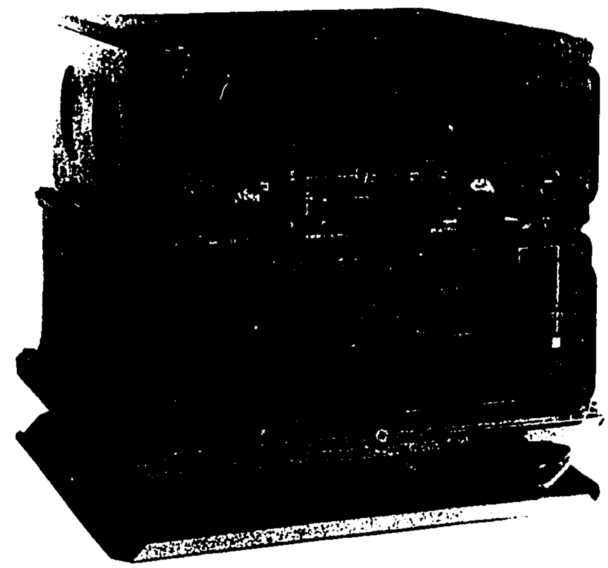


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Figure 3-10.—Radio Transceiver AN/URC-35.

The AN/URC-35 is a general-purpose HF radio set for transmitting and receiving SSB, AM, and CW signals in the 2 to 30 MHz spectrum.

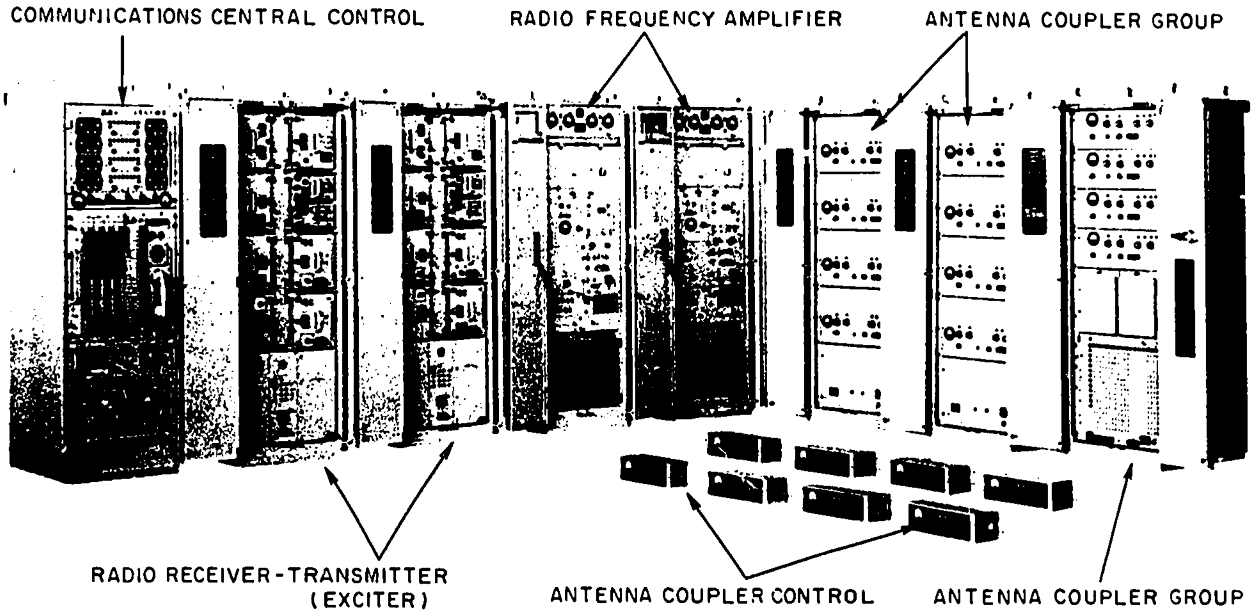
The receiver and transmitter are automatically tuned to the same frequency at all times by common electronic assemblies. All components in the electronic assemblies are transistorized, except the RF amplifiers.

Optional power requirements are met by either internal or external 28 VDC battery supply or by 115 VAC. Three different antennas may be employed: a 15-foot probe or whip, a 25-foot whip, or a 35-foot whip type antenna.

Transmitter-Receiver AN/SRC-16

Communications central AN/SRC-16 (fig. 3-11) is a shipboard, single-sideband communications system with a frequency range of 2 to 30 MHz. In addition to the normal voice, CW, and AFTS communications, the system provides high-frequency reception and transmission for terminal equipment such as HCCS (high-capacity communications system) and NTDS (Navy Tactical Data System). The system uses dual single-sideband equipment and both sidebands are available for use independently for either voice or multitone signals. The system operates on four independent channels, each channel consisting of a single-sideband receiver, a single-sideband transmitter (exciter), and a 500-watt PEP linear power amplifier. The frequency of each receiver and transmitter is phase locked to a system primary frequency standard.

Two transmitters, two receivers, one power amplifier, and one frequency standard are located in each of the two cabinets in the communications central (fig. 3-11).



120.69
Figure 3-11.—Communications Central AN/SRC-16 (doors open).

VHF TRANSMITTERS

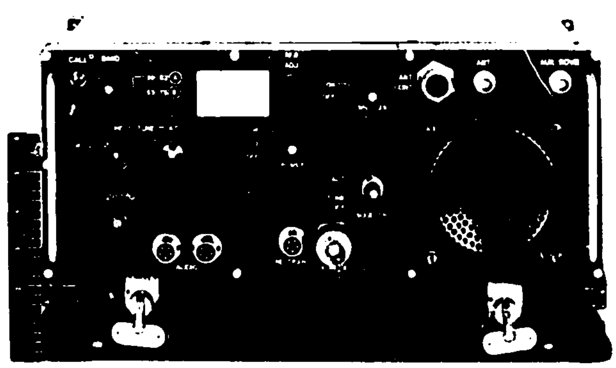
Transmissions in the VHF range normally are restricted to line-of-sight distances. Under certain atmospheric conditions, they have been received at considerably longer distances—500 miles or more.

Shipboard installations of VHF equipments are retained for emergency communications, and for communication with allied forces that have not yet converted to UHF equipments. The VHF equipment is also being used as a backup to UHF equipment.

Tranceiver AN/VRC-46

The AN/VRC-46 transceiver (fig. 3-12) was developed for Signal Corps use, but has been adopted for shipboard and amphibious naval gun fire support and joint communications with tactical Army and Marine Units ashore.

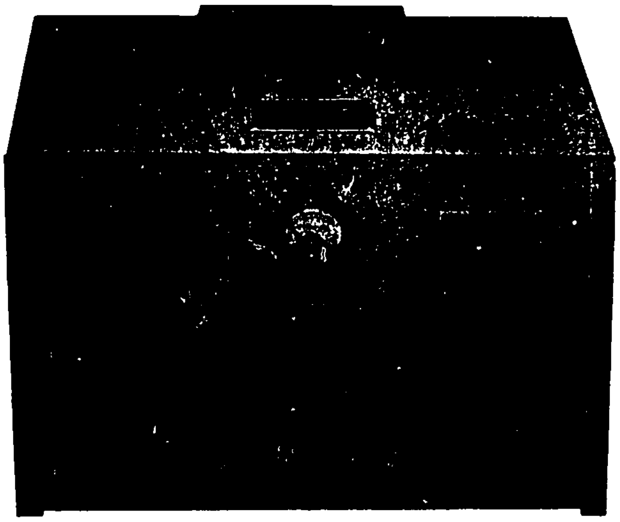
The AN/VRC-46 is a narrow-band FM transceiver capable of 24 VDC or 115 VAC operation in the 30 to 76 MHz (very high frequency) range. It is used for short-range, two-way radiotelephone communications. It replaces the older AN/SRC-10 through -15 wideband FM transceivers.



120.70
Figure 3-12.—Radio Transceiver AN/VRC-46.

Transmitter AN/URT-7( )

The AN/URT-7( ) (fig. 3-13) is a crystal-controlled VHF transmitter that operates in the frequency range 115 to 156 MHz. Although mountings for four crystals are provided, permitting rapid selection of any one of four frequencies, the transmitter must be retuned each time the frequency is changed.



32.40
Figure 3-13.—Radio Transmitter AN/URT-7( ).

With a power output of 30 watts, this equipment provides two modes of operation: radiotelephone and MCW.

UHF TRANSMITTERS

Most UHF radio transmitters (and receivers) used by the Navy operate in the 225- to 400-MHz frequency range. Actually, this range of frequencies covers portions of both the VHF band and the UHF band. For convenience, however, radio equipments operating within this frequency range are considered to be UHF equipments.

The effective range of UHF normally is limited to line of sight distances, however, under certain atmospheric conditions UHF has been received at considerably longer distances—500 miles or more.

Transmitter Model TED

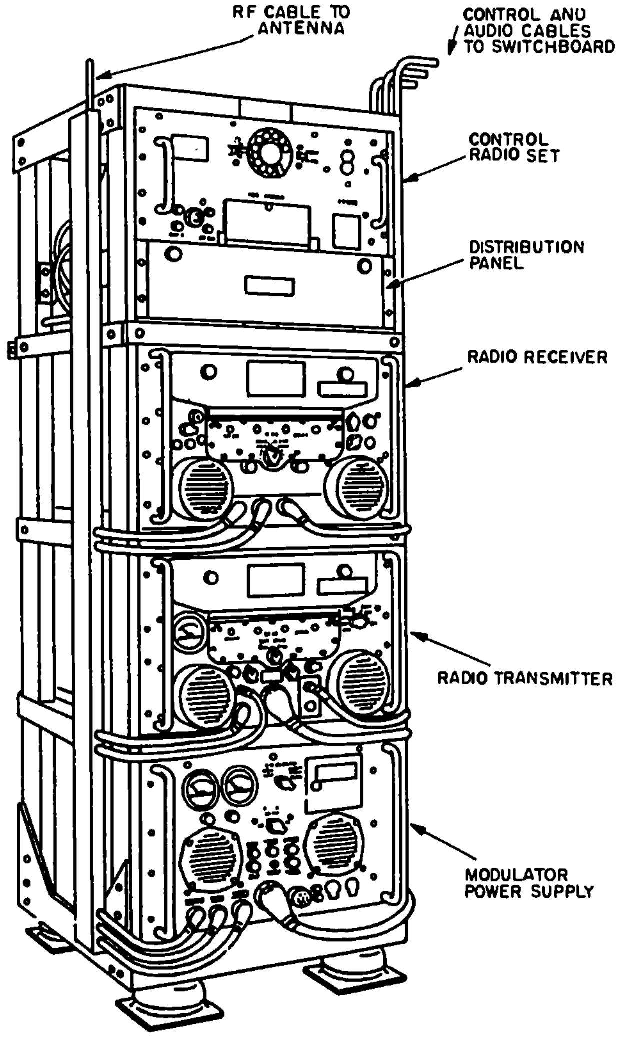
The model TED is a crystal-controlled, single-channel, UHF transmitter that operates in the frequency range 225 to 400 MHz. This transmitter is similar to the VHF transmitter AN/URT-7 described earlier and illustrated in figure 3-12.

The TED has an output power of 15 watts. An RF power amplifier (AM-1365/URT, not shown) boosts the output power to 100 watts.

Transmitter-Receiver AN/GRC-27A

The AN/GRC-27A (fig. 3-14) is a UHF transmitter-receiver set covering frequencies from 225 to 400 MHz. This equipment is used for radiotelephone and MCW communications from ship-to-ship, ship-to-shore, or with aircraft. The AN/GRC-27A is installed principally in carriers and antisubmarine warfare ships, whose primary missions involve the control of aircraft.

The transmitter has a power output of 100 watts. It has three crystal-controlled



32.109.2
Figure 3-14.—Radio Transmitter-receiver AN/GRC-27A.

oscillators, using a total of 38 crystals. These crystals, located within the transmitter, do not require handling by the operator. From the combination and multiplication of these 38 crystal frequencies are produced 1750 frequencies spaced at 100 kHz intervals throughout the transmitter's frequency range. Any 10 of these 1750 frequencies can be preset manually with selector switch dials. Of the 10 preset frequencies, one then can be selected automatically by a telephone-type dial. The automatic selection can be made either locally at the transmitter or from a remote unit at other locations, such as CIC and the bridge. Only 2 to 7 seconds are required to shift automatically from one channel to another in any of the 10 preset channels.

The receiver also operates on any of the 1750 channels. It is a triple-conversion superheterodyne and has crystal oscillators using 38 crystals in a system separate from but similar to that used in the transmitter. Here, again, automatic shifting of channels is done in about 2 to 7 seconds.

Both transmitter and receiver normally use the same antenna. A relay switches the antenna from one to the other.

Radio Transceiver Sets AN/URC-9( ), AN/SRC-20( ), -21( )

Radio set AN/URC-9( ), used separately (fig. 3-15) is a UHF transceiver that provides facilities for AM radiotelephone communications in the frequency range 225 to 400 kHz. The equipment is crystal-controlled and produces 1750 frequencies at 100 kHz intervals within its frequency range. Although it is capable of operating on only one frequency at a time, any 20 of the 1750 available frequencies can be preset for immediate selection from remote positions. Channel selection requires a maximum of 8 seconds. This set has a power output of approximately 20 watts.

When modified by the addition of certain units (fig. 3-15), the AN/URC-9( ) is redesignated either AN/SRC-20( ), (fig. 3-15) or AN/SRC-21( ) (fig. 3-16). These modified sets can be connected to similar sets so that received signals are retransmitted automatically. This feature is useful when a ship (or aircraft) is serving as a relay station between two stations that cannot communicate with each other directly.

The difference between the AN/SRC-20( ) and the AN/SRC-21( ) is that the AN/SRC-20( ) has a linear power amplifier unit that increases the 20-watt power output from the AN/URC-9( ) to a 100-watt output.

PORTABLE AND PACK RADIO EQUIPMENT

Because portable and pack radio sets must be lightweight, compact, and self-contained, they usually are powered by battery or hand generator, have low output power, and are either transceivers or transmitter-receivers. Navy ships carry a variety of these radio sets for emergency and amphibious communications. The numbers and types of this equipment vary according to the individual ship.

Transmitter AN/CRT-3A

Radio transmitter AN/CRT-3A, popularly known as the "Gibson girl," is a rugged emergency transmitter carried aboard ships and aircraft for use in lifeboats and liferafts. It is shown in figure 3-17. No receiving equipment is included.

The transmitter operates on the international distress frequency (500 kHz) and the survival craft communication frequency (8364 kHz).

The complete radio transmitter, including the power supply, is contained in an aluminum cabinet that is airtight and waterproof. The cabinet is shaped to fit between the operator's legs, and has a strap for securing it in the operating position.

The only operating controls are a three-position selector switch and a pushbutton telegraph key. A handcrank screws into a socket in the top of the cabinet. The generator, automatic keying, and automatic frequency changing are all operated by turning the handcrank. While the handcrank is being turned, the set automatically transmits the distress signal SOS in Morse code. The code sequence consists of six groups of SOS followed by a 20-second dash, transmitted alternately on 500 kHz and 8364 kHz. The frequency automatically changes every 50 seconds. These signals are intended for reception by two groups of stations, each having distinct rescue functions. Direction-finding stations cooperating in long-range rescue operations normally make use of 8364 kHz, whereas aircraft or ships locally engaged

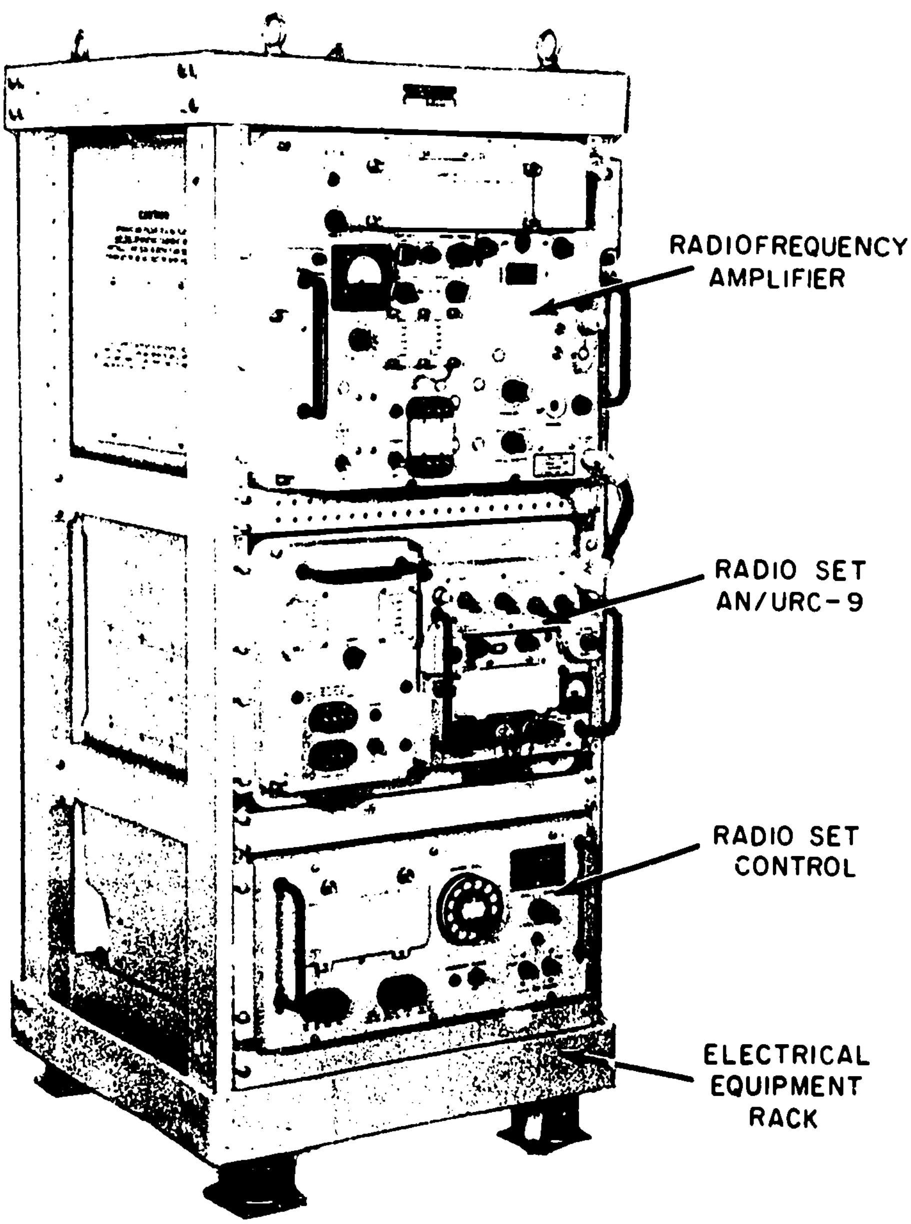


Figure 3-15.—Radio Transceiver AN/SRC-20.

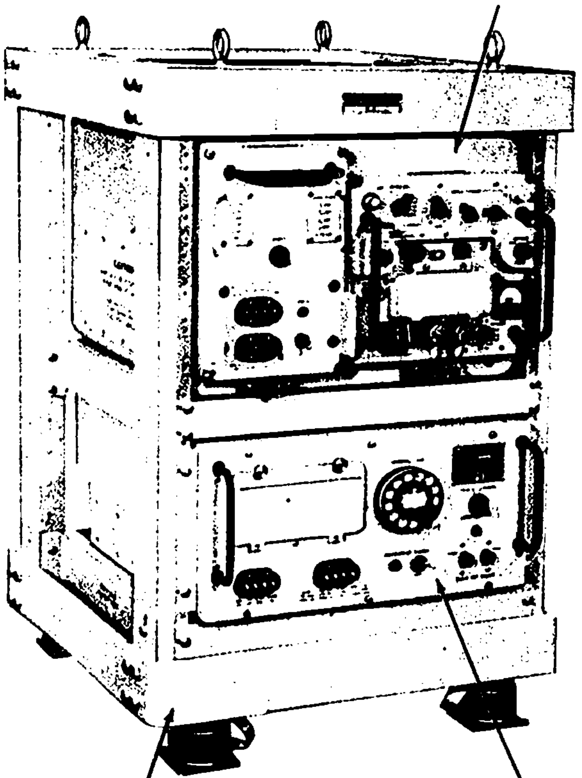


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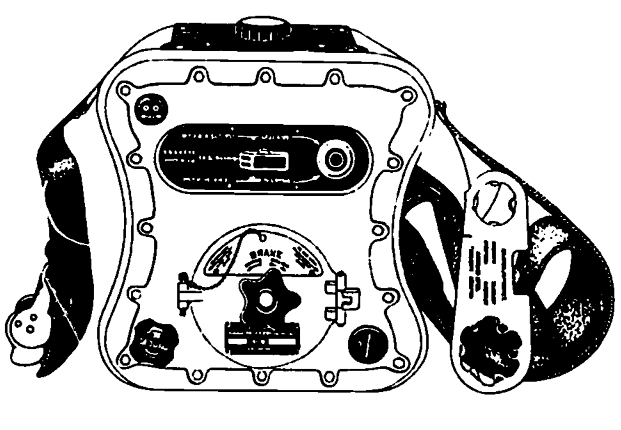
Figure 3-16.—Radio Transceiver AN/SRC-21.



76.32
Figure 3-17.—Emergency lifeboat Radio Transmitter AN/CRT-3A.

in search and rescue missions make use of the 500 kHz signals.

Besides the automatic feature, the transmitter can be keyed manually, on 500 kHz only, by means of the pushbutton telegraph key.

Additional items (not shown) packaged with the transmitter include the antenna, a box kite and balloons for supporting the antenna, hydrogen-generating chemicals for inflating the balloons, and a signal lamp that can be powered by the handcrank generator.

The equipment floats, and is painted brilliant orange-yellow to porovide greatest visibility against dark backgrounds.

Transceiver SCR-536( )

Radio transceiver SCR-536( ), (fig. 3-18) is a low-power, battery-operated transceiver used for voice communication over very short distances (1 to 3 miles). The equipment is crystal-controlled, and operates on a preset frequency in the range of 3.5 to 6 megahertz. The operating frequency is varied by changing the crystal and certain other frequency-determining components within the set. Usually, these changes are made by a technician.

The set is energized by extending the telescopic antenna. When thus energized, it functions as a receiver. Applying pressure on the press-to-talk switch (located on the side of the set) shifts the equipment from a receive condition to a transmit condition. The set remains in the transmit condition as long as the switch is held depressed.

Weighing only 5-1/2 pounds, this portable set comes equipped with a carrying strap. Often the set is used as a means of communication by personnel moving about on foot, as while on shore patrol. Also, it serves as a means of communication between small boats and their parent ships.

Transceiver AN/PRC-10( )

The AN/PRC-10( ) portable radio set (not illustrated) provide voice communications for amphibious operations. These are man-pack FM equipment sets.

Total frequency coverage of the AN/PRC-10( ) is between 38 and 54.9 MHz with an output power of approximately 1 watt. These portable sets have an effective range of approximately 5 miles.

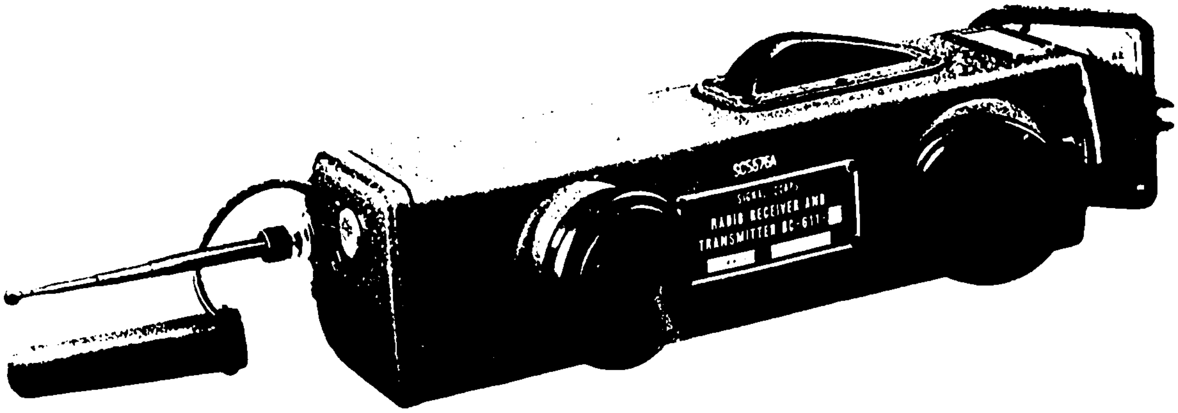


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Figure 3-18.—Radio Transceiver SCR-536( ).

Transceiver AN/PRC-25

The AN/PRC-25 is a VHF man-pack miniaturized radio set (fig. 3-19) now being used. It weights only 22 pounds with batteries, and replaces three sets (AN/PRC-8-9-10) that cover a frequency range of 20 to 55 megahertz. The AN/PRC-25 is an FM transceiver that operates in the 30- to 76-megahertz range and provides 920 channels spaced at 50 kilohertz intervals, with a power output of 2 watts. Stable frequencies are generated for both the transmitter and receiver by a frequency synthesizer.

The unit is transistorized throughout, with the exception of one tube in the transmitter power output stage. A future version will be completely solid state. With 25 modular plug-in subassemblies, the set is easy to service.

Transceiver AN/URC-4( )

The AN/URC-4( ) (fig. 3-20) is a compact, portable transceiver. It is small enough to allow the combined transmitter and receiver to be grasped and held with one hand. This unit is connected by a short cable to its battery case, which is approximately the size of the transceiver.

The complete set is intended to be carried in a special vest type garment worn by airmen while they are on flight missions. It also may be dropped by parachute to personnel in distress.

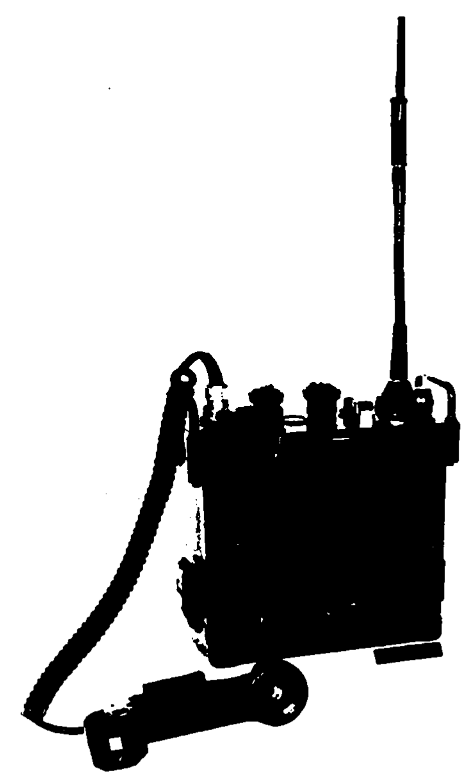

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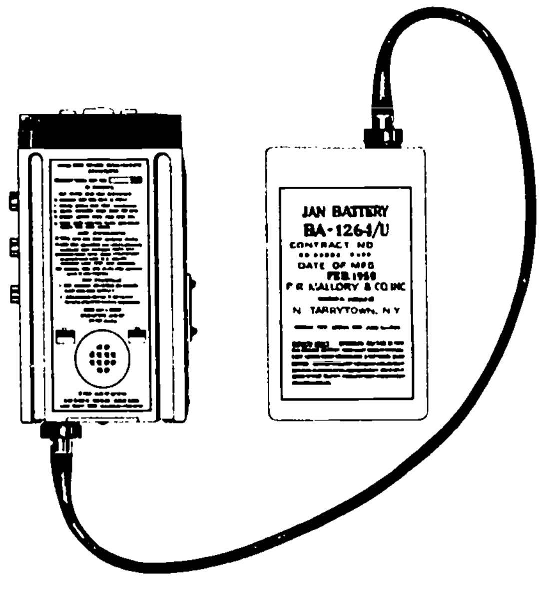
Figure 3-19.—Radio Transceiver AN/PRC-25.



120.6
Figure 3-20.—Radio Transceiver AN/URC-4( ).

The principal use of this set in the Navy is for extremely short-distance distress communication between lifeboats (or liferafts) and searching rescue aircraft or ships.

This transceiver is a crystal-controlled equipment that provides voice and MCW transmissions over two frequency ranges within the VHF band. Frequencies covered are between 120 and 130 MHz and between 240 and 260 MHz. The operating frequency of the set is determined by a single crystal, which must be changed each time the frequency is changed. The set is pretuned, and can be operated by anyone familiar with its purpose.

Transceiver AN/PRC-41

Radio set AN/PRC-41 (fig. 3-21) is a watertight, lightweight, portable UHF equipment that may be operated on any of 1750 channels spaced 100 kHz apart in the 225- to 400 MHz range. Its only mode of operation is AM voice, which it supplies at an average output power of 3 watts. Although designed principally for manpack operation, the set also may be used for fixed station and vehicular operation when complemented by certain accessories. When not in use, the equipment is disassembled and stowed in a compartmentized aluminum transit case similar to an ordinary suitcase.

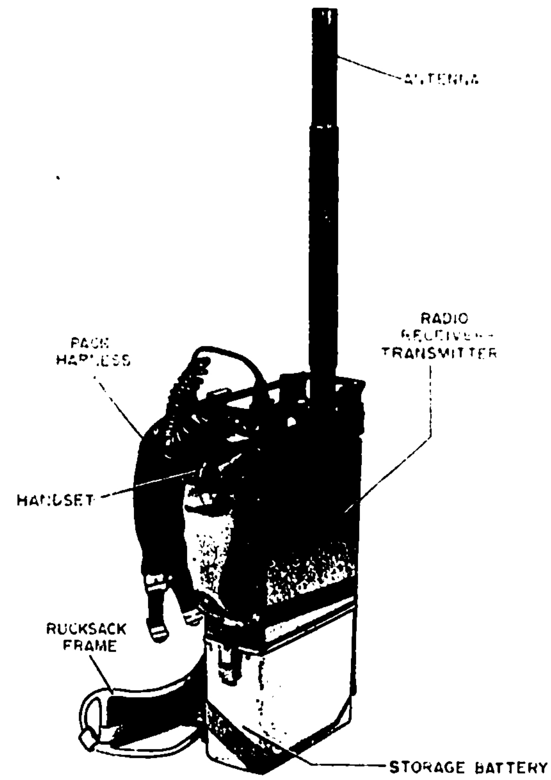


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Figure 3-21.—Radio Transceiver AN/PRC-41.

RECEIVERS

Modern Navy radio receivers are easy to operate and maintain. They are capable of receiving several types of signals and can be tuned accurately over a wide range of frequencies. Because they are not required to produce or handle large currents and voltages, their size is relatively small when compared to the size of most transmitters.

Unlike the receiving units of the transceivers described earlier, the radio receivers discussed in this section are separate equipments that are capable of independent operation.

Receivers with radioteletype capabilities are able to copy either radiofrequency carrier shift or audiofrequency tone shift radioteletype transmission information.

VLF, LF, MF, AND HF RECEIVERS

Most radio receivers operating in the VLF, LF, MF, and HF bands of the frequency spectrum are of the continuous tuning type. They are tunable to any frequency within their frequency range, and they usually cover this range in several tuning bands. Switching from one band to another changes the receiver's frequency-determining components, permitting more accurate tuning than is possible if the entire frequency range were covered by a single set of components.

Radio Receiver AN/BRR-3

Radio receiving set AN/BRR-3 consists of radio receiver R-988/BRR-3, connectors, clamps, and mounting hardware. The receiver is designed for general application aboard all types of U. S. Navy vessels. It covers the frequency range from 14 to 30 kHz and is normally used to receive either on-off keying (ICW or A1) or radioteletype (RFCS or AFTS) types of transmission. The receiver also has the capabilities of receiving facsimile signals (FAX or F4) when provided with additional terminal equipment, and of being used as a homing device when equipped with a Loop Antenna. It is a superheterodyne receiver, the output of which is supplied at a headphone jack for audio monitoring of Interrupted Continuous Wave (ICW) signals. Figure 3-22 shows the radio receiving set and accessory equipment.

Radio Receiver AN/SRR-19A

The AN/SRR-19A is a low frequency multichannel shipboard radio receiver for the 30-300 kHz frequency range (fig. 3-23). This dual-conversion superheterodyne receiver is intended for single sideband, multichannel radio teletypewriter broadcasts, AM and CW reception.

Receiver operation is characterized by extreme stability, permitting long periods of unattended operation. Counter type tuning dials facilitate accurate tuning to a desired frequency, and frequency errors caused by drift in the local oscillators are removed by drift-cancellation circuits. The receiver can be incrementally tuned in steps of 10 hertz or continually tuned (between increments) with partial drift-cancellation during continuous tuning.

Radio Receiver AN/SRR-11

Radio receiver AN/SRR-11 (fig. 3-24) is a modern communication receiver used in all types of Navy ships. The frequency range is divided into five bands from 14 to 600 kilohertz.

The AN/SRR-11 receiver is used for monitoring low and medium frequencies, such as the international distress frequency (500 hertz). Its most general use, however, is for receiving the VLF and LF transmissions of the fleet broadcasts. This receiver can be used for CW, MCW, and AFTS or RFCSRATT and FAX reception.

Radio Receiver RBA

The RBA receiver (fig. 3-25) has been used for many years aboard ship. Although being replaced, many of these old receivers are still in service. The frequency coverage of the RBA is 15 to 600 kHz.

The RBA is a TRF (tuned radiofrequency) receiver. The receiver may be used for CW, MCW, and voice signals, but because of its high selectivity, the RBA is not recommended for radiotelephone use. Most RBA receivers can receive radioteletype and facsimile signals also. The receiver has high sensitivity and good selectivity. As shown in figure 3-25, the power supply is a separate unit from the receiver.

Radio Receiver AN/WRR-3B

Radio receiver AN/WRR-3B (fig. 3-26) is a dual-conversion superheterodyne receiver for surface craft and submarine installations. It receives CW, MCW, and radioteletype signals.

The receiver covers the frequency range from 14 to 600 kilohertz in five bands. They are—

Band 1, 14 to 30 kHz
Band 2, 30 to 63 kHz
Band 3, 63 to 133 kHz
Band 4, 133 to 283 kHz
Band 5, 283 to 600 kHz

The frequency to which the receiver is tuned is read directly from drum type dials.

An internal calibration circuit provides calibration points at each 10 kHz tuning point within the tuning range of the receiver.

Radio Receiver AN/WRR-2B

Another shipboard radio receiver for use over the MF/HF bands is the AN/WRR-2B

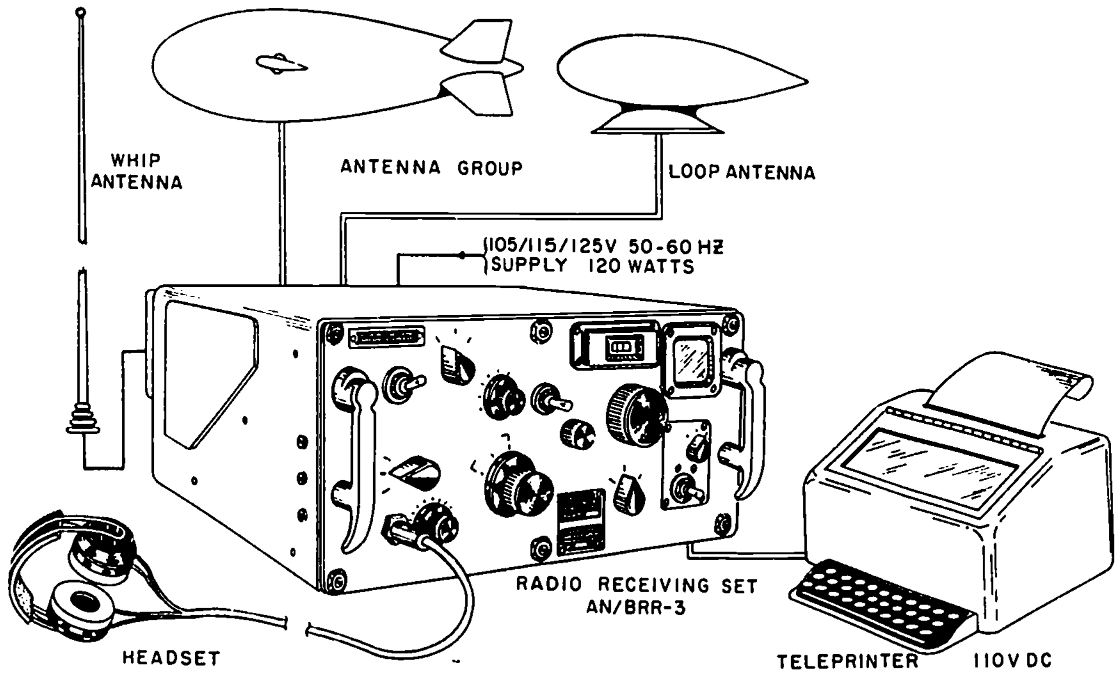

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Figure 3-22.—Radio Receiving Set AN/BRR-3 and accessory equipment.

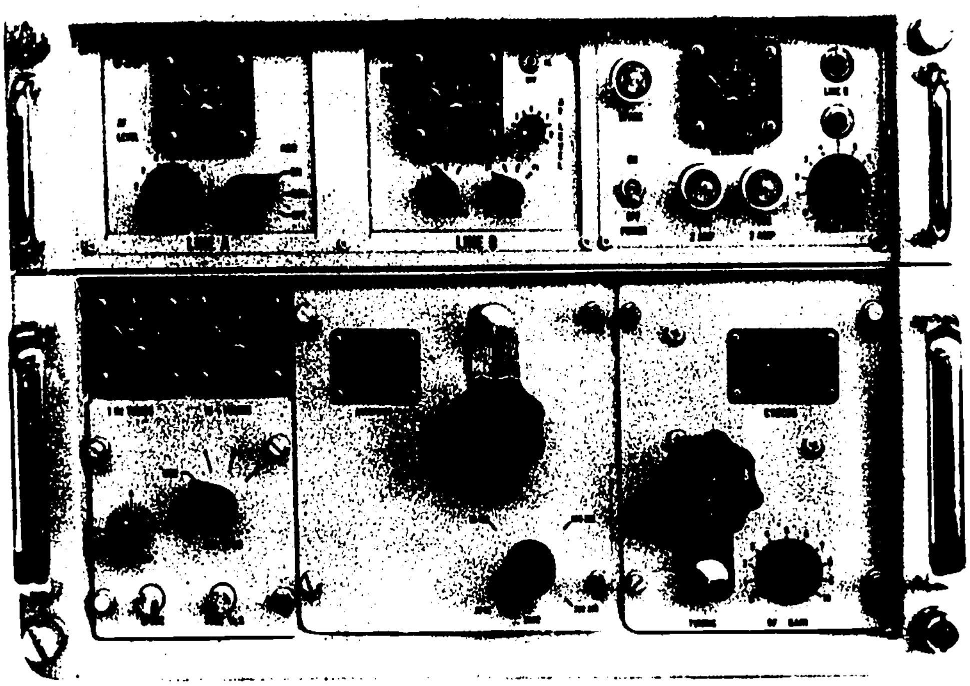

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Figure 3-23.—Radio Receiver AN/SRR-19A.

(fig. 3-27). The same receiver, with rack mounting for shore station use, is called AN/FRR-59.

The AN/WRR-2B is a triple-conversion superheterodyne receiver. It covers the frequency range 2 to 32 MHz. This modern receiver is intended primarily for the reception of single-sideband transmissions with full carrier suppression. It can be used also to receive conventional amplitude-modulated signals of various types, including CW, MCW, voice, facsimile, and radioteletype.

In order to meet strict frequency tolerances, a frequency standard, having a low frequency and very stable oscillator, generates a very accurate fundamental frequency (and harmonics) to provide frequency reference check points throughout the 2 to 32 MHz frequency range. This facilitates accurate tuning and a high degree of stability over long periods of operation. Both upper and lower sideband channels can be used simultaneously for receiving two different channels of intelligence or to receive the same intelligence.

Figure 3-24.—Radio Receiver AN/SRR-11. 1.157

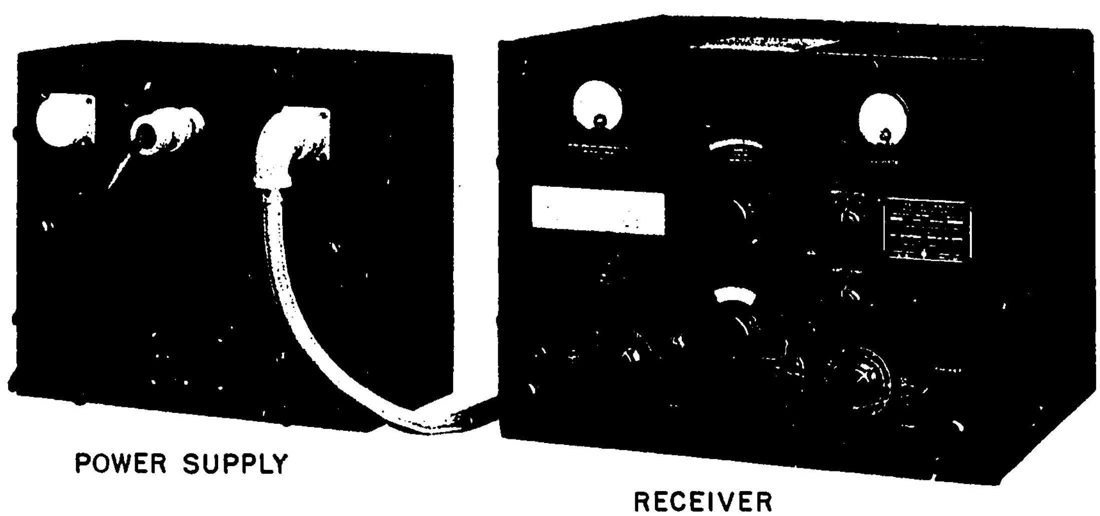
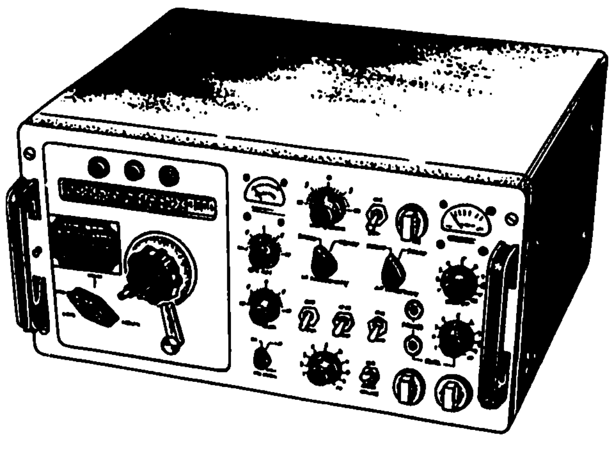
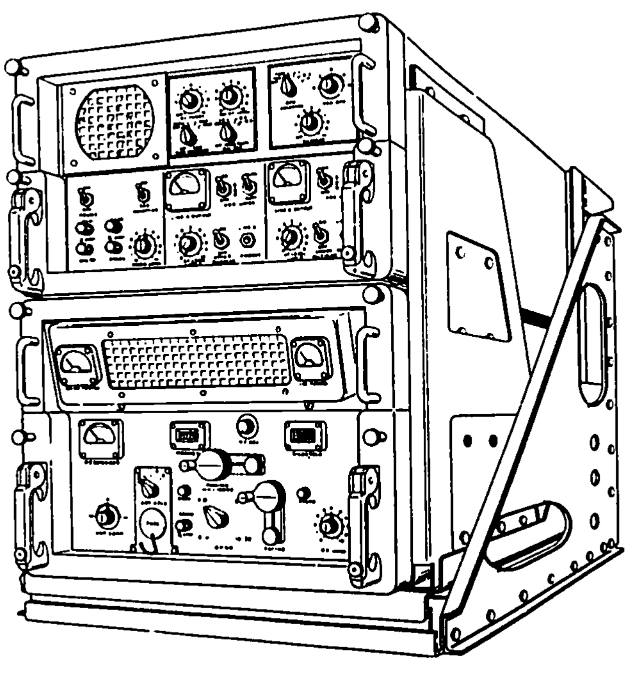


Figure 3-25.—Radio Receiver RBA with power supply. 34.17



76.26
Figure 3-26.—Radio Receiver AN/WRR-3B.



50.40
Figure 3-27.—Radio Receiver AN/WRR-2B.

Other features of the receiver also contribute to its high performance. Any error in frequency resulting from drift in the local oscillator is removed before the last conversion by a drift-canceling circuit. Receiver tuning is in 0.5 kHz steps. Through the use of an interpolation oscillator, each 0.5 kHz increment is scanned either continuously or in 1 kHz steps. Counter type tuning dials permit accurate presetting to any desired frequency.

The frequency range of 2 to 32 MHz is covered in four bands: band 1, 2.0 to 4.0 MHz; band 2, 4.0 to 8.0 MHz; band 3, 8.0 to 16.0 MHz; and band 4, 16.0 to 32.0 MHz.

Radio Receiver AN/URR-44

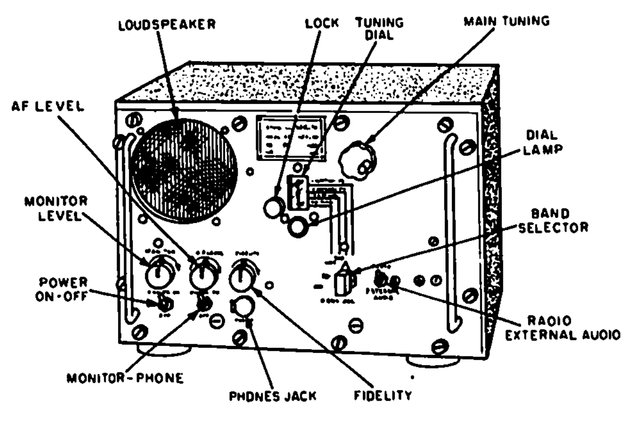
The AN/URR-44 (fig. 3-28) is an eleven tube superheterodyne type radio receiving set designed for use aboard all types of naval surface ships and at naval shore stations. The receiver is designed for voice modulated signal reception on standard broadcast and shortwave bands within the frequency range of 540 kHz to 18.6 MHz.

Radio Receiver R-390A/URR

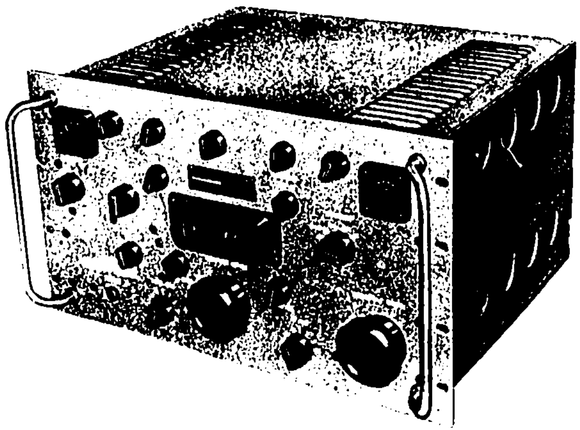
Operating in the frequency range 500 kHz to 32 MHz, radio receiver R-390A/URR (fig. 3-29) is a high-performance receiver for both shipboard and shore station use. It can receive CW, MCW, AM, radiotelephone, radioteletype, and facsimile signals.

The receiver is a superheterodyne type, with multiple-frequency conversion. In the frequency range from 500 kHz to 8 MHz, it uses triple conversion. Double conversion is used in the range from 8 to 32 MHz.

The tuning knob turns an arrangement of gears and shafts to select the frequency to which the receiver is tuned. A counter type



120.74
Figure 3-28.—Radio Receiver AN/URR-44.



34.15
Figure 3-29.—Radio Receiver R-390A/URR.

frequency indicator dial is provided. The dial is calibrated in kilohertz.

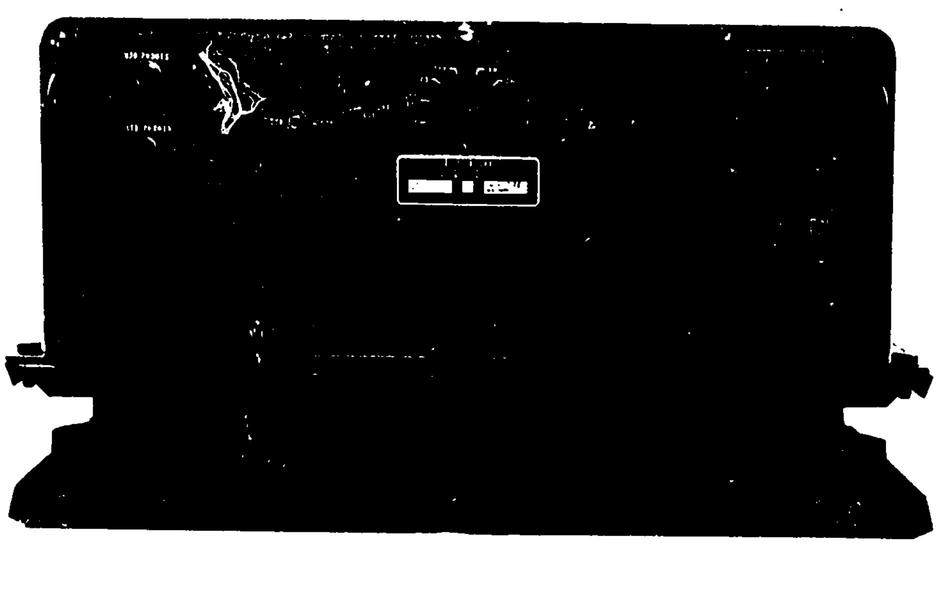
Radio Receiver R-1051B/URR

The R-1051B/URR (fig. 3-30) is one of the newer radio receivers. It is a versatile superheterodyne receiver capable of receiving any type of radio signal in the frequency range 2 to 30 MHz. It can be used as an independent receiver, or, in conjunction with a transmitter, it can be used to form a transmitter-receiver combination, similar to the Radio Set AN/WRC-1( ) described earlier.

Basically a crystal-controlled equipment, the R-1051B/URR uses a digital tuning scheme. An additional fine tuning control provides continuous tuning between 100 kHz increments. This receiver utilizes printed circuit boards and is completely transistorized, except for RF amplifier tubes. It is designated as standard equipment for use aboard all ships.

VHF AND UHF RECEIVERS

In most instances, radio receivers covering the VHF (and UHF) range are operated as crystal-controlled equipments. They are tuned easily and quickly. Once tuned, they operate efficiently for long periods of time without further attention. The trend is that modern transceivers will probably be replacing more radio receivers of this frequency range in the future.



120.8
Figure 3-30.—Radio Receiver R-1051B/URR.

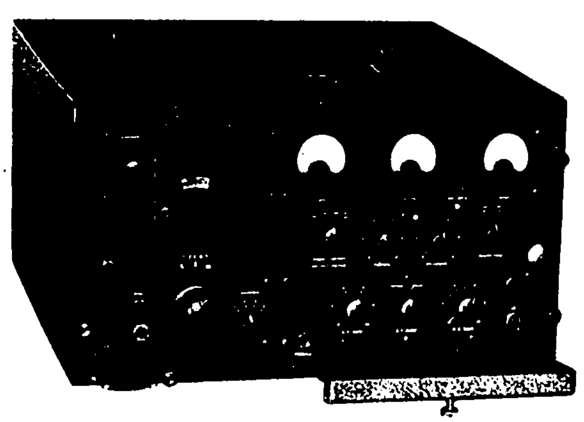
Radio Receiver AN/URR-21( )

The AN/URR-21( ) receiver (fig. 3-31) is used for receiving amplitude-modulated radiotelephone signals, in a portion of the VHF band, from 115 to 156 MHz. It is a crystal-controlled superheterodyne receiver. Although the receiver dial is calibrated continuously, only four channels can be tuned within the frequency range for a given set of four individually selectable crystals. The four crystals are plugged into a crystal holder on the receiver chassis inside the cabinet. Special features include a front panel dial detent mechanism for rapid selection of channels, and continuous tuning of all RF circuits by means of a single tuning control.

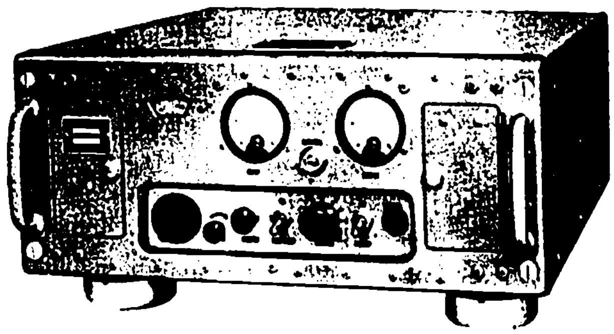
Radio Receiver AN/URR-27( )

Radio receiving set AN/URR-27 (fig. 3-32) provides for reception of amplitude-modulated voice and MCW transmission in the 105 to 190 MHz frequency range. You will note that this range of frequencies slightly exceeds that of the VHF transmitters, which cover a band from 115 to 156 MHz.

The AN/URR-27( ) is a superheterodyne receiver, designed chiefly for operation as a pretuned, single-channel, crystal-controlled receiver. Continuously variable manual tuning is also available. A single tuning control is used for tuning to any frequency for either crystal-controlled or manual tuning operation.



32.56
Figure 3-31.—Radio Receiver AN/URR-21( ).



32.42
Figure 3-32.—Radio Receiver AN/URR-27( ).

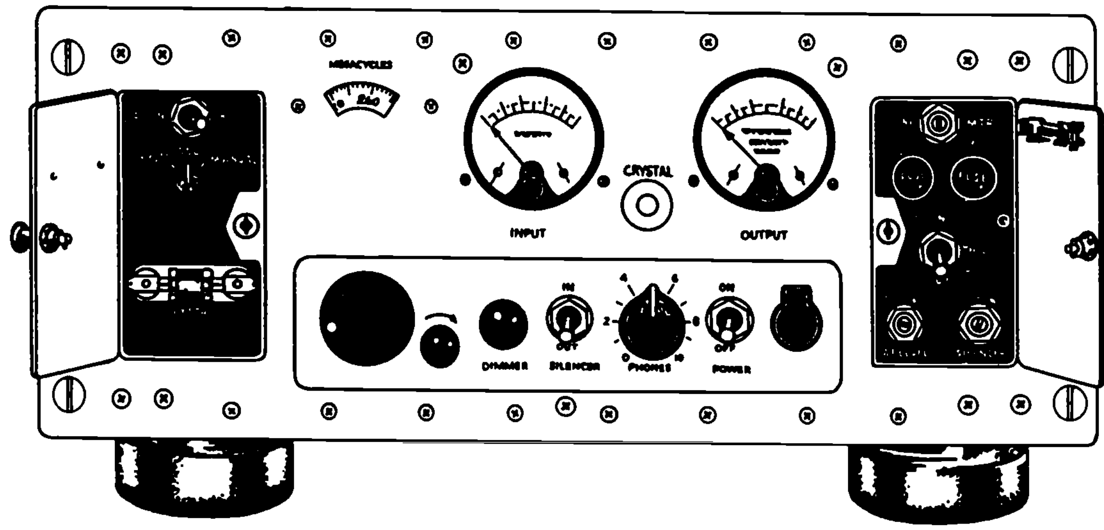
Radio Receiver AN/URR-35C

Radio receiver AN/URR-35C (fig. 3-33) is equipped for radiotelephone and MCW reception for use in tactical communications aboard ship. Although the frequency range of 225 to 400 MHz includes the upper portion of the VHF band, the receiver is commonly called UHF equipment. Designed mainly for single channel, crystal-controlled operation, it may also be used as a continuously variable manual tuned receiver. This receiver is easy to tune and features single tuning controls for tuning to any frequency within its range, for either crystal-controlled or manual tuning. It is a double conversion, pretuned, single-channel, superheterodyne receiver.

The AN/URR-35C receiver is commonly employed with the TED transmitter. This combination is commonly referred to by operators and technicians as a TED/RED group.

SHIPBOARD ANTENNAS

Antennas used for radio communications are so varied in design that it is impractical to describe every antenna you may encounter aboard ship. Consequently, this section deals mainly with the use and physical appearance of some of the more common shipboard communication antennas. Any technical discussion of antenna theory is avoided, when possible. To understand why a particular antenna is suited for use at one frequency (or range of frequencies), yet is unsuited for others, you must have a knowledge of the relationship



32.45

Figure 3-33.—Radio Receiver AN/URR-35C.

between an antenna's length and the frequency at which it is radiating.

The strength of the radio wave radiated by an antenna depends on the length of the antenna and the amount of current flowing in it. Because the antenna is a circuit element having inductance, capacitance, and resistance, the largest current is obtained when the inductive and capacitive reactances (opposition to the flow of alternating current) are tuned out; that is, when the antenna circuit is made resonant at the frequency being transmitted.

The shortest length of wire that will be resonant at any particular frequency is one just long enough to permit an electric charge to travel from one end of the wire to the other end and back again in the time of one cycle. The distance traveled by the charge is one wavelength. Because the charge must travel the length of the wire twice, the length of wire needed to have the charge travel one wavelength in one cycle is half a wavelength. Thus, the halfwave antenna, sometimes called a dipole, doublet, or Hertz is the shortest resonant length and is used as the basis for most antenna theory.

An antenna can be made resonant by two methods: (1) adjusting the frequency to suit a given antenna length; or, as usually is more practicable, (2) adjusting the length of the antenna wire to accommodate a given frequency. Every time the transmitter is changed to a new frequency, it is, of course, impractical to lengthen or shorten an antenna physically. The antenna length may be changed electrically, however, by a process known as tuning, or loading, the antenna.

The dipole—a center-fed, half-wave antenna—is the basis for many complex antennas. When used for transmitting high frequencies, it usually is constructed of wire. At very high and ultrahigh frequencies, the shorter wavelength permits construction with metal rods or tubing. Because the dipole is an ungrounded antenna, it may be installed far above the ground or other absorbing structures.

At low and medium frequencies (below MHz), half-wave antennas are rather long for use aboard ship. Another basic type of antenna, however, affords a solution to the problem of undue length. It is the quarter-wave (Marconi) antenna.

The earth is a fairly good conductor for medium and low frequencies, and acts as a large mirror for the radiated energy. The result is that the ground reflects a large amount of energy that is radiated downward from an antenna mounted over it. It is as though a mirror image of the antenna is produced, the image being located the same distance below the surface of the ground as the actual antenna is located above it. Even in high-frequency range (and higher), many ground reflections occur, especially if the antenna is erected over highly conducting earth or salt water.

Utilizing this characteristic of the ground, an antenna only a quarter-wavelength long can be made into the equivalent of a half-wave antenna. If such an antenna is erected vertically and its lower end is connected electrically to the ground, the quarter-wave antenna behaves like a half-wave antenna. Here, the ground takes the place of the missing quarter-wavelength, and the reflections supply that part of the radiated energy that normally would be supplied by the lower half of an ungrounded half-wave antenna.

Another method of operating a vertical quarter-wave antenna is to use a ground plane with the antenna. The ground plane usually is made of wires or rods extending radially from the base of the antenna. Actually, the ground plane substitutes for the ground connection, thereby establishing the ground level at the base of the antenna. Thus, the antenna can be installed on masts or towers high above ground. Ground plane antennas of this sort are used mostly for VHF and UFH communications.

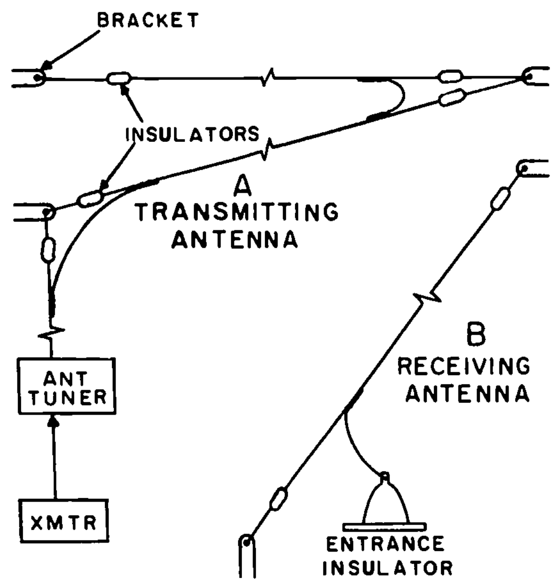
Although discussions of antennas ordinarily concern those used for transmitting, an efficient transmitting antenna for any particular frequency is also an efficient receiving antenna for that same frequency. It must be remembered, however, that there may be other limitations affecting the use of an antenna for both transmitting and receiving.

Problems not usually present in land installations arise when antennas are installed on board ship. Most of the masts, stacks, and other structures above decks are connected electrically (grounded) to the ship's hull and, through the hull, to the water. To obtain adequate coverage from the antenna, it must be installed so that minimum distortion of the radiation pattern results from grounded structures.

The antennas described in the next six topics are only a sampling of the antennas used in the Navy. They are typical of the antennas you can expect to find installed aboard most Navy ships.

WIRE ANTENNAS

Wire antennas (fig. 3-34) are installed on board ship for medium- and high-frequency coverage. Normally, they are not cut for a given frequency. Instead, a wire rope is strung either vertically or horizontally from a yardarm (or the mast itself) to outriggers, another mast, or to the superstructure. If used for transmitting, the wire antenna is tuned electrically to the desired frequency.



1.46
Figure 3-34.—Shipboard wire antennas.

Receiving wire antennas usually are installed forward on the ship, rising nearly vertically from the pilothouse top to brackets on the mast or yardarm. They are located as far as possible from the transmitting antennas so that a minimum of energy is picked up from the local transmitters. The transmission line (lead-in) for each receiving antenna terminates in antenna transfer panels in the radio spaces.

Transmission lines of the transmitting antenna may be of coaxial cable or copper tubing. They are supported on standoff insulators and in some instances, are enclosed in rectangular metal ducts called antenna trunks. Each transmission line connects with an individual transmitter or with an antenna multicoupler (discussed later).

Metal rings, antenna knife switches, antenna hardware, and accessories associated with transmitting antennas are painted red. Hardware and accessories used with receiving antennas are painted blue. This color scheme is a safety precaution, and indicates, at a glance, whether an antenna is used for radiating or receiving.

WHIP ANTENNAS

Whip type antennas have replaced many wire antennas in the frequency range 1.8 to 30 MHz. Because they are essentially self-supporting, whip antennas may be installed in many locations aboard ship. They may be deck-mounted, or they may be mounted on brackets on the stacks or superstructure (fig. 3-35). Whip antennas commonly used aboard ship are 25, 28, or 35 feet in length, and are made up of several sections.

On aircraft carriers, whip antennas located along the edges of the flight deck can be tilted. The tilting whip is pivoted on a trunnion, and is equipped with a handle for tilting and erecting the antenna. A counterweight at the base of the antenna is heavy enough to nearly balance the antenna in any position. The antenna may be locked in either a vertical or horizontal position. Where antennas have water drain holes, it is most important to keep them unplugged during freezing operations.

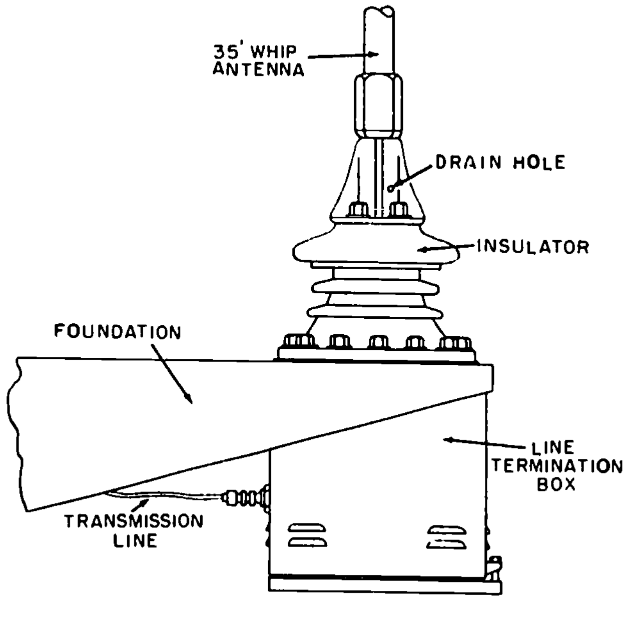
FAN ANTENNA

The fan antenna (fig. 3-36) is highly suitable for shipboard installation. It is known as a broadband antenna since it is capable of radiating over a wide range of frequencies. The fan antenna was designed principally for use in the low-frequency range, but it also performs satisfactorily in the high-frequency band with proper multicouplers.

The antenna usually consists of four radiating elements (wires) that are cut for one-quarter wavelength at the lowest frequency to be transmitted. Whether one or all of these elements are fed energy by the transmitter, the overall effect of the paralleled elements is to increase the radiating surface. Effectively, the fan antenna is a single radiator whose diameter is substantially large in comparison to its length.

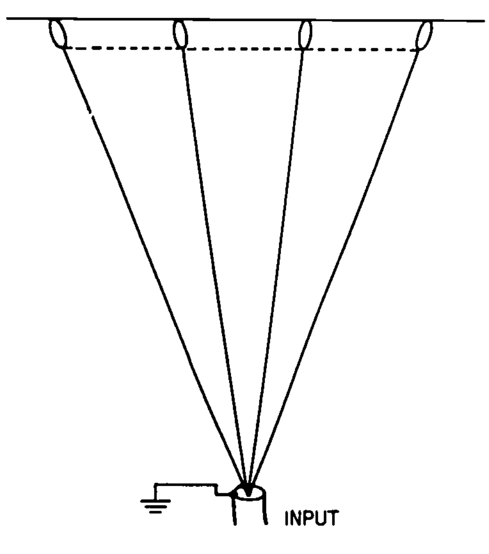
SLEEVE ANTENNA

The sleeve antenna (fig. 3-37), originally developed to fill the need for a versatile, long-distance antenna ashore, now is installed aboard many ships. Essentially, the sleeve antenna is a grounded, quarter-wave antenna that operates over a wide range of frequencies in the high-frequency band. Although similar in appearance to the whip antenna, it is identified



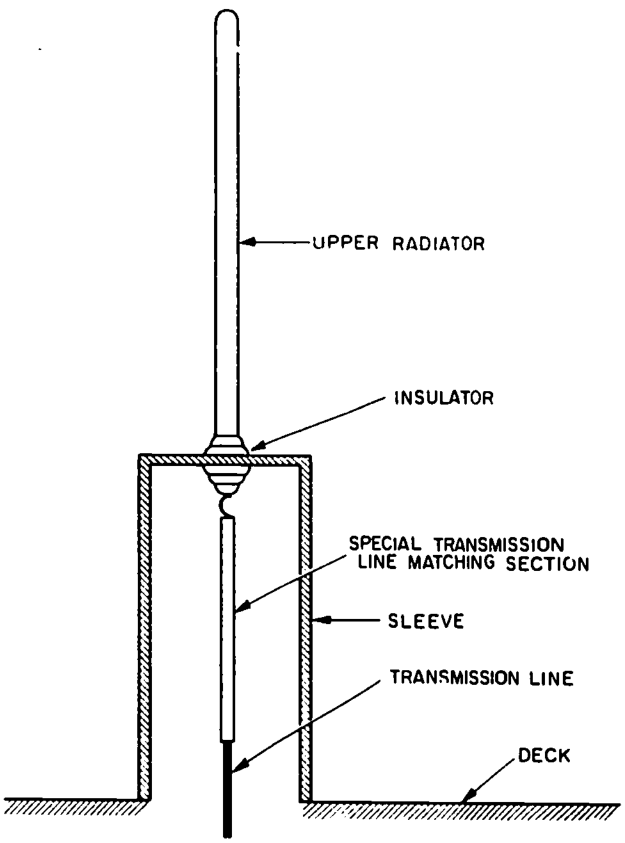
1.47

Figure 3-35.—Whip antenna.



25.126

Figure 3-36.—Fan antenna.



25.217
Figure 3-37.—Sleeve antenna (shipboard).

easily by the large diameter sleeve at its base. The sleeve usually is welded to the deck or superstructure of the ship.

CONICAL MONOPOLE ANTENNA

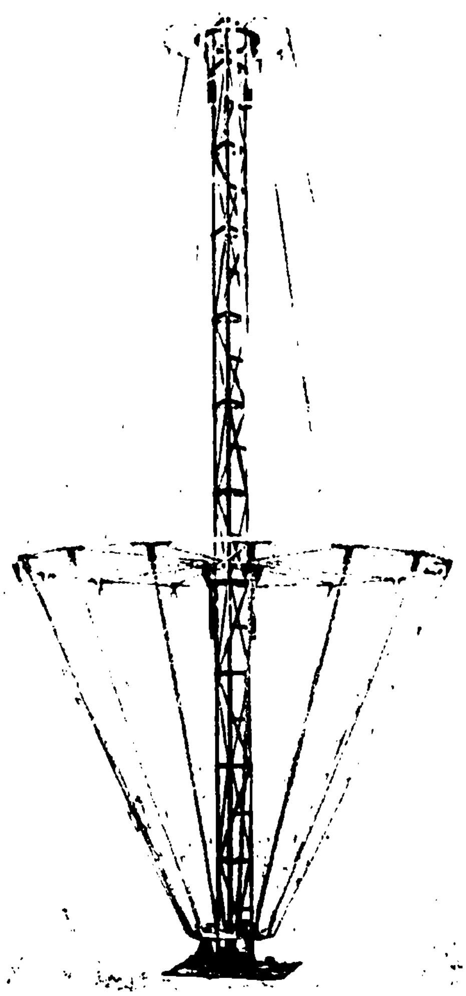
Another broadband antenna used extensively is the conical monopole shown in figure 3-38. Like the sleeve antenna, it is used both ashore and aboard ship.

When operating at frequencies near the lower limit of the high-frequency band, the conical radiates in much the same manner as a regular vertical antenna (omnidirectional on the horizontal plane). At the higher frequencies the lower cone section radiates, and the effect of the top section is to push the signal out at a low angle. The low angle of radiation causes the skywave to return to the earth at great distances from the antenna. Hence, the conical monopole antenna is well suited for long-distance communication in the high-frequency range.

VHF-UHF ANTENNAS

At VHF and UHF frequencies, the shorter wavelength makes the physical size of the antenna relatively small. Aboard ship these antennas are installed as high and as much in the clear as possible.

For best results in the VHF and UHF ranges, both transmitting and receiving antennas must be mounted on the same plane (vertically or horizontally). Vertically mounted

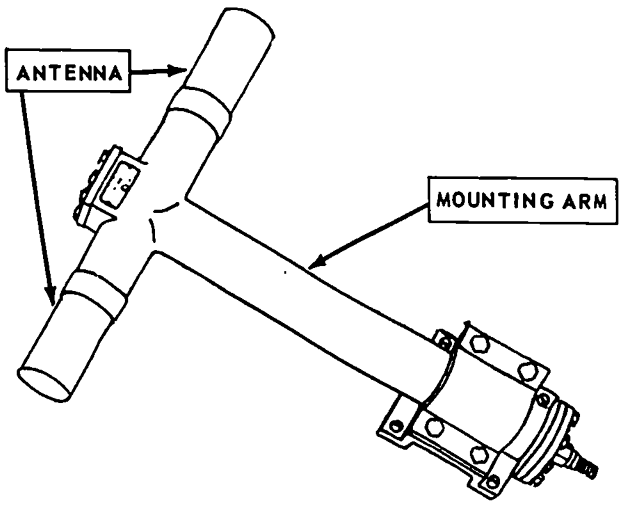


25.214
Figure 3-38.—Conical monopole antenna.

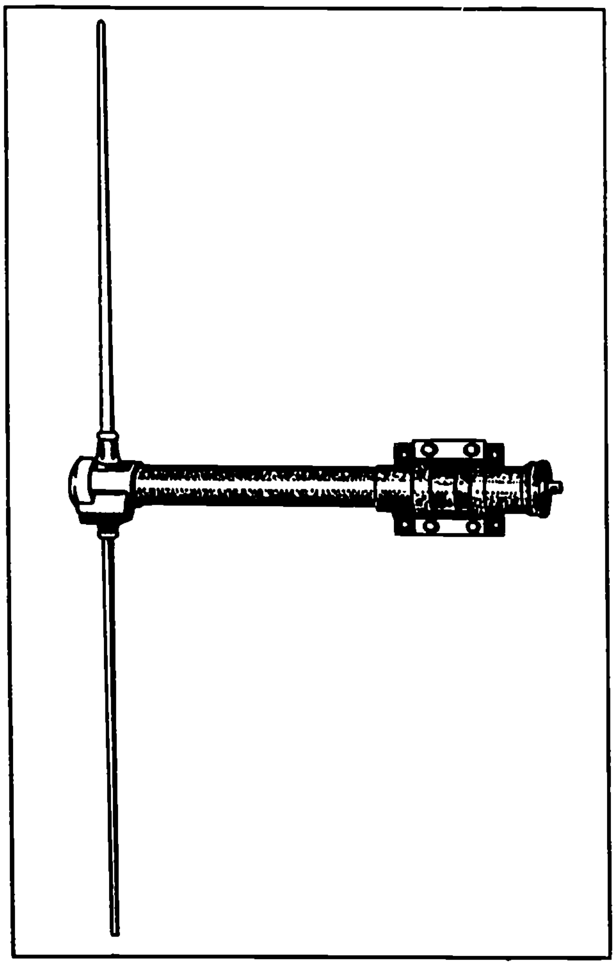
antennas are used for all ship-to-ship, ship-to-shore, and air-ground VHF-UHF communications. Usually, either a vertical half-wave dipole or a vertical quarter-wave antenna with ground plane is used.

The VHF antenna commonly installed aboard ships is Navy type 66095, shown in figure 3-39. The horizontal portion of the antenna does not radiate, but acts as a mounting arm for the antenna and as an enclosure for the antenna feedline. The antenna is installed with the radiating portion in the vertical position. The antenna works with any transmitter and receiver operating in the frequency range 100 to 156 MHz.

An antenna frequently used with UHF installations is the AT-150/SRC (fig. 3-40). This antenna is of the half-wave (dipole) type, and it covers the frequency range 225 to 400 MHz. Like the VHF antenna just described, the horizontal (longer) section does not radiate, but serves as a mounting arm for the antenna. The antenna is mounted so that the radiator is vertical.



25.219
Figure 3-40.—UHF Antenna AT-150/SRC.

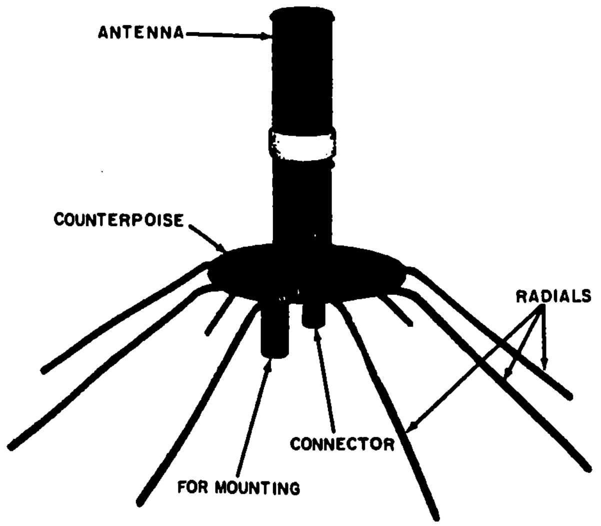


120.10
Figure 3-39.—VHF antenna NT-66095.

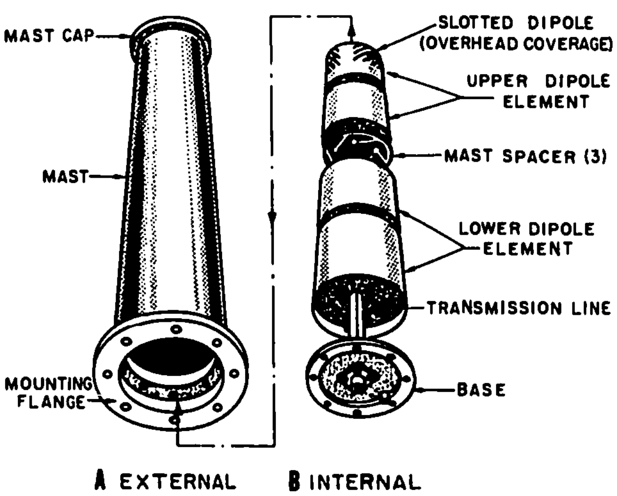
The AS-390/SRC (fig. 3-41) is another UHF antenna that operates at frequencies between 225 and 400 MHz. It is a quarter-wave antenna with a ground plane. The ground plane consists of a round plate (called a counterpoise) and eight equally spaced drooping radials (rods). The antenna is mounted vertically.

The AS-1018/URC (fig. 3-42) is an additional 225 to 400 MHz antenna often installed aboard ships. This antenna is the UHF version of the broadband sleeve antenna and is capable of radiating over a wide range of frequencies. The antenna provides essentially a horizon-to-90° overhead, 360° circular radiation pattern. The antenna is vertically polarized and has lower half power points on or below the horizon. The vertical upward propagation needed to fill the cone of silence is horizontally polarized.

The AS-1018/URC consists basically of the polyester fiberglass 6-foot mast (fig. 3-42A), the two-element colinear dipole array, and the internal transmission line (fig. 3-42B).



25.220
Figure 3-41.—UHF Antenna AS-390/SRC.



109.44(120)
Figure 3-42.—UHF Antenna AS-1018/URC.

AUXILIARY EQUIPMENT

The term "auxiliary" often is misleading, particularly in the field of electronics. In most instances, material categorized as auxiliary equipment is essential to the efficient operation of an overall system. But, because it is subordinate to the primary equipments, such as transmitters, receivers, and antennas, it is classified as an auxiliary.

Some of the more prominent auxiliary equipments used in communication systems are discussed in the ensuing topics of this chapter.

ANTENNA TUNING

Antenna systems are generally not ideal from the standpoint of position, efficiency, and antenna lengths, because of space limitations and the crowded conditions which are often characteristic of naval vessels. Frequently, a relatively short whip antenna may be employed, even for frequencies at the low end of the high frequency range.

Some transmitters are equipped with tuning devices which manually or automatically tune the antenna to the selected transmitter frequency. Proper tuning is necessary in order to obtain maximum transfer of power from the transmitter to the antenna.

Antenna Coupler AN/SRA-22

The antenna coupler AN/SRA-22 (fig. 3-43) is used for whip and other radio antennas normally encountered aboard ship. It consists of the antenna tuner (fig. 3-43A), which is an all weather completely sealed unit mounted near the base of the antenna, and a remote control (fig. 3-43B), which contains all controls and indicators for complete operation of the coupler from the transmitter rack.

The AN/SRA-22 operates on a 120 VAC, 60 hertz power source in the 2 to 30 MHz frequency range. This coupler was originally designed for the AN/URC-32 transmitter, but may be used with other transmitters. Being manually tuned equipment, it will probably be replaced by the AN/URA-38 antenna coupler.

Antenna Coupler AN/URA-38

The AN/URA-38 antenna coupler group consists of an antenna coupler and an antenna coupler control unit (fig. 3-44). The group is an automatic antenna tuning system intended primarily for surface ship and shore use with Radio Transmitting Set AN/URT-23(V). However, the equipment design includes provisions for manual and semiautomatic tuning, thus, making the system readily adaptable for use with other high power radio transmitters in the high-frequency range. The manual tuning

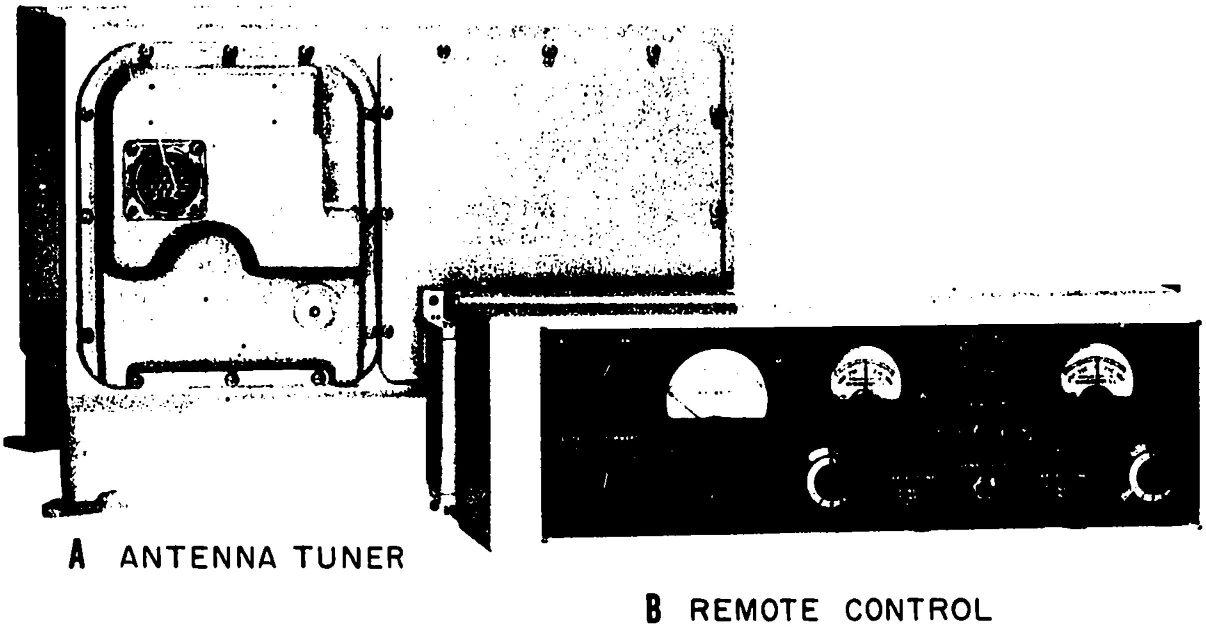


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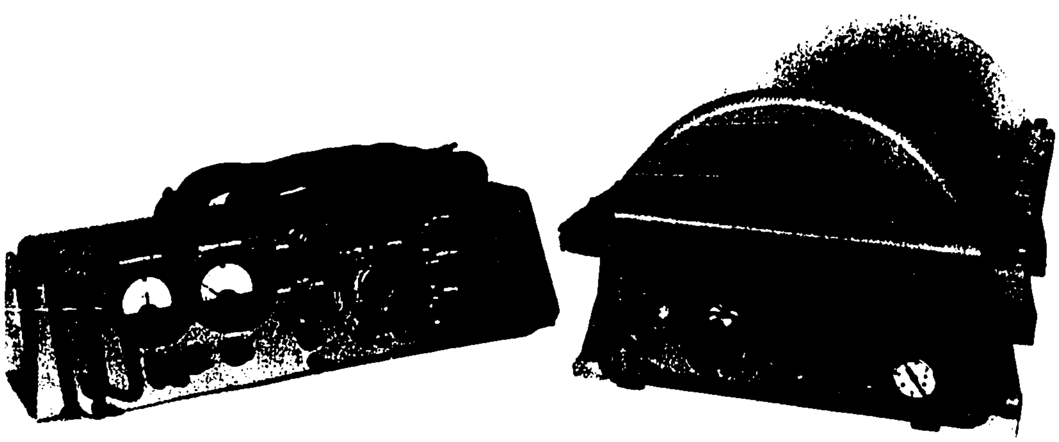
Figure 3-43.—Antenna Tuning Coupler AN/SRA-22.



120.76

Figure 3-44.—Antenna Tuning Coupler AN/URA-38.

capability is useful if a failure occurs in the automatic tuning circuitry. The AN/URA-38 can also be tuned without the use of RF power (referred to as silent tuning). This method is useful in installations where radio silence must be maintained, except for brief transmission periods. The control signals from the antenna coupler control unit automatically tune the antenna coupler matching network. A low power CW signal is required for tuning.

During manual and silent operation, tuning is accomplished by the radioman operating the controls located on the antenna coupler control unit.

ANTENNA MULTICOUPLERS

Because of the large number of transmitters and receivers on board ships, it is infeasible to use a separate antenna for each equipment. One satisfactory approach to the problem is provided by multicouplers.

Antenna multicouplers are devices that permit the simultaneous operation of several transmitters or receivers into (or from) the same antenna. The term "multicoupler" is descriptive of two or more couplers stacked or grouped together to form a single equipment, which then is connected to a broadband antenna. A separate coupler is required for each transmitter or receiver. Normally, the same antenna cannot be used for both transmitting and receiving simultaneously unless proper frequency separation and/or a duplexing system is employed.

Multicouplers AN/SRA-13, -14, -15, -16

Four antenna coupler groups that operate in the MF-HF range are the AN/SRA-13, -14, -15, and -16. They provide complete coverage of frequencies between 2 and 26 MHz. The frequency coverage afforded by each multicoupler is as follows: AN/SRA-13, 2 to 6 MHz; AN/SRA-14, 4 to 12 MHz; AN/SRA-15, 6 to 18 MHz; and AN/SRA-16, 9 to 26 MHz.

Typical of this group is the AN/SRA-15, which is illustrated in figure 3-45. The four couplers comprising the multicoupler provide for the simultaneous operation of four transmitters (each with 500-watt power output) into a single broadband antenna. As long as there is adequate separation between the operating frequencies, the four transmitters connected to the multicoupler may be operated anywhere in the frequency range from 6 to 18 MHz. Separation of 10 percent of the highest operating frequency is considered sufficient, however, a 15 percent figure provides better power transfer and decreases the chance of damage to the equipment in case of temporary malfunction.

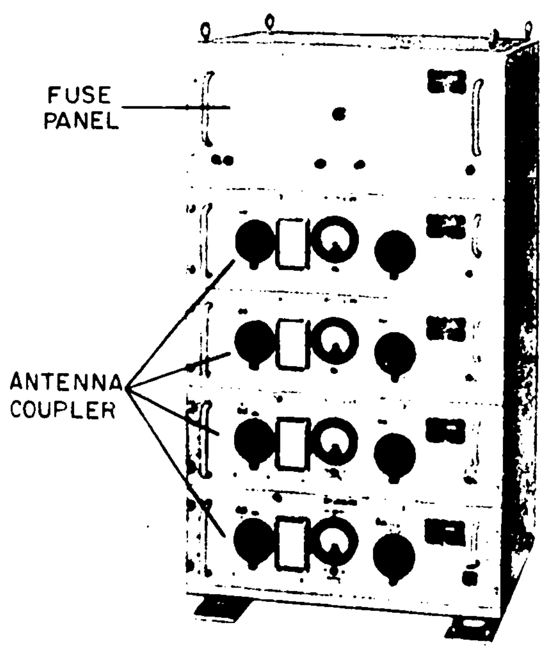
Multicoupler AN/SRA-23

Antenna multicoupler AN/SRA-23, (fig. 3-46) consists of three couplers and associated control and blower units. The couplers cover the frequency range 2 to 27 MHz in three frequency bands. Each coupler operates in a different band. These bands are 2 to 6 MHz, 5 to 15 MHz, and 9 to 27 MHz. The coupler group was developed for use with 500-watt transmitters, but, with minor adjustments, it is capable of handling transmitters with 1000-watt outputs.

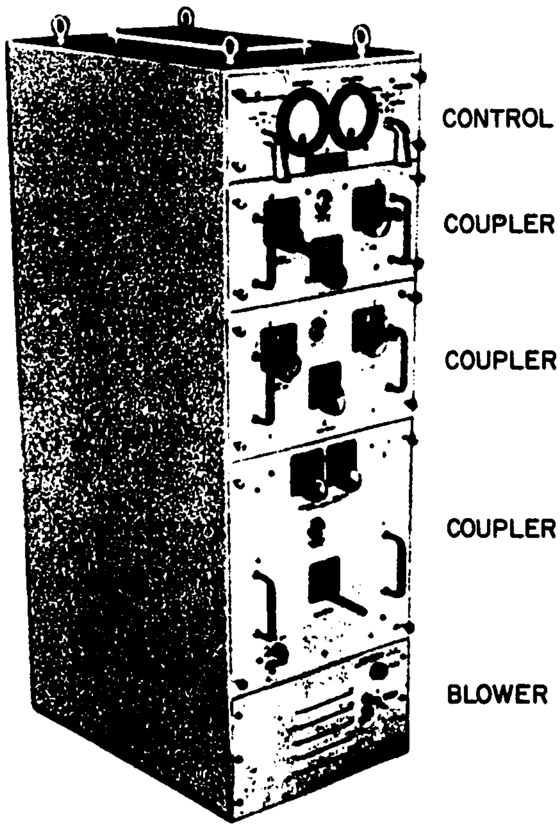
One coupler group accommodates only one transmitter. Provisions are made, however, for connecting up to eight of these groups together to form a multicoupler system. This arrangement permits the simultaneous operation of eight transmitters into a single broadband antenna.

Multicouplers CU-691/U and CU-692/U

Both the CU-691/U and the CU-692/U are VHF-UHF multicouplers operating at



120.11
Figure 3-45.—Antenna Multicoupler AN/SRA-15.



120.12
Figure 3-46.—Antenna Multicoupler AN/SRA-23.

frequencies between 225 and 400 MHz. Except for their physical dimensions and the number of channels, the two sets are identical. The CU-691/U provides for the operation of four transmitters or receivers, whereas the CU-692/U accommodates only two. Both multicouplers are tuned manually. The CU-691/U is shown in figure 3-47.

Like most VHF-UHF couplers, the performance characteristics of these two types of couplers require that operating frequencies on the common antenna be separated by approximately 15 MHz.

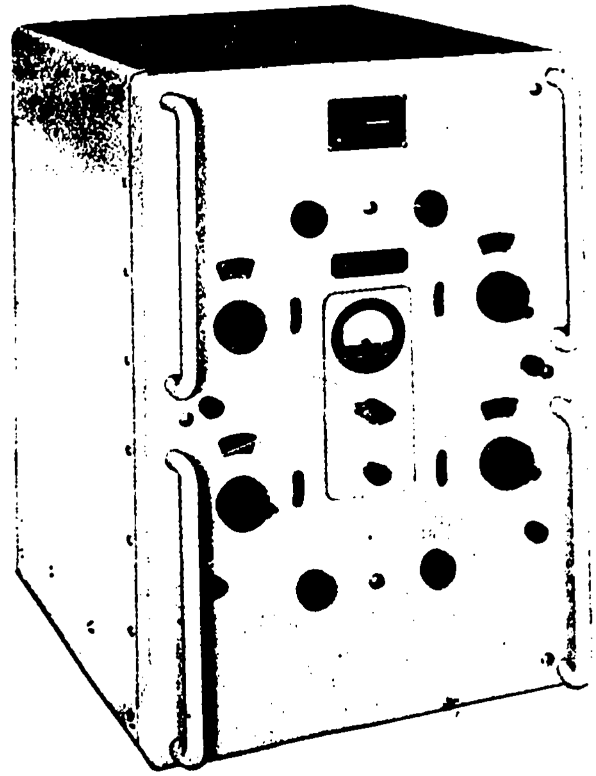
Receiving Multicouplers AN/SRA-12

The AN/SRA-12 (fig. 3-48) filter assembly multicoupler provides seven radiofrequency channels in the frequency range from 14 kHz to 32 MHz. Any or all of these channels may be used independently of any of the other channels, or they may operate simultaneously. Connections to the receivers are made by means of coaxial patch cords, which are short lengths of cable with plugs attached to each end.

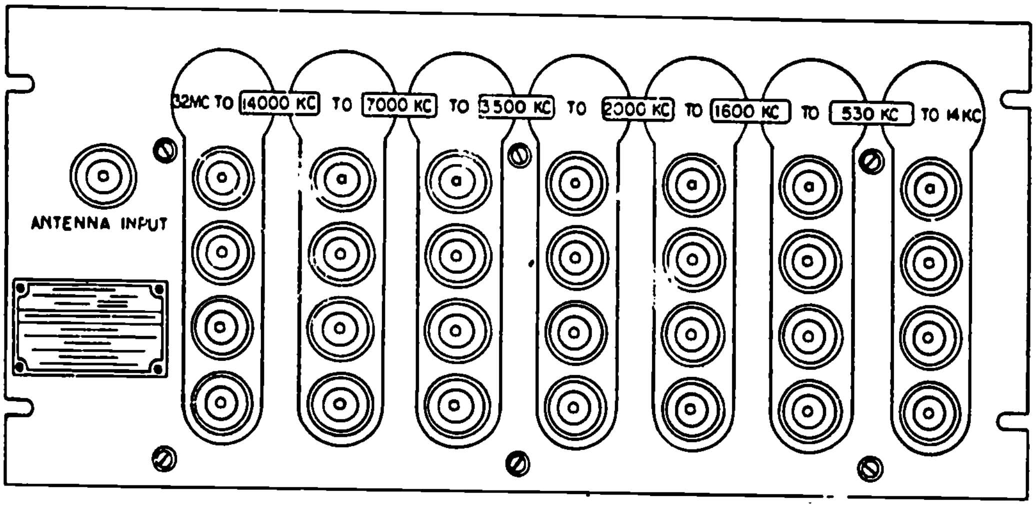
A set of nine plug-in type filter subassemblies is furnished with the equipment, but only seven of them may be installed at one time. The seven filters installed are selected to cover the most-used frequency bands.

TRANSMITTER AND RECEIVER TRANSFER PANELS

Transmitter and receiver transfer panels are an integral part of every shipboard radio system. They make it possible to connect



120.14
Figure 3-47.—UHF Antenna Multicoupler CU-691/U.



1.115

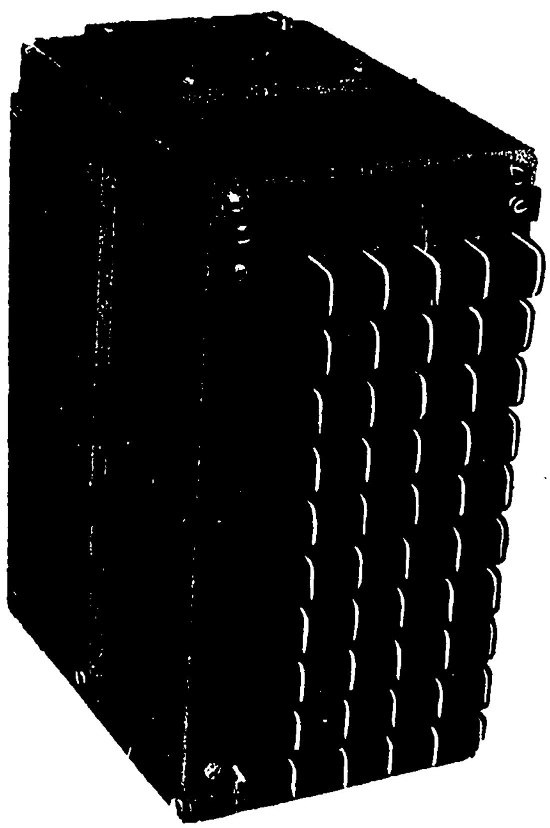
Figure 3-48.—Electrical Filter Assembly AN/SRA-12.

transmitters and receivers to remote control points located throughout the ship. These transfer panels formerly were of the cumbersome patch cord type, but those currently installed aboard ships are of the switchboard type described here.

Receiver Transfer Switchboard SB-82/SRR

Receiver transfer switchboard, type SB-82 SRR, (fig. 3-49) has five vertical rows of ten single-throw (ON-OFF) switches that are continuously rotatable in either direction. One side of each switch within a vertical row is wired in parallel with the same sides of the other nine switches within the row. Similarly, the other side of each switch is wired in parallel horizontally with the corresponding sides of each of the other four switches in a horizontal row. This method of connecting the switches permits a high degree of flexibility.

In general, there are more remote stations than radio receivers, hence the audio outputs of five receivers are fed to the five vertical rows, and ten remote stations are connected to the ten horizontal rows. With this arrangement, a selected receiver output is connected to any or all of the remote stations by closing the proper switch(es). When one switchboard is inadequate for accommodating all of the receivers and remote stations installed in a ship, several of these



36.69

Figure 3-49.—Receiver Transfer Switchboard SB-82/SRR.

switchboards are mounted together and interconnected so that they form a bank of switchboards.

The knob of each switch is marked with a heavy white line to provide visual indication of whether the switch is in the ON or OFF position. Switchboards are always installed with the line positioned vertically when the switch is open (off). To further standardize all installations, receivers usually are connected to the vertical rows of switches, and remote stations are connected to the horizontal rows.

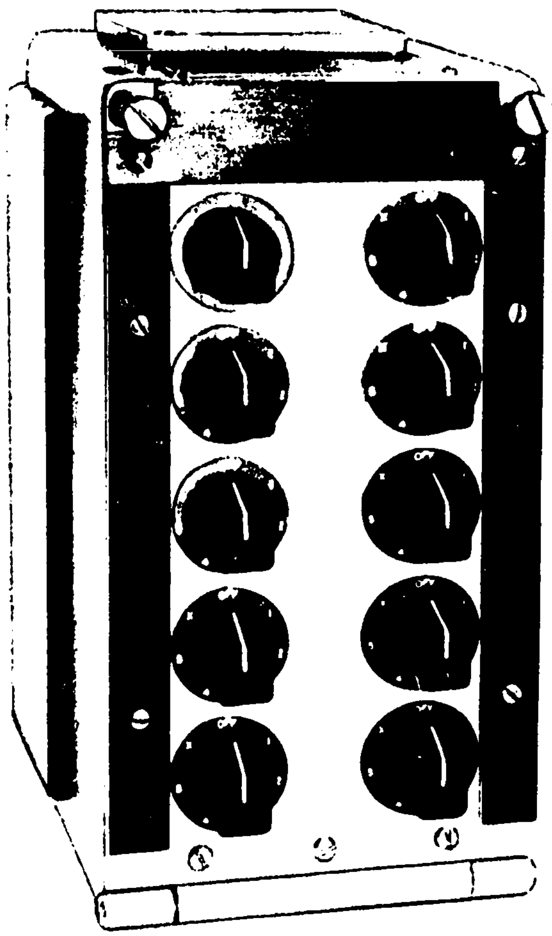
Identification of the Receivers and remote stations is engraved on the laminated bakelite label strips fastened along the top and left edges of the panel front.

Receiver Transfer Switchboard
SB-973/SRR

A recent model receiver transfer switchboard is the SB-973/SRR (fig. 3-50). This switchboard contains 10 seven-position rotary selector switches. Each switch or operating knob relates to a remote control station. Switch positions one through five relate to receivers.

Position X on each switch serves to transfer the remote control stations connected to the original switchboard to the corresponding switches in additional switchboards. In this manner, any one of a number of receivers can be connected to any of the ten remote control stations. An additional switchboard is needed for each five additional receivers.

Switchboards providing facilities for additional remote control stations are mounted in vertical sequence, whereas those containing additional receivers are mounted in horizontal sequence.



120.16
Figure 3-50.—Receiver Transfer Switchboard SB-973/SRR.

Transmitter Transfer Switchboard
SB-83/SRT

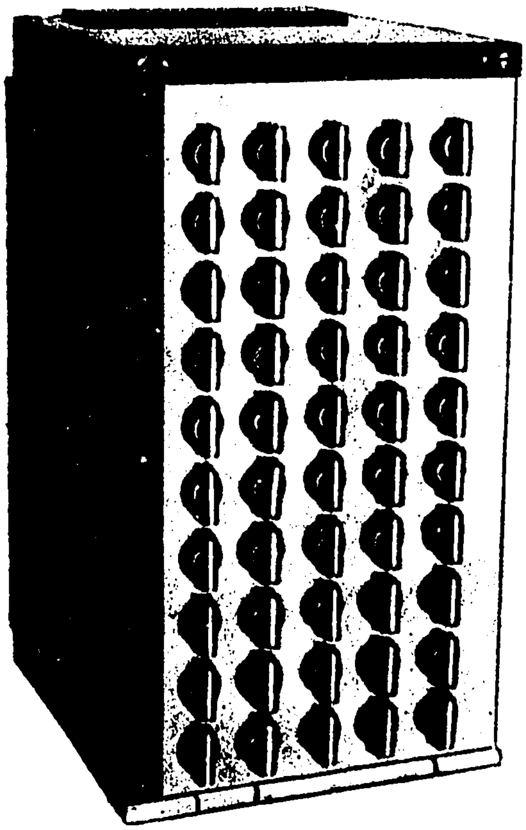
Transmitter transfer switchboard, type SB-83/SRT, (fig. 3-51) has five vertical rows of ten switches. Radio transmitters are wired to the five vertical rows; remote stations are connected to the ten horizontal rows. Switches are off when the white lines on the knobs are vertical.

Although the switches are of the continuously rotatable type, most switchboards are equipped with a spring-loaded, mechanical interlock that allows the switches to be closed by turning the knobs in a clockwise direction. The switches are then opened by turning the knobs counterclockwise. The interlock also prevents additional switches in each horizontal row from being closed when any one of the five switches in that row is closed already. This arrangement prevents serious damage that is certain to result from two or more transmitters feeding a single remote-control station at the same time.

By wiring several of these boards together, facilities are available for transferring any transmitter to any or all remote control stations.

Transmitter Transfer Switchboard
SB-863/SRT and SB-988/SRT

The models SB-863/SRT and SB-988/SRT transmitter transfer switchboards are replacing



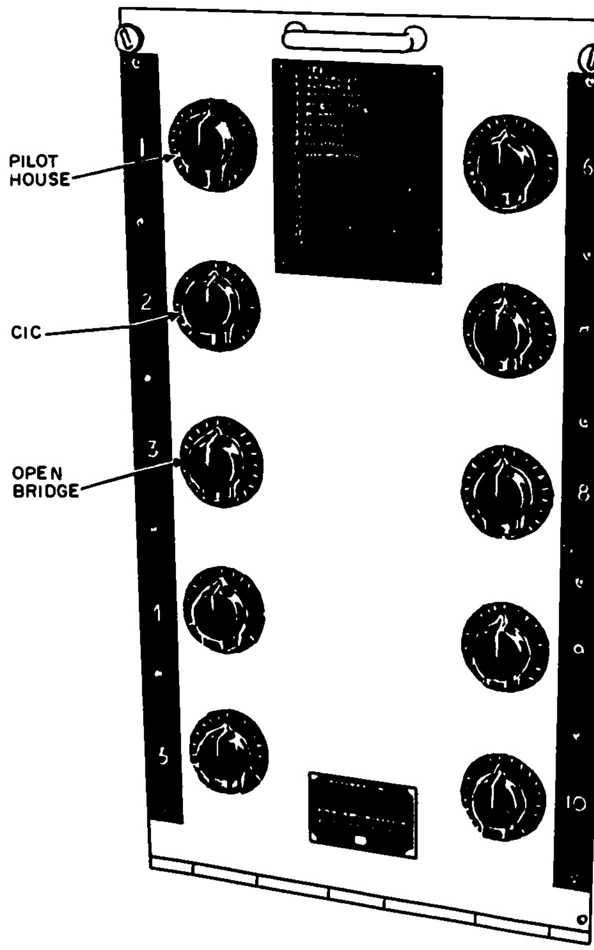
36.70
Figure 3-51.—Transmitter Transfer Switchboard SB-83/SRT.

the SB-83/SRT in shipboard installations. Except for their transmitter-handling capacity, these two newer switchboards are identical. The SB-863/SRT (fig. 3-52) handles up to 19 transmitters, whereas the SB-988/SRT (not illustrated) handles only 6.

Both of these switchboards have 10 rotary selector switches in two vertical columns. Each rotary switch corresponds to a remote-control station, and each switch position either corresponds to a controlled transmitter or serves to transfer the remote station to an adjacent switchboard. The remote station assigned each rotary switch and the transmitter assigned each switch position are identified on the bakelite plates attached to the front of each switchboard.

REMOTE-CONTROL UNITS

To operate radio transmitters from remote locations requires the use of remote-control units. Most of these units are used as radiophone units. (RPUs). They provide for energizing and deenergizing transmitters, for connecting microphones, handsets, chestsets, telegraph keys, and headphones, and for controlling the audio output level (volume) of radio receivers. Some units also enable remote selection of radio channels when they are utilized to control multichannel transmitters and receivers (such as the model AN/GRC-27).



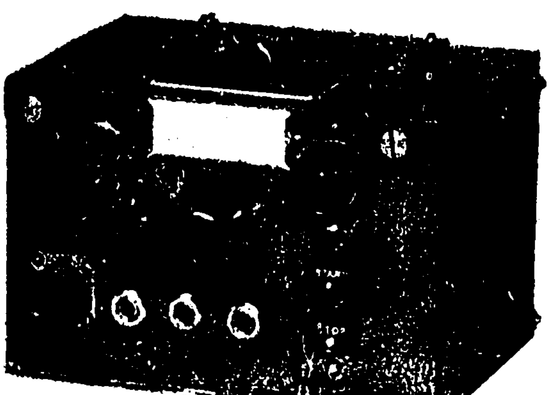
70.64
Figure 3-52.—Transmitter Transfer Switchboard SB-863/SRT.

Radio Set Control C-1138( )/UR

Radio set control C-1138( )/UR (fig. 3-53) is a remote-control unit designed for installation in protected locations, as in the CIC or pilothouse. This unit contains a start-stop switch for turning a transmitter on or off, jacks for connecting a handset or chestset, microphone, headphones, or telegraph key, a volume control for the headphone or loudspeaker, and indicator lamps for transmitter-on (power) and carrier-on indications. Although provisions are made for CW operation, the unit seldom is used for this purpose. In most instances it is utilized for radiotelephone communications.

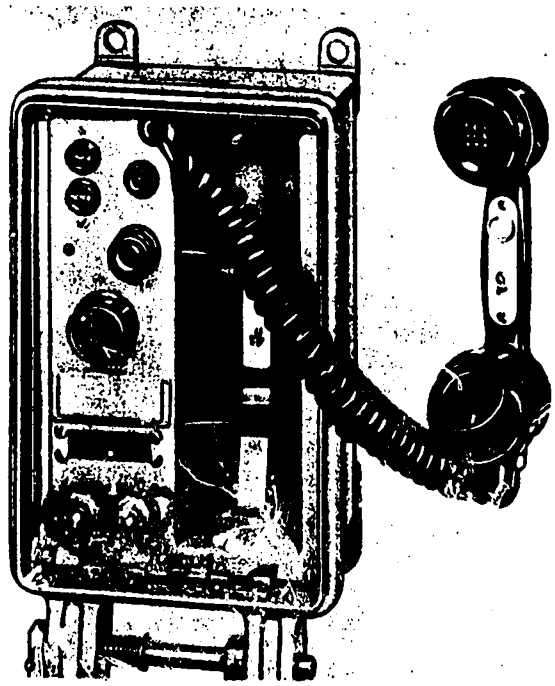
By means of transmitter and receiver transfer switchboards, as many as four of these remote-control units may be connected to the same transmitter or receiver. This arrangement is utilized when it is necessary that a radio channel be controlled from more than one remote location.

The model C-1138( )/UR is an improved version of the older and slightly larger remote-control unit NT-23500, still in service aboard many ships. The two units are similar in appearance and function, hence the older set is not described nor illustrated here.



7.40.2A

Figure 3-53.—Radio Set Control C-1138( )/UR.



7.40

Figure 3-54.—Radio Set Control C-1207( )/UR.

Radio Set Control C-1207( )/UR

Radio set control C-1207( )/UR, (fig. 3-54) is designed for installation in areas that are exposed to the weather. Access to its controls is obtained by opening the front cover, which is hinged to the unit. The controls, consisting of a handset, a transmitter start-stop switch, and a receiver volume control, are mounted on the front panel of the unit. Also mounted on the panel are two indicator lamps that provide visual indication of whether the transmitter power and carrier-on circuits are energized or deenergized, and two jacks for connecting a chestset and a set of headphones.

When connected to a standard shipboard transmitter and receiver, the C-1207( )/UR permits remote control of the following functions: (1) energizing and deenergizing the transmitter, (2) voice modulating the transmitter input, and (3) controlling the receiver's audio level at the earphone(s). As many as four of these units may be connected to the same transmitter and receiver.

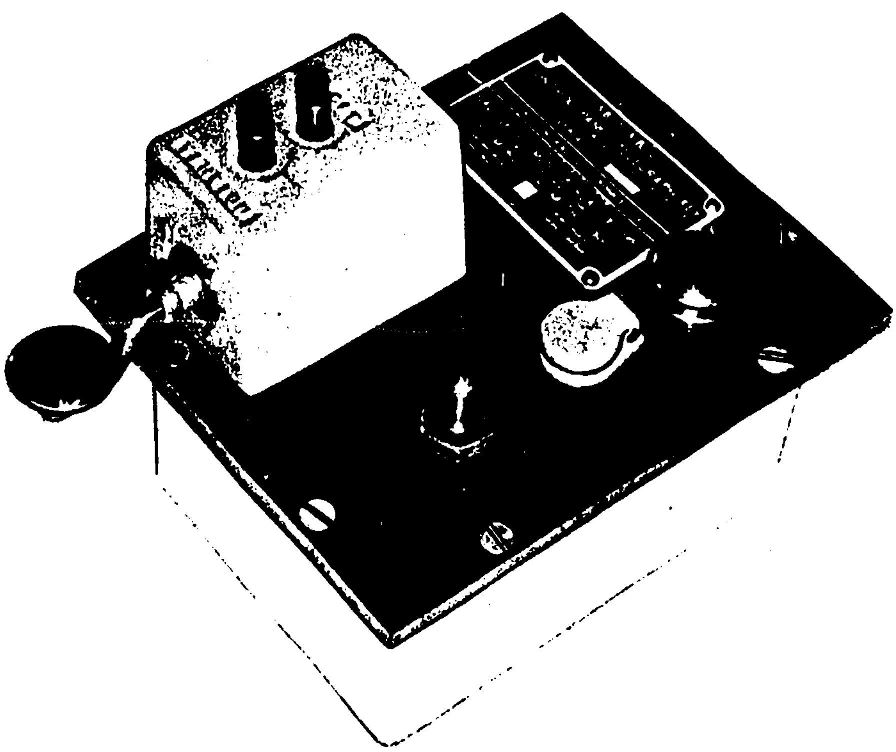
Control Panel Telegraph Key SB-315B/U

Control panel telegraph key SB-315B/U (fig. 3-55) contains the components and circuitry necessary to control the operation of a radio transmitter from a remote position. Located on the plastic control panel are (1) a toggle switch for turning the transmitter on or off, (2) an indicator light that glows red when the transmitter is on, (3) a telegraph key that provides a means for keying the transmitter, and (4) a key jack that provides for an auxiliary telegraph key.

This combination control panel and telegraph key is used in conjunction with a CW or MCW transmitter for the purpose of transmitting messages in international Morse code.

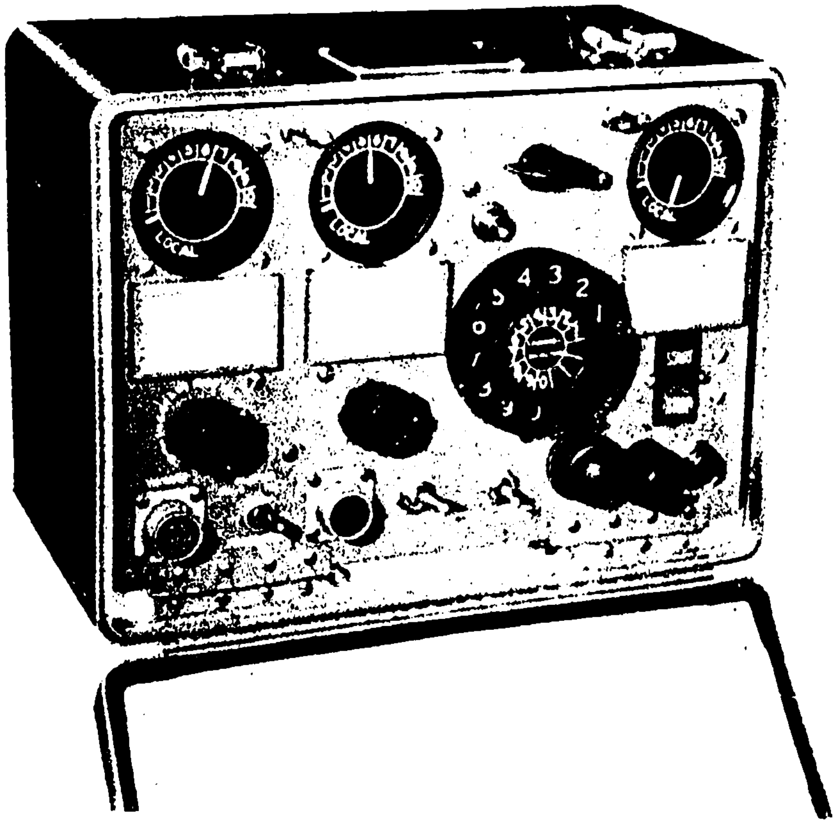
Remote-Control/Indicator Unit NT-23496

Although designed for use with a now obsolete transmitter-receiver combination, the remote-control/indicator unit NT23496 still is used aboard many ships for controlling multichannel transmitters and receivers. The unit, illustrated in figure 3-56, is capable of handling a transmitter and two receivers simultaneously. This arrangement permits guarding two radio channels, with the transmitter available for use on either channel. By operating an equipment selector switch and a dial-type channel selector, the operator can select any of ten preset radio channels on any multichannel transmitter or receiver controlled by the unit. A set of the usual remote controls is provided for each equipment operated by the remote-control unit.



20.18

Figure 3-55.—Control Panel Telegraph Key SB-315B/U.



20.17

Figure 3-56.—Remote-Control/Indicator Unit NT-23496.

Frequency Standard AN/URQ-10 and Frequency Distribution Amplifier AM-2123/U

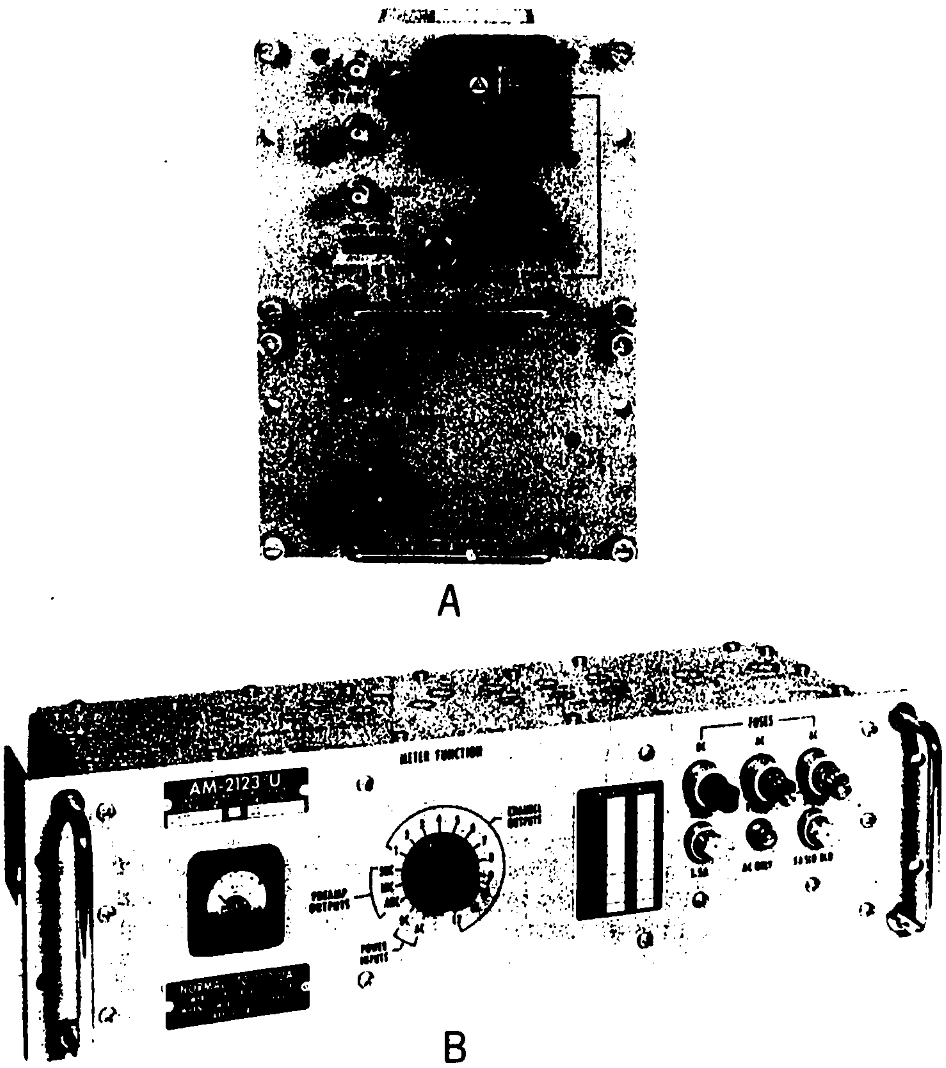
One of the latest frequency standards is the AN/URQ-10 (fig. 3-57A). This compact highly stable frequency standard is designed for continuous-duty use aboard ships and at shore facilities. It has three fixed output frequencies: 5 MHz, 1 MHz, 100 kHz.

Because it is intended as a frequency standard against which other frequency-generating equipment can be compared, the AN/URQ-10 is energized and calibrated at special calibration laboratories. Once it is placed in operation and calibrated properly, the frequency standard must not be turned off. Any interruption in its operation will cause a change in its output frequencies. Hence, the equipment is transferred to the using activity while still operating.

A battery, which is built into the equipment, maintains operation during the time the frequency standard is in transit. It also supplies power to the unit in the event of power failure aboard ship. When fully charged, the battery is capable of operating the equipment for approximately 6 hours.

The frequency distribution amplifier AM-2123/U (fig. 3-57B) is designed to provide a means of distributing the precision frequencies of a frequency standard to many remote locations aboard ship.

The three frequency channels from the AN/URQ-10 are accepted by the AM-2123/U which can provide 12 channels of output frequencies in any combination of the three input frequencies (5 MHz, 1 MHz, 100 kHz).



120.77

Figure 3-57.—Frequency Standard equipment.

ADDITIONAL RADIO EQUIPMENT

The radio equipments described in this chapter have been mostly of the general-purpose communication type. Additional and more specialized types of radio equipment are discussed in the next chapter.

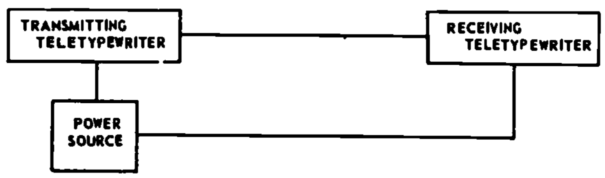
CHAPTER 4

TELETYPE AND FACSIMILE

The teletypewriter is little more than an electrically operated typewriter. The prefix "tele" means "at a distance." Coupled with the word "typewriter" it forms a word meaning "typewriting at a distance." By operating a keyboard similar to that of a typewriter, signals are produced that cause the teletypewriter to print the selected characters (letters, figures, and symbols). The characters appear at both sending and receiving teletypewriters, and one teletypewriter actuates as many machines as may be connected together.

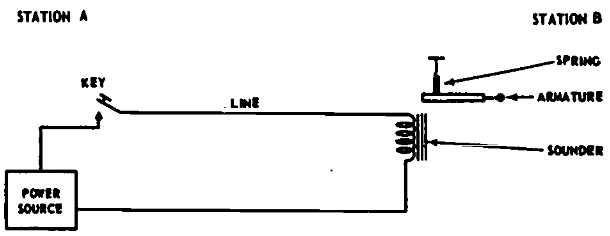
To see how intelligence is sent by teletypewriter, let us consider one of the simpler devices for electrical communication: the manual telegraph circuit. In this series or loop-connected circuit, shown in figure 4-1, we have a telegraph key, a source of power (called battery), a telegraphic sounder, and a movable sounder armature. If the key is closed, current flows through the circuit and the armature is attracted to the sounder by magnetism. This action causes a clicking sound. When the key is opened, current stops flowing and the armature returns to its original position. With these two electrical conditions of the circuit—closed and open—it is possible, by means of a code, to transmit intelligence.

The telegraph circuit in figure 4-1 can be converted to a simple teletypewriter circuit by substituting a transmitting teletypewriter for the key at station A, and a receiving teletypewriter for the sounder at station B. This arrangement for a given word-per-minute system is shown in figure 4-2. In the teletypewriter circuit each current and no current interval consumes a set period of time, whereas in the telegraph circuit these time intervals vary with the code being transmitted by the operator.

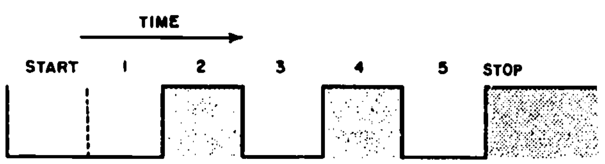


1.200
Figure 4-2.—Simple teletypewriter circuit.

A teletype signal can be represented as mark and space pulses as shown in figure 4-3. Shaded areas show intervals during which the circuit is closed, and the blank areas show the intervals during which the circuit is open. A closed circuit produces a mark and an open circuit produces a space. The signal contains a total of seven units. Five of these are numbered, and are called "intelligence" units. Various combinations of marks and spaces in the intelligence units represent different characters. The first and last units



1.196
Figure 4-1.—Manual telegraph circuit.



1.197
Figure 4-3.—Mark and space signals in the teletypewriter character R.

of the signal, labeled start and stop, are named after their functions: the first starts the signal and the last stops it. These are a part of every teletype code character, and are the means by which the teletypewriter machines and signals are kept in synchronization with each other.

When the sending and receiving teletypewriters are wire connected, the exchange of intelligence between them is direct. But when the teletypewriters are not joined by wire, operation is more complex. Direct-current mark and space intervals cannot be sent through the air. The gap between the machines must be bridged by radio.

RADIOTELETYPE (RATT) SYSTEMS

The Navy uses two basic teletype systems aboard ship. One is the audio frequency toneshift radioteletype (AFTSRATT) used for short range operation and similar to the familiar AM radio method of broadcasting. The other is the radiofrequency carrier-shift radioteletype (RFCSRATT) used for long range operation and similar to the familiar FM radio communications.

TONE-SHIFT MODULATION SYSTEM

A teletypewriter, a tone converter, and a transmitter are used to transmit messages by the tone-shift modulation method. The teletypewriter sends out a DC signal. The signal is changed to audio tones in the tone-shift converter. The transmitter impresses the audio tones on the carrier and sends out a tone-shift modulated carrier wave (fig. 4-4A).

To receive messages with the tone-modulated system, a radio receiver, a tone-shift converter, and a teletypewriter are required. The toneshift modulated carrier wave enters the receiver, which extracts the signal intelligence and sends the audio tones to the tone-shift converter. The converter changes the audio tones into DC mark and space pulses for the teletypewriter (fig. 4-4B).

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

FREQUENCY CARRIER-SHIFT SYSTEM

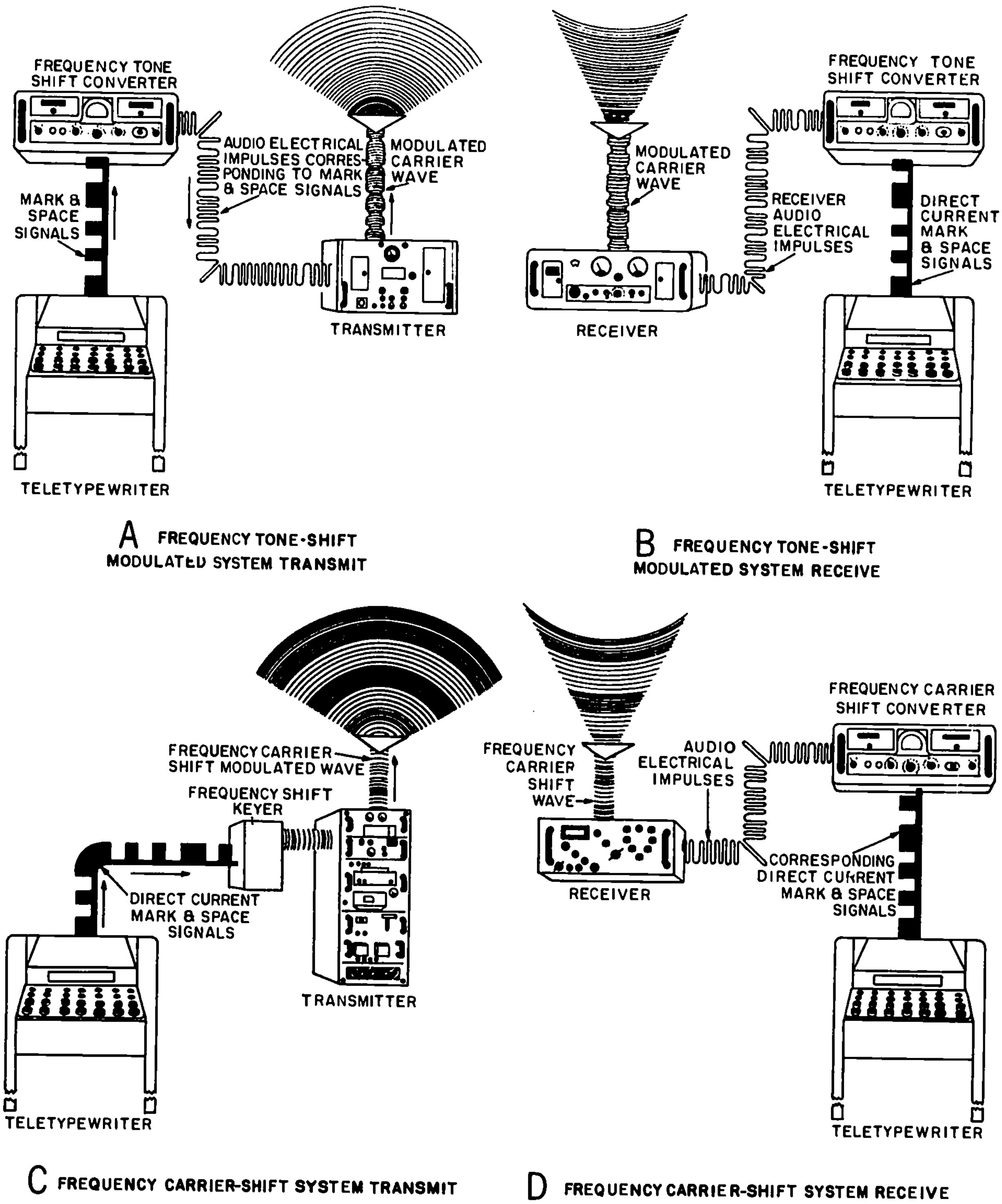
At the transmitting end of the long-range frequency carrier-shift system (fig. 4-4C) is a teletypewriter, a transmitter, and a frequency shift keyer unit. The keyer unit is built into the newer transmitters, but in some older systems it is separate equipment. When the teletypewriter is operated, the DC mark and space signals are changed by the keyer unit into audiofrequency carrier-shift output signals. This AFCSRATT is transmitted by conventional Navy transmitters.

On the receiving side of the long-range system (fig. 4-4D) is a receiver, a frequency carrier-shift converter, and a teletypewriter. When the frequency carrier-shift signal enters the receiver, it is detected and changed into corresponding frequency carrier-shift audio signals. The audio output of the receiver is fed to the converter, which changes the carrier-shift audio signals into DC mark and space signals.

In both the tone-shift system and the carrier-shift system, all teletypewriter signals pass through the teletypewriter panel that controls the looping current in all the circuits. As illustrated in figure 4-5, the teletypewriter (RATT) panel patches the tone-shift modulated system or the frequency carrier-shift system. It provides every possible RATT interconnection available onboard ship. This operational flexibility gives maximum efficiency with the fewest circuits and the least amount of equipment in the Navy's compact RATT systems afloat.

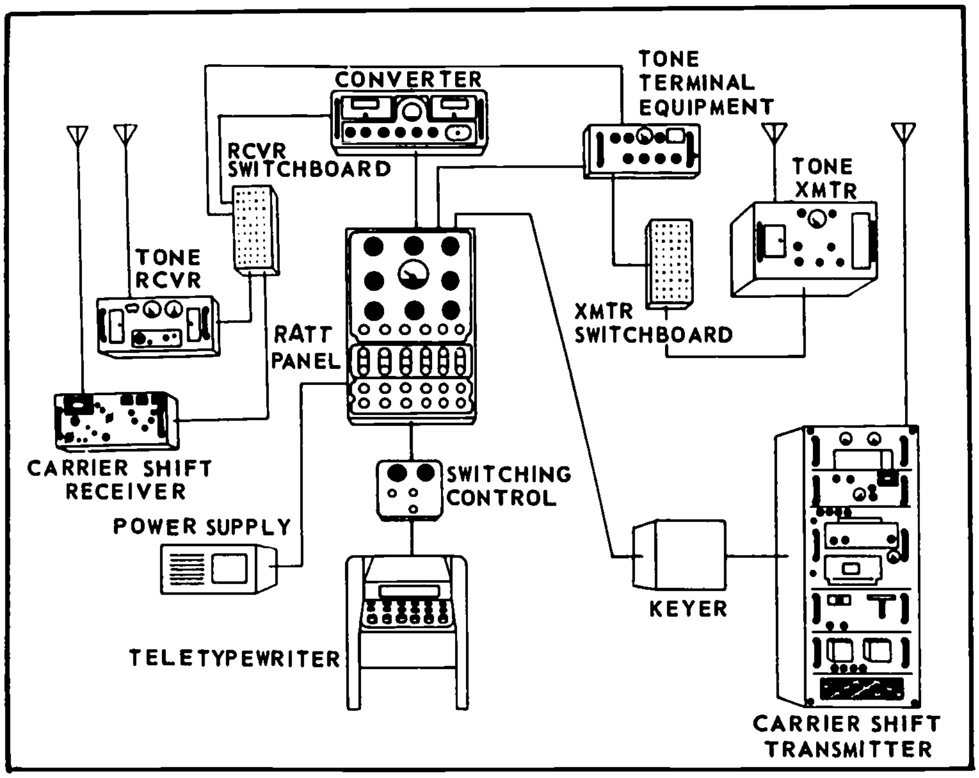
TELETYPE EQUIPMENT

Because of the increasing variety of teletype equipment installed aboard ship, it is impractical to describe every piece of equipment you are likely to encounter. The equipment discussed in the ensuing paragraphs, however, is representative of the types commonly employed in shipboard installations. In some instances, this same equipment may be designated by nomenclature different from that given in this text. But, in most of these instances, this variance in nomenclature merely indicates a modification of the basic equipment described herein.



1.228-.231

Figure 4-4.—Tone and frequency shift modulation.



1.225

Figure 4-5.—Integrated RATT system.

TELETYPEWRITER SETS

Most of the teletypewriter sets used by the Navy belong to the model 28 family of teletypewriter equipments. The model 28 equipments feature light weight, small size, quiet operation, and high operating speeds. They present relatively few maintenance problems, and are suited particularly for shipboard use under severe conditions of roll, vibration, and shock.

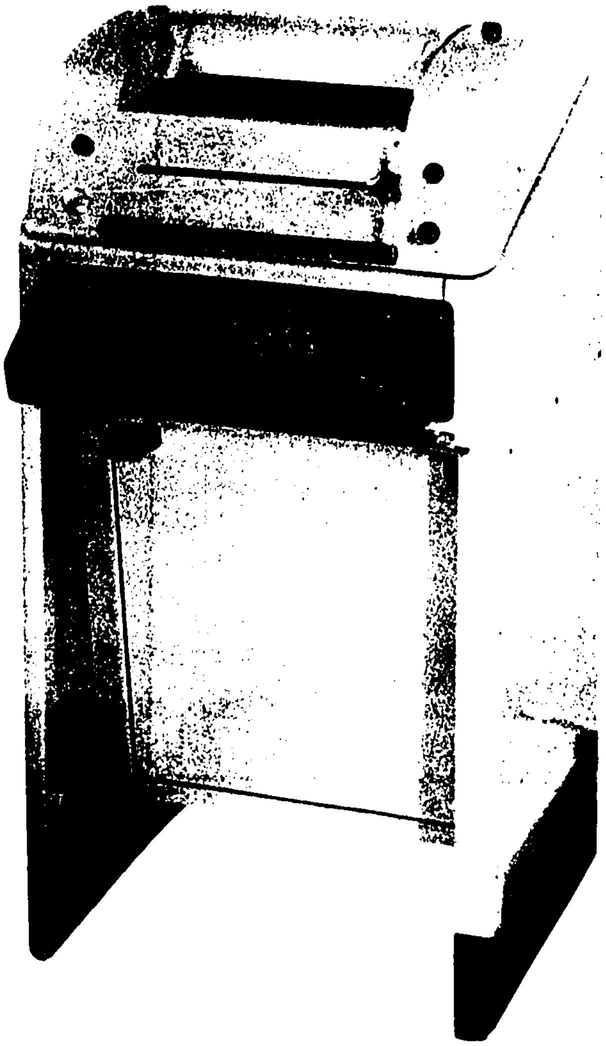
Another feature of the model 28 teletypewriters is their ability to operate at speeds of 60, 75, or 100 words per minute. Conversion from one speed to another is accomplished by changing the driving gears that are located within the equipment. The majority of the Navy's teletypewriters are presently operated at 100 words per minute.

Teletypewriters may be send-receive units or receive units only. They may be designed as floor model, table model, rack mounted, or wall mounted sets.

Model 28 Send-Receive And Receive Sets

These model 28 send-receive teletypewriter page printers are basically the same. The TT-48( )/UG is a floor model keyboard-sending and page-receiving teletypewriter (fig. 4-6). The TT-48( )/UG provides means for exchanging typewritten page messages between two or more ships or stations that are similarly equipped and connected by a radio (or wire) circuit. While transmitting from the keyboard, monitor copy is presented by the typing unit. Hence, messages cannot be transmitted and received simultaneously.

The TT-47( )/UG is an older floor model still in use, and differs from the TT-48( )/UG by the type of motor used. The TT-47( )/UG

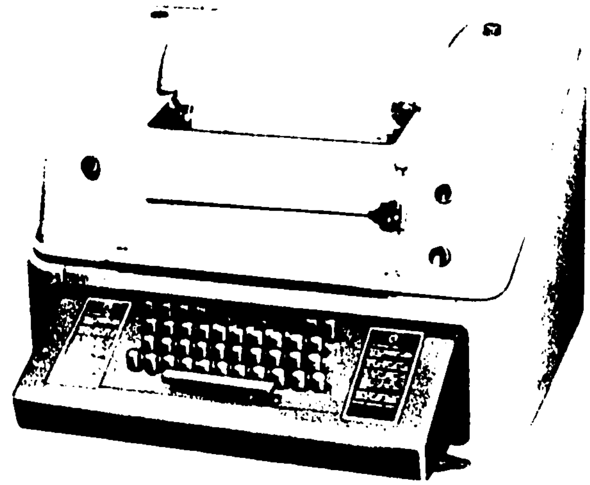


1.217
Figure 4-6.—Model 28 Teletypewriter TT-48( )UG.

has a 60 hertz synchronous motor, and the TT-48( )/UG uses a series governed motor.

Another example of modification is the TT-69( )/UG, (fig. 4-7). Except for being installed in a cut-down cabinet, the TT-69( )/UG is like the above equipment. It serves the same purpose, and it functions in the same manner. Usually, the TT-69( )/UG is installed on small ships where space is of prime consideration.

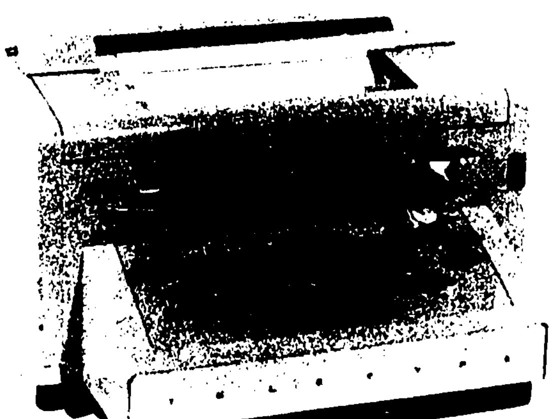
The TT-176A/UG (not illustrated) is like the above equipment except that it is a rack-mounted send-receive teletypewriter.



1.217(76)
Figure 4-7.—Teletypewriter TT-69( )UG.

Rack-mounted units such as, teletypewriter, radio, and sonar equipments are designed narrower in width. They are mounted aboard ships where space is a premium and stand-up operation is necessary.

The AN/UGC-20 (fig. 4-8) is another send-receive teletypewriter which reduces the transmitter keyboard from 32 to 28 typing units.



1.361
Figure 4-8.—Compact Keyboard Send-Receive Teletypewriter AN/UGC-20.

All mechanisms have been mounted to require minimum space. This compact teletypewriter is designed for use where space is of importance.

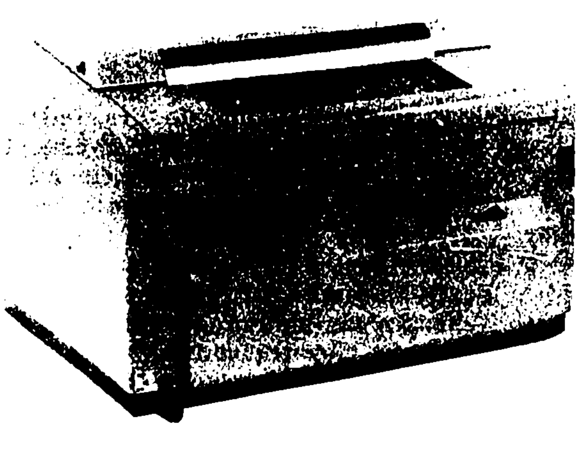
The model 28 receive-only sets are similar to the send-receive sets but have no keyboard sending capabilities. The AN/UGC-25 page printer (fig. 4-9) is a receive-only, compact, table model set seldom found aboard small ships, but used on large ships, chiefly for copying messages from the fleet broadcast.

Teletypewriter Perforator-Reperforator TT-253/UG

An extremely useful teletypewriter equipment is the TT-253/UG (fig. 4-10). Its chief use is for preparing messages in tape form for transmission by automatic means. When connected to an external circuit, however, the machine also can be utilized to transmit and receive messages.

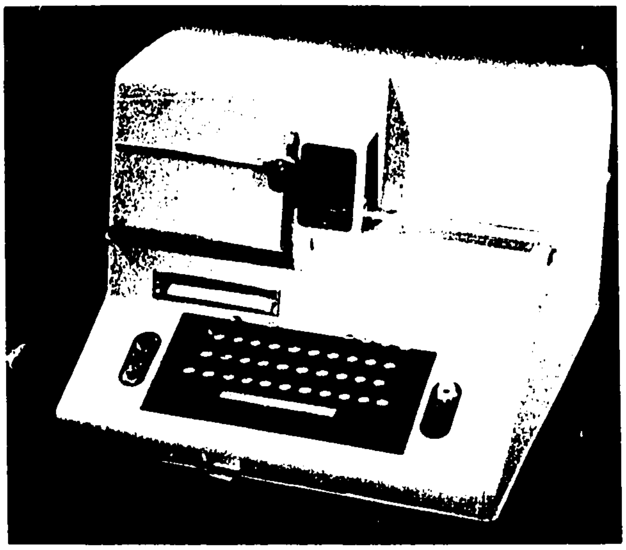
When a character is typed on the keyboard, its corresponding teletype code is perforated in the paper tape. Simultaneous with this action, the character is printed on the tape. In addition, the mark and space combinations for that character are sent from the keyboard directly to the external circuit (if connected).

Signals from the external circuit cause the machine to perform as just described. Thus, the TT-253/UG can be employed for communicating directly with distant stations or for the off-circuit preparation of message tapes. If both tape and printed page copy of a message are desired, the perforator-reperforator is used in conjunction with a page-receiving teletypewriter.



1.362

Figure 4-9.—Compact receive-only Teletypewriter AN/UGC-25.



50.116

Figure 4-10.—Send/Receive Typing Perforator-Reperforator TT-253/UG.

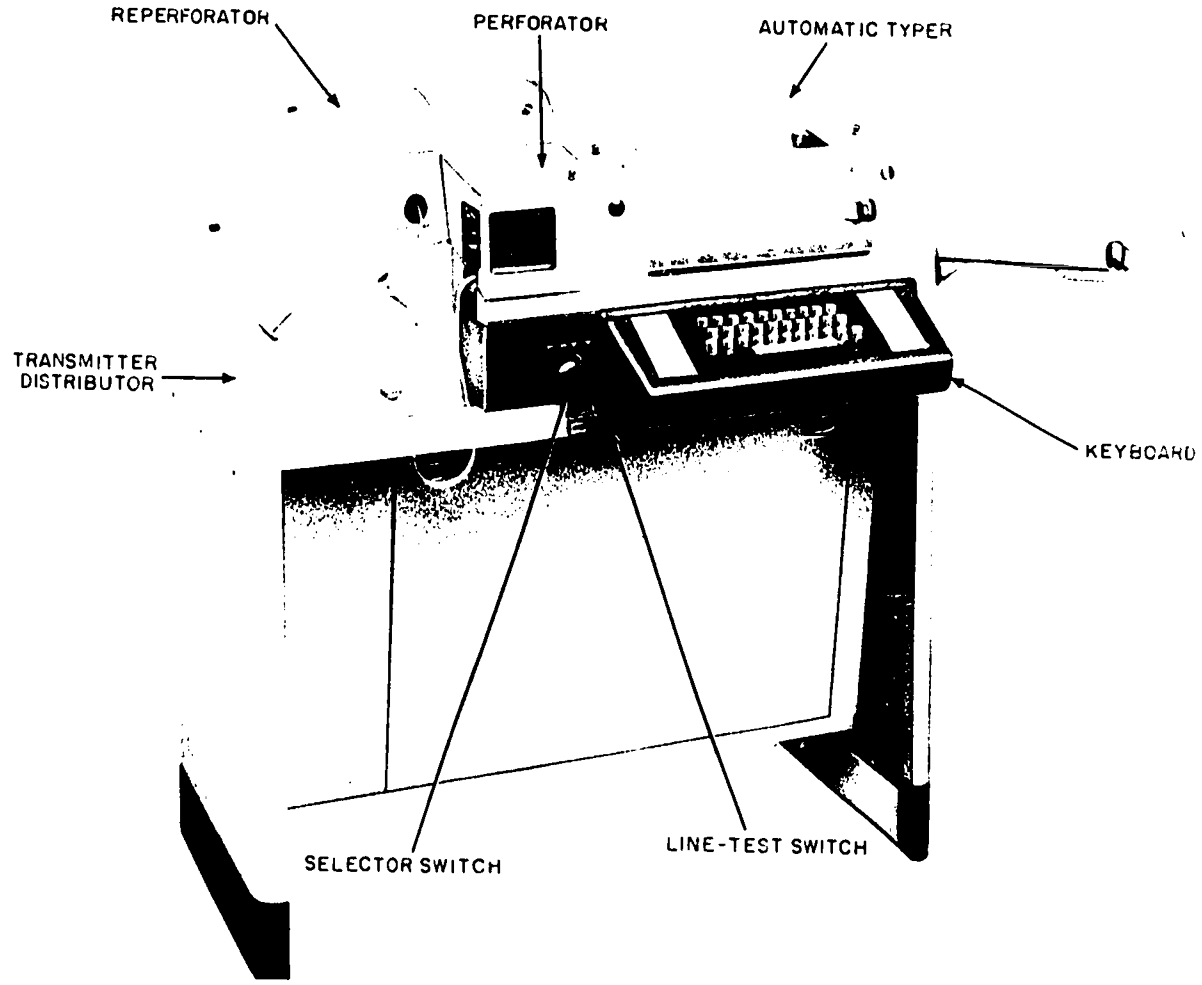
Teletypewriter Reperforator TT-192( )/UG

The TT-192( )/UG (not illustrated) is basically the same as the TT-253/UG just described except for not having a keyboard.

Normally, the reperforator's wiring is terminated in a patch panel (described later in this chapter) so that it can be patched or connected into any teletype circuit wired through the panel. By patching the reperforator into a circuit, a tape copy of each message is obtained, and messages requiring further processing in tape form need not be retyped by the operator.

Teletypewriter Set AN/UGC-6

The AN/UGC-6 teletypewriter (fig. 4-11) is a versatile communication equipment. It receives messages from the signal line and prints them on page size copy paper. In addition, it can receive messages and record them on tape and in printed form. With page-printed monitoring, the teletypewriter transmits



1.217(31)

Figure 4-11.—Teletypewriter AN/UGC-6.

messages that are originated either by perforated tape or by keyboard operation. It mechanically prepares perforated and printed tape for separate transmission with or without simultaneous transmission and page-printed monitoring.

The teletypewriter set is composed of the following components: a cabinet, a keyboard, an automatic typer, a typing perforator, a transmitter distributor, a typing reperforator, and power distribution panels.

In operation, the components are linked by electrical or mechanical connections to offer a wide range of possibilities for sending, receiving, or storing teletypewriter messages. All equipment components are housed in the cabinet. Transmission signals are initiated through the keyboard or through the transmitter distributor. Signals are received, and local transmission can be monitored, on the automatic typer. The typing perforator and typing reperforator are devices for preparing tapes on which locally initiated or incoming teletypewriter messages can be stored for future transmission through the transmitter distributor.

The keyboard, typing perforator, automatic typer, and transmitter distributor are operated by the motor mounted on the keyboard. Selection of these components for either individual or simultaneous operation is by the selector switch located at the front of the cabinet, to the left of the keyboard. All these components are connected in series in the signal line, but the selector switch has provisions for excluding various components from the line. The external signal line is connected to the equipment through a line-test switch located below the selector switch on the front of the cabinet. This arrangement provides a means of disconnecting the equipment from the line for local testing of the components. The typing reperforator is operated by a separate motor and power distribution system. It also is connected to a separate external signal line.

To become a part of the Naval Tactical Data System (NTDS), the AN/UGC-6 is modified to provide input/output communications with a selected data processing computer.

Teletypewriter AN/UGC-13

The Teletypewriter Set AN/UGC-13 when modified with Adapter becomes a part of the Naval Tactical Data System (NTDS). The adapter (contained in the teletypewriter cabinet, fig. 4-12) modifies data to provide compatibility between a computer and the teletypewriter unit. With the addition of the adapter, not only can the teletypewriter set communicate with other stations, but also can exchange information with the digital-data processing computer.

The teletypewriter keyboard consists of a set of manually operated keys which generate teletypewriter codes. The printing unit may accept teletypewriter codes from the keyboard, transmitter-distributor, or the computer. The transmitter-distributor (fig. 4-12) reads perforated paper tape and converts it into teletypewriter codes which can be transmitted to the printing unit, the typing reperforator, the auxiliary typing reperforator, and the computer. The maintenance and control section produces the control signals and the interrupt codes which are sent to the computer indicating the condition which exists in the adapter. By use of the maintenance controls, the teletypewriter set can be disconnected from the computer and adapter so teletypewriter operation can be tested.

An auxiliary line relay circuit (fig. 4-13) permits the adapter to perform multiplex operation with equipment other than this teletypewriter machine. An auxiliary line relay, built into the teletypewriter cabinet, is connected in the teletypewriter adapter loop. This line relay permits radio link equipment and/or other teletypewriter equipment to be connected into the teletypewriter adapter data loop. Compared to computer operation, the teletypewriter set is a slow-speed device. This permits the computer to perform other functions during the time between teletypewriter codes.

Teletypewriter Projector
Unit AN/UGR-1

Teletypewriter projector unit model AN/UGR-1, (fig. 4-14) enables a teletypewriter message to be read simultaneously by groups of persons. It is installed in the pilot readyrooms in aircraft carriers and in teletypewriter conference rooms ashore.

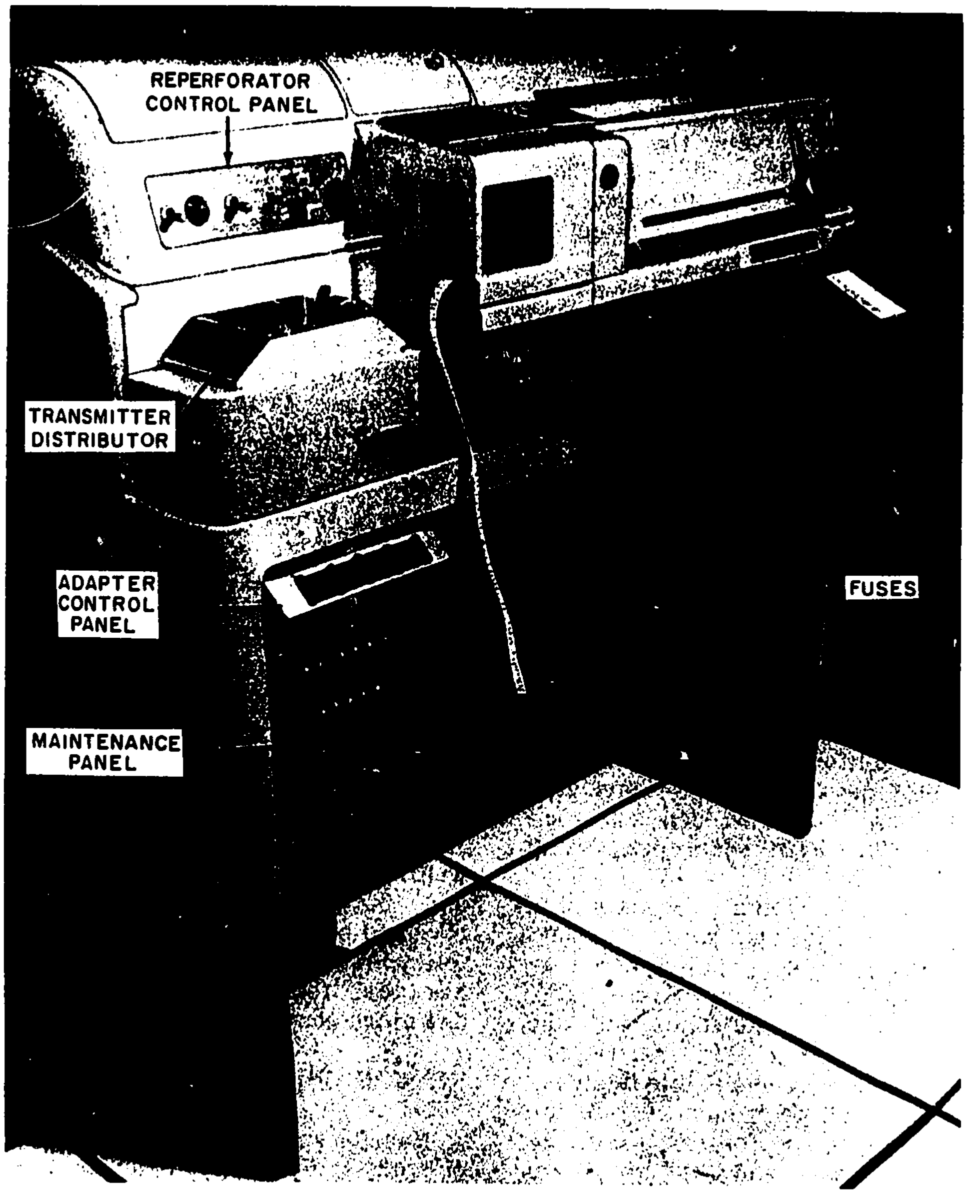
The bottom of the cabinet houses a page-printing teletypewriter. The message is printed on a roll of transparent cellophane. An optical lens system with a powerful lamp enlarges the image of the teletypewriter message and projects it onto a tilted mirror at the top rear of the cabinet from where it is reflected onto the translucent screen. The message is visible along the lower edge of the screen as it is being printed. With each successive line the message advances upward on the screen one line at a time and finally moves out of view at the top. A tape-typing unit provides a permanent typewritten record of transmissions in the projector unit, but at most installations this feature is not used because a page copy from an additional teletypewriter patched into the same circuit has been found to provide a more readable and more convenient file copy.

KEYERS AND CONVERTERS

Keyers and converters are an integral part of every radioteletype system. In some instances, the keyer is built into the radio transmitter, but the converter is a separate piece of equipment.

Tone-Shift Keyer/Converter
AN/SGC-1( )

Tone—shift keyer/converter model AN/SGC-1( ) is used for short-range RATT operation. Normally it is used for communication on UHF and VHF bands, but it can be used with any transmitter designed for voice modulation. The AN/SGC-1( ) is shown in figure 4-15, with blocks indicating other equipment necessary for a complete tone-shift system.



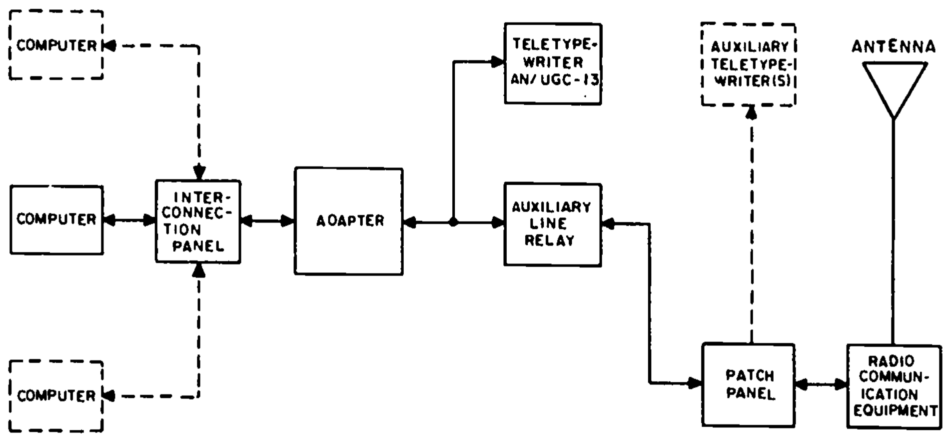
1.217

Figure 4-12.—Teletypewriter AN/UGC-13 with adapter.

In tone modulation transmission, the teletypewriter pulses are converted into corresponding audio tones, which amplitude modulate the carrier frequency of the transmitter. Conversion to the audio tones is accomplished by an audio oscillator in the tone converter, which operates at 700 hertz when the teletype loop is in a closed-circuit (mark) condition and at 500 hertz when the loop is in an open-circuit (space) condition.

An internal relay in the tone converter closes a control line to the radio transmitter, which places the transmitter on the air when the operator begins typing a message. The control line remains closed until after the message is transmitted.

When receiving messages, the tone converter accepts the mark and space tones coming in from an associated radio receiver and converts the intelligence of the tones into signals



31.29(124)

Figure 4-13.—Teletypewriter system for NTDS.

that close and open the contacts of a relay connected in the local teletypewriter DC loop circuit. This action causes the local teletypewriter to print in unison with the mark and space signals from the distant teletypewriter.

Converter-Comparator Groups AN/URA-8( ) and AN/URA-17( )

The AN/URA-8( ) frequency carrier-shift converter-comparator group (fig. 4-16) is used for diversity reception of RATT and FAX signals. The equipment consists of two frequency shift converters (top and bottom units) and a comparator (middle unit).

For either space diversity or frequency diversity reception, two standard Navy receivers are employed in conjunction with the converter-comparator group. In space diversity operation, the two receivers are tuned to the same carrier frequency, but their receiving antennas are spaced some distance apart. Because of the required spacing between antennas, space diversity usually is limited to shore station use. In frequency diversity operation, the two receivers are tuned to different carrier frequencies that are carrying identical intelligence. Frequency diversity reception commonly is used aboard ship for copying fleet broadcasts, which are keyed simultaneously on several frequencies.

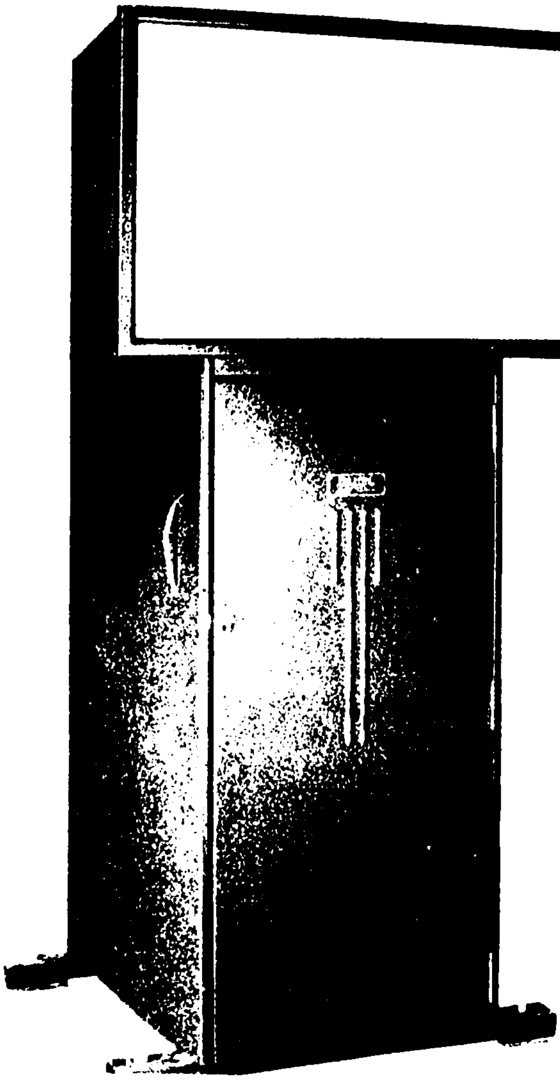
In diversity reception, the audio output of each receiver is connected to its associated frequency shift converter, which converts the frequency shift characters into DC pulses. The DC (or mark-space) pulses from each converter are fed to the comparator. In the comparator, an automatic circuit compares the pulses and selects the better mark and the better space pulse for each character. The output of the comparator is patched to the teletypewriter. The converter units also can be used individually with separate teletypewriters to copy two different FSK signals.

The newest converter-comparator group, the AN/URA-17( ) (fig. 4-17 is a completely transistorized equipment designed to perform the same functions as the AN/URA-8( ). Although present procurement of frequency shift converters is confined to the AN/URA-17( ), there are relatively few installations compared with the larger number of AN/URA-8( ) converters.

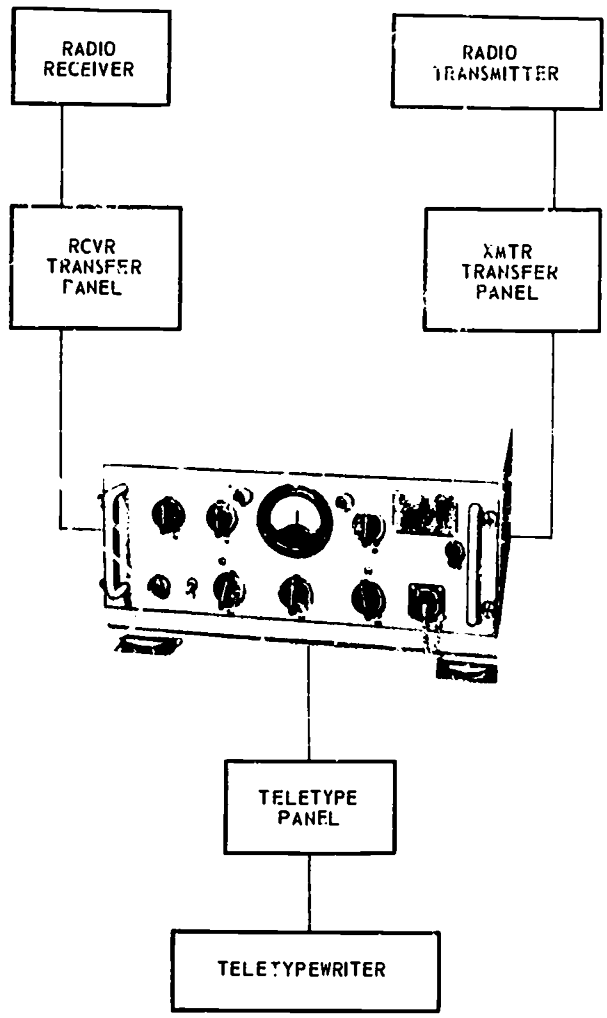
The AN/URA-17( ) consists of two identical converter units. Each converter has its own comparator circuitry. Hence, a separate comparator unit is not required. The physical size of the AN/URA-17( ) is further reduced by using transistors and printed circuit boards. The complete equipment is less than half the size of the older AN/URA-8( ).

TELETYPE PATCH PANELS

To provide flexibility in teletype systems, the wiring of all teletypewriter and associated equipments is terminated on jacks in teletype patch panels. The equipment then is connected electrically in any desired combination by means of patching cords (lengths of wire with



31.34
Figure 4-14.—Teletypewriter Projector Unit AN/UGR-1.



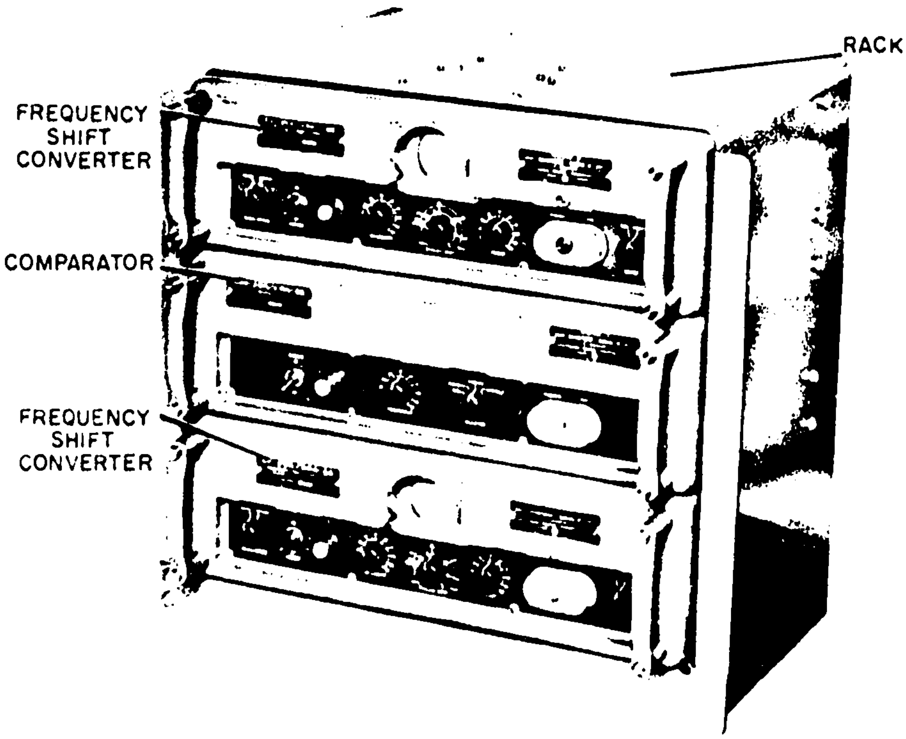
1.240
Figure 4-15.—Tone Shift Keyer/Converter AN/SGC-1( ).

plugs on each end). The plugs on the cords are inserted into the jacks at the front of the panel. In some instances, commonly used combinations of equipment are permanently wired together within the panel (called "normal-through"). They are wired in such a manner, however, that the individual pieces of equipment can be "lifted" from the combination, and then used alone or in other combinations.

In addition to providing flexibility, teletype panels also furnish a central point for connecting the DC voltage supply into the teletypewriter circuits. Thus, one source of supply can be used for all circuits passing through a particular panel.

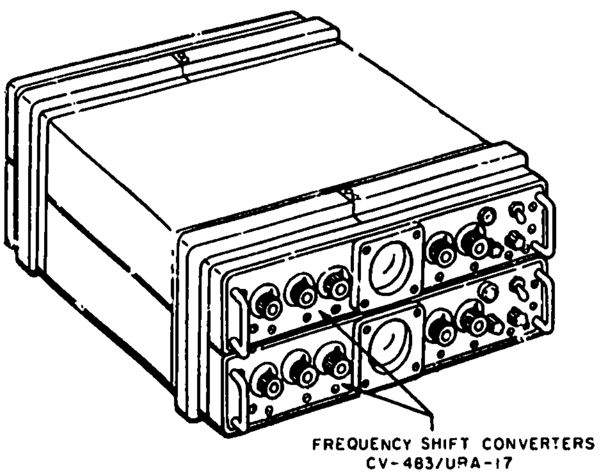
Teletype Panels SB-1203/UG and SB-1210/UGQ

Teletype panels SB-1203/UG and SB-1210/UGQ (fig. 4-18) are used for interconnection and transfer of teletypewriter equipment aboard ship with various radio adapters, such as frequency shift keyers and converters. The SB-1203/UG is a general-purpose panel, whereas



1.235

Figure 4-16.—Converter-Comparator Group AN/URA-8( ).



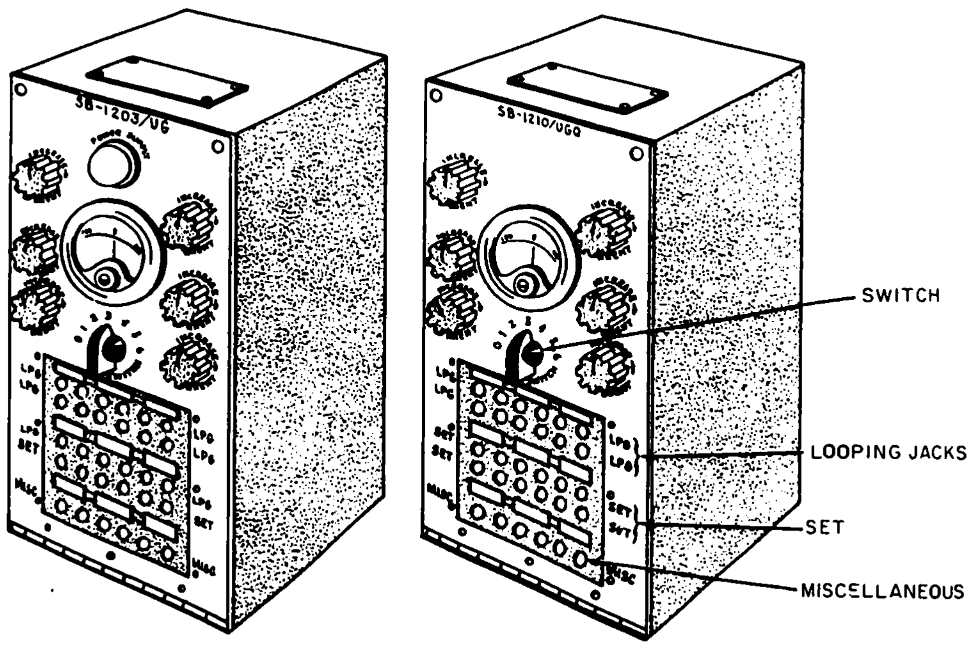
50.76

Figure 4-17.—Converter-Comparator Group AN/URA-17( ).

the SB-1210/UGQ is intended for use with cryptographic devices. The colors RED and BLACK are used to identify crytographic equipments. A patch panel used cryptographically is commonly painted red and has red bands installed or painted on its cables. Black is used to identify a nonsecurity patch panel.

Each of the panels contains six channels, with each channel comprising a looping series circuit of looping jacks, set jacks, and a rheostat for adjusting line current. The number of looping and set jacks in each channel varies according to the panel model. Each panel includes a meter and rotary selector switch for measuring the line current in any channel. There are six miscellaneous jacks to which may be connected any teletypewriter equipment not regularly assigned to a channel.

If the desired teletype equipment is wired in the same looping channel as the radio adapter (keyer or converter) to be used (normal through connection), no patchcords are required. But, if the desired teletypewriter (for example,



70.79
Figure 4-18.—Teletype Patch Panels SB-1203/UG and SB-1210/UGQ.

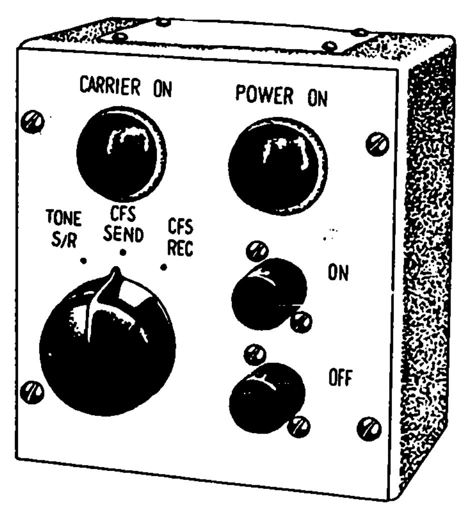
in channel 1) is not wired in the same looping channel as the keyer or converter to be used (for example, channel 3), one end of the patch cord must be inserted in the set jack in channel 1, and the other end in either one of the two looping jacks in channel 3.

In any switching operation between the various plugs and jacks of a teletype panel, the cord plug must be pulled from the looping jack before removing the other plug from the set (machine) jack. Pulling the plug from the set jack first open-circuits the channel, causing all teletype messages in the channel to be interrupted. It may also produce a dangerous DC voltage on the exposed plug.

REMOTE TRANSMITTER CONTROL UNIT C-1004( )/SG

Another piece of equipment used with teletypewriter installations aboard ship is the C-1004( )/SG control unit shown in figure 4-19. This unit is mounted close to the teletypewriter keyboard and permits remote control of the radio transmitter. It has a transmitter power on-off switch, a power-on indicator lamp, a carrier-on indicator lamp, and a three-position rotary selector switch.

The TONE S/R switch position is used for both sending and receiving when using a tone shift keyer converter. When using frequency carrier-shift mode of operation, the operator must switch to SEND position for transmitting and to REC position for receiving.



1.244.1
Figure 4-19.—Remote Control Unit C-1004( )S/G.

MULTIPLEXING

The number of communication networks in operation per unit of time throughout any given area is increasing constantly. In the not-too-distant past, each network was required to operate on a different frequency. As a result, all areas of the radio-frequency spectrum had become highly congested.

The maximum permissible number of intelligible transmissions taking place in the radio spectrum per unit of time can be increased through the use of multiplexing. The main purpose of a multiplex system is to increase the message-handling capacity of radio communication, or teletypewriter channels and the transmitters and receivers associated with them. This increase in capacity is accomplished by the simultaneous transmission of several messages over a common channel. The frequency division multiplexing telegraph terminal employs a number of tone channels slightly displaced in frequency. Each tone channel carries the signals from a separate teletypewriter circuit and modulates a common carrier frequency. Receiving equipment at a distant station accepts the multiplex signals, converts them to mark-space signals, and distributes them in the proper order to a corresponding number of circuits.

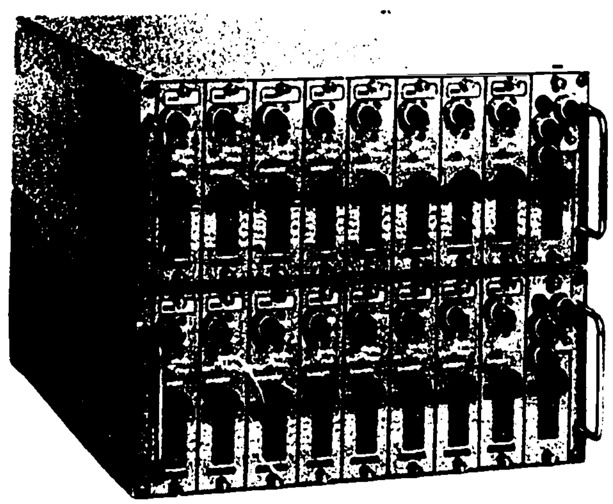
Most of the active fleet is equipped with multiplex equipment.

TELEGRAPH TERMINAL SET AN/UCC-1(V)

Tha AN/UCC-1(V) (fig. 4-20) consists of frequency division multiplex terminal equipment for use with radio (or wire) circuits. The equipment is completely transistorized.

Each of the two electrical cabinets (fig. 4-20) houses one control-attenuator (right-side) for switch control. The module will also have either 8 keyers for transmission, or 8 frequency-shift converters for receiving, or any combination of both.

Each channel has its own keyer and will have one or more converters that will accept a keying speed of 100 WPM. When keyed by teletypewriter signals, the keyers generate one frequency representing a mark and another representing a space (2 modes for each channel). The converters receive the signals and reverse the process performed by the keyers. They accept a particular frequency-shift signal and convert it to the DC marks and spaces for operation of the teletypewriters.



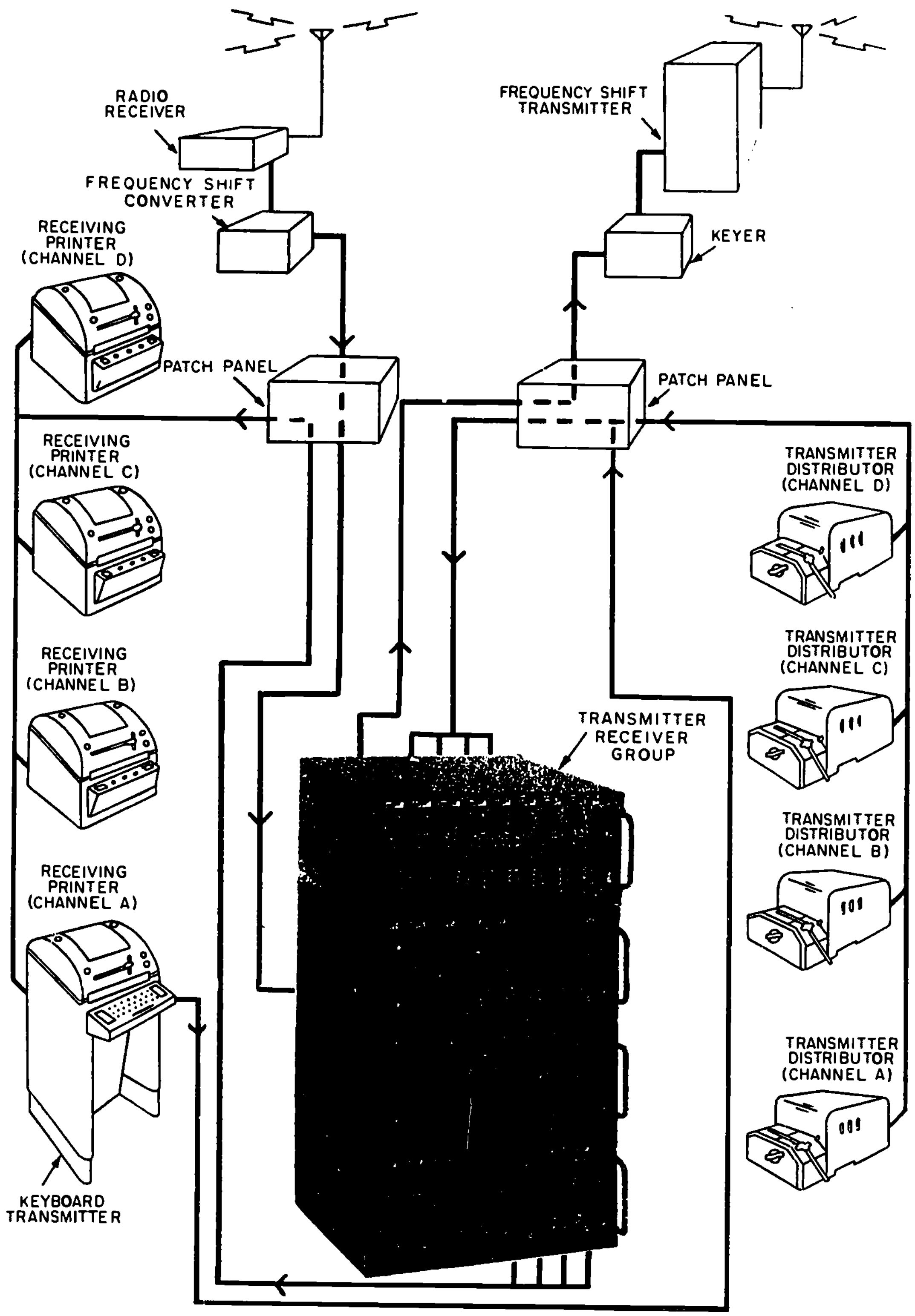
120.26(120C)
Figure 4-20.—Telegraph Multiplex Terminal AN/UCC-1(V).

Because of its light weight, small size, and high message-handling capacity, the AN/UCC-1(V) is suitable for installation on most types of ships.

A schematic representation of a 4-channel multiplex installation is shown in figure 4-21. The frequency shift transmitter, the keyer, the radio receiver, the converter, the patch panels, and the teletypewriter equipment are included to show the complete send-receive system.

Teletypewriter signals are fed to the terminal equipment's transmitting group from two, three, or four separate circuits. The signaling speed can be 60, 75, or 100 wpm, but the speed must be the same for each circuit. In the transmitting group, the teletypewriter signals are converted to multiplexed signals that are arranged in sequential order for transmission over a single radio circuit. The multiplexed output of the transmitting group is fed through the patch panel and frequency shift keyer to the radio transmitter, where the frequency-shifted multiplex signal is placed on the air.

At the receiving station, the multiplex signals from the radio receiver are processed through the frequency shift converter. Then, they are patched to the receiving group. The receiving



50.83(120C)

Figure 4-21.—Multiplex installation employing 4-channel terminal equipment.

group converts the multiplexed signals back into standard teletypewriter signals and distributes the DC marks and spaces to the proper teleltypewriters.

FACSIMILE

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

The scanning operation consists of subdividing the picture in an orderly manner into a large number of elemental segments. This process is accomplished in the facsimile transmitter by a scanning drum and phototube arrangement.

The picture to be transmitted is mounted on a cylindrical scanning drum, which rotates at a constant speed and at the same time moves longitudinally along a shaft. Light from an exciter lamp illuminates a small segment of the moving picture and is reflected by the picture through an aperture to a phototube. During the transmission of a complete picture, the light traverses every segment of the picture as the drum slowly spirals past the fixed lighted area.

At any instant, the amount of light reflected back to the phototube is a measure of the lightness or darkness of the tiny segment of the picture that is being scanned. The phototube transforms the varying amounts of light into varying electrical signals, which, in turn, are used to amplitude modulate the constant frequency output of a local oscillator. Then, the modulated signal is amplified and sent to the radio circuits.

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

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

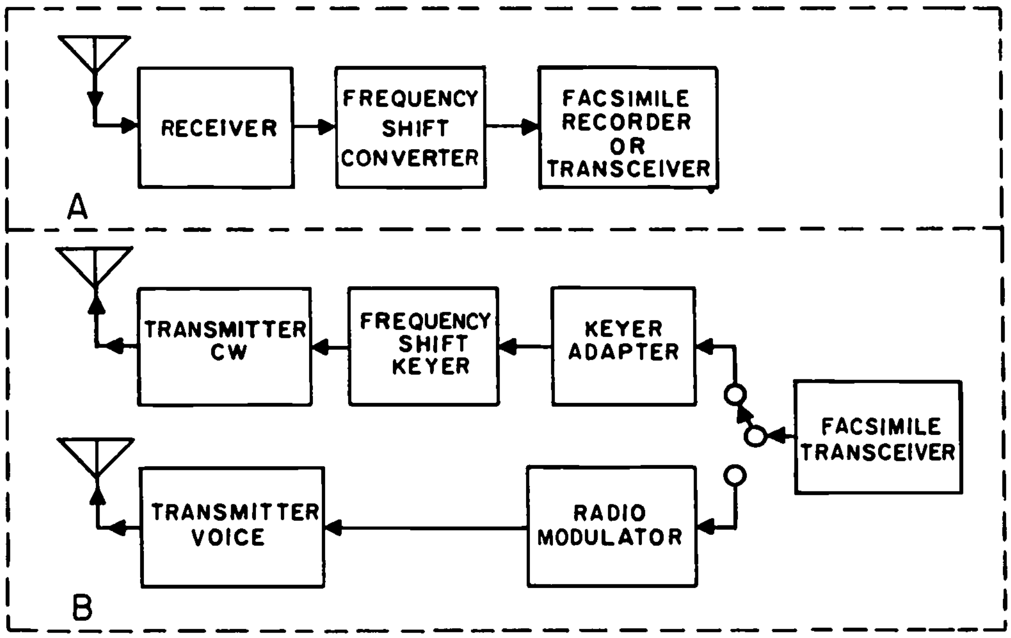
Framing (orienting) the receiver drum with respect to the transmitter drum is accomplished by transmitting a series of phasing pulses just before a picture transmission is to begin. The pulses operate a clutch mechanism that starts the scanning drum in the receiver so that it is phased properly with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

The equipment necessary for radio facsimile operation and its relationship to other units in the various receiving and transmitting systems are illustrated by block diagram in figure 4-22. As shown in part A of the figure, the receiving system consists of a standard radio receiver, a frequency shift converter, and a facsimile recorder. Part B shows two systems for transmitting facsimile signals. One, the upper row of blocks, is for long-range, carrier frequency shift transmission and consists of a facsimile transceiver, a keyer adapter, a frequency shfit keyer, and a CW transmitter. The other, the lower row of blocks, is for short-range, audiofrequency shift transmission and employs a facsimile transceiver, a radio modulator, and a voice transmitter.

The equipment discussed in the remaining portion of this chapter is representative of that used in shipboard facsimile installations.

FACSIMILE TRANSCEIVERS TT-41( )/TXC-1B AND TT-321A/UX

Facsimile transceiver TT-41( )/TXC-1B (fig. 4-23), is an electromechanical-optical facsimile set of the revolving-drum type for both transmission and reception of page copy. Colored copy may be transmitted, but all reproduction is in black, white, and intermediate shades of gray. Received copy is recorded either directly on chemically treated paper, or photographically in either negative or positive form. The equipment transmits or receives a page of copy 12 by 18 inches in 20 minutes at

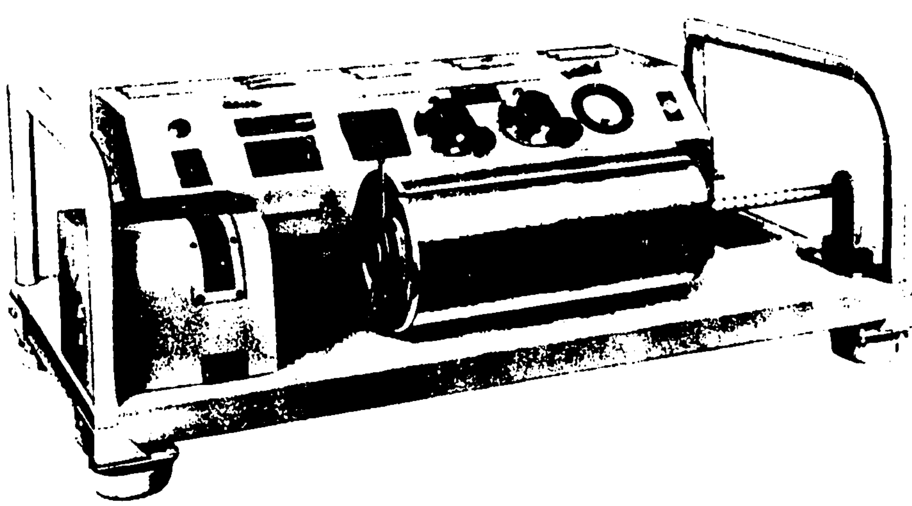


70.14

Figure 4-22.—Radio facsimile systems.

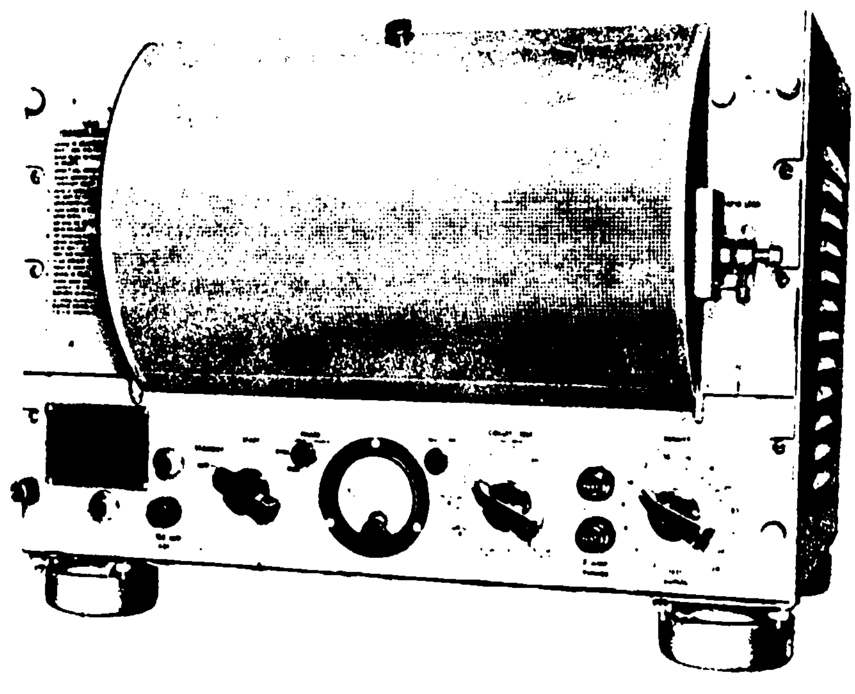
regular speed (60 RPM=LPM), or in 40 minutes with half-speed (30 lines per minute, LPM) operation.

The TT-321A/UX facsimile transceiver, also shown in figure 4-24 is the same transceiver as above but has an increase in motor speed.



13.70

Figure 4-23.—Facsimile Transceiver TT-41( )/TXC-1B and TT-321A/UX.



13.71

Figure 4-24.—Facsimile Recorder RD-92( )/UX.

The TT-321A/UX transmits or receives a page of copy 12 by 18 inches in 10 minutes at regular speed (120 LPM), or in 20 minutes with half-speed (60 LPM) operation.

A facsimile transceiver (or transmitter) generates an amplitude-modulated signal, and the recorder is designed to operate on this type of signal. The signal generated by the transmitter is unsuitable, however, for transmission by means of radio. For this reason, it is necessary to use signal conversion equipment between the facsimile transmitter and the radio transmitter, and between the radio receiver and the facsimile recorder.

FACSIMILE RECORDER RD-92( )/UX

Facsimile recorder RD-92( )/UX, shown in figure 4-24, is used for direct stylus recording only. Unlike the transceivers described earlier, it cannot be used for transmitting facsimile, nor can it be used to receive on photographic film.

When receiving copy, the recorder drum rotates at a speed of 60 rpm. (No provision is made for multispeed operation.) As the drum rotates, a mechanical mechanism holding a stylus needle is moved across the drum to the right. The stylus needle records on paper fastened on the drum at the rate of one scanning line for each revolution of the drum. When the paper is covered completely, from left to right, the stylus is returned automatically to the left side of the drum so that it will be ready to record the next transmitted copy.

This basic RD-92( )/UX facsimile recorder was updated to meet NATO requirements of 60-90-120 LPM by modifying the recorder and using a combined pair of equipments to get desired results. The modified model RD-171( )/UX operates from 60-90 LPM: the RO-160( )/UX operates from 60-120 LPM: and the RD-172( )/UX operates from 90-120 LPM. Any two combinations met requirements of 60-90-120 LPM.

FACSIMILE RECORDER AN/UXH-2B

A more modern facsimile recorder than the one just described is the model AN/UXH-2B shown in figure 4-25. Instead of recording on paper that is attached to a revolving drum, the AN/UXH-2B makes direct recordings across a continuous page of paper. Paper is supplied from a roll within the machine.

Recording is accomplished by using three recording heads that are carried across the page on a rubber belt. The heads are spaced on the belt so that only one head is touching the paper at any given time, and the speed at which this head moves across the paper is the same as the scanning speed at the transmitter. Recording speeds can be 60, 90, or 120 scans per minute, making this recorder compatible for operation with most Navy facsimile transmitters.

When receiving signals from a transmitter capable of sending the necessary control signals, the AN/UXH-2B can be left unattended. Upon receipt of the proper signals, it automatically phases, starts recording at the beginning of a transmission, stops when the transmission is complete, and compensates for changes in signal level during the recording.

KEYER ADAPTER KY-44( )/FX

For frequency carrier-shift transmission, the amplitude-modulated audio signal from the facsimile transmitter must be converted to DC keying voltages before being applied to the frequency shift keyer. This is the function of keyer adapter KY-44( )/FX shown in figure 4-26.

The output of the adapter is a DC signal that varies in amplitude from 0 to 20 volts, depending on the frequency of the audio input signal. When the DC signal is used to key a frequency shift keyer, and when the frequency shift keyer, in turn, is controlling a radio transmitter, the end result is transmitted frequency carrier-shift signal similar to a

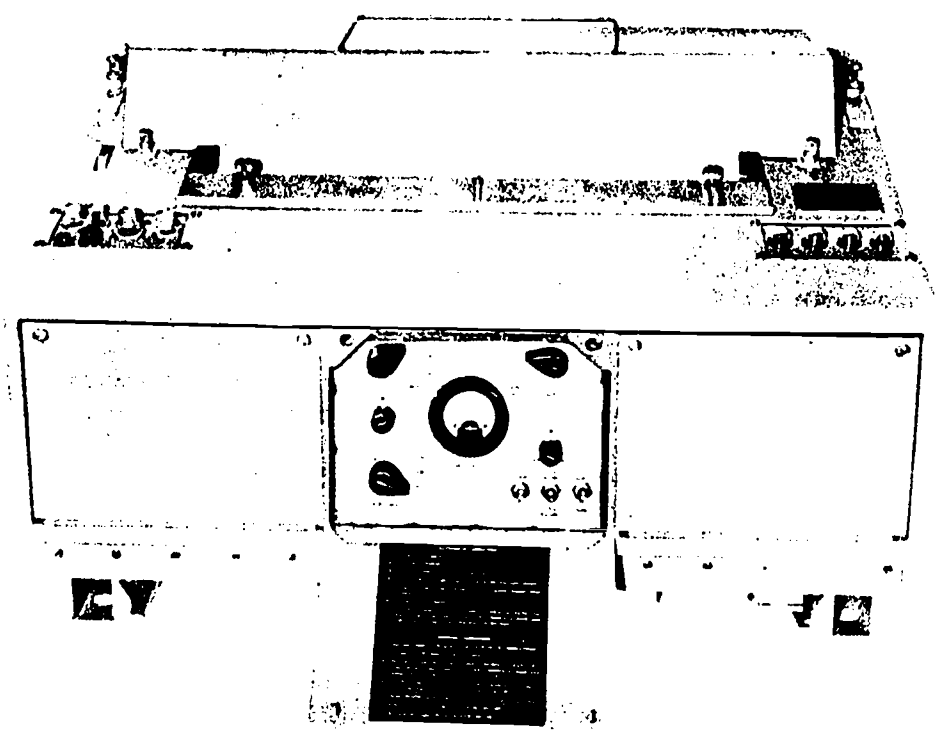


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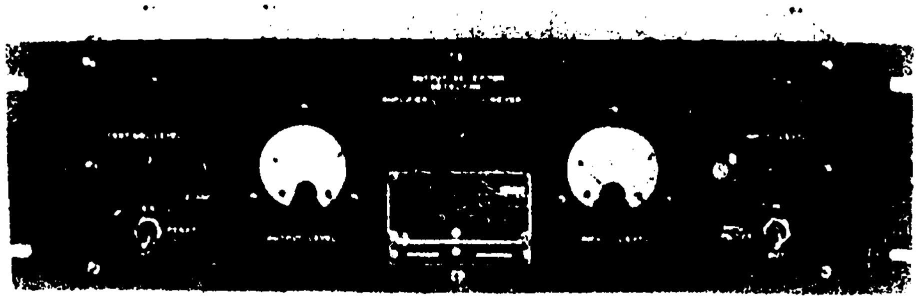
Figure 4-25.—Facsimile Recorder AN/UXH-2.



70.81

Figure 4-26.—Keyer Adapter KY-44( )/FX.

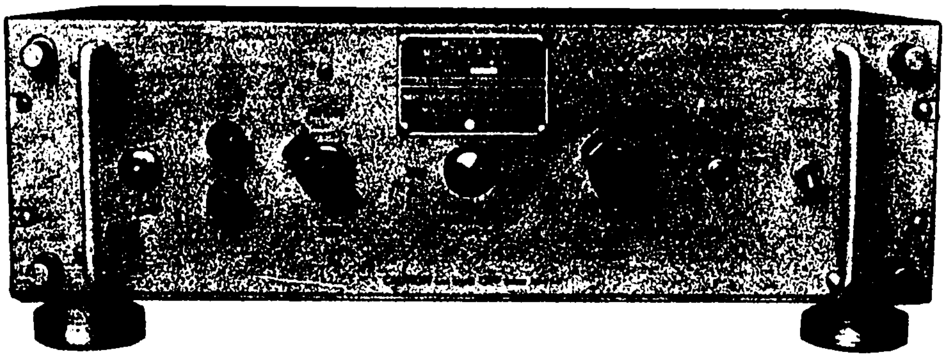
radioteletype signal. As stated previously, this method of transmitting facsimile signals is used for long-range transmissions.

MODULATOR MD-168( )/UX

For transmission of facsimile signals by the audio-frequency shift method, a radio modulator, such as the MD-168( )/UX (fig. 4-27), is required between the facsimile transmitter and the radio transmitter. The modulator converts the amplitude-modulated signal from the facsimile transmitter to constant amplitude frequency modulation, which varies at frequencies between 1500 and 2300 Hz. This frequency variation is used to modulate the radiotelephone transmitter. Modulator MD-168( )/UX can be employed with any transmitter capable of being voice modulated. In general, the audio-frequency shift method is used for short-range transmissions.

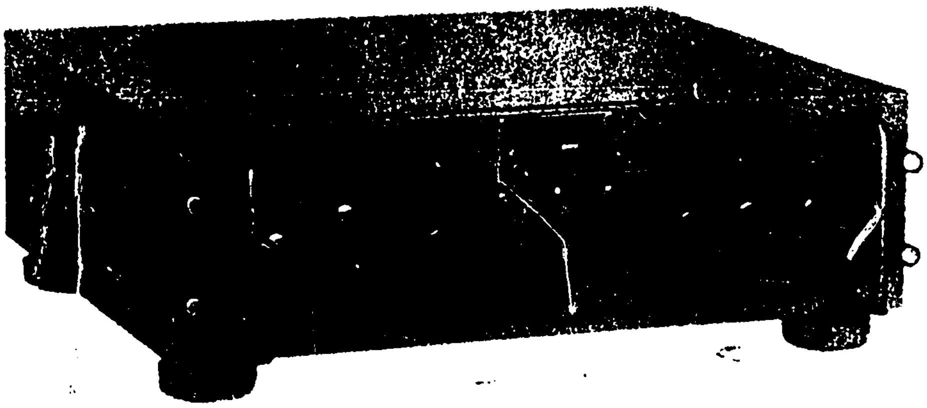
FREQUENCY SHIFT CONVERTER CV-172( )/U

With either the frequency carrier shift or the audiofrequency shift methods of transmitting facsimile signals, the output of the radio receiver at the receiving station is an audio-frequency shift signal of constant amplitude. The function of frequency shift converter CV-172( )/U (fig. 4-28) is to convert the receiver's output to an amplitude-modulated signal that varies between 1200 and 2300 Hz. which is



70.82

Figure 4-27.—Modulator MD-168( )/UX.



70.85

Figure 4-28.—Frequency Shift Converter CV-172( )/U.

the signal required for proper operation of the facsimile recorder.

The CV-172( )/U is not the only frequency shift converter used by the Navy in facsimile installations, but it is the one most commonly found aboard ship. Others you may encounter are models CV-97/UX and the CV-1066/UX. They all perform the same function.

CHAPTER 5

RADAR

Radar (from the words radio detection and ranging) is one of the greatest scientific developments that emerged from World War II. It makes possible the detection and range determination of such objects as ships and airplanes over long distances. The range of radar is unaffected by darkness, but it often is affected by various weather conditions; for example, heavy fog or violent storms.

THEORY OF OPERATION

The basic principles of radar are similar to those of sound echoes or wave reflections. If a person shouts in the direction of a cliff or some other sound-reflecting surface, he hears his shout return from the direction of the cliff. Sound waves, generated by the shout, travel through the air until they strike the cliff. There they are reflected or bounced off, and some are returned to the originating spot. These reflected waves are the echo that the person hears.

Time elapses between the instant the sound originates and the time the echo is heard. Because sound waves travel through air at approximately 1100 feet per second, the distance of the reflecting surface from the shouter can be computed as $(1100)t/2$, where $t/2$ is one-half the elapsed time, corresponding to one-half the round trip distance out and back.

Most radar systems operate on a principle very much like that just described. The major difference is that radar utilizes radiofrequency electromagnetic waves, instead of sound waves, to detect the presence of reflecting surfaces.

At least three methods of radar detection are in use today. These are (1) the continuous-wave method, (2) the frequency-modulation method, and (3) the pulse-modulation method. This last method is the most common.

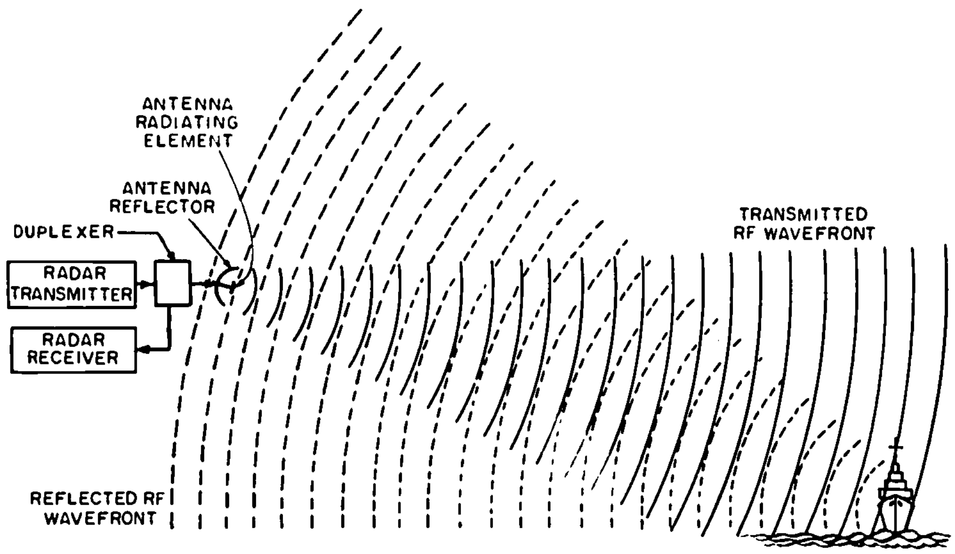
In the pulse-modulated method (fig. 5-1), the transmitter sends out short pulses of RF energy at regular intervals. Depending on the particular radar, the duration of the transmitter pulse ranges between 0.1 and 5.0 microseconds. Each transmitting period is followed by a receiving period of relatively much longer duration than the transmitting period. The transmit-receive cycle is repeated many times per second. This repetition rate depends on the design of the set.

RANGE DETERMINATION

The employment of radar to determine the range (distance) to a target is made possible by (1) our knowledge of the velocity of the transmitted radiofrequency energy in space, and (2) the measurement of the time required for the energy to reach a target and return.

Once radiated into space, radiofrequency energy travels at the speed of light. In terms of distance traveled per unit of time, it travels approximately 186,000 land miles per second, or 164,000 nautical miles per second. To make practical use of this velocity-distance relationship, it is necessary to consider distance in terms of yards, and time in terms of microseconds (μs). Computing mathematically, we find that RF energy travels 328 nautical yards in 1 microsecond. This means that approximately 6.18 microseconds are required for the energy to travel 1 nautical mile, or 2027 yards (6080 feet). For convenience, however, all Navy radar ranging (including equipment calibration) is based on a flat figure of 2000 yards (6000 feet) per nautical mile; and the 6.18 microseconds is rounded of to 6.1.

The action of range determination is explained with the aid of figure 5-2 and a target at a 20-mile range. Information obtained during the radar operation is presented visually on the face of a cathode-ray tube (scope). (See discussion of A-scope later in this chapter.) The tube face (screen) for certain types of



120.78

Figure 5-1. —Pulse-modulated method.

indicators usually is covered with a translucent scale graduated from 0 to the maximum range (in yards or miles). In this instance the maximum range is 20 miles. A horizontal sweep voltage causes the cathode ray beam to trace across the screen beneath the scale. Scale readings indicate the actual target range.

We discuss the A-scope only because it is an easy method of explaining how distance is determined by radar. The A-scope has been replaced by the PPI (planned position indicator) in general-purpose radar sets. See discussion of PPI-scope later in this chapter.

In figure 5-2A, a radiofrequency pulse is transmitted and is just leaving the antenna. A small "pip" is produced at the zero-mile mark on the scope at the instant the radar energy is transmitted. The leading edge of this pulse serves as the reference from which target distance is measured.

In part B, 61 μs later, the transmitted pulse has traveled 10 miles toward the target. The sweep trace, which is timed to show true range by indicating one-half the distance the RF pulse has traveled, is now at the 5-mile mark.

In view C of figure 5-2, 122 μs after the transmission interval, the RF energy has reached the target, 20 miles away; a relatively small RF reflection, or echo, has started back. The scope trace is now at the 10-mile mark.

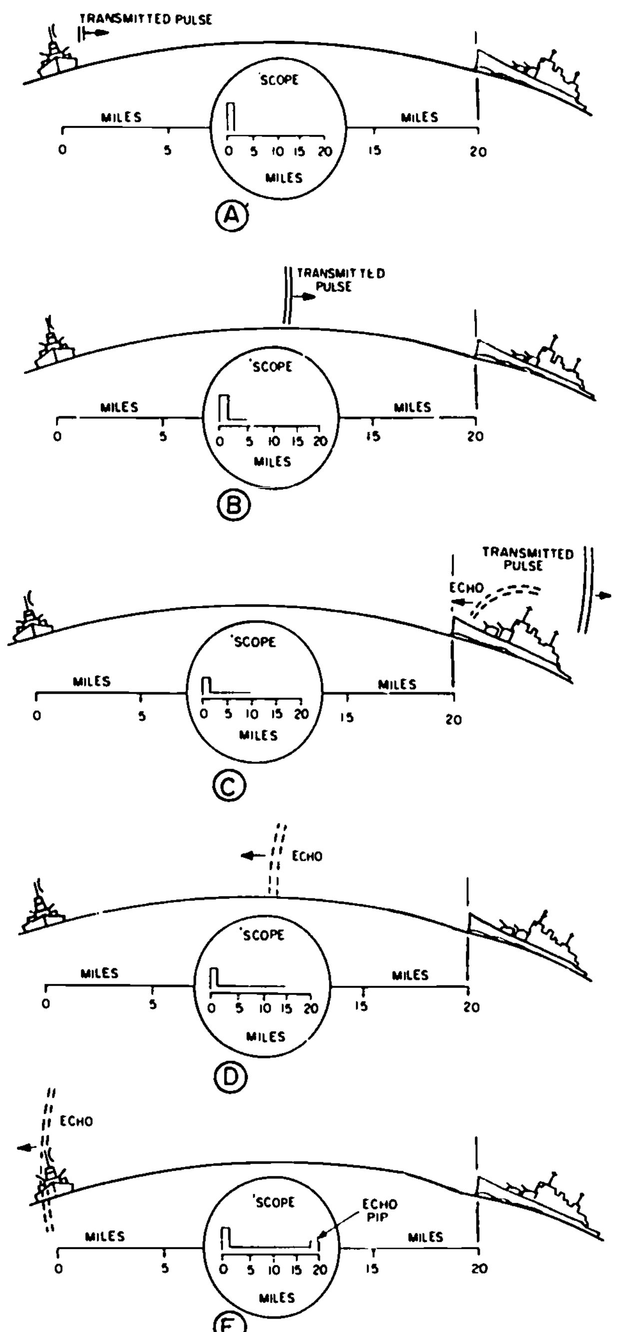
In part D, 183 μ s after transmission, the echo has returned half the distance from the target, and the scope is now at the 15-mile mark.

Finally, at part E of the illustration, 244 μ s after transmission of the initial pulse, the echo has returned to the radar receiving antenna. This relatively small amount of RF energy is amplified and applied to the vertical deflection system of the scope, and an echo pip of smaller amplitude than the initial pip is displayed at the 20-mile mark.

If two or more targets are in the path of the transmitted pulse, each returns a portion of the transmitted energy in the form of echoes. The target at the greatest distance away (assuming all targets are similar in size and type of material) will return the weakest echo.

BEARING DETERMINATION

Bearing (also called azimuth) is the direction of an object from the observer, expressed in degrees clockwise through 360° around the horizon. True bearing is measured from true north; relative bearing is measured from the heading of the ship. In radar applications,



20.282
Figure 5-2. —Radar range determination.

bearing (true or relative) of the target may be determined by concentrating the radiated energy in a narrow beam, and by knowing the beam direction when a target pip is picked up.

Radar antennas are designed to produce a single narrow beam of energy in one direction (fig. 5-3). The receiving pattern is the same as the transmitting pattern. The antenna and associated lobe of RF energy are either rotated in the horizontal plane through 360° or "rocked" back and forth so that they sweep over a given area. When a target is encountered (fig. 5-3A), a return signal is received. The antenna may then be positioned so that the received echo signal is maximum (fig. 5-3B). The maximum signal strength indicates that the axis of the lobe passes through the target. The radar set is equipped with bearing indicators so that target bearing can be measured either from true north or with respect to the heading of a ship (or aircraft) containing the radar set.

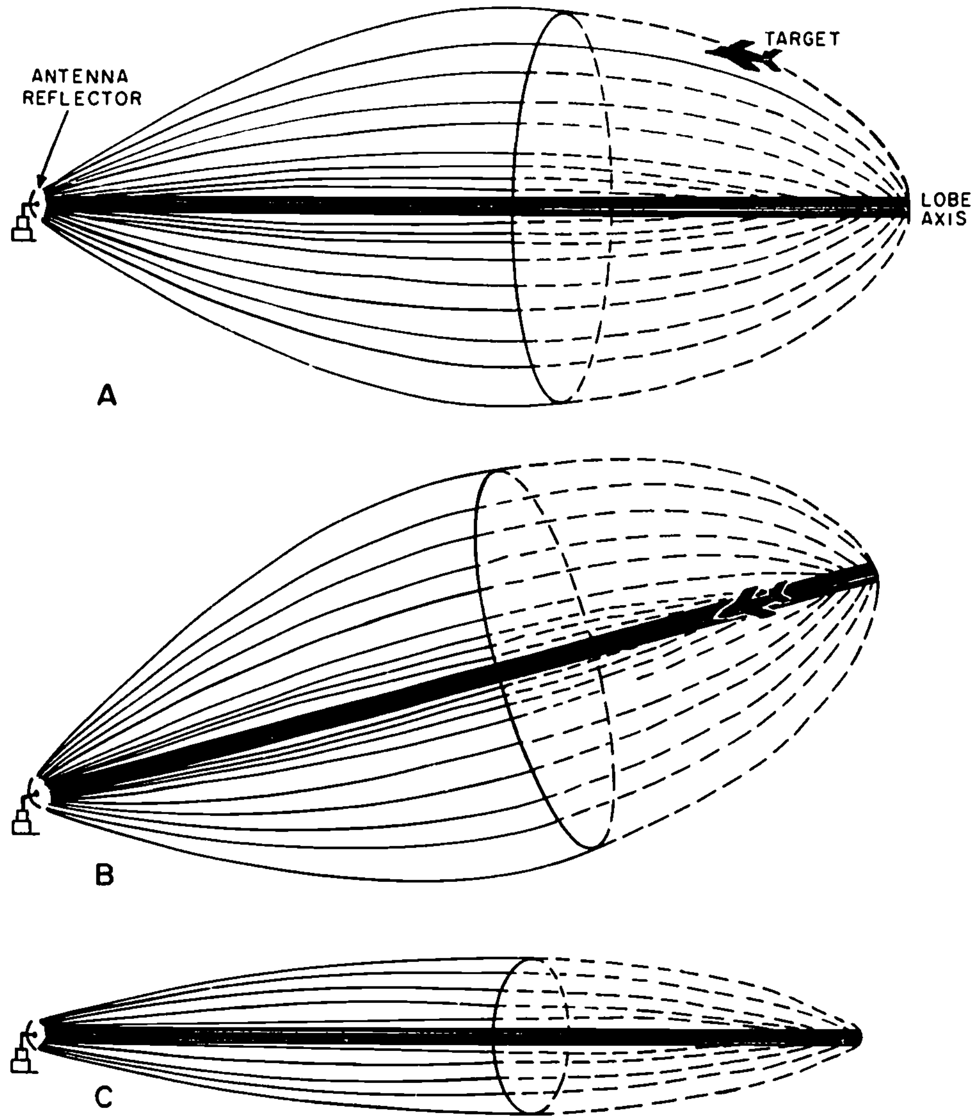
The bearing of a target can be determined in several ways. When the single-lobe method is used, the sensitivity of the system depends on the angular width of the lobe pattern. If the signal strength changes appreciably when the antenna is rotated through a small angle, the accuracy with which the on-target position can be selected is great.

When the antenna lobe is rotated from position A to position B (fig. 5-3), the increase in the signal strength received is small. Thus, the bearing of the target cannot be determined accurately. When a radar has a narrow lobe of concentrated energy (fig. 5-3C), the change in signal strength is greater as the antenna is rotated to the target and a more accurate determination of bearing is possible.

ALTITUDE DETERMINATION

The remaining dimension necessary to locate completely an object in space can be expressed either as an angle of elevation or as an altitude. If one is known, the other can be calculated from one of the basic trigonometric ratios. A method of determining the angle of elevation and the altitude is shown in figure 5-4. Slant range (fig. 5-4A) is obtained from the radarscope indication as the range to the target. The angle of elevation is the same as that of the radar antenna (fig. 5-4B). Altitude is equal to the slant range multiplied by the sine of the angle of elevation.

In radar equipment with antennas that can be elevated, altitude determination by slant range is computed automatically be electronic means.

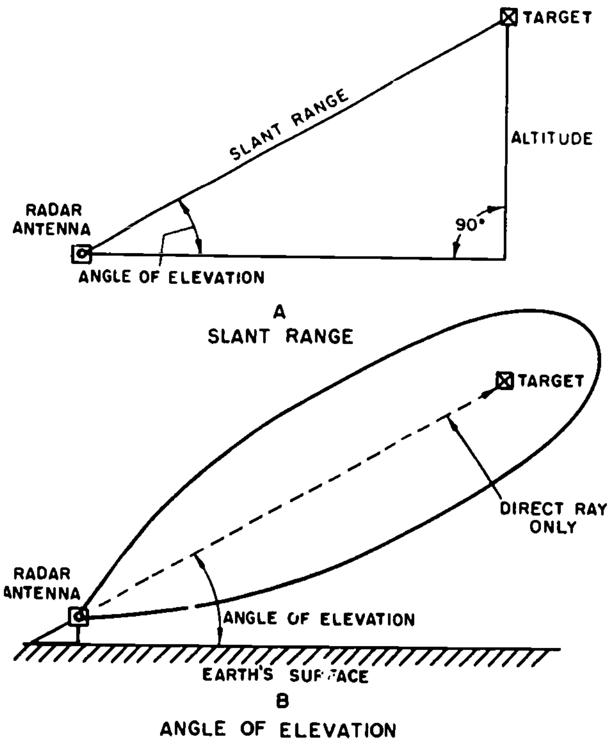


20.284(120C)

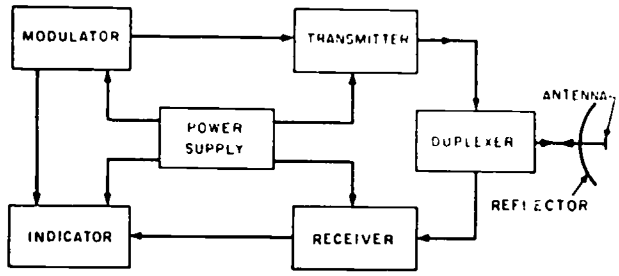
Figure 5-3. —Radar determination of azimuth or bearing.

BASIC PULSED RADAR SYSTEM

A block diagram of the basic units of a pulse-modulated radar system is shown in figure 5-5. The modulator produces the timing pulses that trigger the transmitter and indicator. These timing pulses are converted by the transmitter into high-power pulses of RF energy at the assigned frequency. The use of one antenna for both transmitting and receiving is made possible by the duplexer. It directs the transmitter outgoing pulses to the antenna (away from the receiver) and the incoming echo pulses to the receiver (away from the transmitter). The antenna system radiates the RF energy as a directional beam, and receives the echo pulses only from the direction in which the antenna reflector is pointing. The receiver amplifies the received echo pulses reflected from the target, and applies them to the indicator. There they are displayed on a cathode-ray tube. Necessary



20.285(120C)
Figure 5-4.—Radar determination of altitude.



72.59
Figure 5-5.—Block diagram of a pulse-modulated radar system.

power for the various radar functions is supplied by the power supply. A more detailed description of some of the individual blocks follows.

MODULATOR

The transmit-receive periods in a pulsed radar system are controlled by synchronizing signals generated in the modulator or synchronizer. Usually, the basic control device within the modulator is a very stable oscillator. The oscillator output is amplified, shaped as required, and fed as synchronizing pulses to the transmitting, receiving, and indicating sections.

The transmit period in a radar system is much shorter in duration than the receive period. Sufficient time must be allowed during the receive period (between transmissions) to ensure the return of echoes from the maximum desirable range of the system. Thus, the maximum range from which echoes can be received for a target of given size depends on the relationship of the time between transmission bursts (pulse repetition) and the RF power generated.

The relationship between pulse repetition rate (PRR) and maximum range is explained with the aid of the following example. Assume that sufficient power is transmitted to produce useful echoes from a target of appreciable size. The pulse repetition period is the reciprocal of the pulse repetition rate. Thus, PRP=1/PRR. If the PRR is 250 pulses per second (PPS), the period is 1/250=.004 sec or 4000 μ s. Assuming further that the transmission period contained in this time period is of negligible duration, and by knowing that each mile traversed by the RF energy requires approximately 6.1 μ s to travel in each direction (or 12.2 μ s per mile), it is seen that the maximum range is 4000 μ s/12.2 μ s = 328 miles.

Although maximum range increases with a decrease in pulse repetition rate, it should be noted that the antenna system is rotated at a relatively rapid rate, and the beam of energy strikes a target for a relatively short time. During this time, a sufficient number of pulses must be transmitted and their echoes received to produce a visual indication of target presence. The most desirable pulse repetition rate, then, is a compromise between maximum range and indicator requirements.

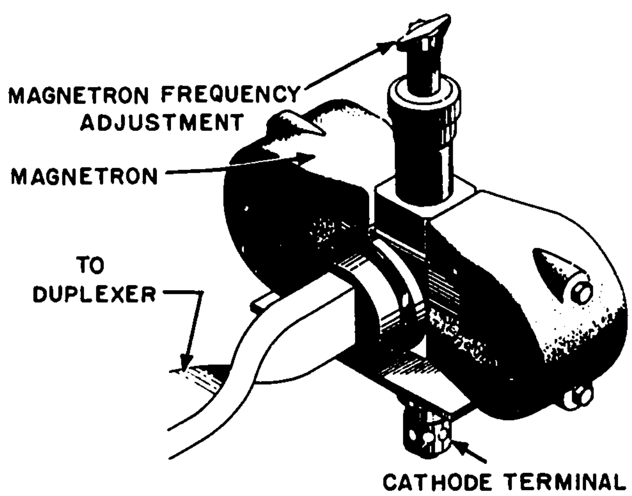
The minimum range at which a target can be detected is governed largely by the width (duration) of the transmitted pulse. If a target is so close to the transmitter that the echo is returned before the transmitter is turned off, reception of the echo is masked by the transmitted pulse. Hence, for short ranges, the transmitted pulse must be of short duration to permit the detection of close-in targets.

The choice of pulse repetition rate, pulse width, frequency, and transmitter power output is decided by these five conditons: (1) the tactical use of the system, (2) accuracy required, (3) range to be covered, (4) overall physical size, and (5) the most practical method of generating and receiving the signal.

TRANSMITTER

An outgoing radiofrequency pulse of extremely short duration is generated by the transmitter each time a keying pulse is received from the modulator. The frequency of the RF pulse is high. The directivity of the radiated beam is greater at high frequencies. Moreover, the higher the frequency, the shorter the wavelength; hence, the smaller and lighter will be the antenna system components.

A special microwave oscillator tube, called a magnetron (fig. 5-6), frequently is used as the transmitting tube in radar systems. A pulse from the modulator, shaped and amplified to form a strong negative pulse, is applied to the magnetron cathode. The presence of this pulse causes the tube to oscillate for the duration of the pulse. The frequency of the magnetron oscillations may approximate several



32.180

Figure 5-6.—Magnetron.

thousand megahertz. Usually the peak power output ranges between 100 and 1000 KW but, because the short duration of the pulse results in a much lower average power, the components are relatively small.

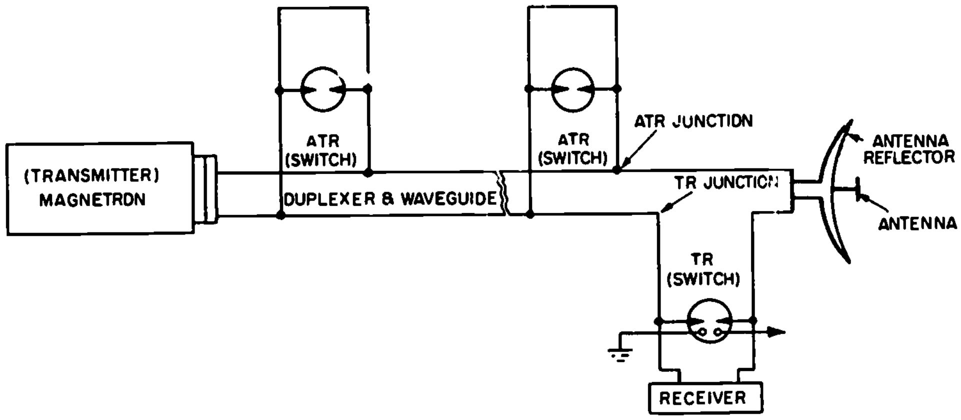
In a radar system using a magnetron (fig. 5-7), the magnetron output is fed to the radar antenna through a duplexer and a waveguide. The duplexer consists of antitransmit-receive (ATR) and transmit-receive (TR) switches that prevent the high-powered RF output of the transmitter from entering the receiver, but permit the returning signal to enter the receiver unimpeded. The duplexer and the waveguide physically connect the transmitter to the antenna.

Some radar transmitters are similar to radio (communication) transmitters. Figure 5-8 is a block diagram of a radar transmitter. Instead of the single magnetron, the radar transmitter consists of an electron tube oscillator, amplifiers, frequency multipliers, drivers, and power amplifiers. Although the stages and their purposes are the same as those in a communication transmitter, the peak power requirements are much higher in a radar transmitter, and it is necessary to use special power amplifier tubes. Klystrons and traveling wave tubes are examples of these tubes, but, because of their complexity, they are not treated in this text.

In the electron tube type of radar transmitter, frequency stability is ensured by using only the most stable type of oscillator-buffer arrangement, and by operating the oscillator at a submultiple of the transmitter output frequency. Frequency multipliers then are used to produce the desired output frequency. The driver stages increase the RF power. The modulator supplies keying pulses to the final power amplifier stages, thereby controlling the duration and repetition rate of the transmitted pulses. Finally, as in the magnetron type of transmitter, the duplexer and the waveguide provide the physical connection between the transmitter and the antenna. Monitoring circuits along the waveguide produce information necessary for tuning the transmitter and receiver, as well as for various tests.

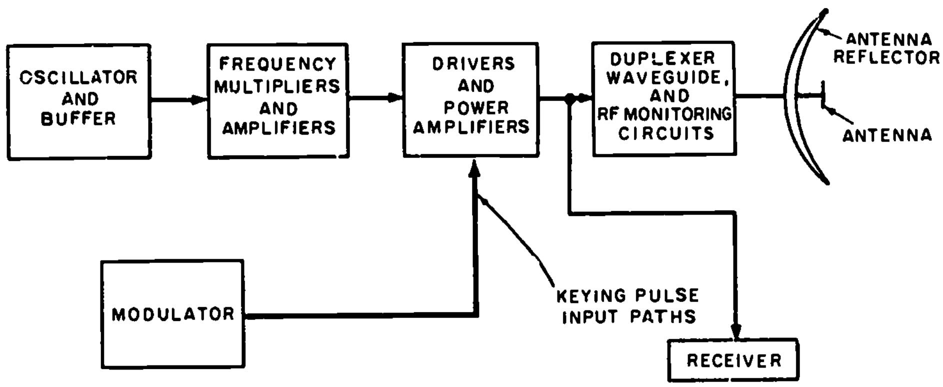
RECEIVER

The receiver used in a particular radar system depends on the design of the transmitter. In the system with the magnetron, the receiver (fig. 5-9) does not have RF amplifiers



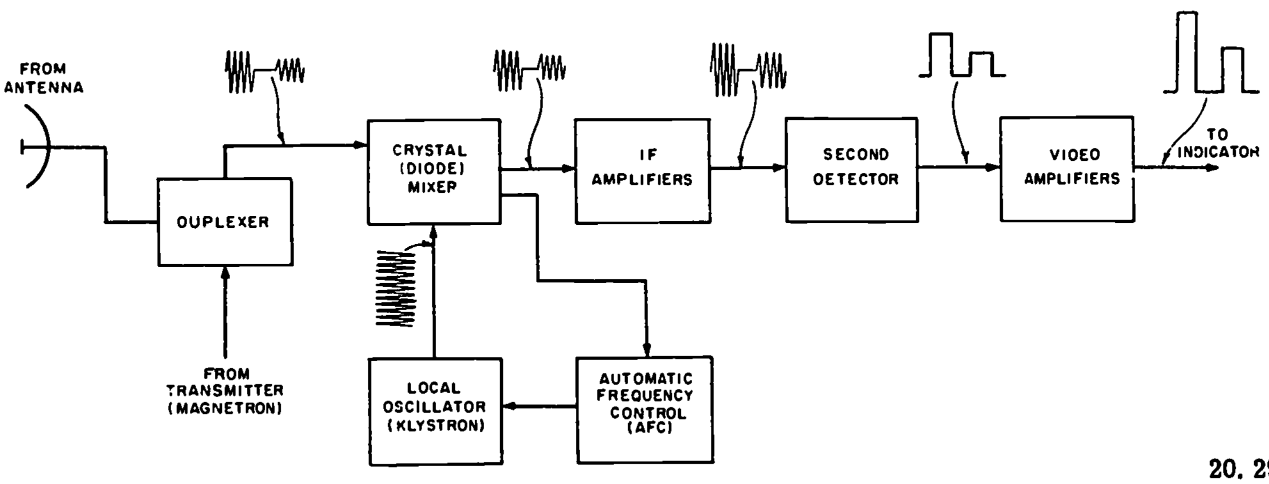
32.183

Figure 5-7.—Transmitting section of pulsed radar system using a magnetron.



72.60

Figure 5-8.—Transmitting section of pulsed radar system using oscillator, multipliers, and amplifiers.



20.293

Figure 5-9.—Radar receiver used in conjunction with a magnetron transmitter.

preceding the mixer stage. The incoming signal (echo) is fed, via the duplexer, directly from the antenna to the mixer. In the mixer, the incoming signal is mixed (heterodyned) with an unmodulated RF signal generated by the local oscillator. Heterodyning in the mixer produces the intermediate frequency, which, in turn, is fed through several IF stages before it is detected. The detector output (called "video") is amplified in several stages before being fed to the indicator where a visual indication of the received echo is produced.

Another output from the mixer goes to the automatic frequency control (AFC) circuit. This circuit produces a DC voltage proportional to the amount of error (if any) in the frequency of the IF signal. The error voltage is applied to the local oscillator in such a manner that it changes the oscillator frequency until the mixer output IF is on frequency. This action ensures a constant intermediate frequency, regardless of changes in the magnetron frequency or tendencies of the local oscillator to drift.

Some radar receivers (not illustrated) differ from the type just described in that they require the use of RF amplifiers ahead of the mixer stage. Essentially, these receivers are of the conventional superheterodyne type.

INDICATOR (REPEATER)

The purpose of the indicator is to present visually the information gathered by the radar set. In the early days of radar, the indicator was a part of the main radar console. With the increase in numbers and purposes of radar sets aboard ship, however, remote indicators (radar repeaters) became necessary.

A representative radar repeater is shown by block diagram in figure 5-10. The repeater consists of a scope (cathode-ray tube), a power supply, video amplifiers, a sweep generating section, a sweep positioning system, impedance matching circuits, and a range marker circuit.

When the modulator sends a keying pulse to the transmitter, it also sends a triggering pulse to the indicator. This trigger pulse, processed through the sweep generating section of the indicator, appears on the face of the scope coincidently with the transmission of the RF pulse from the antenna. In other words, the trigger pulse initiates the trace or sweep across the face of the scope, and the beginning of the trace indicates the time the radar signal is transmitted.

The target echo pulse (video) from the receiver is increased in amplitude by video amplifiers. It then is applied to the scope via impedance matching circuits. Depending on the type of presentation employed, the echo appears on the trace (or sweep) as a pip or a bright spot. As stated earlier, the time of appearance of the echo pulse is indicative of the target range.

Information from the ship's gyrocompass and the radar antenna assembly is applied to the indicator through a sweep positioning system. This system positions the sweep to a true bearing. At the same time the sweep positioning system synchronizes the rotation of the sweep with the rotation of the antenna. Without true bearing data from the gyro, the position of the sweep indicates a relative bearing.

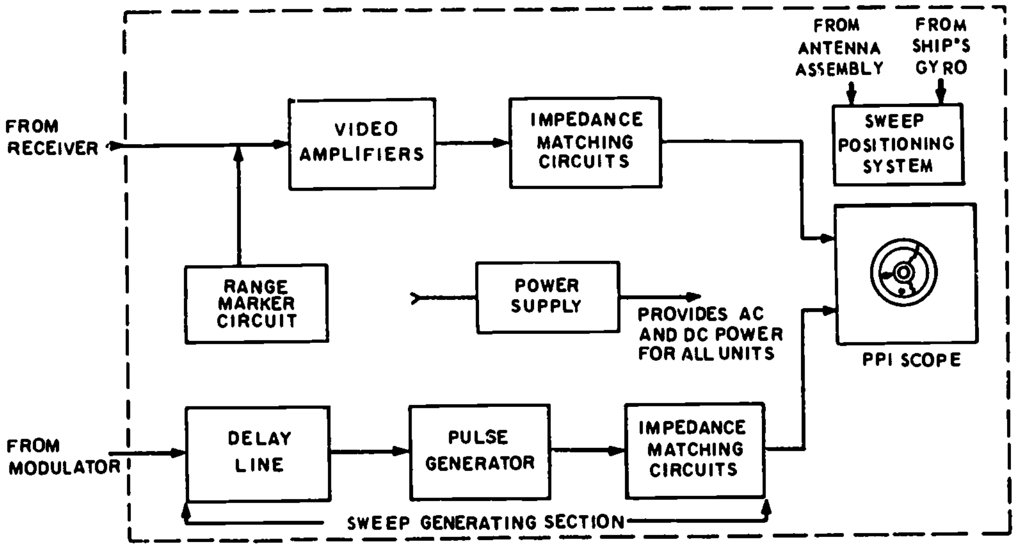
Range markers can be displayed on the screen to aid the operator in estimating the range of a target. In addition, most radar repeaters are equipped with a mechanical or electronic cursor that facilitates the accurate reading of bearing. Some radar repeaters also are equipped with a range strobe or bug that permits accurate measurement of range.

Types of Presentations

While the radar beam is systematically scanning the surrounding area, the results of each scan are presented on various scopes. Several types of scope presentations (or scans) are used to display the target information. Only the basic types are discussed here, however. In each type, the screen of the cathode ray tube is illuminated by an electron beam (spot), which moves swiftly across the screen, leaving a line of light (called the sweep or trace) in its wake. The manner in which the sweep appears on the screen depends on the type of presentation.

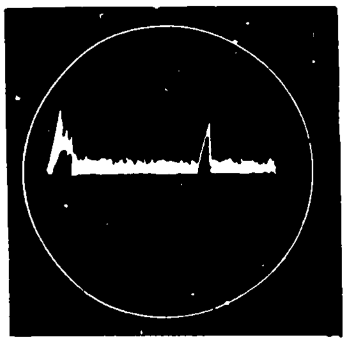
A-SCOPE.—Earlier types of scope presentations were identified by a single letter of the alphabet, such as the A-scope shown in figure 5-11. The A-scope is used to determine range only. Its screen has a short persistence; that is, it glows for only a short time after the illuminating spot is removed. The echo is presented on the screen as a vertical displacement of the horizontal trace, and the point at which the displacement occurs indicates the range to the target.

At one time, the A-scope presentation was the major type of display. For accurate



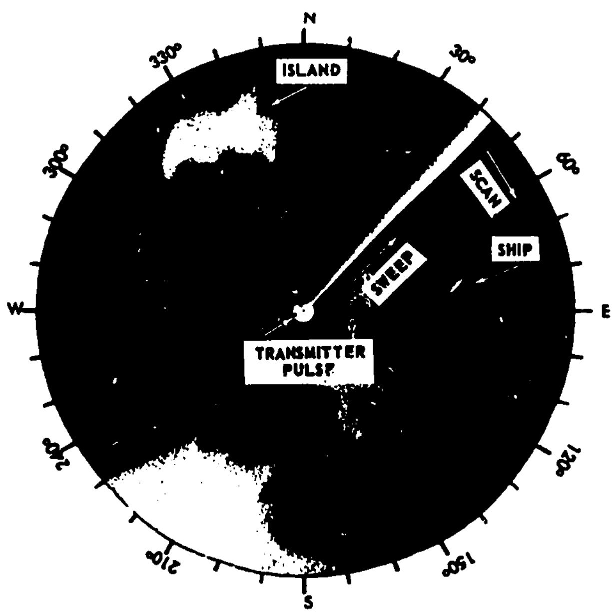
72.61

Figure 5-10.—Radar indicator.



59.4

Figure 5-11.—A-scope presentation.



53.109

Figure 5-12.—PPI presentation.

measurements, however, the antenna had to be stopped and pointed directly at the target. This disadvantage was overcome by the development of the planned position indicator (PPI) type of display.

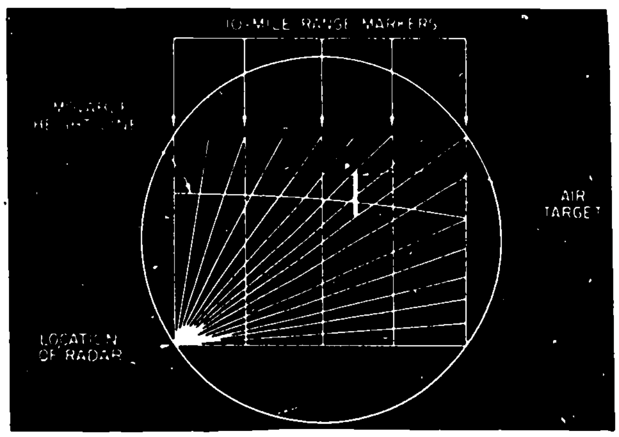
PPI SCOPE.—The PPI scope (fig. 5-12) presents both range and bearing information. Usually this scope is employed in a radar system whose antenna is uniformly rotated around the vertical axis. The trace on the scope rotates in synchronization with the antenna.

Large numbers of pulses are transmitted for each rotation of the antenna. As each pulse is transmitted, the scan spot starts at the center of the screen and moves toward the edge of the screen along a radial line. Upon reaching the edge, the spot quickly returns to the center and begins another trace with the next transmitted pulse. The return trace of the spot is eliminated from the screen by a process called blanking.

When an echo is received, the intensity of the scanning spot increases considerably, and a bright spot remains at that point on the screen. The position of the radial line on which the echo appears indicates the target bearing. The distance of the target pip from the origin of the radial line indicates the target range.

Unlike the A-scope, the PPI scope has long persistence. Because of this characteristic, it is possible to produce a map of the surrounding territory on the scope face, making the PPI presentation useful as an aid to navigation. The PPI scope presentations also provide the observer with instantaneous changes of target positions in all directions.

RHI SCOPE.—Some radars are equipped with special antennas that enable altitude information to be obtained. The range height indicator (RHI) scope is used to display altitude data. (See fig. 5-13.)



59.11

Figure 5-13.—RHI presentation.

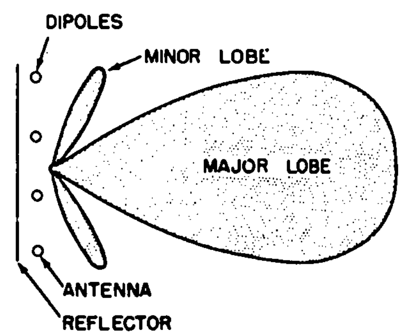
Except for the type of information displayed, the RHI is similar to the PPI. On both scopes, the sweep pivots from one point, and target echoes are shown in bright relief against the background. The sweep on the RHI screen, however, does not go through 360°. Instead, the sweep is synchronized with an antenna that scans vertically through a few degrees and returns to a preset elevation.

An altitude cursor appears across the face of the RHI scope. The cursor, curved to conform to the earth's surface, can be moved up or down. The vertical movement of the cursor is recorded by an associated set of counters. With the cursor aligned so that it bisects the target, altitude is read on these counters. The slant range to the target is indicated along the baseline of the sweep.

Because bearings cannot be read from an RHI scope, the RHI operator usually works in conjunction with the PPI operator who coaches him onto the target on which altitude information is desired.

ANTENNAS

Instead of emitting radio waves in all directions, the radar antenna must send them out in a concentrated beam. One method of obtaining this directional effect is to arrange two or more dipoles so that radiation from the dipoles adds in some directions and cancels in other directions. (Dipoles are conductors that are one-half wavelength long at the carrier frequency of the radar.) When a reflector (either metal or another set of dipoles) is placed behind the dipoles, radiation occurs in one direction, and the resulting lobes of transmitted energy are similar to those shown in figure 5-14.



33.108

Figure 5-14.—Directivity of radar beams.

Another method of obtaining directivity in the emitted radar beam is to situate the open, flanged end (feed horn) of the waveguide so that the RF energy is sprayed against the reflector. Then, the reflector is shaped so that the beam is concentrated as desired.

Many types of antennas are used with military radar systems, and they vary in appearance considerable. Although the radiating element actually is the antenna, the entire antenna array is implied when the term "antenna" is used in this text.

BEDSPRING ARRAY

The bedspring array (fig. 5-15), so called because of its resemblance to a bedspring, is used with air-search radars. It consists of a stacked dipole array with an untuned reflector. The more dipoles that are used or stacked in one dimension (horizontal, for example), the more narrow the beam of radiated energy becomes in that same plane. Consequently, the size of the antenna is not the same for all installations.

PARABOLOIDAL ANTENNA

The paraboloidal (or parabolic) antenna, (fig. 5-16), consists of a dipole or feed horn radiator and a parabolic or dish type reflector. This type of antenna produces a narrow beam, the degree of whose concentration is determined by the size and shape of the reflector.

Because the lobe produced by the parabolic antenna is narrow and sharp, its chief function is with fire control and special-purpose radars. It is not used with most shipboard air-search or surface-search radars, because the roll of the ship could cause the very narrow vertical beam to miss a target. It is currently being used, however, with height-finding radars which do have the pitch and roll stabilization systems.

BARREL STAVE ANTENNA

With a simple modification to the reflector, the parabolic antenna becomes the barrel stave antenna. (See fig. 5-17.) Essentially, the barrel stave reflector is a parabolic reflector with the top and bottom cut away, leaving only the center part of the reflecting surface.

The lobe produced by the barrel stave reflector still is narrow horizontally. But, because there is no surface to restrict its vertical height, the lobe becomes a high vertical beam suitable for surface-search. The height of the lobe is great enough to prevent the roll of the ship from causing a target to go undetected.

BILLBOARD ARRAY

A billboard or fixed array is one in which an antenna or antenna system is placed in front of a large plane-reflecting surface. Such an antenna is shown in figure 5-18. The reflecting surface may consist of rods (joined at the end), mesh, or a solid sheet of conducting material.

Because of their large size and weight, fixed array installations presently are limited to larger ships. The installation consists of four billboard antennas built into the superstructure so that each antenna covers a 90° sector around the ship. This type of installation ordinarily is used with air-search radars.

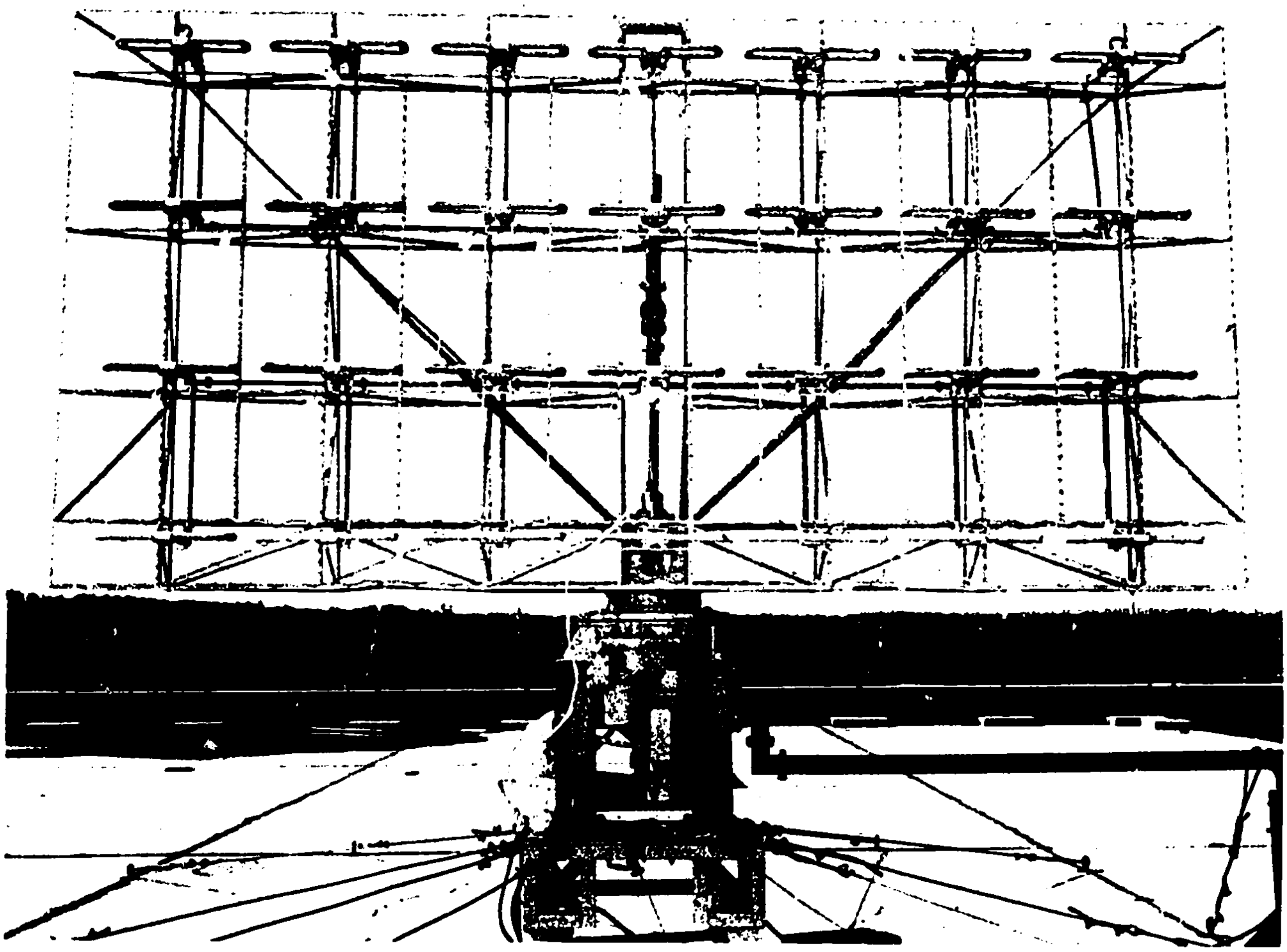
RADAR FUNCTIONS AND CHARACTERISTICS

No single radar set has yet been developed to perform all the combined functions of air-search, surface-search, altitude-determination, and fire control because of size, weight, power requirements, frequency band limitations, and so on. As a result, individual sets have been developed to perform each function separately.

Most of the radar sets that are designed for a specific purpose, such as surface-search, have certain system constants or general characteristics in common. The remainder of this chapter is devoted to a brief discussion of the functions and characteristics of various radar and radar ancillary systems.

SURFACE-SEARCH RADARS

The principal function of surface-search radars is the detection and determination of accurate range and bearing of surface targets and low-flying aircraft while maintaining 360° search for all surface targets within line of sight distance of the radar antenna. The system constants of this radar vary from those of the air-search radar. Because the maximum range requirement of a surface-search radar is limited mainly by the radar horizon, very high frequencies are used to



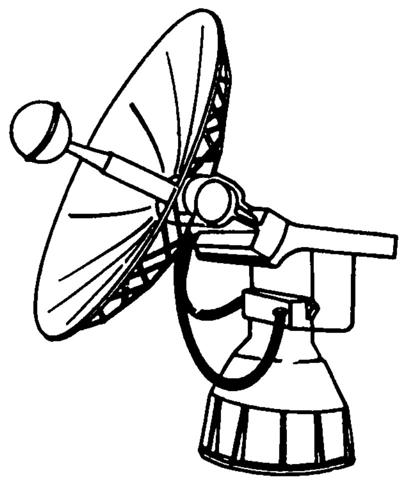
33.109

Figure 5-15.—Bedspring array.

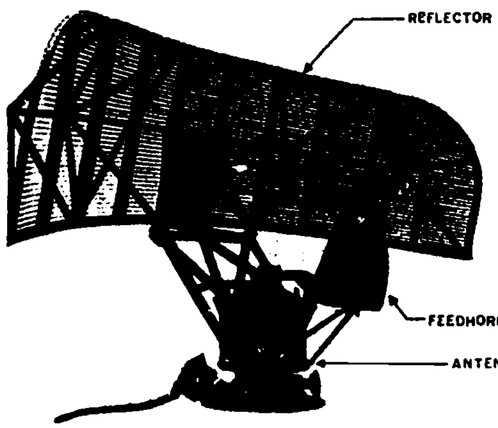
give maximum reflection from such small target-reflecting areas as ship masthead structures and submarine periscopes. Narrow pulse widths permit short minimum ranges, a high degree of range resolution, and greater range accuracy. High pulse repetition rates are used for best illumination of targets. Medium peak powers can be used to detect small targets at line of sight distances. Wide vertical beam widths are used to compensate for pitch and roll of own ship and to detect low-flying aircraft. Narrow horizontal beam widths permit accurate bearing determination and good bearing resolution.

AIR-SEARCH RADARS

The chief function of an air-search radar is the detection and determination of ranges and bearings of aircraft targets at long ranges (greater than 50 miles), maintaining complete 360° search from the surface to high altitude. System constants must be selected with this function in mind. Low frequencies are chosen (P- or L-band) to permit long-range transmissions with minimum loss of signal. Wide pulse widths (2 to 4 microseconds) increase the transmitting power and are used to aid in detecting small targets at greater distances.

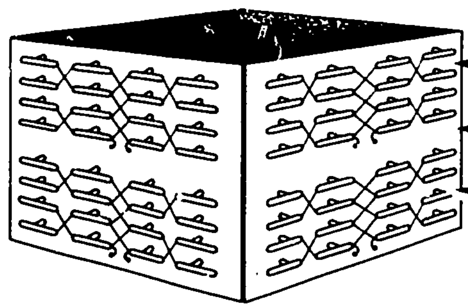


120.28
Figure 5-16.—Parabolic antenna.



32.186
Figure 5-17.—Barrel stave antenna.

Low pulse repetition rates are selected for greater maximum measurable range. High peak power permits detection of small targets at long ranges. Wide vertical beam width is used to ensure detection of targets from the surface to relatively high altitude and to compensate for the pitch and roll of the ship. Medium horizontal beam width gives fairly accurate bearing determination and bearing resolution while maintaining 360° search coverage.



120.29(120C)
Figure 5-18.—Billboard array.

ALTITUDE-DETERMINING RADARS

The function of the altitude-determining radar is to find the accurate range, bearing, and altitude of aircraft targets detected by air-search radar. Its antenna must be tilt-stabilized to provide a stable reference for altitude determination. High frequencies (S-band) are chosen as a compromise between the long-range capabilities of lower frequencies and the narrow beam-forming characteristics of higher frequencies. Narrow pulse widths (1 microsecond) are chosen to permit good range resolution. High pulse repetition rates (600 to 1000 PPS) permit detection of small aircraft targets at medium ranges (30 to 50 miles). High peak power permits the detection of small aircraft targets at medium ranges while using narrow pulse width. Narrow vertical and horizontal beam widths (1° to 3°) are selected to permit accurate bearing and position angle determination and good bearing and elevation resolution.

FIRE CONTROL RADARS

The principal function of fire control radars is the acquisition of targets originally detected and designated from search radars, and the determination of extremely accurate ranges, bearings, and position angles of targets. Antennas must be tilt-stabilized to compensate for pitch and roll of own ship. Very high frequencies are chosen (X-band and K-band) to permit the formation of narrow beam widths with comparatively small antenna arrays, detection of targets with small reflecting areas, and good definition of all targets. Pulse widths (0.1 to 3 microseconds) provide a high degree of range accuracy, short minimum range, and excellent range resolution. Repetition rates (1500 to 2000) afford maximum target detection while using narrow pulse widths. Because very long ranges are not required, low peak power permits the use of smaller components by keeping the average power low. Narrow vertical and horizontal beam widths (0.9° to 3°) provide accurate bearing and position angles and a high degree of bearing and elevation resolution.

MISSILE GUIDANCE RADARS

In general, missile guidance radars operate on the same principles as the air-search, altitude-determining, and fire control radars just described. The guidance systems for the missiles we are concerned with can be divided into four groups: (1) self-contained, (2) command, (3) beam-rider, and (4) homing.

In a self-contained (inertial) guidance system all the guidance and control equipment is inside the missile. The guidance system neither transmits nor receives signals during the missile's flight. This is a major advantage, since only limited countermeasures can be used against it. This means that the trajectory that the missile must follow to hit the target must be calculated and fed into the missile before it is launched. The heart of the inertial guidance system is an arrangement of accelerometers that detect motions along their sensitive axes. The inertial guidance system is used for long range surface-to-surface missiles, such as the Polaris.

A command guidance system is one in which directional commands are sent to the missile from some outside source. One radar aboard ship tracks the target, another radar tracks the missile, and a computer takes the two sets of tracking data and issues radar signals which guide the missile to the target. The equipment in the missile consists of a receiver and a control system. The shipboard equipment consists of two radars and a computer.

The beam-rider guidance method is very similar to the radar command guidance method. The principle difference is that the command system gives specific signals to "turn right, or turn left, etc.," while in the beam-rider system the shipboard control equipment transmits information only, not commands. The missile guidance equipment must interpret this information contained in the received radar beam and formulate its own correction signals. Therefore, we say the missile rides the beam to the target. The beam-rider system is highly effective for use with short-range and medium-range surface-to-air and air-to-air missiles.

Two types of beam-rider systems are possible. In the simplest type, a single radar director is used for both target tracking and missile guidance. In the other, one radar director is used for tracking, while another provides the very narrow guidance beam. The single-radar system has the advantage of simplicity, but it is not nearly as effective as the two-radar system.

In the two-radar system, a computer is used between the radars, and the missile guidance radar is controlled by the computer. The computer takes target information--speed, range, and course—from the tracking radar, and computes the course that must be followed by the missile. The output of the computer controls the direction of the guidance radar antenna, and points the guidance beam toward the point of target interception. Because the computer receives information constantly, it is able to alter the missile course as necessary to offset evasive action or changes in course by the target.

The homing guidance system controls the course of the missile by a device in the missile that reacts to radiation given off by the target, such as heat, light, radio, or radar radiation. The radiation may be generated by the target or reflected from the target when generated by some outside source. This system is commonly used.

AEW RADARS

Airborne early warning (AEW) systems are used extensively in the Navy. These systems are special shipboard and aircraft radar equipment that work together as a single unit.

The purpose of the AEW system is to extend the normal radar horizon by placing the radar set in an airplane, and relaying the radar information to the AEW ship for presentation on the ship's indicator. Thus, targets can be seen at considerable greater distances than is possible with standard shipboard radar sets. For example, a plane at a 1000-foot altitude will have a minimum radar detection range of 55 miles on a target 50 feet high. If the plane is relaying radar information to a mother ship 50 miles away, then the ship has an effective search range of 105 miles in the plane's direction. If a relay is directly over a mother ship at 5000 feet, the ship has an effective 360° search range of 100 miles.

DOPPLER EFFECT

The doppler effect is the change in the frequency resulting from motion between a source and a receiver. To illustrate this concept, consider two persons, source (S) and receiver (R) (fig. 5-19A), standing along a swift-flowing stream some distance apart. Source (S) is tossing fishing bobs into the water at a steady rate, say 10 BPM (bobs per minute). Receiver (R) has a stopwatch, and as the bobs begin to pass he takes a count for one minute, counting 10 bobs. In this illustration the time was one minute, distance remained constant between S and R and rate of frequency of the bobs was the same at S and at R. This would be known as zero-doppler.

Source (S) begins moving steadily away, tossing bobs into the stream at the same rate 10 BPM, figure 5-19B. Again receiver (R) counted bobs for one minute as they passed (say that he counted only 8 BPM). R observed that the bobs were spaced farther apart, therefore the frequency at R is less (lower). The time interval has stayed the same, but distance between bobs has increased; the rate of frequency has decreased, although the source frequency has remained constant. This would be known as down or low doppler.

Likewise, if S moves toward R tossing bobs at the same rate (fig. 5-19C), the bobs will be closer together and observer (receiver) R would see a higher frequency (say 12 BPM). Again the time interval is the same. Distance between bobs has decreased and frequency increased. This would be up or high doppler.

High doppler is explained again in figure 5-19D. If the receiver runs toward the source, who is stationary, he views the bobs more frequently and the effect is the same as in figure 5-19C.

Doppler effect may be observed in sound waves when listening to a phonograph turntable, if the turntable's speed is varied. At a higher RPM, the voice is at a higher pitch, and at a lower RPM the voice is at a lower pitch. Another common example of the doppler effect by sound waves is at a train crossing (fig. 5-20). You listen to the high-pitch whistling sound as the train approaches, and the low-pitch sound as the train passes and goes away. As the train approaches you, the relative motion will cause your ear to receive more cycles per second than when there is no relative motion, and as the train moves away your ear encounters fewer cycles per second. This is the doppler effect and is due to frequency change of the sound signal in relation to the observer.

The doppler effect is also noted in electromagnetic frequency waves, and extensive use is made of this phenomena in electronics.

CONTINUOUS WAVE RADAR

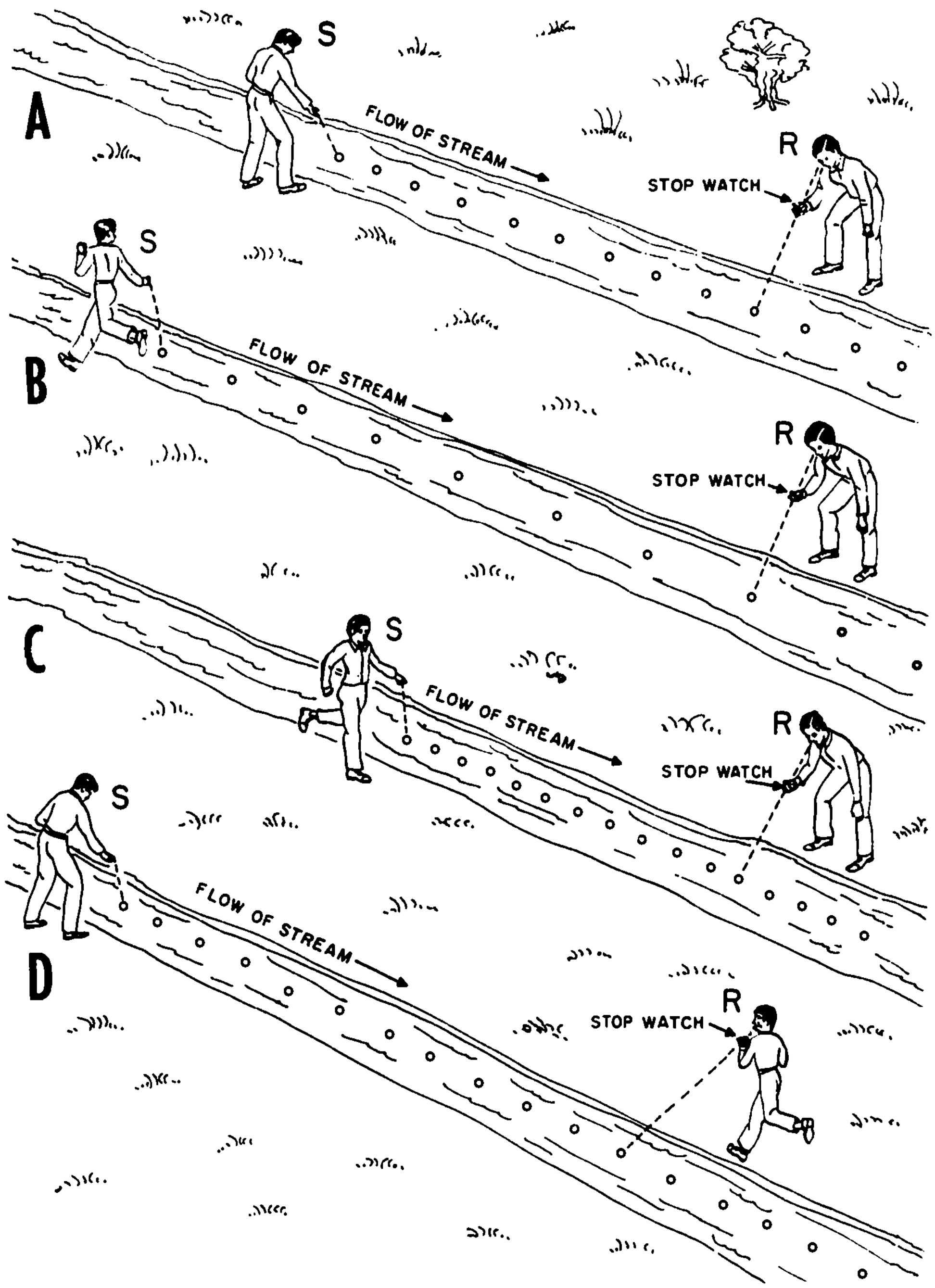
Continuous-wave radar is used as a speed measuring device. CW radar cannot measure distance because the wave is continuous and has no time reference as compared to pulse radar. CW radar (fig. 5-21) uses two separate antennas since the transmitter and receiver operate simultaneously.

The transmitter (fig. 5-21) has a modulator to shape the high power input of the RF oscillator. The RF oscillator sends two signals. One is a weak signal sent directly to the receiver mixer which can be compared to figure 5-19A having no-doppler and the other is a very strong signal radiated at the transmitter antenna which has a high-doppler as compared with figure 5-19D. The aircraft in this radar beam is shown reflecting some of the RF energy to the receiver antenna. The aircraft, in effect, becomes a second emitter of waves which gives the high-doppler effect as shown in figure 5-19C.

The heterodyne receiver compares the internally received frequency, which has no-doppler, with the transmitted frequency which has high-doppler, the difference being the frequency shift. The radar can only indicate the aircraft's presence and its relative speed. To determine direction of the aircraft, high- or low-doppler must be determined by the addition of a local oscillator.

The doppler frequency shift is then amplified, detected, and sent to the indicator system for interpretation. If the doppler frequency is in the audio range, a head set can be used to indicate the presence of a target.

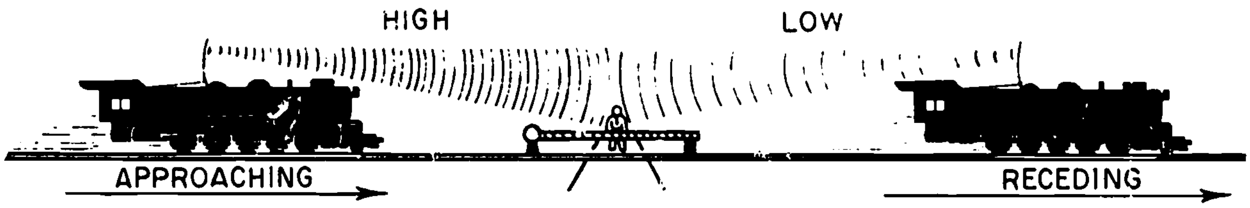
Continuous wave radar and pulse radar systems can be combined to measure a target's velocity toward or away from you and also measure the distance and transit time. This is known as pulse-doppler radar.



120.79

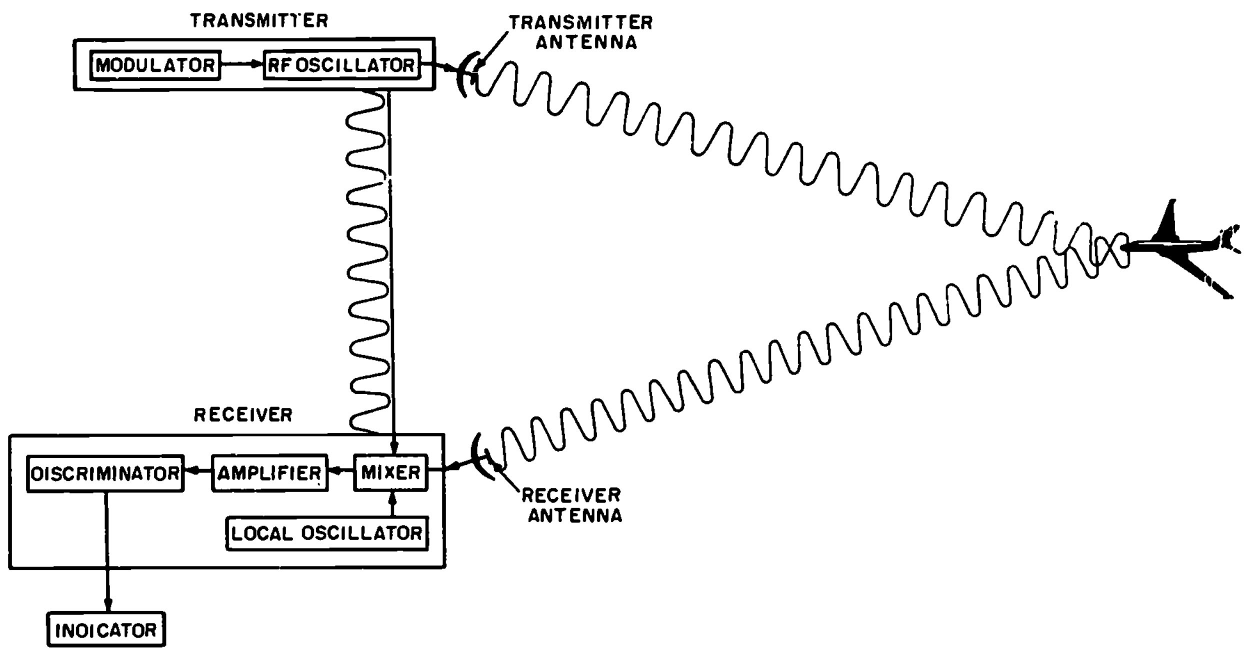
Figure 5-19.—Doppler principle.

Let's look at a pulse radar in its simplest form. The transmitter generates a very short pulse of high energy radiofrequency. As the transmitter pulse leaves the antenna, the radar's receiver becomes operative, allowing it to receive and amplify any RF energy reflected by a target. The time between the transmission of the RF energy and the echo return is measured electronically and displayed graphically by a CRT (cathode-ray tube).



71.37(120C)

Figure 5-20.—Principle of doppler sound waves.



55.58(120C)

Figure 5-21.—Principle of continuous wave doppler radar.

Thus the pulse radar can measure range accurately, and does not depend on target's movement for detection. Therefore it can detect both stationary and moving targets.

The CW echo is changed in frequency by a moving target. This change, as you remember, is called Doppler shift. The Doppler frequency is used for target detection, and to indicate the target's range rate. It is possible, by use of filter circuits, to reject all targets except those traveling at or near a selected velocity. Normally a CW radar will not detect stationary targets. If the CW radar radiates energy continuously, at a constant frequency, there is no reference by which we can measure range directly. Even with a form of carrier modulation its ranging is crude.

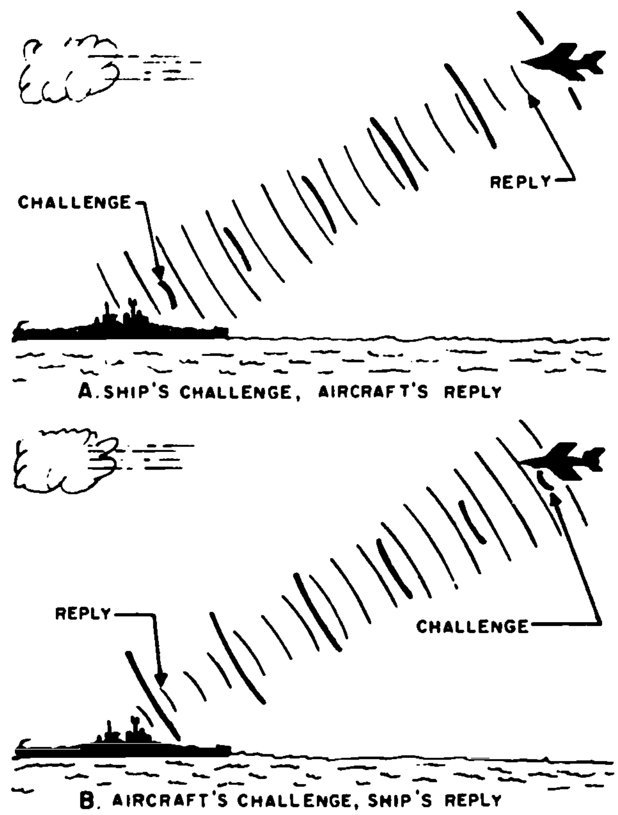
On the other hand, pulsed radar radiates energy at a selected time interval. This interval determines the usable range of the radar. Pulse radar, with its precise measurement of transit time, has a very accurate range measurement capability.

The pulse-Doppler radar combines the best features of CW and pulse radar. The pulse-Doppler method uses high frequency CW, in the form of short bursts, or pulses. The pulse repetition rate (PRR) is much higher than that of a conventional pulse radar, and the pulse length is longer.

A measure of the target's velocity toward or away from the radar can be obtained by means of the Doppler shift. This can be accomplished in the same manner as in CW radar.

IFF SYSTEMS

Although technically not a radar equipment, an electronic system that is employed with radar 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 (IFF) (fig. 5-22). It consists of a pair of special transmitter-receiver units. One set is aboard the friendly ship; the other is aboard the friendly unit (ship or aircraft). Because space and weight aboard aircraft are limited, the airborne system is smaller, lighter, and requires less power than the shipboard transmitter-receiver. The airborne equipments are automatic, and operate only when triggered by a signal from a shipboard unit.



120.80

Figure 5-22.—IFF systems.

The 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 (Mk III), whereas the fire control number is an Arabic numeral (Mk 29).

The IFF system operates as follows: An air-search radar operator sees an unidentified target on his radarscope. 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, decodes it, and displays it on the radarscope 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.

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

The interrogator-responder performs two functions. It transmits an interrogating signal, and it receives the reply. The transponder also performs two functions. Not only does it receive the interrogating signal, but it replies automatically to the interrogating signal by transmitting an identifying signal. The two types of interrogation are direct and indirect. Interrogation is direct when the interrogating signal that triggers the transponder is a pulse from the radar equipment. 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. Direct interrogation proved unsatisfactory, however, because the transponder was required to respond to radars that differed widely in frequency. Later IFF systems, consequently, make use of indirect interrogation within a special frequency band reserved for IFF operation.

CHAPTER 6

RADAR EQUIPMENT

The modern warship has several radars. Each radar is designed to fulfill a particular need, but it also may be capable of performing other functions. For example, most height-finding radars can be utilized as secondary air-search radars; in emergencies, fire control radars have served as surface-search radars. To familiarize you with some of the capabilities and limitations of radars and radar accessories, this chapter is devoted to describing the characteristics and uses of various shipboard radar equipment.

Because there are so many different models of radar equipment, the radars and accessories described herein are limited to those common to a large number of ships in the active fleet, and to those that are replacing older equipment currently installed in the fleet.

SURFACE-SEARCH RADARS

As you learned in the preceding chapter, the principal function of surface-search radars is the detection of surface targets and low-flying aircraft and the determination of their range and bearing. A common surface-search radar in use today is the AN/SPS-10( ).

RADAR SET AN/SPS-10( )

Designed for installation aboard destroyers and larger ships, the AN/SPS-10( ) is a medium-range, two-coordinate (bearing and range) surface-search and limited air-search radar (fig. 6-1). Its maximum range when detecting surface targets is greater, normally, than the optical horizon as viewed from the antenna reflector. Actual detection range depends on a number of conditions, including antenna height, target size and composition, weather conditions, and the density of the atmosphere. You can normally expect to detect targets 1 1/4 times the optical horizon, due to the refraction of RF energy near the earth's surface. In some instances, targets have been detected at distances exceeding 100 miles.

The AN/SPS-10( ) operates in the frequency range 5450 to 5825 MHz, with a peak power output of 285 KW. Its magnetron is tunable over the entire frequency range. This feature is desirable so that its operating frequency can be changed to minimize interference from other radar sets operating at the same frequency.

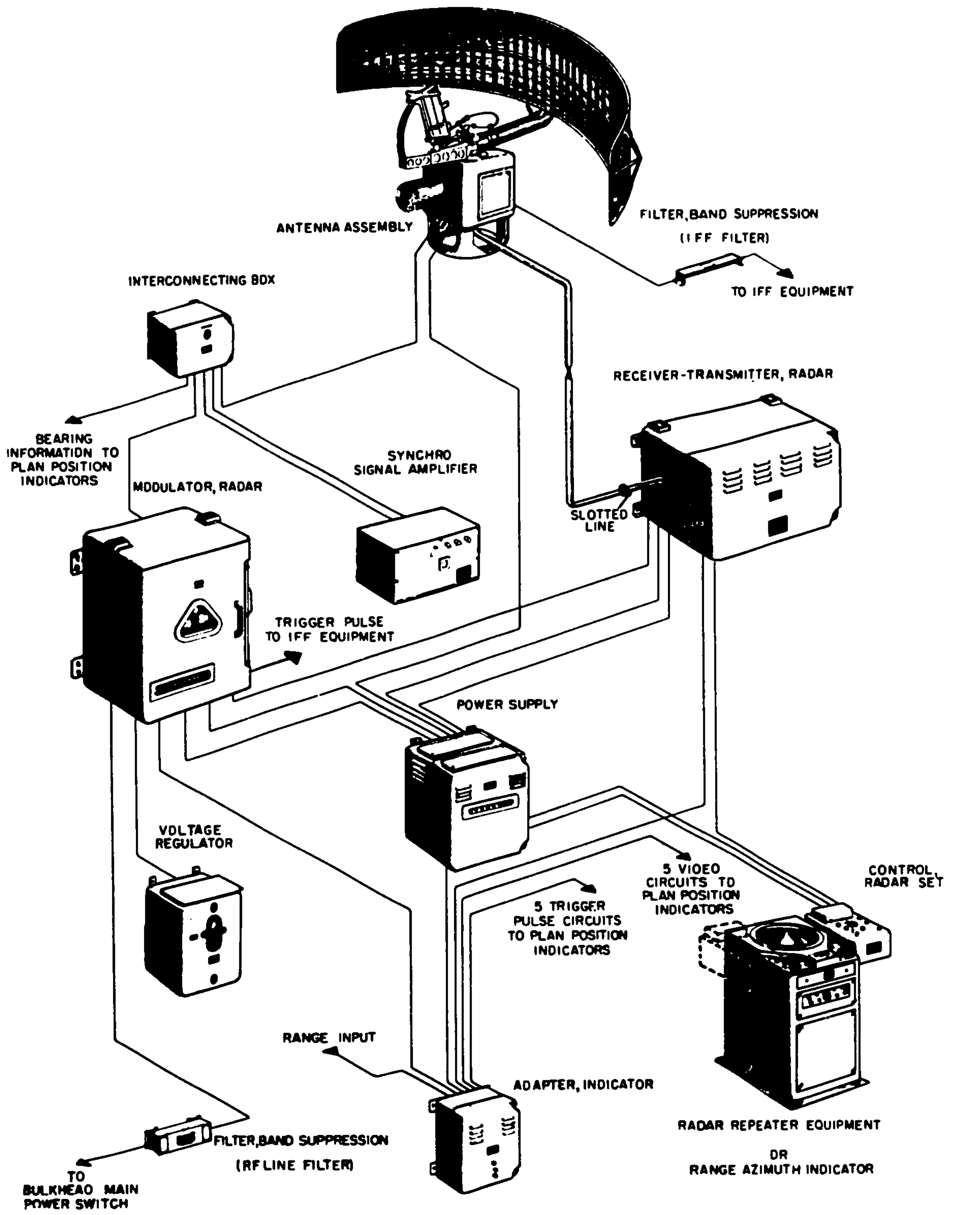
Two pulse widths are available. The long pulse (1.3μsec) provides a longer detection range than the short pulse (0.25μsec). In addition, the pulse repetition rate (PRR) can be varied between 625 and 650 pulses per second (PPS), which will enable the operator to check for "second time around echos".

The antenna used with the AN/SPS-10( ) is a horn-fed, truncated parabolic reflector, which rotates in a clockwise direction at an average speed of 16 RPM. Radiated signals have a beam width of 1.5° in the horizontal plane and between 12° and 16° in the vertical plane.

The major units of the AN/SPS-10( ) are shown in figure 6-1. These units are typical of those employed in most surface-search radar systems.

RADAR SET AN/SPS-5( )

The AN/SPS-5( ) radar set is used on ships of escort size and smaller. Classed as a medium-range surface-search radar, the AN/SPS-5( ) has a tunable magnetron that permits selection of any operating frequency between 6275 and 6575 MHz. (Later models of the AN/SPS-5 have a frequency range of 5450 to 5825 MHz.) Power output varies between 170 and 285 KW, depending mostly on the operating frequency selected. A pulse length of 0.37μsec is used as a compromise between long



32.172

Figure 6-1.—Surface-search Radar Set AN/SPS-10( ) system.

and short ranges. The antenna is similar to that of the AN/SPS-10( ).

RADAR SET AN/SPS-21( )

The AN/SPS-21( ) is a short-range, compact surface-search radar designed principally for installation aboard small ships. It also is installed on some of the larger auxiliary ships for use as a close-range navigational radar. Being a short-range equipment (75 yards to 16 miles), the set has a narrow pulse width of 0.2 μ sec and a low power output of 10 KW. Its operating frequency is selectable within the frequency range 5500 to 5600 MHz, and it employs a parabolic antenna that radiates a beam 2° wide in the horizontal plane and 15° high in the vertical plane.

RADAR SET AN/SPS-53 A

Radar Set AN/SPS-53 A (fig. 6-2) is a surface-search radar operating in the 9345 to 9405 MHz band and is capable of detecting surface targets up to maximum range of 32 miles. The set operates from a 115-volt, 60 hertz power source.

The antenna rotates at 15 RPM to provide search facilities for both surface and low-flying targets. The feed assembly, containing the slotted-array radiating element, produces a vertical beam width of 20 degrees and a horizontal beam width of 1.6 degrees. The vertical plane beamwidth allows enough latitude to keep the target in the beam pattern during ship's pitch and roll.

AIR-SEARCH 2-COORDINATE RADARS

The primary function of air-search radars is the long-range (greater than 50 miles) detection of aircraft targets and the determination of their ranges and bearings. These radars search 360° in azimuth from surface to high elevation angles.

Some of the most widely used 2-coordinate air-search radars in the fleet are: AN/SPS-6C; AN/SPS-29( ); AN/SPS-40; -40A; AN/SPS-37, -37A; and AN/SPS-43, -43A. These radar sets use the PPI display indicators for determining range and azimuth.

The main design features of the 2-coordinate air-search radars are basically the same. They may, however, vary in frequency, range, type of antenna, and in design techniques. All of these radar sets, except the AN/SPS-6C use a Moving Target Indicator (MTI) to discriminate against clutter of stationary objects and to emphasize only moving targets.

All of the above 2-coordinate radars, except the AN/SPS-6C and -29, transmit long pulses from a generated narrow pulse and then receive and compress the long pulse back into a narrow pulse. This minimizes the peak power requirements of the radar set without impairing the range resolution. These modified shaped pulses also reduce interference with other shipboard electronic equipments.

RADAR SET AN/SPS-6C

The AN/SPS-6C is a ship-borne, air-search, 2-coordinate radar for target bearing and ranging. This high-power (500 KW) long-range set is used in the fleet for detecting, ranging, and tracking both conventional and jet aircraft.

A description of the AN/SPS-6C radar set follows. The power transformer (fig. 6-3) steps down the ship's voltage to the 115 volts required for operation of the radar set. The line disconnect switch is bulkhead mounted. The electrical filter assembly prevents any RF pickup of the main power circuits from entering the radar transmitter-receiver.

The radar transmitter-receiver console (fig. 6-3) has the operating controls in the top compartment. The echo box is used to measure frequency. The transmitter-receiver is tunable to any operating frequency within the range of 1250 to 1350 MHz, and provides a choice of pulse lengths (1 or 4 μ sec). The transmitter RF signal is transmitted through the rectangular waveguide to the antenna. The directional coupler permits a sample of transmitted RF energy to be coupled to the echo box.

The antenna is a unidirectional transmitting and receiving type with a 30° vertical beam width and a 3 1/2° horizontal beam width. The reflecting surface is a section of a parabola. The feed horn is a dual frequency radiator for radiating RF energy for both radar and IFF recognition sets. The antenna control unit supplies DC power to rotate the antenna pedestal.

The radar set control contains the remote controls used for operation. Antijamming controls are also located here in recess behind a small door.

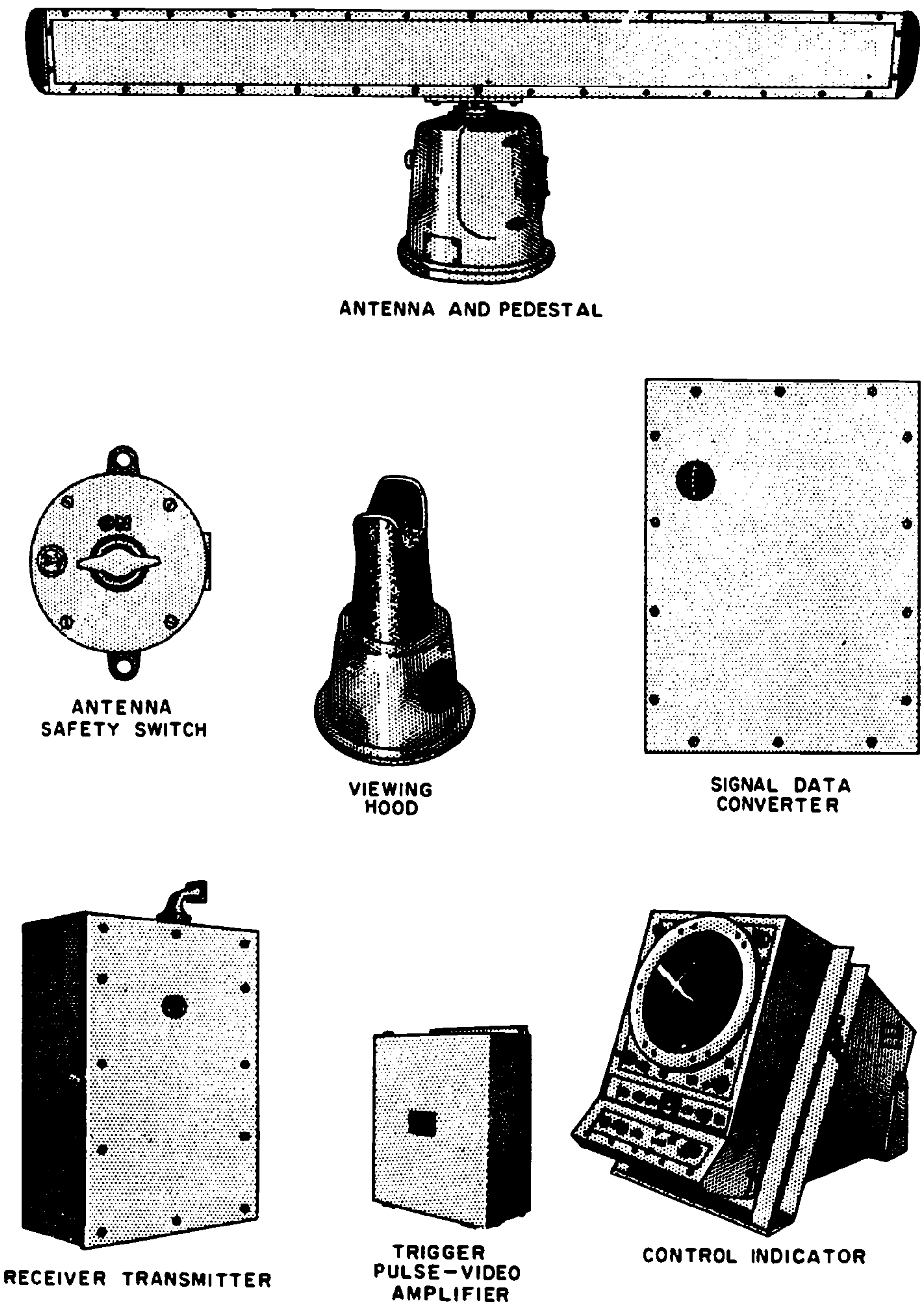


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Figure 6-2.—Surface-search Radar Set AN/SPS-53A units.

The video amplifier amplifies signals from the radar receiver and supplies video outputs to the PPI indicator. This cabinet is designed for bulkhead mounting.

The range indicator is used to indicate target range information. The 5-inch screen is accompanied with a viewing hood.

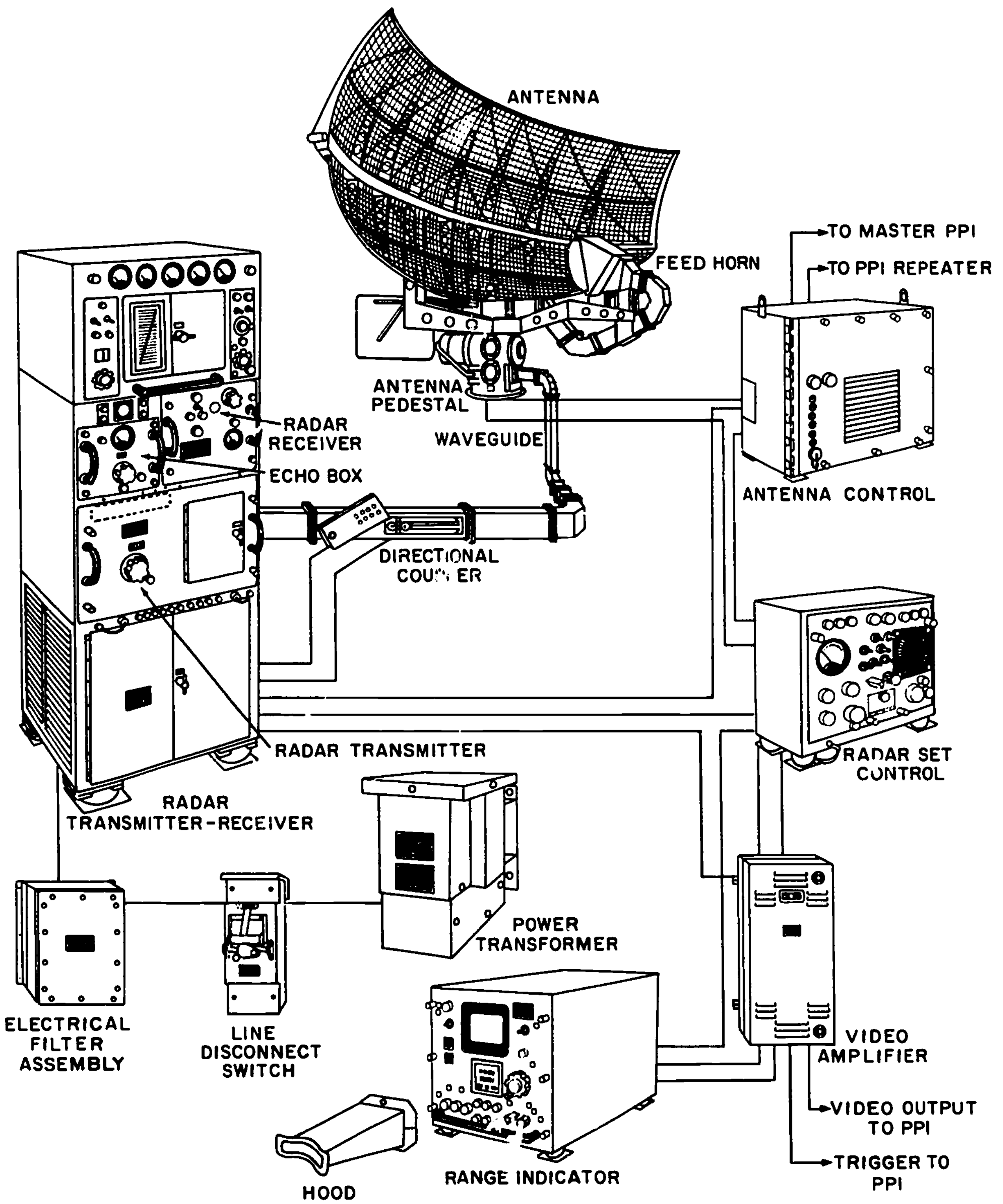

Figure 6-3.—Air-search Radar Set AN/SPS-6C system.

The AN/SPS-6C is an older set but still being used on destroyers and auxiliary ships. The set is capable of tracking aircraft at low altitudes. It also is suitable for limited surface tracking and navigation. This radar excels, however, in detecting targets of small reflective surface at high altitudes. Jet aircraft are detected at altitudes up to 40,000 feet and at distances as far out as 60 miles. Large conventional aircraft flying at high altitudes normally are picked up in the range of 70 to 140 miles, whereas smaller targets (such as fighters) are detected when they are between 60 and 80 miles away.

RADAR SET AN/SPS-29( )

The AN/SPS-29( ) is a representative type of air-search radar found on ships of DD size and larger. It uses the co-linear broadside antenna. The radar is used to detect high flying aircraft.

RADAR SET AN/SPS-40

The AN/SPS-40 and -40A feature an integral IFF antenna and radar antenna combination, thereby eliminating the need for separate units. Being a light weight and a smaller radar system, the AN/SPS-40 and -40A have the capability of being installed on smaller ships which have a 2-dimensional requirement. The AN/SPS-40 and -40A is a long-range radar used largely on escort ships and destroyers. A general pictorial and nomenclature of units are included on the AN/SPS-40 (fig. 6-4).

Radar Sets AN/SPS-37 or -37A And AN/SPS-43 or -43A

Both radar sets are high power, very long range, 2-coordinate air search radars used on large ships. They are used for early warning and are capable of detecting fast moving targets at very long range.

AIR SEARCH 3-COORDINATE RADARS

Among the height-finding radars currently installed aboard Navy ships, some of the most common are the AN/SPS-8A, AN/SPS-30, AN/SPS-42, AN/SPS-39A, AN/SPS-52, and AN/SPS-48(V).

The 3-coordinate radar functions much like the 2-coordinate system, but will provide elevation, in addition to a horizontal search pattern, a vertical search pattern.

Most radars present only range and bearing, so their beams are narrow in azimuth and broad in the vertical plane. The beams of height-finding radars are quite narrow vertically, as well as in the horizontal plane.

Azimuth is provided as the antenna rotates continuously at speeds varying up to 15 RPM or selected data rates. The antenna may be controlled by the operator for searching in a target sector.

There are two types of height-finding radars, those with stabilized antennas and those with unstabilized antennas. The stabilized radar antennas have a stabilized servosystem which keeps the antenna essentially in a horizontal plane regardless of the ship's pitch and roll. (A system of this type is discussed at the end of this chapter.) For those radar antennas that rotate in the deck plane, the physical antenna being unstabilized with reference to the horizontal plane, their departure from the horizontal plane is noted for each target detected and the target data corrected electronically to the horizontal plane. Essentially, the antenna's position is sensed at the moment of data acquisition and corrected electronically to stabilized coordinates. Altitude information depends upon knowing the exact angular position of the beam above the horizon and the slant range to the target.

The elevation scanning is accomplished by one of two methods: (1) mechanical scanning vertically up-and-down with an antenna-feed (rotary-switch) type, while the antenna rotates horizontally, as in the AN/SPS-8A and AN-/SPS-30 radar sets, or (2) electronic scanning vertically, as in the other radar sets listed above, by changing the frequency of the transmitted beam in discrete increments (steps). Each applied frequency causes the radar beam to be radiated at a different elevation angle. Each step has its own particular scan frequency. As the frequency increases or decreases, so does the slant range conversion factor. A computer can electronically synchronize the radiated frequency and give electronic scanning 3-coordinate radars a high data rate and high angle conversion.

In addition to radar indicators used for 2-coordinate radar systems, the 3-coordinate systems also employ a RHI (range height

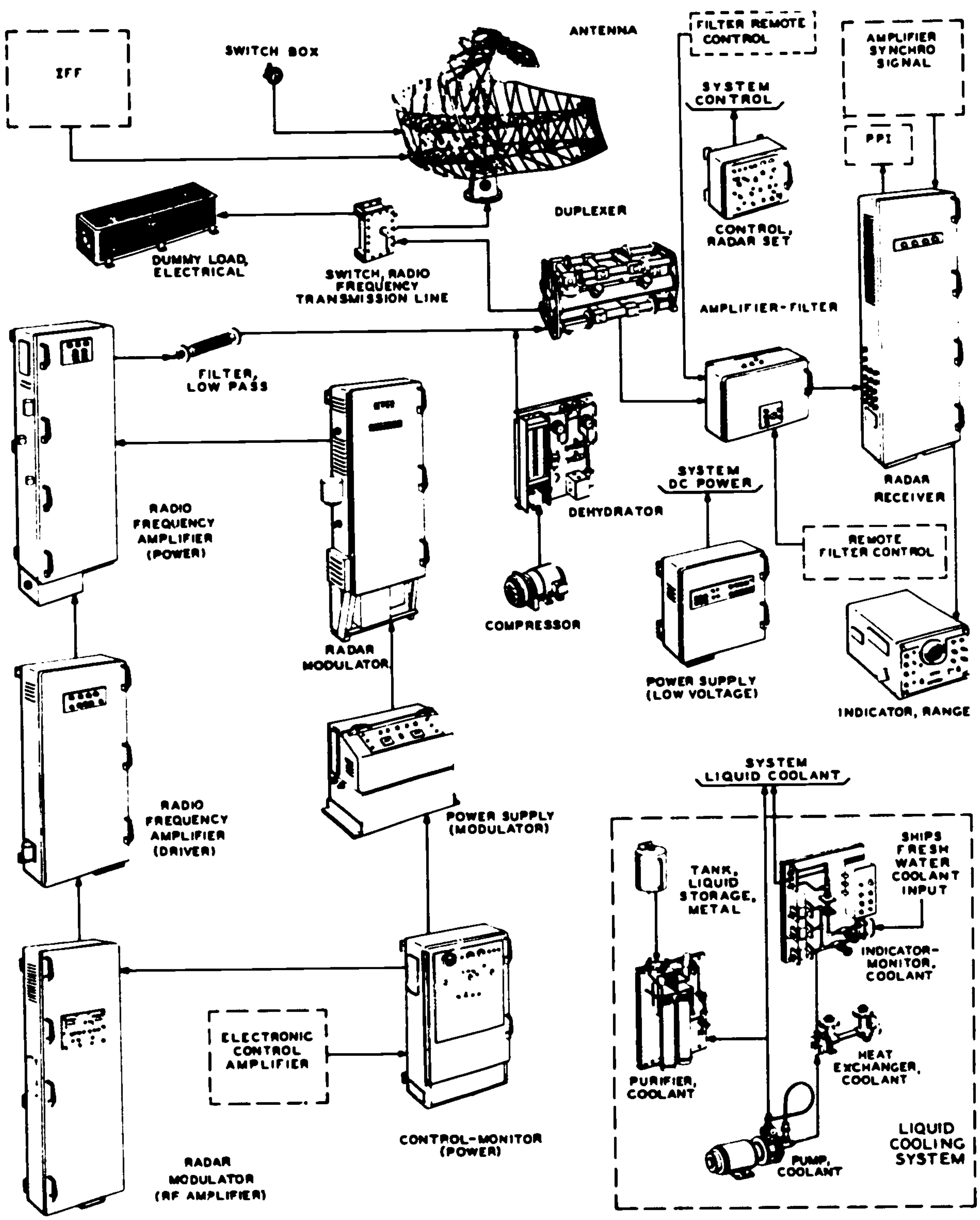

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Figure 6-4.—Air-search Radar Set AN/SPS-40 system.

indicator) for air search and interceptor direction. These radars may use noise clutter and pulse compression techniques.

RADAR SET AN/SPS-8A

Radar Set AN/SPS-8A is a high-power, shipboard, height-finding radar system, and may be used for fighter aircraft direction. The set presents target height, slant range, bearing, and beacon (IFF) information on remote radar repeaters and range-height indicators. The AN/SPS-8A radar is found on large ships (cruisers and carriers mostly) and many destroyer radar picket ships.

The operational characteristics of the AN-/SPS-8A are: frequency in the 3430 to 3550 MHz range, peak power 650 KW, pulse width 1 or 2 μ sec, PRR 500 to 1000 PPS, vertical beam width 1.1°, and horizontal beam width 3.5° scanning any vertical 12° sector from 0 - 36°. Antenna rotation rates are 1, 2, 3, 5, or 10 RPM. The antenna may be made to scan any sector from 30° to 200° horizontally, or it may be trained manually. Maximum range using 1-μ sec pulse is 83 miles; with 2-μ sec it is 165 miles. Minimum range is approximately 4,500 yards.

RADAR SET AN/SPS-30

The AN/SPS-30 (fig. 6-5) is a high-power, long-range shipboard radar system for air search and interceptor direction of aircraft. It provides information for individual and multiple targets at a fast data rate and presents the information on PPI and RHI indicators. The AN/SPS-30 uses a stabilizing servosystem and mechanical scan, the same as the AN/SPS-8A.

RADAR SETS AN/SPS-42 AND -39A

The AN/SPS-42 with minor modifications became the AN/SPS-39A radar set. These 3-coordinate radar sets provide three-dimensional position data under all weather conditions on surface and airborne targets. The radar sets provide a means for detecting moving targets in the presence of obscuring echoes and for detecting targets that would be obscure due to large antenna side lobe return. The main functional sections are: the synchronizing, transmitting, receiving, side lobe suppression, antenna positioning, indicating, power distribution, waveform converting, and testing.

RADAR SET AN/SPS-52

The AN/SPS-52 (fig. 6-6) is a long-range and short-range radar. It is largely installed on guided missile destroyers. It provides the target input data required to support the missile system and employs air intercept control techniques.

The AN/SPS-52 radar utilizes a general-purpose digital computer with both automatic and off-line diagnostic test routines. In addition, it is possible to change the radar programs by use of the input/output radar printer. To enhance detection and accuracy, a digital display indicator is furnished with the radar set.

The radar set employs a planar high gain antenna radar system which allows a larger part of the radar system to be located in compartments below deck.

RADAR SET AN/SPS-48(V)

The AN/SPS-48(V) is a very versatile radar with many modes of operation. It provides the necessary target input data required to support the Navy surface missile systems (Tartar, Terrier, Talos) and also fills the requirement for air intercept control. The system is installed on guided missile destroyers, frigates, cruisers, and aircraft carriers.

The radar is composed of six major units: antenna, transmitter, receiver, two computers and frequency control group, plus a number of small auxiliary power units, data converters, and a control console.

The equipment uses solid state, modular construction techniques extensively and operates on 400 hertz primary power. The below decks weight of the radar is approximately 17,000 pounds and the antenna weights 4,500 pounds.

FIRE CONTROL AND MISSILE GUIDANCE RADARS

Electronic equipment in the fire control and missile guidance systems is closely related to mechanical and optical equipment both physically and electrically. Although the use of radar is merely a part of a whole fire control or missile

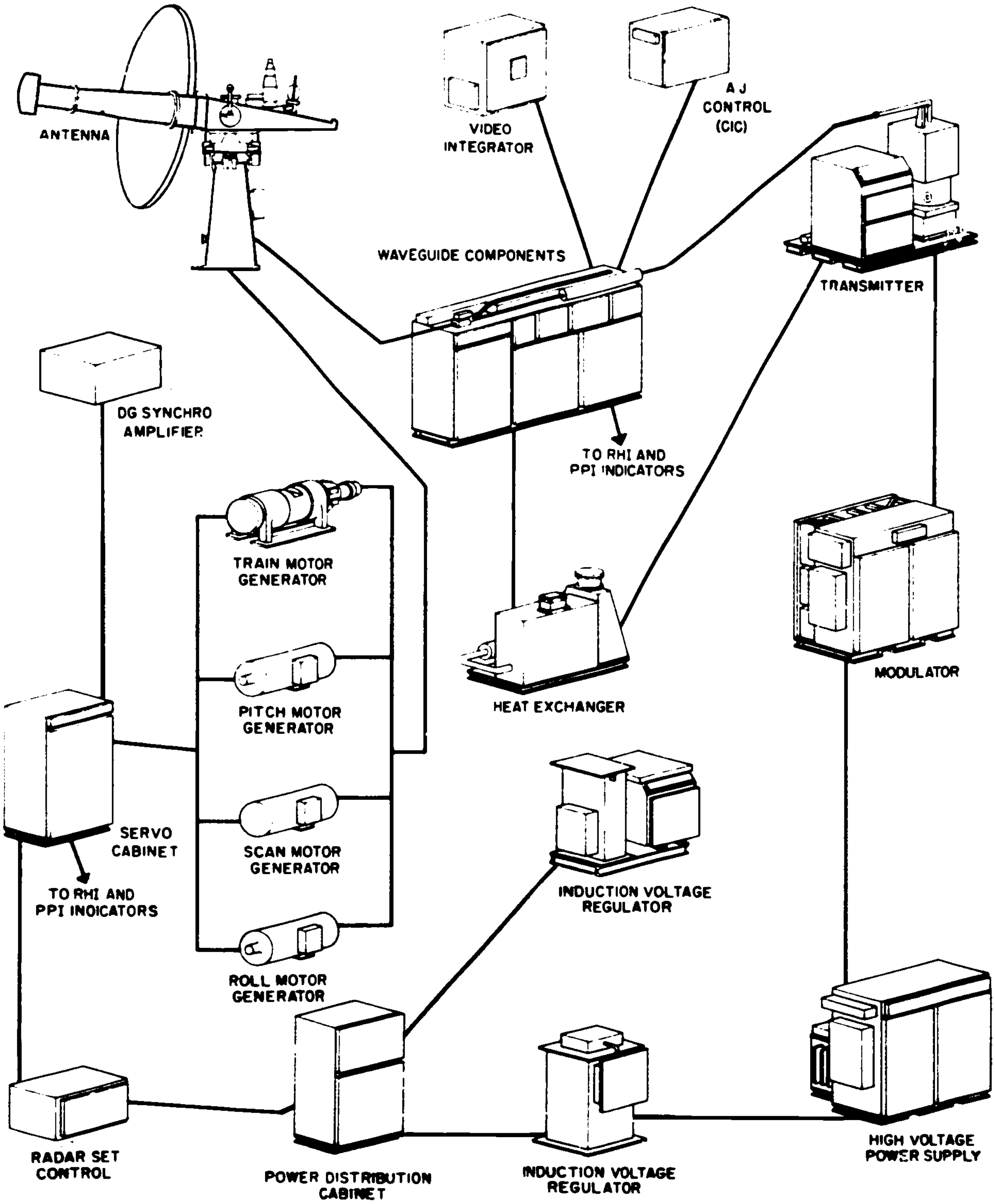

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Figure 6-5.—Air-search Height-finding Radar Set AN/SPS-30 system.

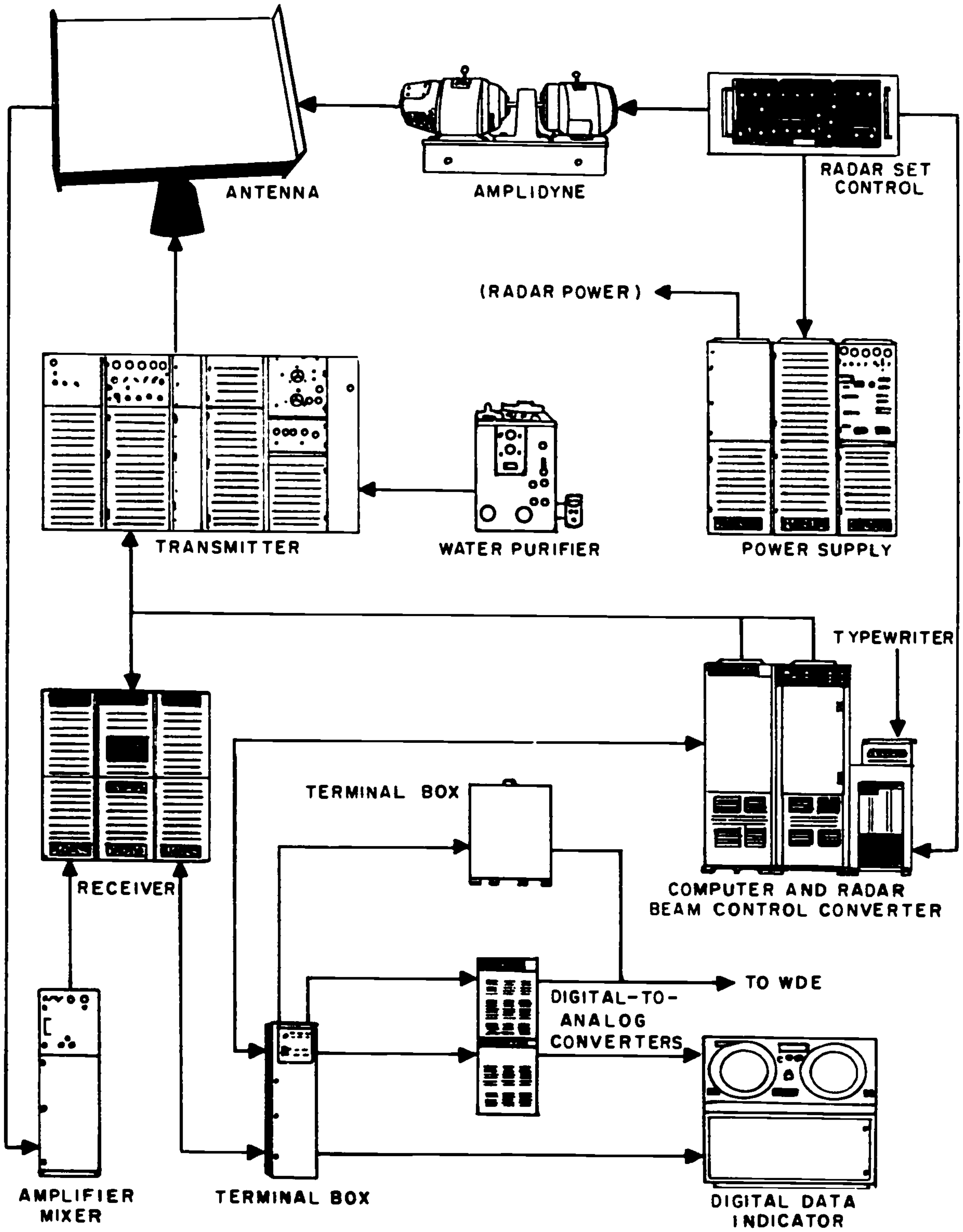

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Figure 6-6.—Air-search Height-finding Radar Set AN/SPS-52 system.

guidance problem, only the radar is discussed in this text.

FIRE CONTROL RADARS

Among the radars used for gun fire control are radar sets Mk 25, Mk 34 (also designated AN/SPG-34), Mk 35, AN/SPG-50, and AN/-SPG-52. The Mk 25 and Mk 34 are described here.

Mk 25 Mod-( )

The Mk 25 radar (fig. 6-7 an extremely accurate equipment, is capable of tracking either surface or air targets. It is used principally in 5-inch 38-caliber gun fire control systems, but serves equally well for controlling guns of other calibers.

This equipment operates on 5200 to 10,900 MHz frequency band, with a peak power output of 50 KW and a pulse width of 0.2μsec. Its accuracy in bearing is ±0.1°; range in yards is ±15 yards to ±0.1 percent of the range; and elevation is ±0.1°.

Early models of the Mk 25 has a maximum range of 50,000 yards. Those now in use can track targets at distances up to 100,000 yards.

Mk 34 Mod-( )

Another fire control radar capable of tracking either surface or air targets is the Mk 34. It was designed for heavy machinegun batteries, but its most common use today is in the Mk 63 fire control system that controls our 3-inch guns. When used in this system, the radar usually is listed as the AN/SPG-34.

Operating in the 5200 to 10,900 MHz frequency band with a peak power output of 32 KW and a pulse width of 0.5μ sec, the Mk 34 can track targets at distances greather than 30,000 yards. Its maximum range, however, is considerably less than the range of the Mk 25.

The antenna for this radar may be found on the gun platform itself (Mk 63 system) or on a separate director.

MISSILE GUIDANCE RADARS

Missile guidance radars currently installed in the fleet are listed here for the purpose of making the reader aware of their existence and use. The Tartar missile weapons system utilizes Radar Set AN/SPG-51. This radar provides a continuous wave radiofrequency output for the Tartar homing missle.

The Terrier missile weapons system uses 1 of 4 radar models. The AN/SPQ-5 and AN/-SPG-55 models are for beam riding Terrier missiles only. The AN/SPG-55A have dual capabilities. It can be used with Terrier beam rider or Terrier homing missiles.

The Talos missile weapons system uses two radar sets: the AN/SPW-2 for beam riding guidance; and the AN/SPG-49 for tracking.

AUXILIARY EQUIPMENT

The equipment covered in the remainder of this chapter is used with the various radars we have discussed. In some instances, this auxiliary equipment is in a system that facilitates the use of radar; in others, it is in the radar system itself.

REPEATERS (INDICATORS)

As the tactics of warfare became more sophisticated, there was more and more evidence that the information obtained from radar would have to be displayed at any one of several physically separated stations. The size and weight of the relatively bulky and complex radar console made it unsuitable for remote installations. The need was for a smaller and lighter general-purpose unit, capable of accepting inputs from more than one type of radar. To fulfill this need, the present-day remote indicator (repeater) was developed.

Several types of radar repeaters currently installed on Navy ships are described in the following topics.

Remote Indicator AN/SPA-4( )

The AN/SPA-4( ) range-azimuth general-purpose indicator (fig. 6-8), a remote PPI type of repeater, is used chiefly for surface search and station keeping. It utilizes a standard 10-inch, flat-face cathode-ray tube to show range and azimuth of a target. It is a self-contained unit designed for operation with any standard Navy search radar system having a pulse repetition frequency between 140 and 3000 PPS. This repeater may be employed to select radar information from any one of several radar systems. A

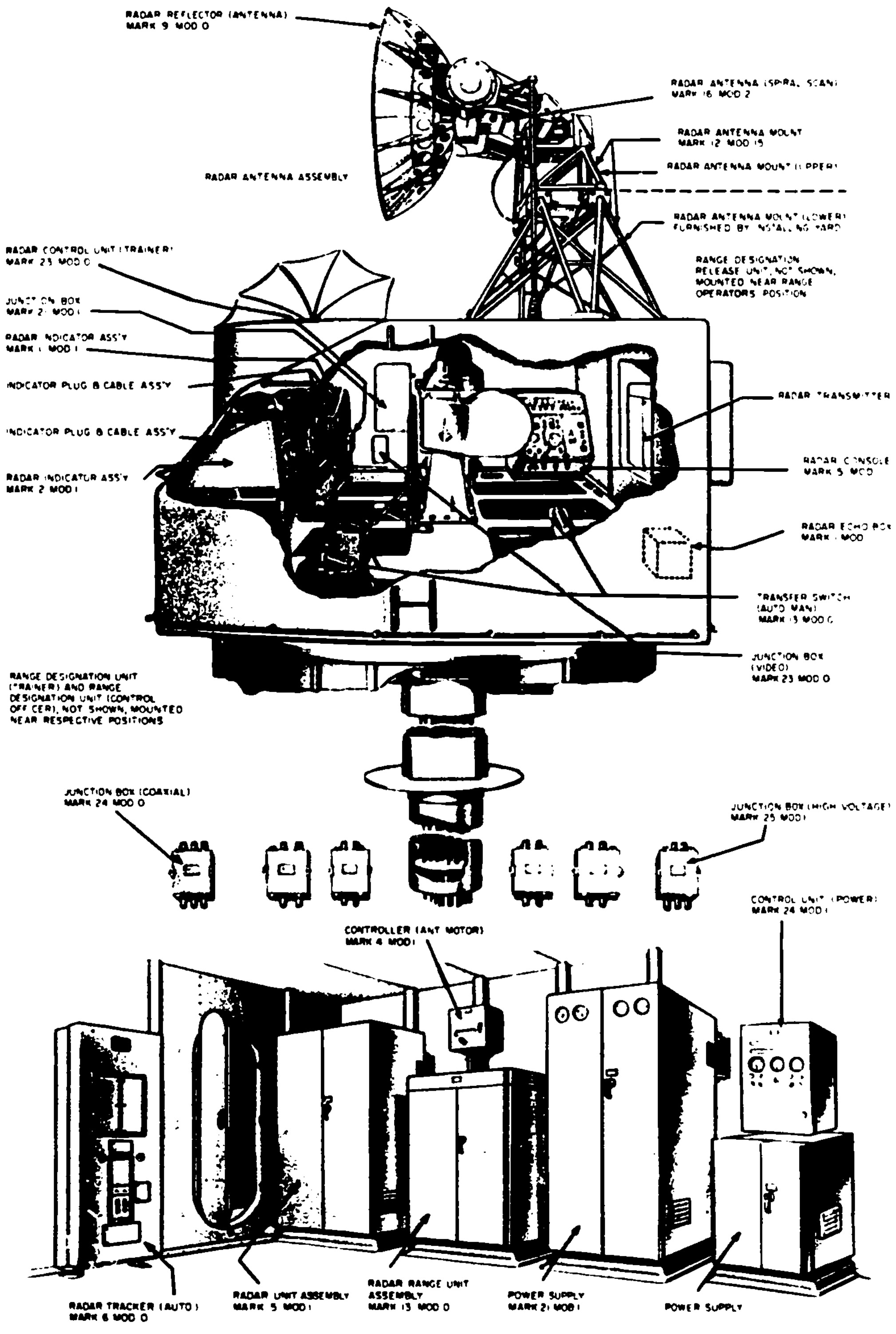

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Figure 6-7.—MK 25 radar system.

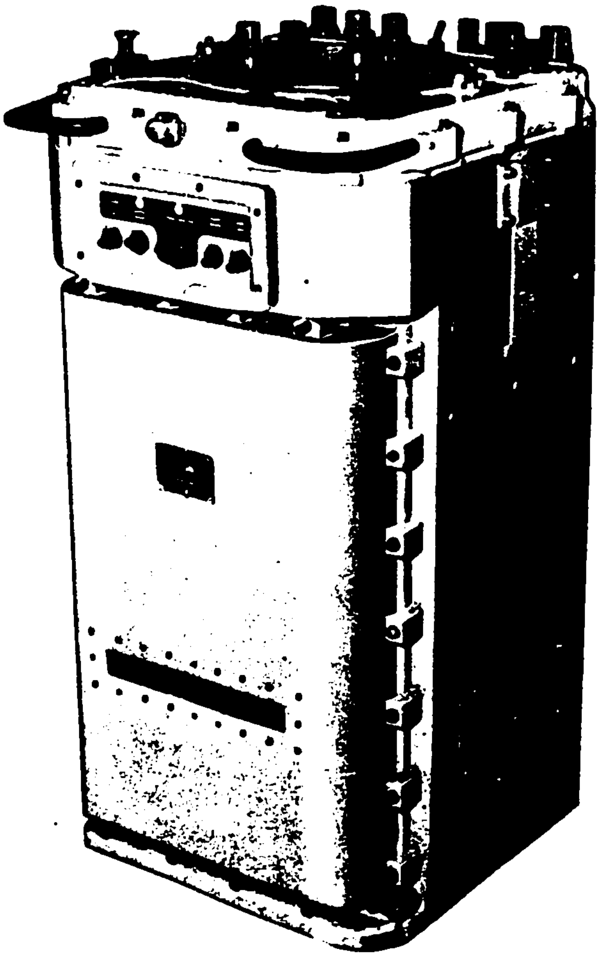

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Figure 6-8.—Range-Azimuth Indicator AN/SPA-4( )

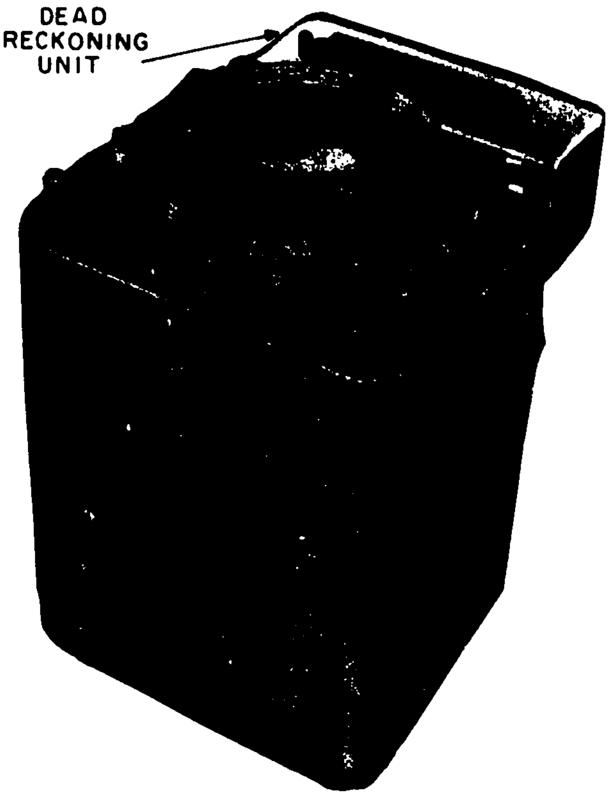

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Figure 6-9.—Range-Azimuth Indicator AN/SPA-25 with dead reckoning auxiliary unit attached.

variable (rubber) range control is incorporated, whereby the range may be varied continuously from 1 to 300 miles.

Remote Indicator AN/SPA-25

The Range-Azimuth Indicator AN/SPA-25 (fig. 6-9) is a light-weight transistorized general-purpose plan position indicator with a standard 10-inch screen designed for operation with any standard Navy search radar system having a pulse repetition frequency of 10 to 5000 PPS (pulse per second). The indicator can be employed to display radar information from any one of up to seven radar systems, depending on the installation. The AN/SPA-25 incorporates continuous range variation from 1 to 300 miles, time sharing of the electronic cursor sweep with the video sweep, and a sweep offset capability when a Dead Reckoning Auxiliary Unit is employed. Without the dead reckoning unit, the indicator does not have the offset capability.

Range may be determined in two ways: by using the range rings, which occur at 1/2-, 1-, 2-, 5-, 10-, 20-, or 50-mile intervals for the operator's selection, or by using the electronic range strobe and a direct-reading mechanical counter.

Bearing (azimuth) may be determined in two ways: by using the electronic cursor and azimuth scale or by using the electronic cursor and a direct reading mechanical counter.

Remote Indicator AN/SPA-18

The AN/SPA-18 is a small, compact, remote PPI that presents range and bearing information on a 7-inch screen. It is designed for installation on small ships where space is limited. The unit is sealed in a sprayproof cabinet, and can be mounted in unprotected areas either on the bulkhead or on a shelf.

This repeater has a continuously variable range scale of 2 to 30 miles. It can be operated with any standard Navy search radar having a PRR of 57 to 3000 PPS.

Remote Indicator AN/SPA-50A

Range-Azimuth Indicator AN/SPA/50A (fig. 6-10) is a transistorized, direct-view, large-screen (22-inch) PPI designed to display the output of any standard search-radar system having a pulse rate frequency between 15 and 5000 PPS. The indicator unit will display the signals from any standard search radar.

It normally uses only the electronic bearing cursor, although a mechanical cursor can be installed.

A reflector plotter is shown separately in figure 6-10. A plotting head enables the operator to plot the position and motion of a radar target accurately on a planned position indicator.

The foregoing AN/SPA-4, -25, -18, and -50 remote indicators are used primarily with surface search radars. The following Remote Indicators AN/SPA-8, -33, -59, -34, -66, -40, -41, and -43 are used more with air search radars.

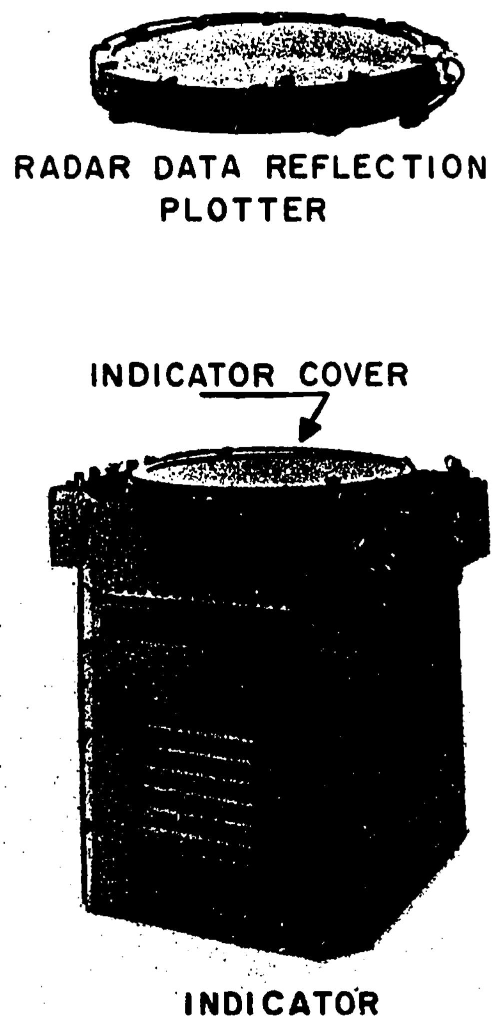

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Figure 6-10.—Range-Azimuth Indicator AN/SPA-50A.

AN/SPA-8( ) Remote Indicator

The AN/SPA-8, -8A, -8B, -8C, are general-purpose PPIs employed with shipboard radars to display range and bearing information. These repeaters have offcentering capabilities and may be used as master or remote PPI indicators, as relay search repeat indicators, or as radar relay search repeat indicators, or as radar relay search tracking indicators. They have the capability for being utilized as tracking and repeat indicators with the shipboard section of the airborne early warning (AEW) system.

This equipment features (1) continuous-range sweep variation without loss of target, (2) time sharing of the electronic cursor and range sweeps or the strobe and range sweeps, and (3) sweep and cursor offcentering, which make target identification possible without geographic distortion. All these features are incorporated in the indicators. The AN/SPA-8 cannot be used for tracking but is used for a repeater (sometimes called a slave.) The AN/SPA-8A, -8B, and -8C are single indicators used either for tracking purposes or as slaves. Some of its special features follow.

1. Manual offcentering: Any target within 250 miles may be centered on the scope.

2. DRA offcentering: Information from the ship's dead reckoning analyzer (DRA) may be fed to the repeater. This DRA information cancels own ship's motion, and shows all targets

(including own ship) moving on their true courses.

3. Electronic cursor and range strobe: Provided with a centered or offcentered electronic cursor and range strobe. Origin of offcentered cursor and strobe may be controlled independently from sweep by tracking cranks.

4. Range scale: Rubber range, 4 to 300 miles, continuously variable, with a choice of six different scale spacings between range rings.

5. Tracking cranks: Used to position origin of strobe or electronic cursor. The tracking cranks may be locked so that the repeater can be used as a final (repeat) AEW indicator.

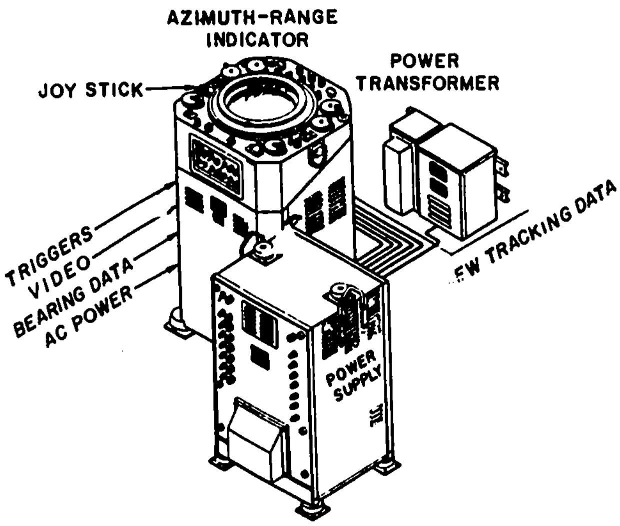
Remote Indicators AN/SPA-33 and AN/SPA-59

The AN/SPA-33 and -59 are remote indicators (fig. 6-11) which have offcenter capabilities and may be operated either as a general-purpose PPI or as a part of an AEW system. The only difference between these two sets is that the AN/SPA-33 has a 300-mile range and the AN/SPA-59 has a 400-mile range.

They have practically the same controls and capabilities as the AN/SPA-8A, -8B, -8C. At first glance they look alike, but a closer check shows that the AN/SPA-33 and AN/SPA-59 have two joysticks (switches) in place of the range and bearing cranks on the AN/SPA-8( ). The joystick on the left is for the cursor orgin; the one on the right is for the range strobe and cursor bearing line. Another difference between the two repeaters is that the AN/SPA-8A, -8B, 8C has provision for a DRA (dead reckoning analyzer) input, whereas the AN/SPA-33 and AN/SPA-59 do not.

Remote Indicators AN/SPA-34

The AN/SPA-34 remote indicator incorporates into a single console the desirable features of the AN/SPA-8( ) and the AN/SPA-33. Depending on the mode of operation selected, it functions as a general-purpose off-centering type PPI, as an AEW tracking indicator, or as an AEW repeat indicator. Because of its size and weight, the AN/SPA-34 is installed only on ships of DD size and larger.



120.34
Figure 6-11.—Range-Azimuth Indicators AN/SPA-33( ) or AN/SPA-59( ) system.

Remote Indicator AN/SPA-66

The AN/SPA-66 (fig. 6-12) has improved capabilities with respect to accuracy and will replace the AN/SPA-34. The Remote Indicators AN/SPA-8A, -33, -59, -34, and -66 are all long range and all perform the same function. They differ somewhat in range scales and accuracies, however.

Remote Indicator AN/SPA-40

The AN/SPA-40 is shipboard equipment used with various height-finding radar systems (fig. 6-13). The range-height indicator (RHI) displays target information by the sweep trace on the screen. The height of the radar beam is presented vertically to a maximum of 150,000 feet. The range is presented horizontally to a maximum of 300 nautical miles. The RHI supplies the third-dimension for a PPI's two-dimension target range and azimuth.

The general-purpose indicator AN/SPA-40 displays a height-line cursor. This cursor is a straight line painted across the width of the screen. The vertical position of the cursor is controlled by the joystick which is centrally located a few inches below the bottom of the screen. The indicator provides an angle mark

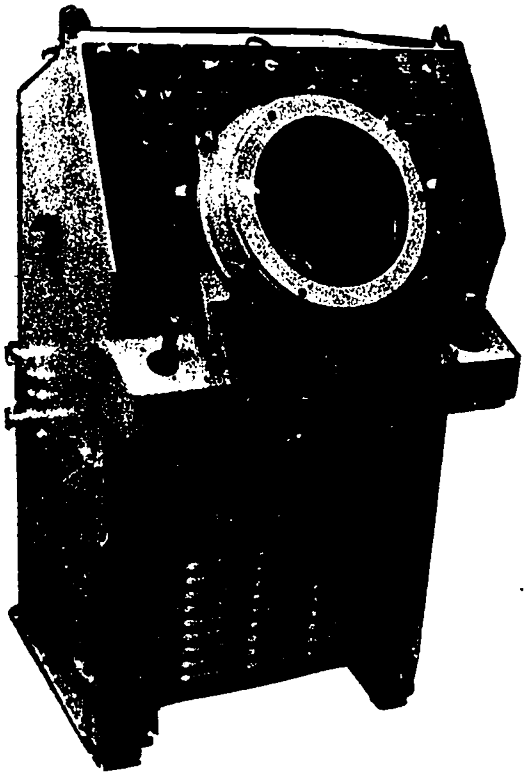


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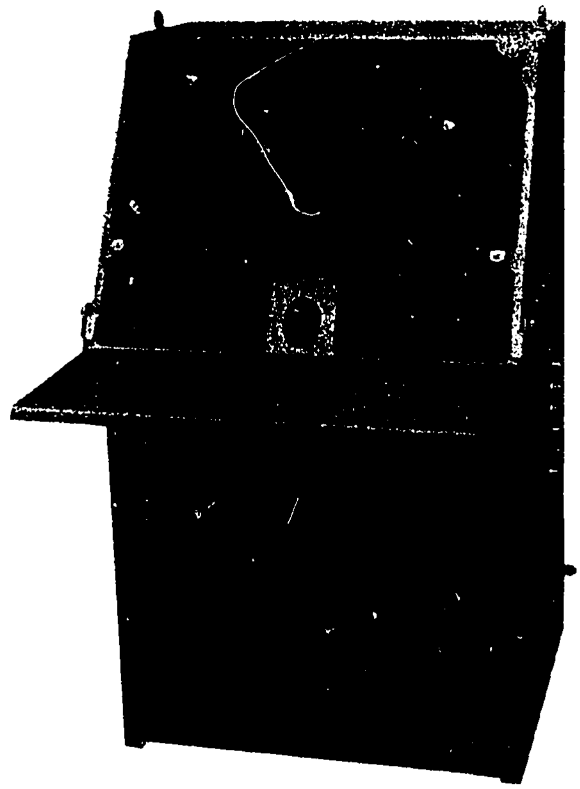
Figure 6-12.—Range-Azimuth Indicator AN/SPA-66.



120.86

Figure 6-13.—Height-finding Indicator AN/SPA-40.

cursor used to determine the elevation angle of the target.

The operator may select a delayed sweep of a traverse 30-mile range segment to heights (above sea level) of 0 to 150,000 feet, 50,000 to 150,000 feet, or 0 to 70,000 feet. The center of the range segment may be adjusted anywhere between 15 and 285 miles.

The height-determining capabilities of the indicator are produced by an analog computer. After calibration, this computer solves equations to provide the target height above sea level which is accurate within ± 200 feet. The errors due to earth curvature and refraction of the radar beam are adequately corrected.

Remote Indicator AN/SPA-41

The height-finding Indicator AN/SPA-41 is replacing the AN/SPA-40. The AN/SPA-40 displays either target traces or angle-mark cursor, but not both simultaneously as does the AN/SPA-41.

Intercept Tracking and Control Group AN/SPA-43

The AN/SPA-43 intercept tracking and control computer is designed to aid the air controller in conducting air intercepts.

AEW TERMINAL EQUIPMENT

The purpose of the AEW system is (1) to obtain an extended radar horizon by operating search radar equipment in an aircraft at high altitude, and (2) to make available to surface ships in the vicinity the extended radar and IFF information thus obtained. This action is accomplished by transmitting to the surface craft radio signals containing the radar and IFF information. From these signals the original display at the airborne radar is reproduced on the shipboard indicators.

Two radio receiving sets and a video decoder currently used in shipboard AEW installations are the AN/SRR-4, the AN/WRR-1, and the KY-71/UPX. A description of each follows.

Radio Receiving Set AN/SRR-4

One or two radio receivers, a video decoder, and a data converter make up the AN/SSR-4 radio receiving set. These units are mounted one above the other in a framework rack. The number of receivers is governed by the type of antenna available. If an omnidirectional antenna is used with the set, only one radio receiver is required.

Because a satisfactory location for an omnidirectional antenna is unavailable on most surface ships, the usual installation of this equipment includes two radio receivers and two antennas operating as a diversity system. The antennas are mounted on opposite sides of the ships's superstructure so that each antenna covers half of the azimuth circle. The antenna and receiver arrangement that intercepts the strongest signal takes control of the system automatically. With this arrangement, reception of the strongest possible signal is assured at all times.

In either type of installation, the receivers provide video outputs that are used for display on the indicators. They also supply decoded synchronizing pulses for further processing and use in the control of the indicator sweeps and associated IFF and beacon equipment.

Radio Receiving Set AN/WRR-1

The AN/WRR-1 radio receiving set is a refinement of the AN/SRR-4. Although the two sets perform the same functions, they have somewhat different components. The AN/WRR-1 consists of a signal generator, a radio receiver, a signal converter, and a power supply mounted one above the other in the same equipment cabinet.

For diversity operation, the AN/WRR-1 employs a single receiver and two directional antennas. Each antenna covers half of the azimuth circle. The antenna that intercepts the strongest signal is connected automatically to the receiver by means of an antenna switching device.

Video Decoder KY-71/UPX

The KY-71/UPX is a video decoder used in conjunction with the shipboard AEW equipment. Radar data and the identification information (IFF) are transmitted on a common link, and it is the function of this unit to separate the data into separate circuits.

By using this unit in conjunction with other standard identification data distribution accessories, an operator may display the identification data with or without the radar information. He also may display radar information without the identification data. Simultaneously, the other operators are able to select and display identification and/or radar data as they desire.

IFF EQUIPMENT

Today's high-speed aircraft present a critical problem in detection, identification, tracking, and evaluation. When enemy aircraft are approaching, they must be detected and identified at the greatest possible distance in order to provide ample time for initiating appropriate action.

The Selective Identification Feature (SIF) is a recent development that makes the system of identifying friendly units much more secure and more positive. The SIF operates in conjunction with the Mk X system but is a separate piece of equipment.

Currently, the Mk X IFF system is in common worldwide use by both civilian and military. It received wide distribution during and after World War II. Today, pursuit effort is directed to the Mk XII system that provides greater flexibility and security by use of more extensive and complicated interrogations and replies.

Among the various models of IFF equipment currently installed aboard ships are the AN/UPX-1( ), AN/UPX-11, AN/UPX-12( ), AN/UPX-17, AN/UPA-24 ( ), and AN/UPA-38( ). Of these six models, only the AN/UPX-1( ) and the AN/UPA-24( ) are discussed in this text.

Radar Recognition Set AN/UPX-1( )

The AN/UPX-1( ) radar interrogator-recognition set (fig. 6-14) is designed to operate in conjunction with shipboard radar equipment.

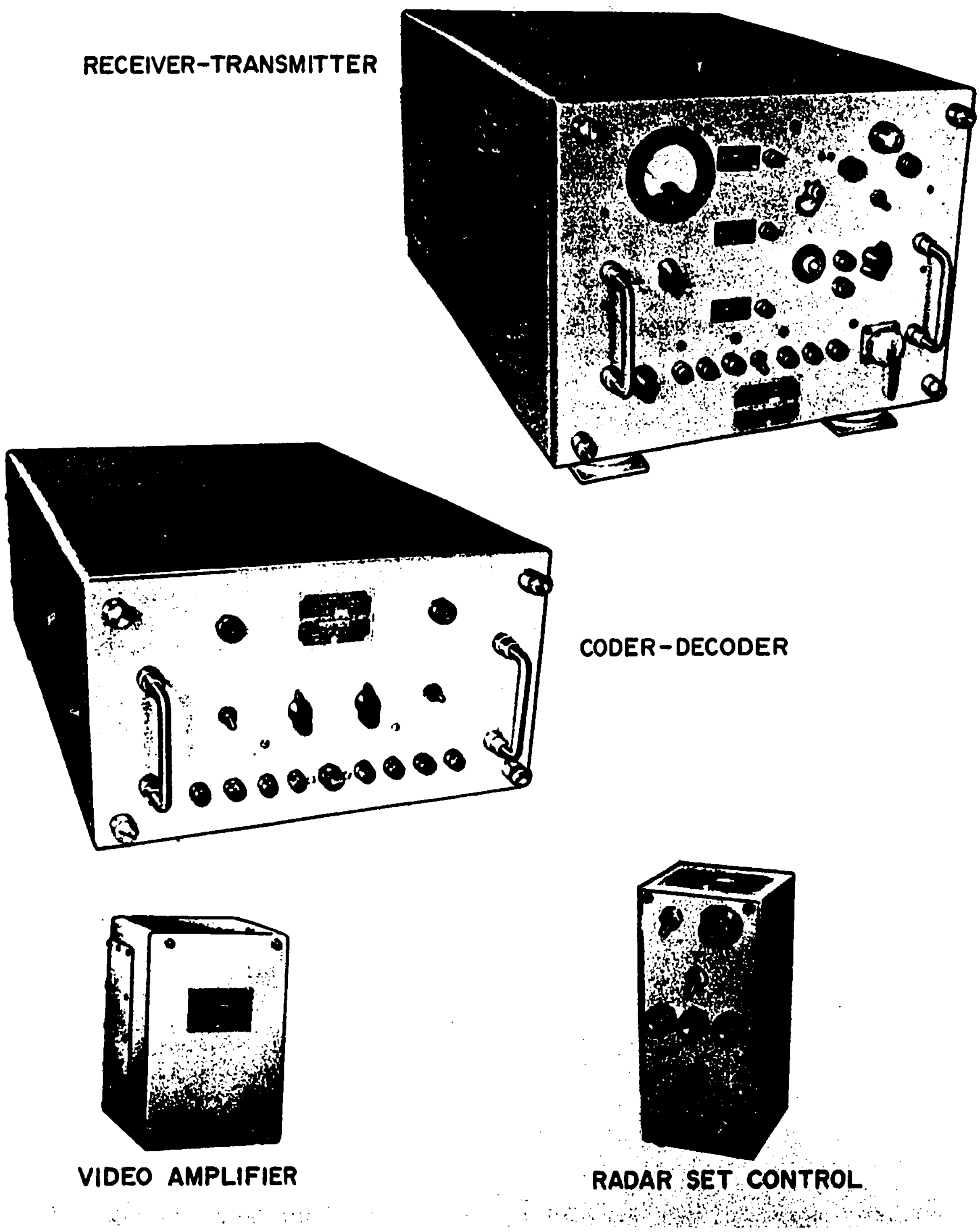


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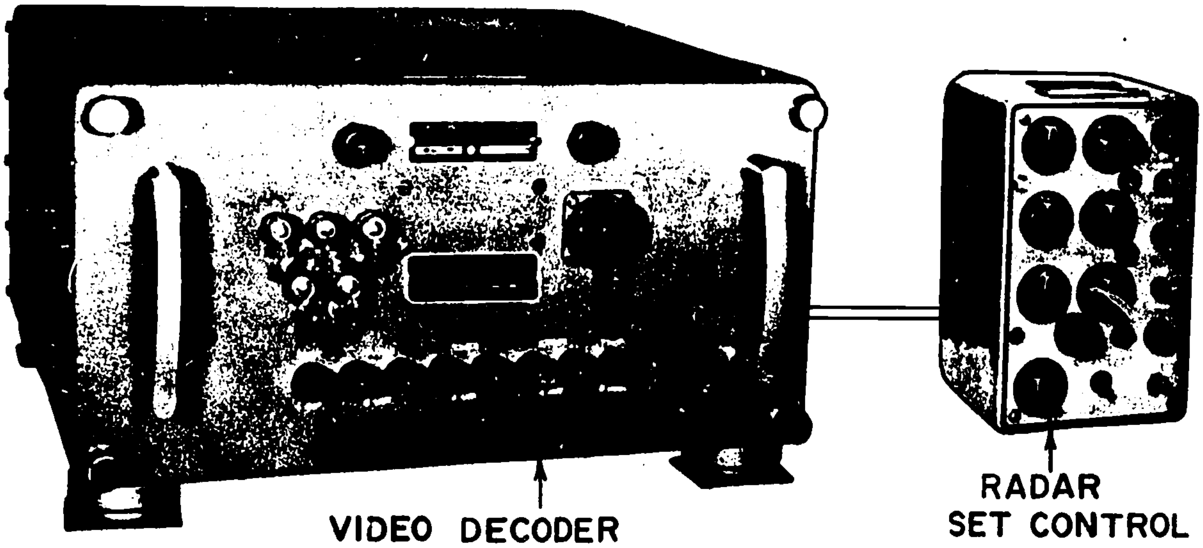
Figure 6-14.—Radar Recognition Set AN/UPX-1( ).



120.39

Figure 6-15.—Decoder Group AN/UPA-24( ).

It uses the radar display for presentation of its IFF data. Its antenna is either integral to or slaved with the associated radar antenna.

The AN/UPX-1( ) is used chiefly for challenging unidentified radar targets. It also can be used to further identify friendly targets as specific aircraft or ships, thereby providing additional security and useful tactical information.

Although it is not discussed in detail in this text, the AN/UPX-12( ) is the shipborne quipment that responds to the challenges transmitted by the AN/UPX-1( ).

Decoder Group AN/UPA-24( )

The AN/UPA-24( ) decoder group, shown in figure 6-15; facilitates the interpretation of coded IFF signals received from a radar recognition set. It selects a coded video pulse-train from the recognition set and presents the coded signal to a decode network. If the pulse-train is coded correctly, an indication in the form of a single decode pulse is displayed on the radar indicator. If the pulse-train is coded incorrectly, a decode pulse is unavailable for presentation.

The AN/UPA-24( ) permits the presentation of the coded or decoded IFF signal alone, the radar signal alone, or the radar signal mixed with either coded or decoded IFF signals. It also provides the means for controlling the operation of the recognition set.

ANTENNA STABILIZATION DATA EQUIPMENT

The AN/SSQ-14 stabilization data set 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, their output axes vertical. Output of these gyro units—with their associated servo loops—maintain this platform in a horizontal position. By means of transmitting synchros, geared to the pitch and roll axes of the stabilized platform, the pitch and roll angular correction is sent to the desired destination (the system that keeps the radar antenna stabilized, for example).

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

CHAPTER 7

SONAR

Sonar (derived from the words SOund Navigation And Ranging) uses pulsed transmission of sound waves in water for detecting, tracking, and ranging of underwater objects, and is analogous to radar which uses pulsed transmission of radio waves to detect, track, and determine the range of objects on the surface or in the air. Because ships afloat are partially submerged, sonar is used for the detection of surface ships and submarines, for measuring water depths (depth sounding), and also as a navigational aid. Commercially, sonar is used for detecting shoals of fish.

Sonar equipment may be of an active nature, transmitting sound energy into the water and then obtaining bearing and range information from returning target echoes; or it may be of a passive nature, depending upon the sound originating from the target (such as screw cavitation, machinery noise, and the like) for bearing information.

Before discussing the various sonars, let's briefly review some of the basic principles of sound.

SOUND

Everything you hear is a sound. This statement does not mean, however, that when you hear nothing there is no sound, because many sounds are beyond the frequency range of the human ear. Sound is a mechanical disturbance of the surrounding medium and may be divided into three frequency groups. They are (1) ultrasonic—those frequencies above the audiofrequency range; (2) sonic—those frequencies within the audiofrequency range, and (3) subsonic—those frequencies below the audiofrequency range. As stated in chapter 2, the audio range is from approximately 15 to 20,000 hertz. The actual range of frequencies that the human ear can detect varies with the individuals themselves.

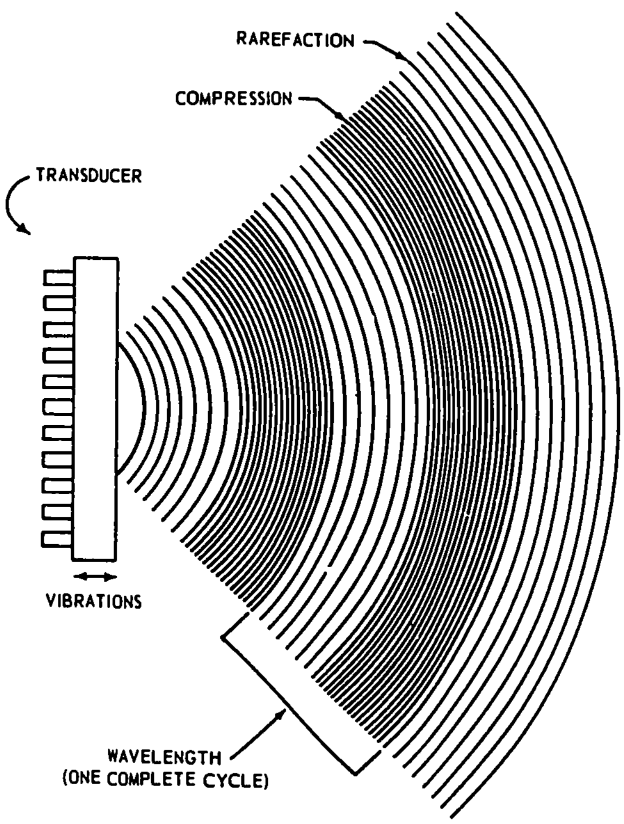
To make use of sound, it is necessary to have a sound source, a medium for the sound to travel through (sound does not travel in a vacuum), and a detector to pick up the sound so that information can be obtained from it.

GENERATION AND TRANSMISSION OF SOUND

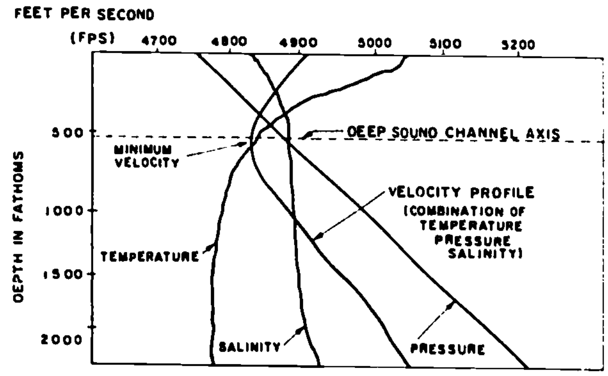
Any object that vibrates back and forth disturbs the material surrounding it, whether that material is a gas, solid, or liquid. The object that vibrates is the sound source (fig. 7-1). It may be a bell, a loudspeaker, or a sonar transducer.

A transducer is any device that converts energy from one form to another. In sonar, the transducer contains a diaphragm that is made to vibrate at the frequency of an applied voltage. When the diaphragm moves out, the medium next to it is compressed. As the diaphragm moves back, the particles in the medium move apart, causing a rarefaction or low pressure area next to the diaphragm. When the diaphragm moves out again, a new compression is produced. The out-and-in movement of the diaphragm continues, and the alternate compressions and rarefactions spread in a series of waves called compression waves. Compression waves, propagated through a medium, are sound waves.

The number of complete cycles (one compression and one rarefaction) completed in each second is the frequency of sound wave train. This frequency, of necessity, is the frequency of the vibrating body (source). The speed at which the sound wave train travels outward depends upon the nature of the material or medium surrounding the body. In 35 percent salt water, sound travels at approximately 4800 feet per second at 39°F.



4.221
Figure 7-1.—Producing sound waves.



120.87
Figure 7-2.—Velocity profile for the ocean.

VELOCITY PROFILE OF THE OCEAN

The temperature, pressure, and salinity of sea water all affect the velocity of sound in the medium of the ocean. In each case, as the values of these variables increase, so does the speed of sound increase, or: higher temperature = higher velocity; higher pressure = higher velocity; and higher salinity = higher velocity.

Because sound will refract, or "bend" from areas of high velocity to those of low velocity, oceanographers say the "sound is lazy." Each of the variables affecting the speed of sound in ocean water is therefore important.

The effects of temperature, pressure, and salinity combine to form a velocity profile for the ocean (figure 7-2). Temperature is the variable exerting the greatest impact upon velocity near the surface. Relatively abrupt and large changes may occur in the first few hundred feet of depth. The temperature of the ocean levels off, often after the first few thousand fathoms, and remains at about 30°F., so that it is less important as a variable at great depths. Pressure as shown on the graph, is a steadily increasing effect, becoming greater as the depth increases and thereby increasing velocity in a linear function. Salinity varies less throughout the deep ocean areas, and has relatively less effect on the speed of sound than temperature and pressure.

The velocity profile, resulting from these effects, shows a point of minimum velocity, normally occurring between 500 and 700 fathoms below the surface. This area, where the speed of sound is lowest, is called the deep sound channel axis. Below the channel, pressure causes velocity to increase, and above it, temperature has the same tendency. Within this area, low frequency sounds can travel thousands of miles at the reduced velocities they seek.

SOUND PATHS AND MODES OF DETECTION

Most submarine detection by shipboard sonars is made using the surface duct path of sound travel. This is so, because most sonars in today's ships are capable of only this mode of operation and because submarines operate in the first few hundred feet of water, or in the surface duct. As the ocean's sound velocity profile shows, temperature has much more effect near the surface than do either of the other variables causing sound to refract.

Information about the sea's temperature is gained from a device called a bathythermograph, which is described in the next chapter.

Thermal Gradients

Thermal gradients are indices of the changes in temperature vs depth near the surface. There are three types of thermal gradients:

NEGATIVE GRADIENTS.—A negative gradient exists where an increase in depth is accompanied by a decrease in temperature. Sound in a negative gradient will bend down, seeking the lower velocity caused by cooler water (fig. 7-3).

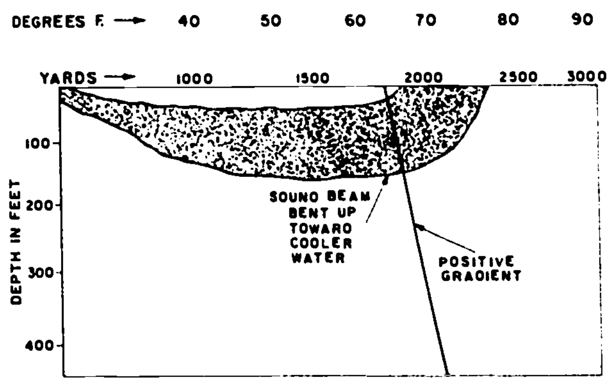
POSITIVE GRADIENT.—A positive gradient is one where cooler water overlies warm, and an increase in depth yields a rise in temperature. Sound will refract upward toward the surface where the cooler water produces lower velocities (fig. 7-4).

ISOTHERMALS.—Isothermals are the third type of gradient, and exist where a change in depth shows no change in temperature. Sound in an isothermal will bend slightly upward because of the effect of pressure. Lower pressures result in lower velocities; the reduced pressure at the surface will be sought by sound where temperature does not change (fig. 7-5).

Layer Depth

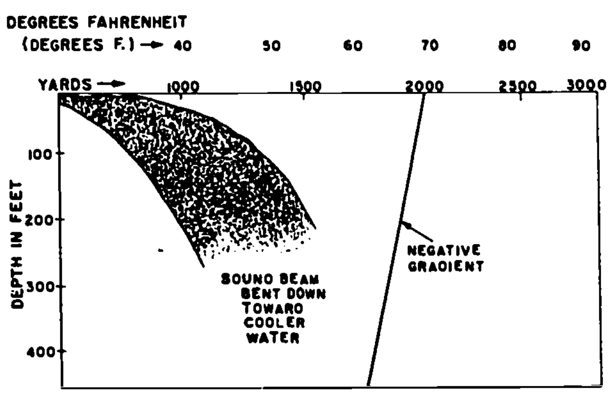
Layer depth is defined as the "greatest depth at which the maximum temperature is found." Layer depths are the most important single factor determining sonar ranges in the surface duct. A layer can be caused by an isothermal condition terminating in a negative gradient (fig. 7-6) or a positive gradient into a negative (fig. 7-7). Sound in either the isothermal or positive gradients will bend upward causing it to return to the surface; while sound in negative gradients will bend downward resulting in shorter ranges. Generally, the deeper the layer, the greater the surface duct sonar range (figs. 7-6 & 7-7).

BOTTOM BOUNCE.—For long-range search in water depths over 500 fathoms, a bottom reflection or bottom bounce mode of operation may be conducted with newer sonar equipments.



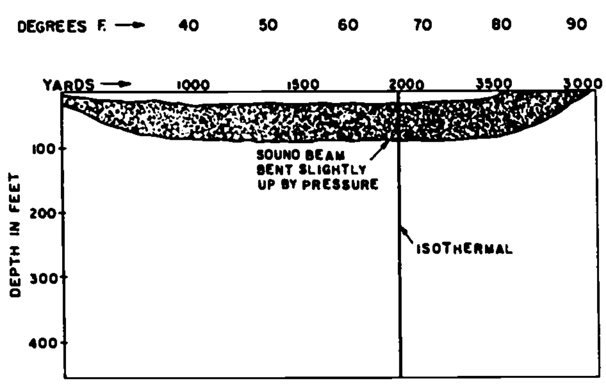
71.30(120C)

Figure 7-4.—Positive gradient.



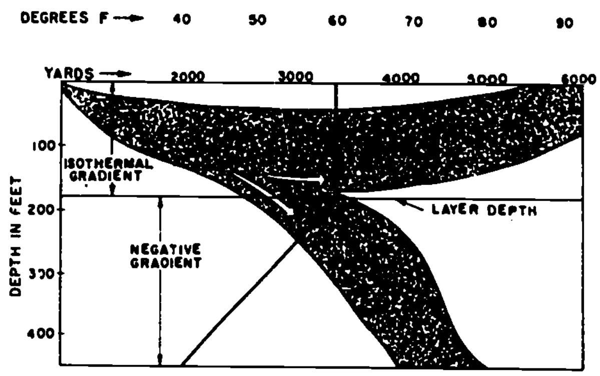
71.31(120C)

Figure 7-3.—Negative gradient.

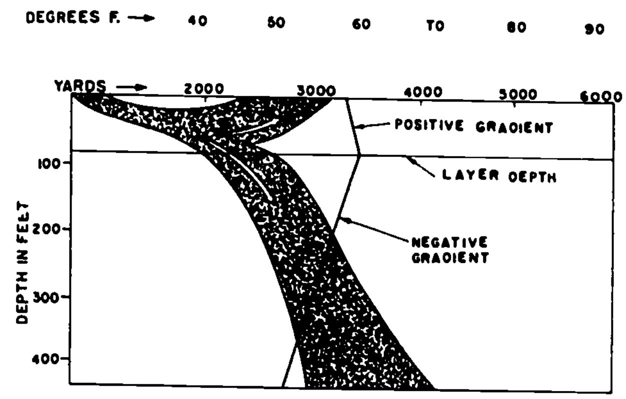


120.88

Figure 7-5.—Isothermal gradient.



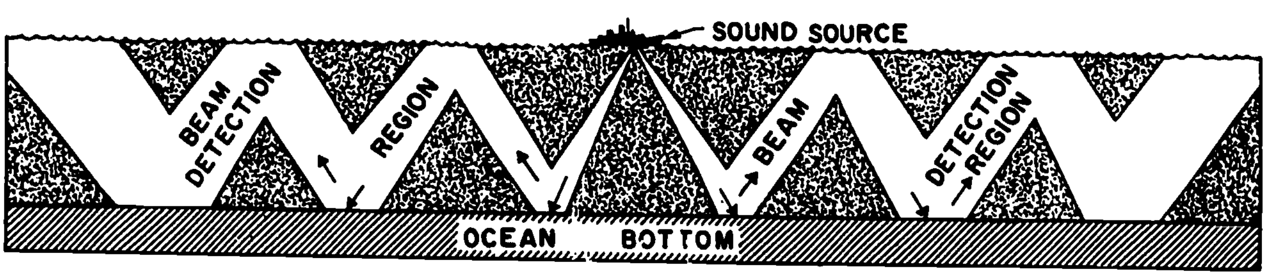
120.89
Figure 7-6.—Isothermal gradient into a negative gradient.



120.90
Figure 7-7.—Positive gradient into a negative gradient.

The bottom bounce effect is accomplished by using automatically selected transducer angles to reflect the sound beam up from the ocean floor. Preselected transmission angles cause sound to be reflected from the bottom into regions not normally possible with the velocity structure. The bottom bounce effect is illustrated in figure 7-8.

Bottom bounce is in part successful because the angle of the ray path (0° to 42°) is such that the sound energy is affected to a lesser degree by velocity changes than the more nearly horizontal ray paths of other transmission modes. Transmission loss for bottom bounce can usually be predicted on the combined basis of: (1) spherical spreading along the slant range to the receiver; (2) absorption loss dependent on water temperature and frequency of sound source; (3) a loss associated with successive bottom reflections; and (4) bottom composition. Long range paths can occur with water depths greater than 1000 fathoms depending on bottom slope, but at shallower depths multiple bounce paths develop which produce high intensity loss. For this reason, bottom bounce is not used in less than 500 fathoms. It is estimated that 85 percent of the ocean is deeper than 1000 fathoms, and bottom slopes are generally less than or equal to one degree (as an average figure). However, the slope must be 3 degrees or less before any bottom bounce operation is possible. On this basis, relatively steep angles can be used for single bottom reflection to ranges of approximately 20,000 yards. With steep grazing angles, transmission is relatively free from thermal effects in the surface region and the major part of the sound path is in nearly stable water.

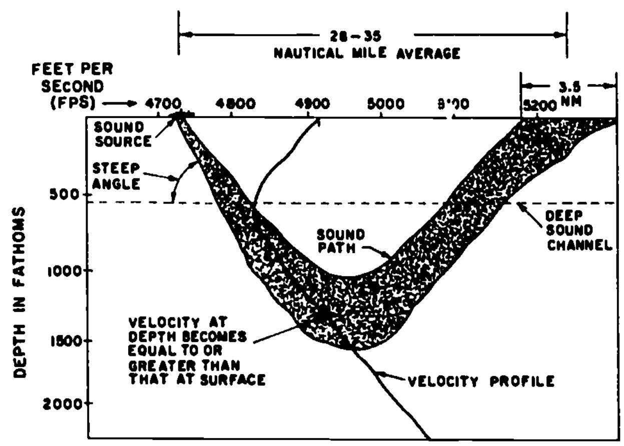


51.7(120C)
Figure 7-8.—Bottom bounce.

Each bottom reflection is received from a limited range, and the maximum range of reception for each reflection is defined by the limiting ray which depends on bottom slope and the sound velocity profile. The minimum range of reception is determined by the critical angle ray. Where rays strike the bottom at angles more horizontal than the critical angle ray, there is perfect reflection, and the interval of best reception is between the limiting ray and the critical angle ray.

The rays which strike the bottom at angles steeper than the critical angle ray are partially refracted into the bottom with energy loss; this loss increases with increasing frequency of the source and grazing angle.

CONVERGENCE ZONE DETECTION.—Convergence zone detection (fig. 7-9) is made



51.8.1(120C)
Figure 7-9.—Convergence zone detection (steep angle).

possible by a phenomenon in the ocean which causes sound, after reaching a great depth, to return to the surface approximately thirty miles from its source. In discussing this mode of detection, and the deep sound channel detection in the following paragraph, we are no longer concerned with the shallow water and layer depths discussed above. In order for sound to travel the convergence zone path, two criteria must be met; (1) The sound must travel through the point of minimum velocity, or deep sound channel, at a steep angle (if it reaches this area at a shallow angle as shown in figure 7-10, it will be trapped, or ducted); and (2) the sound must reach a depth at which the velocity profile (fig. 7-9) shows a speed equal to or greater than that at the surface. When this point is reached, the effect on velocity due to pressure will cause the sound to return by a path similar to the one it followed going down.

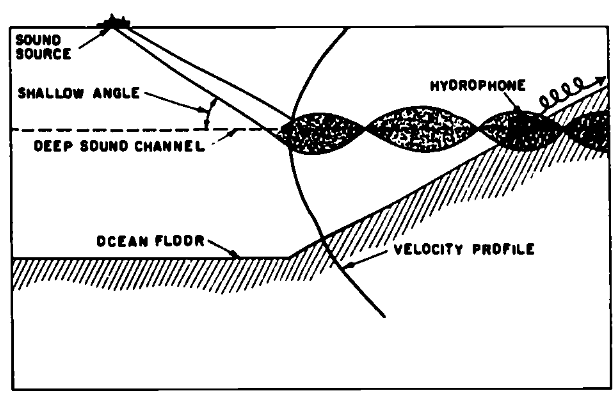
DEEP SOUND CHANNEL DETECTION.—The fourth path of sound travel again involves the velocity profile. If sound enters the deep sound channel, in the vicinity of 500-700 fathoms, at a shallow angle, it can be trapped since it tends to remain at low velocity. The shallow angle allows the sound to be influenced gradually and once trapped, low frequency sounds can be ducted over thousands of miles. Systems using hydrophones on the ocean floor make use of this path of sound travel.

TRANSDUCERS

A transducer is a device that converts energy from one form into another. An example is the changing of electrical energy into mechanical energy or vice versa. This is the principle by which sonar transducers operate.

MAGNETOSTRICTIVE PROCESS

Magnetostriction is a process whereby changes occur in metals when they are subjected



51.8.2(120C)
Figure 7-10.—Convergence zone detection (shallow angle).

to a magnetic field. If a tube made of nickel is placed in a magnetic field, for example, it changes length as a result of the magnetostrictive effect.

The elements of the transducer each have nickel laminations pressed in a thermoplastic material and wrapped with a coil of wire. Permanent magnets are so mounted that they provide energy for polarizing the nickel, thus establishing an operating bias for the system. During transmission when alternating current is passed through the coil, the tubes shorten or lengthen with each half-cycle of the alternating current. The resultant displacement of a diaphragm attached to the ends of the nickel tubes causes sound frequency vibration to be transmitted through the water.

ELECTROSTRICTIVE PROCESS

The electrostrictive process in transducers relies on the ability of certain manmade ceramics to produce a mechanical force when a voltage is applied; or conversely, produce a voltage when a mechanical force is applied.

When ferroelectric material such as lead zirconate titanate compound is placed in an electric field, it changes in dimensions. This effect is very similar to the piezoelectric effect found in some natural crystals whose oscillations change in step with changing electrical or mechanical forces. For the ceramic material to acquire the piezoelectric characteristic however, an extremely high voltage is initially applied to the material for several minutes to polarize it permanently to give an operating bias to the system. Then, as alternating current is applied, the material will shorten or lengthen with each half-cycle to set up mechanical vibrations at the desired frequency.

Ceramic tranducers have high sensitivity, high stability with changing temperature and pressure, and relatively low cost. Their greatest advantage lies in the mechanical properties of the material, which allow construction of almost any reasonable shape or size.

CYLINDRICAL ARRAY

A cylindrical array (fig. 7-11) illustrates a transducer made up of many individual elements stacked in vertical columns called staves. Each stave (shaded area, fig. 7-11) has nine elements, and the total number of staves arranged in cyclindrical form gives a 360° search in azimuth. The physical size of the individual elements in the transducer is related to the operating frequency and power output. The power output required determines the physical dimensions of the array.

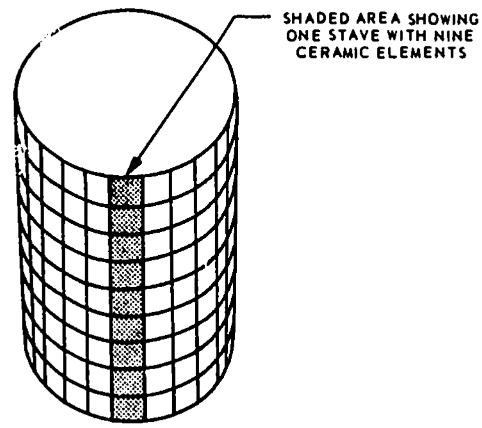


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Figure 7-11.—Cylindrical array arrangement.

TYPES OF SONAR

The two general types of sonar are referred to as active sonar and passive sonar. The active sonar is a transmitting (pinging) and receiving apparatus. It is capable of transmitting underwater sounds that strike targets and are returned in the form of echoes. The echoes so returned are received and presented in a manner to indicate the range and bearing of the target. Passive sonars do not transmit sound. They merely listen for sounds produced by the target to obtain accurate bearing. Estimated range information can be obtained by triangulation.

Active sonars normally are associated with surface ships, whereas passive sonars are used primarily by submarines. Submarines also have active sonars. Integrated sonar systems aboard ASW vessels often employ passive equipment in conjunction with active equipment to extend their capabilities.

PASSIVE SONAR

Passive sonar depends entirely upon the target's noise as the sound source. So efficient is passive sonar that sounds many miles away may be identified and their source tracked.

An electoacoustic transducer, called the hydrophone (fig. 7-12), is used to detect underwater sounds. The hydrophone contains either

72.62
Figure 7-12.—Hydrophone.

a ceramic material or a metal alloy that reacts to mehcanical stress. When subjected to stress, such as that caused by sound waves striking the hydrophone, the material vibrates or undergoes a change in size. These vibrations or changes in size cause a small voltage output from the hydrophone. The frequency of the output voltage is essentially the same as that of the received sound waves.

Passive sonars at one time used the single line hydrophone system, which was trained physically to obtain bearing information. Today's passive sonars utilize a hydrophone array, consisting of a number of hydrophones connected together around a cylinder. Although the array is not trained physically, a directional effect is obtained electrically by employing a compensator switch. The switch is rotated and positioned by the sonar operator at the control console. A simplified block diapgram of the array type of passive sonar is shown in figure 7-13.

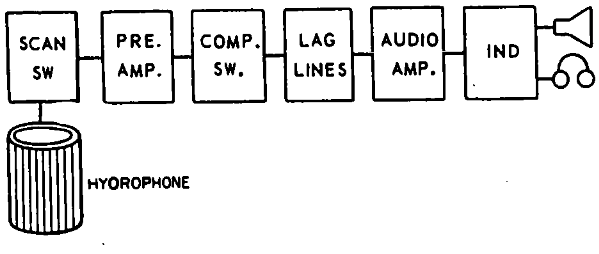

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Figure 7-13.—Block diagram of array type of passive sonar.

When the sound waves are received by the individual hydrophones, they are converted to electrical energy. The electrical signal from each hydrophone in the array is then fed to a separate preamplifier. After amplification, the signals are collected by the compensator switch as it samples the output of each preamplifier. From the switch, the collected signals enter the lag lines. The position of the switch indicates the direction from which signals are being received.

The circular arrangement of the hydrophones causes the signals to be out of phase with one another at the output of the preamplifiers. For the signals to be usable, they must be placed in phase with one another. This action is accomplished in the lag lines by delaying the first received signals a proportional amount until the last received signals catch up. Once the signals are in phase, they are additive. As a result, we have a strong signal to feed to the audio amplifier.

From the audio amplifier, the signal is fed to the indicator, and there it is presented both visually and audibly.

ACTIVE SONAR

The major components of a simplified active sonar system are similar to those seen in figure 7-14. In this set, the sonar transmitter consists of an audiofrequency oscillator and an amplifier. The transmitter feeds a short powerful pulse to the transducer for transmission into the water. The signal pattern is transmitted in 360° of azimuth in an omnidirectional pulse.

The transducer converts electrical signals into sound waves. It also changes the received sound echoes back to electrical signals.

Another important part of the active sonar system is the sonar receiver. It functions much the same as the conventional superheterodyne receiver. In this unit, the extremely small audiofrequency electrical signals resulting from the echo are amplified and converted to stronger signals that can be heard through a loudspeaker. The sonar receiver also feeds the amplified echo signal into the various video indicating devices such as the cathode-ray tube (CRT) on the control indicator.

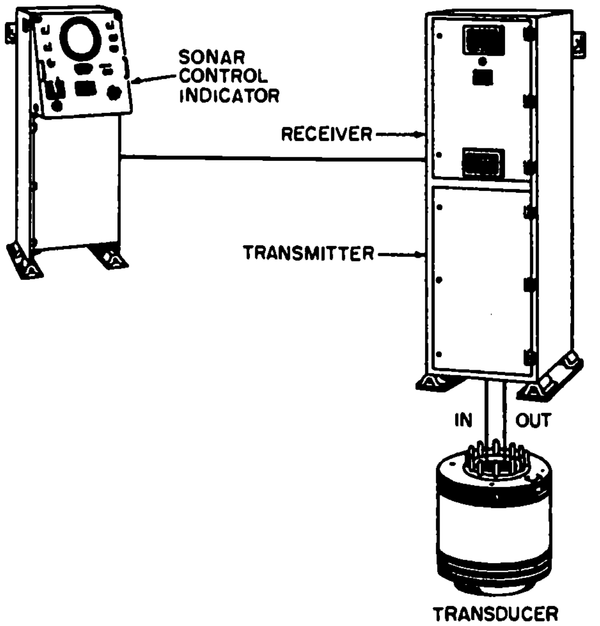

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Figure 7-14.—Simplified active sonar system.

Types of Transmission Modes

There are two widely used transmission modes. These are the omnidirectional transmission mode (ODT) and the rotational direction transmission mode (RDT). Omnidirectional transmission involves the radiation of sound energy in all directions to produce a 360° circular radiation pattern. This nondirectional sonar tranducer also receives returning echoes from all directions and converts them to intelligible video and audio information, thus providing indications of all underwater objects around the ship.

Rotational direction transmission involves the transmission of a directional beam which can be pointed through 360 degrees. An analogous effect can be obtained by holding a flashlight horizontally and turning it on and off (pulsing) while rotating yourself clockwise to complete a circle (azimuth). By electronically scanning in this manner, the transducer can also receive echoes from all degrees of azimuth.

Transmission

The functions of the principal components in a scanning sonar system are understood best by breaking them down into three basic operations: transmission, reception, and presentation. In the following discussion, refer to the block diagram in figure 7-15. This illustration shows the keying pulses and transmitted output signals in solid lines; returning echo signals are indicated by dotted lines.

Initiating keying pulses is an automatic function of the keying circuits in the sonar control indicator. The time between pulses, as well as the duration of each pulse, is determined by the position of the controls on the indicator console.

A pulse originating in the keying circuits is sent simultaneously to the transmit-receive (T/R) switch and to the transmitter. When this pulse is received by the transmit-receive switch, the transducer is switched from the receiver circuits to the transmitter circuits, and it remains connected there until the outgoing signal is transmitted. At the end of the transmission, the switch automatically reconnects the transducer to the receiver circuits.

The key pulse triggers the audio oscillator in the sonar transmitter. The signal generated by the oscillator is amplified to the required power level, and then is delivered to the transducer via the transmit-receive switch. The signal is applied simultaneously to all of the transducer staves (fig. 7-11), and a sound pulse is emitted in all directions.

The acoustical wave released into the water by the tranducer continues outward, ever expanding as it goes. When this wave strikes an object capable of reflecting the sound, a small portion is reflected back to the transducer.

Reception

When a portion of the transmitted signal is returned to the transducer, it is converted to an electrical signal for use by the equipment. After conversion the signal is fed to a preamplifier (via the transmit-receive switch) for amplification to a usable energy level. Each stave of the transducer has its own preamplifier. The outputs of the preamplifiers are sent to the transducer scanning assembly for distribution to the receiver. The transducer scanning assembly contains a video scanning switch and an audio scanning switch.

The video scanner rotates continuously, thereby sampling the echoes from each element of the transducer, giving an effect similar to

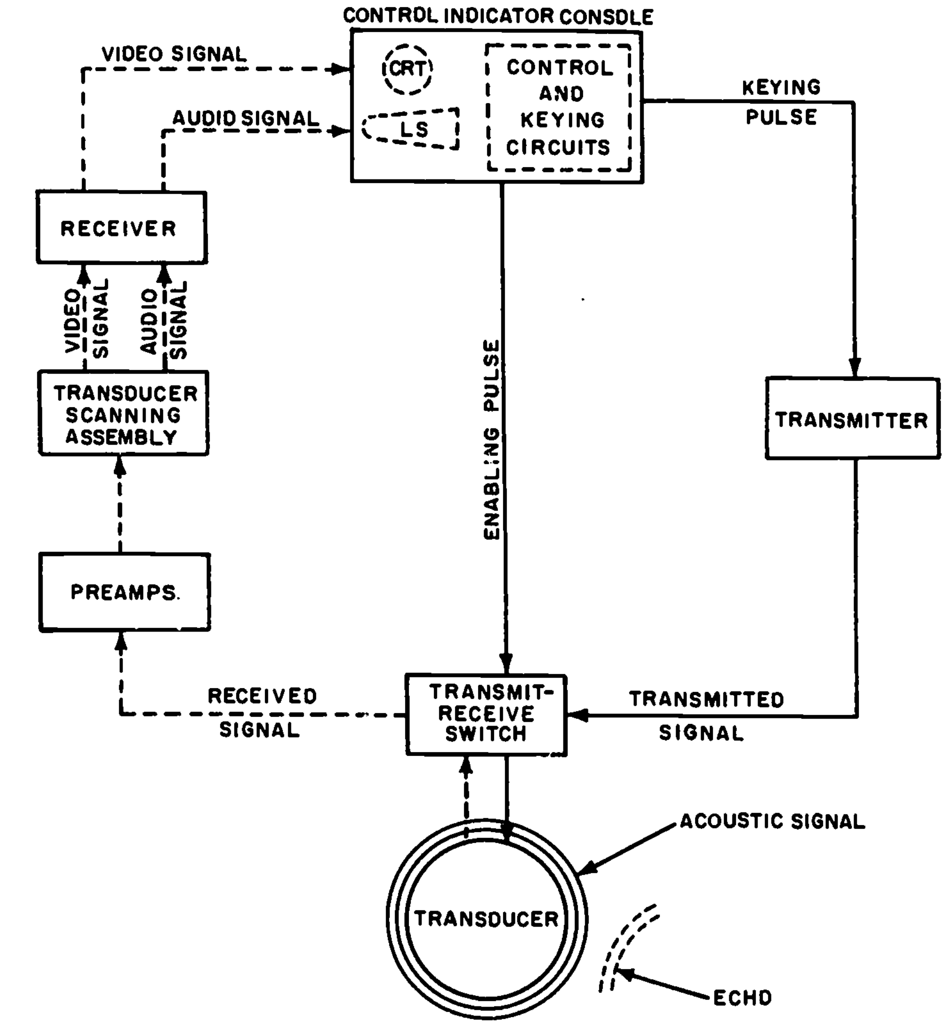

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Figure 7-15.—Block diagram of a basic scanning sonar system.

that produced by a rapidly rotating and highly directional transducer. The received signal at the receiver input comprises both video and audio signals (fig. 7-15).

The audio scanner does not rotate continuously. It is positioned as desired by the sonar operator. In this manner, audio signals can be received from any particular direction. The output from the audio scanning switch is applied to the audio channel of the receiver.

In the receiver, the video and audio signals are detected and amplified, as necessary, for presentation in the control indicator console.

Presentation

For the returning echo to be of any value, it must be presented in such a manner that the information it represents can be interpreted.

Before entering the receiver, the returning echo is converted from acoustical energy to electrical energy in the transducer, from which it is sent to the video scanning switch (not shown). The rotation of this switch is synchronized with the sweep presentatation, and the echo appears as a brightening of the sweep on the CRT at the bearing from which it originated. The sweep, seen on the CRT as an expanding circle, is adjusted to expand at a rate proportional to half the speed of sound in water. This adjustment is necessary because the transmitted pulse must travel to the target and return.

For a target 2000 yards away, as an example, the sound must travel a distance of 4000 yards. By adjusting the sweep on the CRT to travel at half the speed of sound, the sweep reaches a point equivalent to 2000 yards from the center of the scope at the same time the sound energy returns to the transducer. This energy, or echo, produces a brightening on the scope at a distance from the scope center. The distance can be measured to find the range to the target.

The audio signal is sent from the receiver to the loudspeaker or headset. Together with the CRT information, the audio intelligence is utilized in ascertaining the nature of the target.

A line called the cursor is printed on the scope after each sweep. Because of the long persistency of the cathode-ray tube, the target echo remains visible for a short time to determine range and bearing. The operator can control the direction (bearing) and length (range) of the cursor with the bearing and range handwheels. By placing the tip of the cursor on the target, he can read the target's true bearing and range from the dials located on the sonar control indicator.

Various switchs and controls also are located on the sonar control indicator. Their purpose is to give a better target presentation. These switches and controls are explained in the equipment technical manual supplied with each sonar equipment.

VARIABLE DEPTH SONAR

The thermal layer in the ocean is one of the problems affecting the ability of sonar to detect and maintain contact with a submarine. These layers reflect or bend sonar signals so, that a submarine lying or cruising below a particular layer may go undetected. To overcome this obstacle, the variable depth sonar (VDS) was developed.

To differentiate between the two types of sonars, the conventional sonars are sometimes referred to as hull systems while the VDS are referred to as towed transducer systems.

Because the target depth usually is unknown, a combined use of VDS and hull-mounted sonar provides coverage for both deep and shallow targets. (VDS alone does not always give adequate coverage for shallow operating targets.)

When used in this manner, there are four operating conditions which can be selected by the operator. They are (1) hull transmit and receive, (2) towed transmit and receive, (3) towed transmit and hull receive, and (4) hull transmit and towed receive. Operating frequency of the towed transducer is derived from the existing shipboard sonar equipment.

The general function of the VDS equipment is to make use of the pulsed power for the transmission of sonar signals by the shipboard sonar equipment. This pulsed power is transmitted via the electrical cable that extends through the center of the mechanical armor of the tow cable to the towed transducer. The transducer, operating on acoustic principles, converts the electrical energy to mechanical energy and transmits it to the surrounding water. When the transmitted sound wave strikes an object with adequate reflective characteristics, a portion of the total energy is reflected back to the towed transducer. The direction of the echo indicates the bearing of the object. The transducer then converts the mechanical energy of the echo into an electrical signal, whose magnitude and phase are determined by the intensity of the received echo. This electrical signal is transmitted up through the tow cable to the sonar system for display and interpretation.

A later type of VDS is the IVDS (independent variable depth sonar) which has its own hoist and sonar system independent of ships sonar system.

MINE HUNTING SONAR

Until relatively recent years minesweeping was the only available means for eliminating the danger of mines in naval warfare. It still is one of the prime methods of removing or neutralizing these hazards to safe navigation, but supplementing this plan is the procedure of detecting the actual location of the mines so that sweeping operations may be employed in only the exact required locations.

In many instances, the known location of mines is sufficient to neutralize their effectiveness. Marking the location of a minefield with buoys permits ship traffic to remain clear of the danger area. Thus no further action is required when this obstruction can be bypassed safely and expeditiously.

Mine hunting includes all measures for detecting, accurately locating, identifying, and clearing mines individually. The location of mines by means of high-resolution, short-pulse sonar, mine detecting sets is becoming increasingly successful. Mine hunting sonar aids in distinguishing between mines and the accumulated debris cluttering the bottoms of busy harbors and their approaches.

FATHOMETER (DEPTH-SOUNDING SONAR)

The depth of the sea can be measured by several methods. One is by dropping a weighted, distance-marked line (lead line) to the bottom of the water, and observing the depth directly from the line. The chief disadvantage of this method of determining depth is that its use is limited to very shallow water.

Sound is another method of measuring depth. A sound pulse is transmitted, aimed at the bottom of the sea, and its echo is heard. The time between transmission and echo reception is considered in relation to the speed of sound through water, then the depth is determined thereby. Depth-sounding sonars, or fathometers, apply this principle of sound physics to determine the distance to the bottom of the sea.

Usually, depth-sounding sonars are called fathometers. They operate on the same principle as subm' rine-detecting sonars, but, because of the reduced power requirement, they are much smaller in size and have fewer components. A representative block diagram of a depth-sounding sonar system is shown in figure 7-16.

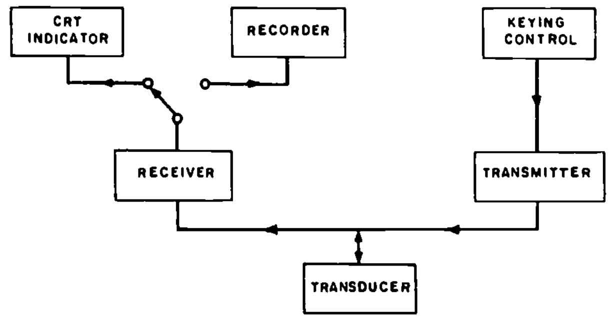

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Figure 7-16.—Block diagram of depth-sounding sonar system.

When the system is keyed (either automatically or manually), a pulse is generated in the transmitter. The pulse is amplified and applied simultaneously to the transducer and the receiver circuit. The transducer converts the signal to acoustical energy and transmits it downward into the water.

The returned bottom echo is converted by the transducer to electrical energy and applied to the receiver. The received signals are amplified and presented on the recorder or the cathode-ray tube indicator.

SONAR ACCESSORIES

In many instances, it is difficult to categorize an equipment as an accessory because of its role in the overall sonar system. For example, the remote indicator is seldom thought of as an accessory. It is not essential to the operation of the basic sonar system, consequently it is an accessory. The bathythermograph is isolated from any sonar system. The information obtained from the bathythermograph is necessary, however, for the effective utilization of sonar.

The foregoing accessories and others are described and illustrated in the next chapter.

CHAPTER 8

SONAR EQUIPMENT

The future success of the Navy in maintaining control of the seas will depend to a considerable extent on her ability to cope with the high-speed nuclear submarines.

Immediate and compelling, then, is the need for submarine detection capabilities at significantly increased ranges, with reliable performance independent of the water characteristics of any particular operating area.

Sonar sets are used for detecting, tracking, displaying underwater targets, and navigation. This is accomplished by echo ranging and passive listening. Target presentation is provided visually on indicator scopes and audibly by loudspeakers or headphones.

Passive (listening) sonars are used more aboard submarines and at harbor defense activities than aboard ships. Therefore, they are not covered in as much detail in this chapter as are the active sonars.

SURFACE SHIP EQUIPMENTS

Sonar equipment installed on board surface ships include hull-mounted equipments, variable depth equipments, mine hunting equipments, fathometers and sonar accessories. Representative types of these equipments follow.

SONAR SET AN/SQS-4( )

The AN/SQS-4( ) search sonar is an old set which is found on a few ships of the active fleet. It operates on the azimuth scanning principle. Like other scanning sonars, it is an omnidirectional echo ranging and passive listening equipment. It provides a continuous video display of acoustic reception in all directions, and an audio response from any desired single direction.

The AN/SQS-4 also has a built-in test set and control unit. The test set and its control provide facilities for testing and calibrating the sonar system, and for training sonar operators in the use of the system.

Most of the AN/SQS-4 equipments have been modified. The modifications (identified as MODS 1 through 4) can operate in the RDT mode and have received new designations as shown in table 8-1.

Table 8-1

OPERATING FREQUENCY	NEW DESIGNATION	OLD DESIGNATION
8 kHz	AN/SQS-29 ( )	AN/SQS-4 Mod 1
10 kHz	AN/SQS-30 ( )	AN/SQS-4 Mod 2
12 kHz	AN/SQS-31 ( )	AN/SQS-4 Mod 3
14 kHz	AN/SQS-32 ( )	AN/SQS-4 Mod 4

SONAR SETS AN/SQS-29( ) TO -32( )

The AN/SQS-29( ) to -32 sonar sets are identical except for frequency determining components. Because of this similarity, only the AN/SQS-31 (fig. 8-1) is shown as representative of all of these equipments. The frequency bands are spaced so that interference between sets is held to a minimum. The nominal operating frequency of each is listed in table 8-1.

These sonar sets offer a choice of pulse lengths, namely 2, 7, 30, or 120 milliseconds. The pulse length controls the amount of energy leaving the transducer. The power output can vary between 4 KW in handkey modes to 50 KW in normal echo ranging modes.

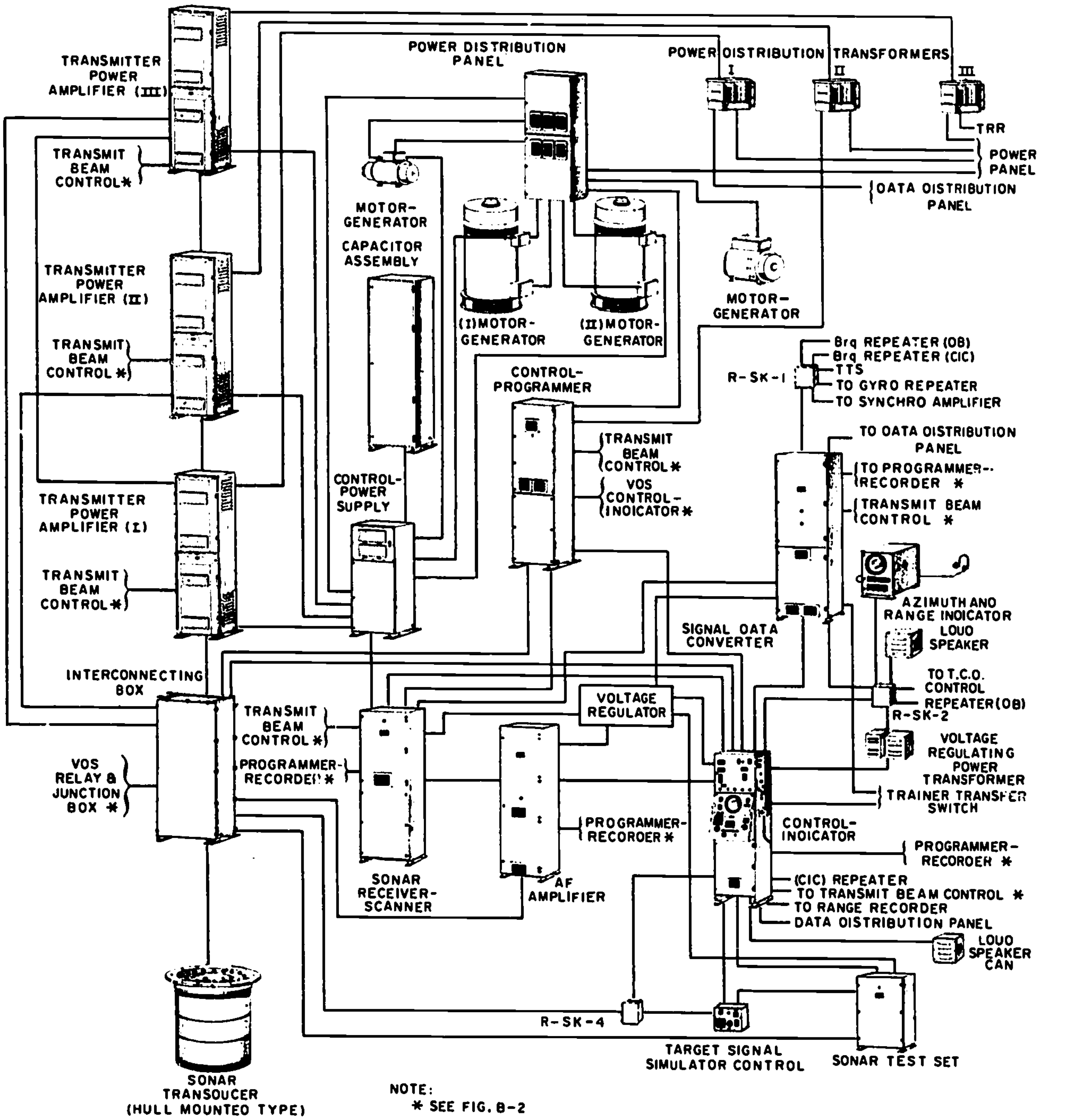

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Figure 8-1.—Sonar Set AN/SQS-31 system.

Available modes of operation are (1) listening for echoes without transmitting (passive listening), (2) echo ranging at 1000, 2500, 5000, 10,000, 15,000 and 30,000 yards, (3) omnidirectional transmission and (4) rotating directional transmission (RDT).

When the equipment is set for passive listening, the scope picture is a continuously expanding circular sweep using the outer two-thirds of the PPI. The sweep recycles at the same rate as the 5,000 yard scale. Signals from an underwater noise source appear on the screen as a narrow radial line or a wedge of light. Bisecting the wedge with the cursor gives the bearing of the noise source. Range cannot be determined because the noise source is not returning an echo.

In the echo ranging mode of operation, the cycle commences with the cursor appearing on the PPI scope at the instant a transmitted pulse is leaving the transducer. After the pulse is transmitted, the cursor disappears from the scope, and an electron beam spirals out from the center of the screen in an ever enlarging circle at a rate proportional to one-half the speed of sound in sea water. Sweep of the electron beam is synchronized with the rotation of the video scanning switch in such a way that a returning echo brightens the scope at a spot corresponding to the range and bearing of the object that produced the echo. Because the system is alert in all directions and echo indications remain for a short time on the screen, the scope becomes a map of all echo-producing objects in the vicinity of the ship. After each scan period, the circular sweep fades out (or blanks), the transmitter is energized with a new pulse of energy, the cursor reappears, and a new cycle begins.

When operating in the rotating directional transmission (RDT) mode of operation, the total power available for omnidirectional transmission will be concentrated into a directional transmission beam that covers a narrow sector at any given instant. This beam is then caused to rotate a maximum of 360° in azimuth around the ship. Coverage is limited to a maximum of 300° and a minimum of 30°, selectable by the operator. In normal operation for search, the transmit sector width is 300° oriented about the ship's bow. The benefits attained from RDT are greater power of transmission and improved ranges.

The AN/SQS-29 to -32 series have a test set and control unit as a part of the system. The test set and its control unit provide facilities for testing and calibrating the sonar receiving system.

These sonar sets, along with later sonars, may utilize Acoustic Short Pulse Echo Classification Technique (ASPECT) equipment, giving a short burst of transmissions in a steered beam for greater accuracy in classifying sonar contacts.

When ASPECT equipment is installed (fig. 8-2) a transmit-beam control and a programmer-recorder are added to the sonar equipment. The transmit-beam control has a steered beam transmit scanner for short pulse operation. The programmer-recorder controls transmission and reception periods and receives the returning short pulse-echoes, printing them on a recorder chart. Programming eliminates the necessity of continual changes as the range increases or decreases. Since the sonar scope is blanked during ASPECT operation, this gives the highest information rate while minimizing the probability of losing the target echo due to changes in range.

A few of the AN/SQS-29 to -32 series are further modified to permit use of the AN/SQS-10 variable depth sonar (discussed later in this chapter).

When the AN/SQS-29 to -32 series receives the MARK (Maintainability And Reliability Kit) modification, the sets will become the AN/SQS-39, -40, -41, and -42 series sonars. The MARK program is a combined effort to extend the usable life of the sonar sets and improve their operation and maintainability.

SONAR SET AN/SQS-23( )

The AN/SQS-23( ) sonar detecting-ranging set is a scanning type of search and attack sonar equipment which uses some of the desirable features of the AN/SQS-29 to -32 series of sonars. Besides passive listening, as with all sonars, it will echo range at any one of six range scales; 1000, 2500, 5000, 10,000, 20,000 and 40,000 yards with a 5 kHz operating frequency and pulse lengths of 2 (later models 5), 30, or 120 milliseconds.

A directional sonic beam rotates around the transducer to form the echo ranging transmissions. The transducer is designed so that it can be excited without damage at moderately high-power levels. The transmission frequency of the equipment, combined with rotating directional transmission (RDT), makes this set effective for longer range target detection than previous sonars.

Features incorporated into the AN/SQS-23( ) include: (1) a means of lowering or raising the normal operating frequency a slight amount to minimize interference during multiship

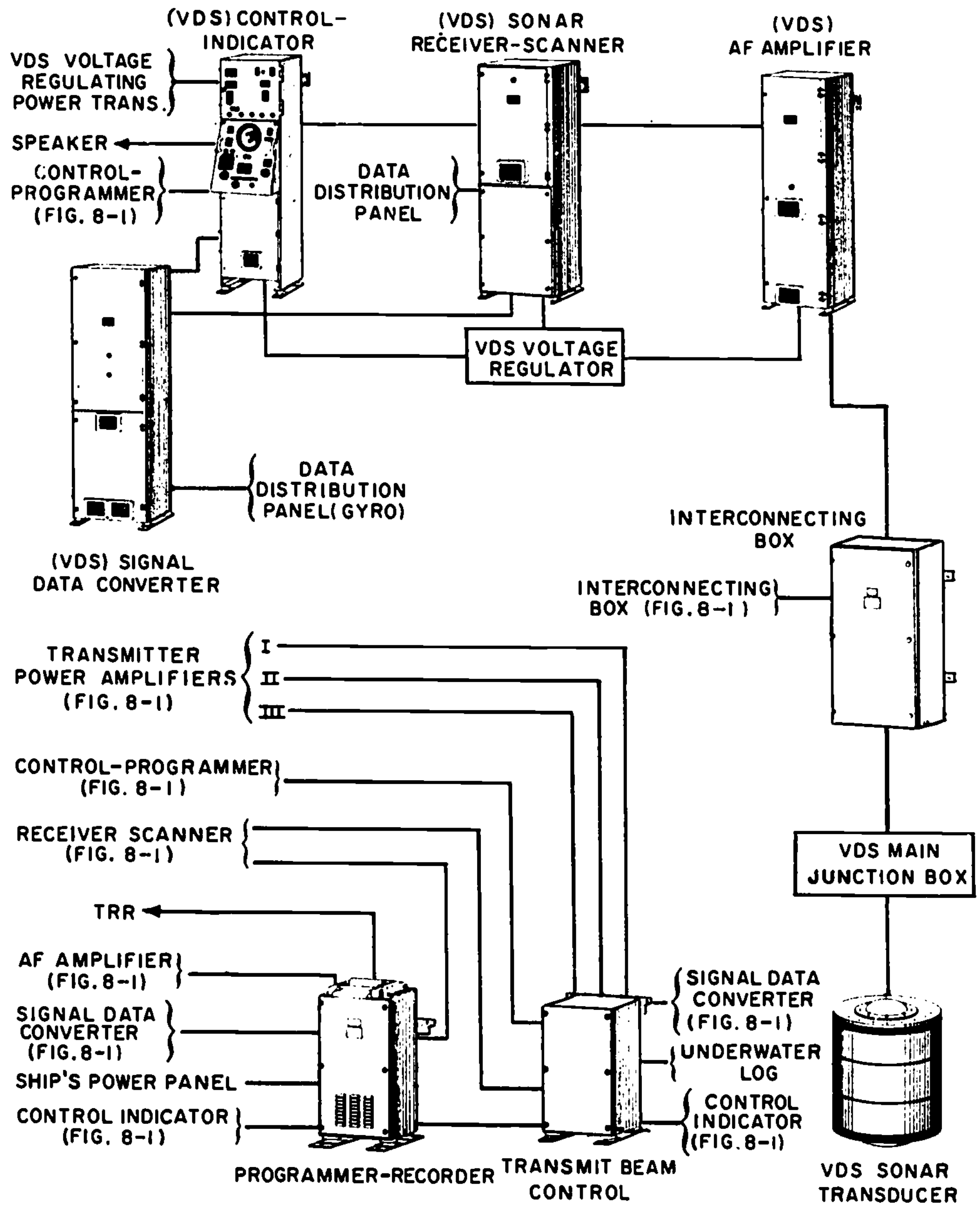

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Figure 8-2.—ASPECT system and variable depth sonar AN/SQA-10.

operations; (2) a beam depression control that permits a downward tilt of the transmitting and receiving beams for use in maintaining contact with close targets; (3) a built-in test set for use in evaluating the overall performance of the system; and (4) a unit for inserting synthetic and maneuverable target signals into the receiving circuits to provide for operator training.

Special programs have been developed for later models of the AN/SQS-23( ) sonar sets. These include TRAM (Test Reliability And Maintainability), and PAIR (Performance And Integration Retrofit). When the equipment has either the TRAM or PAIR modification, the Performance Monitoring Equipment (PME) is an integral part of the sonar system. This eliminates the necessity of having to open various receiving units to obtain a test point for metering and monitoring circuits that must be checked and adjusted for peak operation. The PME may also be used to record and reproduce taped signals for the indicator scope and loudspeakers for training in tactical situations.

The Test Reliability And Maintainability (TRAM) improves the test, reliability, and ease of maintenance of the sonar sets. This is accomplished by modifying the transmitting system.

The Performance And Integration Retrofit (PAIR) will improve total system performance by replacing the entire receiver indicator group.

When these special programs have been completely installed in the present AN/SQS-23 it is scheduled to be designated the AN/SQQ-23 integrated sonar system.

SONAR SET AN/SQS-26( )

The AN/SQS-26( ) sonar is a more recently developed advanced search track and attack sonar that represents a radically improved approach in concept and in application to the present-day problems of submarine detection. Detection features and operational flexibility of this equipment permit long-range coverage independent of the depth and speed of the target.

The 5. basic modes of operation for the AN/SQS-26( ) are: (1) omnidirectional transmission (ODT); (2) rotating directional transmission (RDT); (3) convergence zone (CZ), (4) bottom bounce, and passive detection.

VARIABLE DEPTH SONAR SET AN/SQA-10

Essentially, the variable depth sonar (VDS) is a conventional sonar that is modified to transmit and receive signals through a transducer contained in a towed vehicle (fig. 8-3). By means of a crane type hoist and a tow cable, the vehicle is lowered below the interferring thermal layers and then towed behind the ship. Thus, the effect of the surface thermal layers on the sonar signals is minimized.

At present, the most widely used variable depth sonar is the AN/SQA-10 Sonar Set. This set is used extensively with the AN/SQS-29 to -32 sonar series and sometimes with Sonar Set AN/SQS-23( ).

With the VDS modification, transmission and reception are available through either of two transducers, one hull mounted and the other a variable depth transducer. Either omnidirectional or RDT transmission, as selected by the operator, is available through each transducer in VDS. The towed or variable depth transducer permits transmission and reception at a selected depth below the surface of the water to achieve optimum sonar performance, and repositioning of the transducer as oceanographic conditions and tactical situations change. The VDS system (fig. 8-2) may incorporate its own receiving and display system, or use the normally installed equipment. In the latter case the operator selects the transducer to be used by means of a selector (Hull/VDS) switch.

MINE-HUNTING SONAR

Mine hunting includes all measures of accurately detecting, locating, identifying, and clearing mines INDIVIDUALLY. The clearance may be accomplished by explosive destruction, by rendering safe, or by sweeping. The following are two mine-hunting equipments which are used for detecting and locating mines.

Mine-Detection Set AN/SQQ-14

The AN/SQQ-14 (fig. 8-4) is a dual-purpose sonar, which can be installed either as a hull-mounted sonar or operated as a variable-depth sonar. When operating as a VDS system, a towed body is used to house the transducers making it possible to operate at various depths. The high detection probability of the set is accomplished by a wide scanned field of view and a high resolution in both range and azimuth.

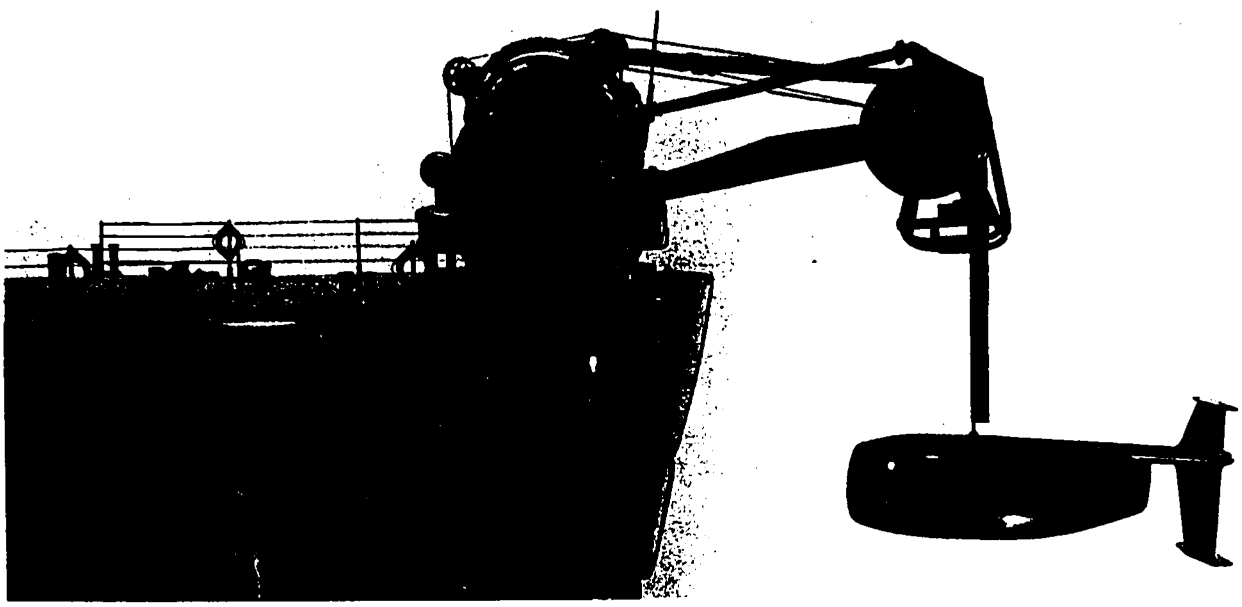

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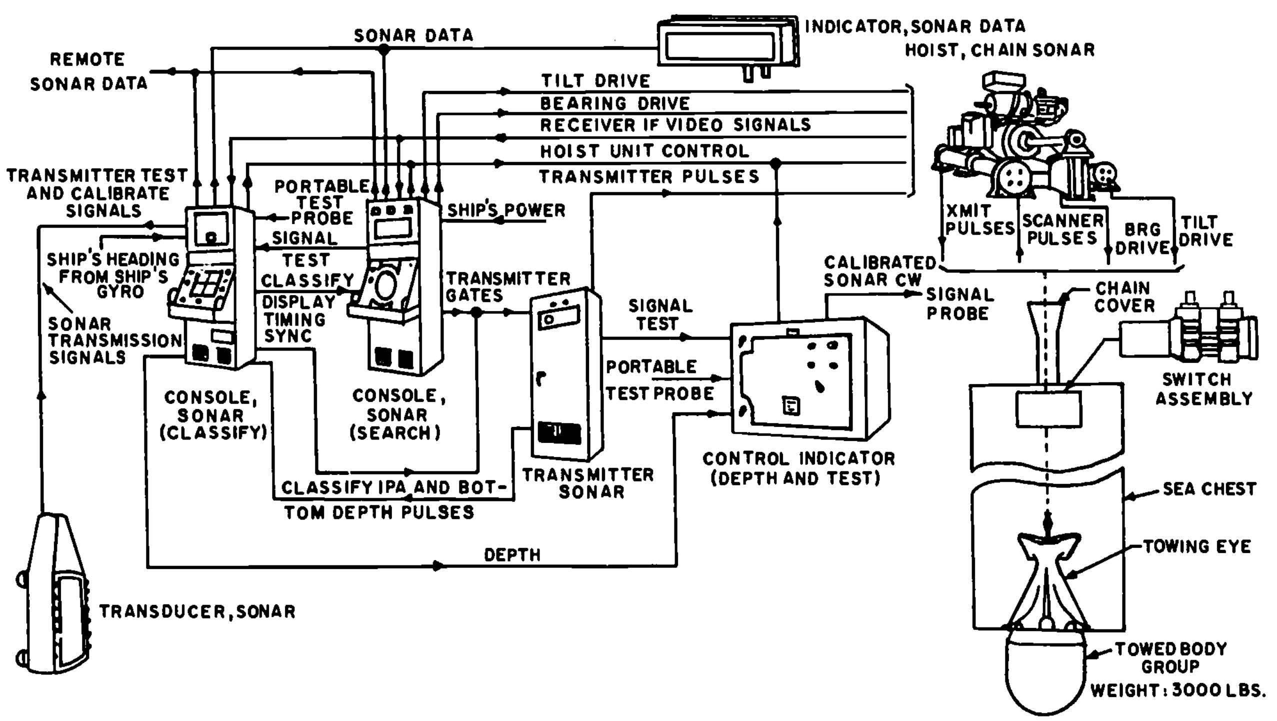
Figure 8-3.—Towed vehicle for VDS (in suspension).



120.93

Figure 8-4.—Mine-Detection Set AN/SQQ-14 system.

After detecting an object, the sonar's classification mode allows a trained operator to quickly distinguish whether the object is minelike, or non-minelike bottom clutter such as sunken oil drums, foot lockers, or anchors. The two consoles permit one operator to search and the other to classify mines simultaneously.

Mine-Detection Set AN/UQS-1( )

The AN/UQS-1( ) sonar (not shown) employs two transducers (transmitting and receiving) enclosed within a single housing. The transmitting (projecting) transducer uses the electrostrictive process to transmit a sonic beam into the water that covers an arc 60° in azimuth and 10° vertical. Echoes reflected from underwater objects are received by the receiving transducer, converted into an electrical signal, and applied to the PPI scope, showing an indication of range and bearing of the object.

Either manual or automatic searching is available. In manual operation, the transducers are caused to rotate as a bearing handwheel is rotated, searching through 360° in azimuth at selectable ranges of 200, 500, and 1000 yards. When operating automatically, the transducers may be caused to rotate through 360° in azimuth, to search all around the ship, or to rotate back and forth through an arc 90° in azimuth, searching from 315 relative to 045 relative ahead of the ship. (A field change to the equipment provides for an automatic sweep of 180° ahead of the ship.) For automatic search, the equipment can be set to search in ranges of 200, 500, or 1000 yards. Whether searching manually or automatically, the operating angle of the transducers is controlled manually by a handwheel. The transducers may be tilted to cover from plus 5° to minus 50° in depression. The angle of tilt can be observed on a depression indicator dial, which shows the angle of depression of the sound beam.

The scan pattern appears on the face of the scope as a 20° triangular sector with the vertex of the sector at the center. Targets are indicated on the scope as a bright spot at the correct range and bearing of each target.

Mine Detection Range Set AN/PQS-1C

The AN/PQS-1C (fig. 8-5) is a portable hand-held sonar set used by SCUBA divers during diving operations. It is incased in a waterproof hemispherical housing. A compass is located on top of the housing which can be illuminated by a switch to provide the diver with an indication of the location of the detected underwater objects.

The AN/PQS-1C has two modes of operation. The search mode and the passive-listening mode. The search mode transmits an ultrasonic wave which sweeps through a 30 kHz bandwidth within the limits of a 50 to 90 kilohertz frequency range. A transducer and reflector directs the transmitted ultrasonic waves into a narrow beam to provide precise angular sensing of the target location. The returning ultrasonic echo is combined with a sample of the transmitted signal, producing a difference in frequency proportional to the distance from the target. The lower the tone of this audiofrequency, the closer the operator is to the reflecting object. Three angle scales (20, 60, and 120 yards) are provided. The receiver compensates for variations in echo signal strength and delivers 100 milliwatts of power to the head set within the audiofrequency range of 250 to 2500 hertz.

During search operations, SCUBA divers will set the range switch to a range commensurate with the depth of the water and submerge to the desired depth while holding the equipment so an echo is received from the bottom. The tone thus produced becomes lower in pitch as the bottom is approached. The range switch (fig. 8-5) enables the diver to search in a circular area having a radius of 120 yards slowly scanning the target area with the sonar beam and listening for a short-duration echo tone in the headset as the beam sweeps past an echo producing object. He continues moving toward the object until the audio tone in the headset is at a low pitch. The selector switch is then set on the 60 yard range position, and the audio tone will immediately increase to twice the pitch on the 120 yard range. This allows the operator to continue to close-in on the target, while listening for change in pitch. He continues moving toward the target until the audio tone is again at low pitch. The same procedure is continued at the 20 yard range until the exact object is located. If the target is a mine, procedures can be initiated for its destruction.

In the passive-listening mode, the equipment can be used to locate marker beacons

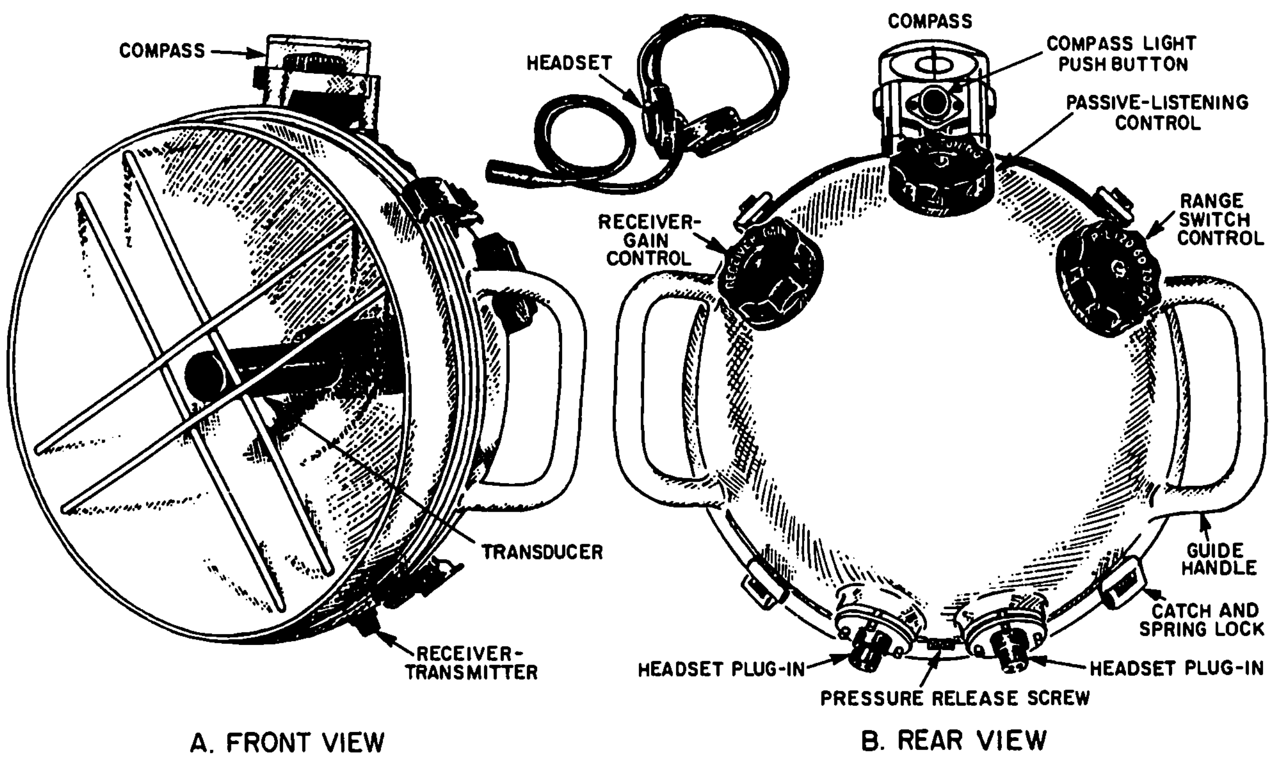


Figure 8-5.—Mine-Detection Range Set AN/PQS-IC.

operating in the 30 kHz to 40 kHz frequency range.

FATHOMETERS

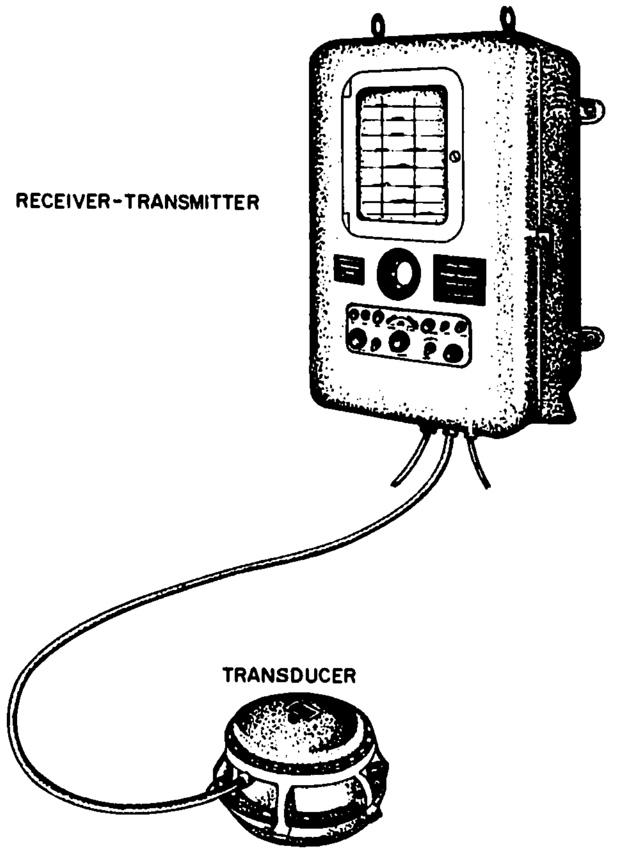
Fathometer equipments transmit accoustical pulses vertically downward and echo pulses are reflected back to the fathometer from ocean floor or from intervening objects. The interval of time required between transmission and reception is converted into a depth indication on a recorder chart or cathode ray tube (CRT) indicator. The fathometer is used primarily for navigation purposes. It also serves as an aid in gathering depth information for oceanographic topography, and is occasionally used as a sonar contact classification aid. The two fathometers used chiefly by the fleet in depth sounding for navigational purposes are the AN/UQN-1( ) and AN/UQN-4.

Depth-Sounding Sonar AN/UQN-1( )

The AN/UQN-1( ) fathometer and its transducer are shown figure 8-6. This fathometer is a compact unit, capable of giving reasonably accurate readings at a wide range of depth--from about 5 feet to 6000 fathoms. It uses the electrical stylus and sensitized paper method of recording depths. For shallow depths, it has a visual scope presentation.

Three recorder chart ranges are provided on the AN/UQN-1( ). They are 0 to 600 feet, 0 to 600 fathoms, and 0 to 6000 fathoms. In addition to recorder chart indications, two visual indicator ranges are available: 0 to 100 feet; and 0 to 100 fathoms. The equipment may be keyed manually or automatically.

When the fathometer is operating in any of the three recorder chart scales, a stylus starts down the recorder chart simultaneously with the transmission pulse. The stylus moves at a constant velocity and marks the paper twice—once at the top of the chart when the pulse is transmitted, and again on the depth indication when the echo returns. A depth recording made by a fathometer of this type is seen in figure 8-7. The recording illustrated was made from a ship sailing over a sea



62.9
Figure 8-6.—Depth-sounding Sonar AN/UQN-1( ).

whose depth was decreasing steadily. The first part of the trace was recorded on the 6000-fathom scale. Inasmuch as the paper moves from right to left, you can see, in the section of the paper shown, that the depth decreased from 4000 to 600 fathoms. (Later depth information is to the right of the paper.) When depth was about 600 fathoms, the scale was shifted to the 600-fathom setting. Because the depth decreased still further, the scale was shifted to the 600-foot setting when a depth of about 100 fathoms was recorded.

Visual indication is supplied by a circular sweep on the face of a cathode ray tube. Transmitted pulse and returning echo deflect the sweep trace radially. The visual indicator, pointing to a depth of 82 (feet or fathoms, depending upon the scale setting), is shown in figure 8-8.

Depth-Sounding Sonar AN/UQN-4

Sonar Sounding Set AN/UQN-4 is designed to indicate water depths ranging from 4 feet to 6000 fathoms, transitorily on a digital numeric display and permanently on a strip chart recorder. Digital numeric depth indication is achieved by counting the number of pulses provided by a clock frequency during the interval between the transmission of a transducer-generated sound pulse into the water and the reception of its echo from the sea bed. This count, after processing by digital countdown circuits, is indicated as feet or fathoms of depth on the numeric display.

To prevent false bottom depth indication by echoes returning from fish shoals, plankton layers or other anomalies, a "Range Gate" circuit insures that only signals received from within the confines of the gated range shall be effective at the digital readout. A permanent record is recorded on chart paper (similar to that shown in fig. 8-7) by a strip chart recorder.

The AN/UQN-4 has the capability of transmitting numeric depth information to remote indicators or sonar computers which can be located up to 1000 feet from the fathometer.

SONAR ACCESSORIES

Supplementing the basic sonar system are a number of equipments that either extend the capability of the system or facilitate its use. Some of this supplementary or accessory equipment forms an integral part of the overall sonar system, whereas other equipment in this category is completely isolated from the system.

AZIMUTH-RANGE INDICATORS

A complete azimuth search sonar installation includes one or two remote units called azimuth-range indicators. These units are remote video repeaters of the scope presentation at the sonar control indicator. They provide an indication of target bearing and range, and they have provisions for monitoring the audio response from targets.

The PPI (scope) display modes of operation (echo ranging or listening) may be presented in either of two ways: the ship center display

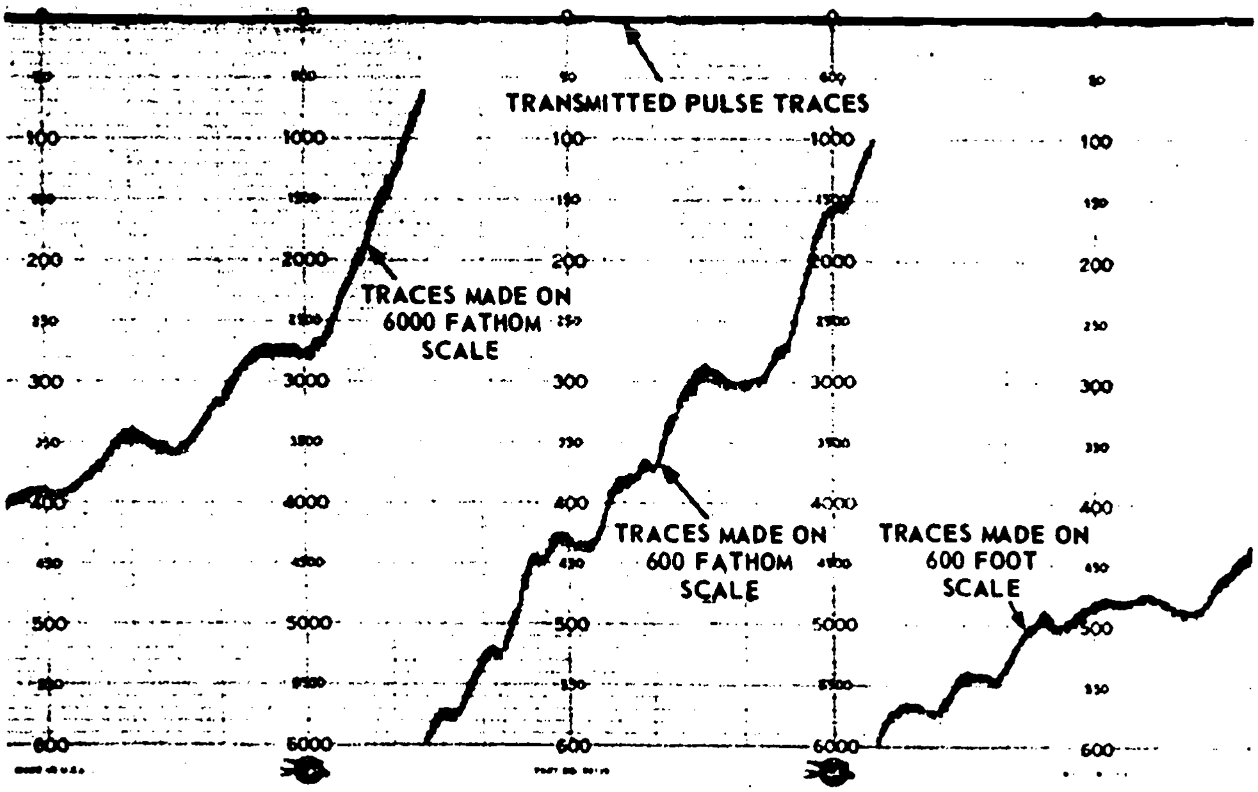


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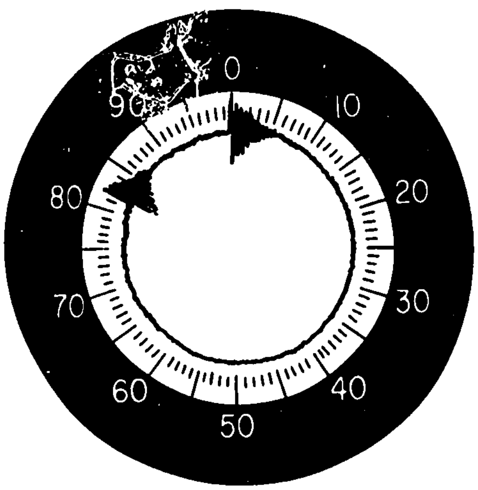
Figure 8-7.—Fathometer depth recording.



71.57

Figure 8-8.—Visual depth indicator.

(SCD), whereas the ship is depicted in the center of the scope display; or the target center display (TCD) in which the target is represented in the center of the display whenever the end of the bearing cursor is on target.

The SCD (fig. 8-9) utilizes a circular sweep starting at or near the center of the screen which indicates the position of own ship. Various underwater objects are represented by the bright spots (pips) that appear on the screen. The SCD is the normal operating mode because it allows the operator to observe many targets around the ship at one time.

The TCD (fig. 8-10) uses an expanded sweep with the target at the center of the scope. The sweep is enlarged to 2 1/2 times its normal size and is offset from the center on a reciprocal bearing from the cursor. This mode is used only as an aid to classification.

One common type of azimuth-range indicator, the IP-286/SQ, is illustrated in figure 8-11. This particular unit is used with installations

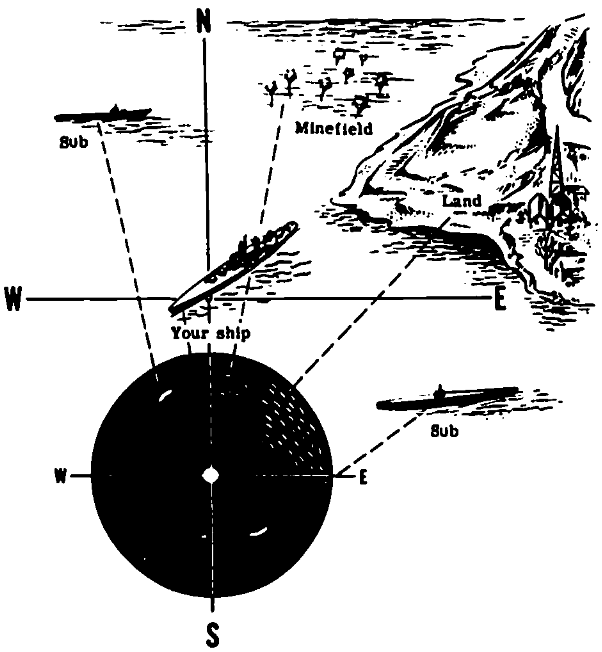


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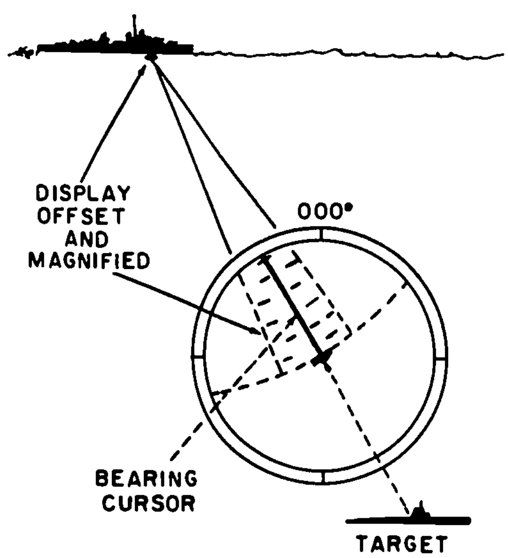
Figure 8-9.—SCD sonar presentation.



51.55(120C)
Figure 8-10.—TCD sonar presentation.

of the AN/SQS-29 to -32 series of sonars (discussed earlier). A similar unit, designated IP-481/SQ (not shown) is used with the AN/SQS-23 sonar equipment.

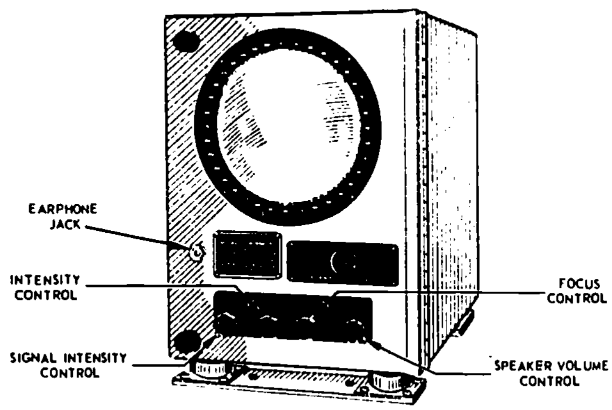


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Figure 8-11.—Azimuth-range indicator IP-286/SQ.

Controls on the front panel of the azimuth-range indicator affect the audio and video response of the remote unit, but do not affect operation of the sonar console. Three of the four controls are for adjusting the video display. The fourth, labeled SPEAKER VOLUME CONTROL, is used to adjust the audio output level.

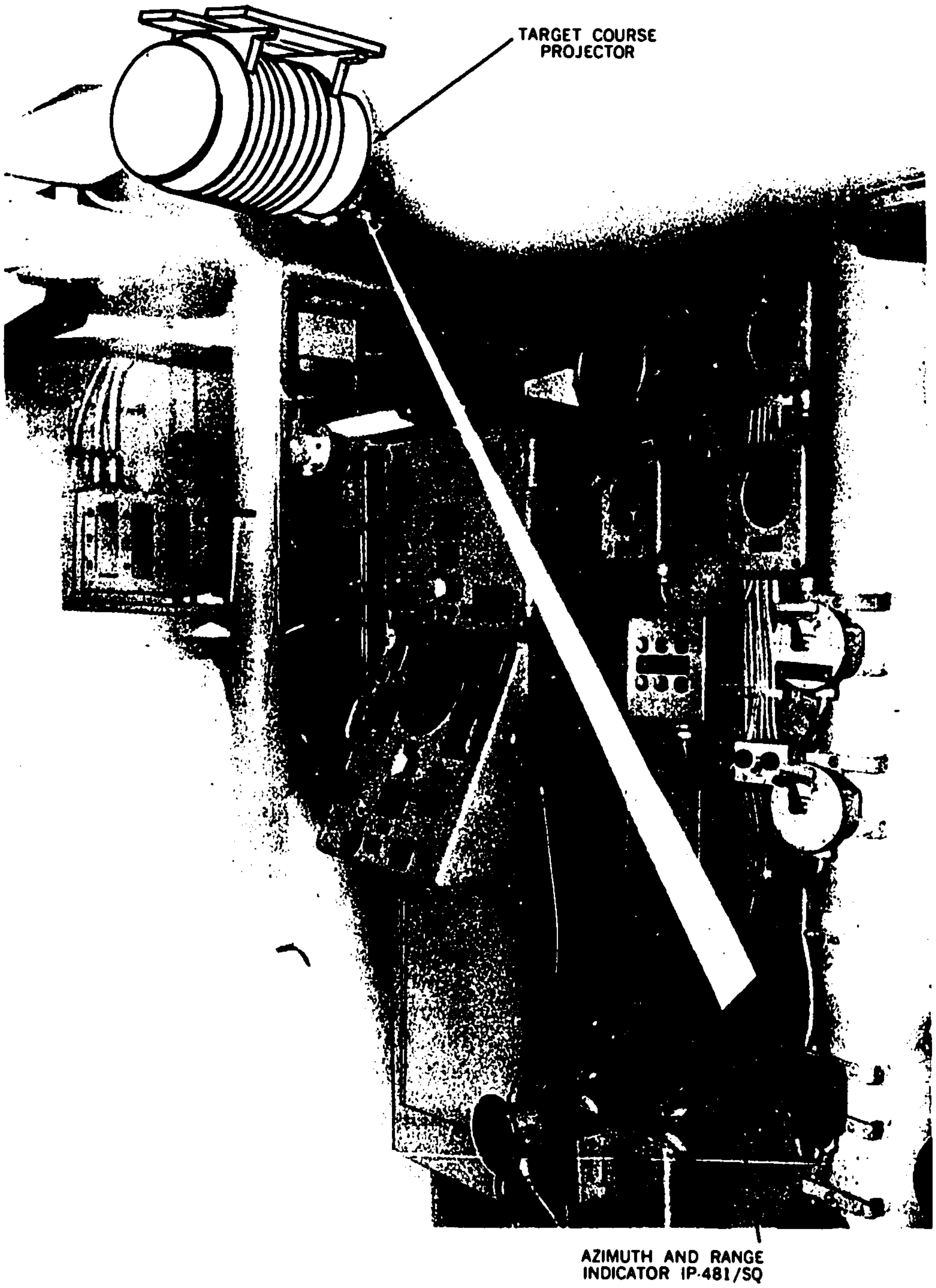
Target bearing is read from an azimuth ring surrounding the video presentation. Target range is indicated on two dials that are visible through a window opening. Audio response is heard from either an external speaker unit or headphones, as desired.

TARGET COURSE PROJECTOR

The target course projector (fig. 8-12) has a servosystem, transistor amplifier, and optical system. This unit is a sonar accessory which responds to target course orders from fire control, and projects a cursor image in the form of a red line on the screen of the range and azimuth indicator. The unit is located 4 to 5 feet from the CRT screen and mounted in such a position on the overhead that persons viewing the screen do not obstruct the light beam.

RECORDER-REPRODUCER

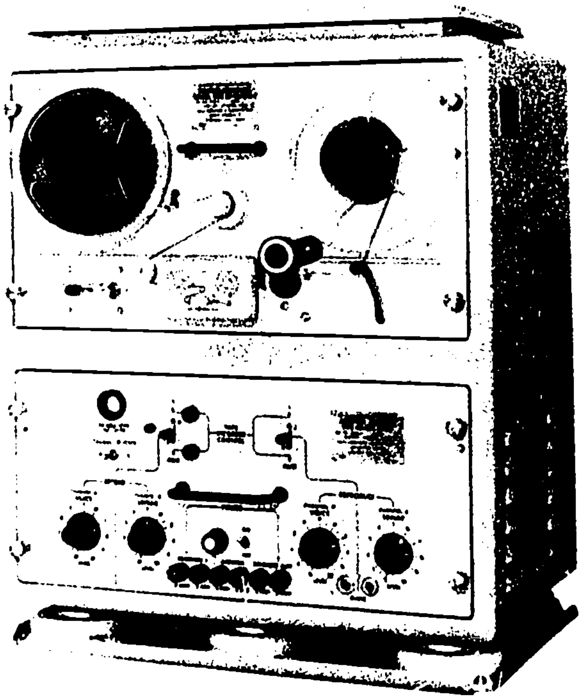
A tape recorder-reproducer is employed with most sonar installations to record audible sonar information of actual ASW operations.



15.99
Figure 8-12.—Target course projector, relationship to range and azimuth indicator.

Information thus obtained is utilized for post-analysis of ASW actions and for the aural training of sonar operators in echo recognition.

The AN/UNQ-7( ) recorder-reproducer set (fig. 8-13) is a two-track recorder and reproducer that uses magnetic tape to record its information. It stores for playback (immediately



7.54
Figure 8-13.—Tape recorder AN/UNQ-7( )

or indefinitely) the sounds it "hears" within the limits of the audible spectrum. Two channels (A and B) are utilized. Voice information from the vicinity of the sonar operator's station is fed to channel A. Channel B track normally is fed underwater sound information directly from the sonar equipment. Both tracks can be (usually are) recorded simultaneously, although either one may be recorded separately. In addition, the tape recorder allows simultaneous recording and reproducing of sounds. This feature permits monitoring what is being recorded as it is recorded.

When a recording is played back, both tracks can be heard at the same time, and both tracks can be controlled in volume or can be cut out entirely. In short, the AN/UNQ-7( ) tape recorder-reproducer acts as a combination of two tape recorders, coupled together, to allow superimposing upon each other, two audio information sources.

The top half of the tape recorder-reproducer, as seen in figure 8-13, is the actual recorder and reproducer. The lower portion is the amplifier section. It includes controls and indicators that directly affect the recording and playback of tapes. The recording controls are to the left of the amplifier section. Playback controls are at the right of the amplifier section. Both channels have separate controls for recording and reproducing.

BATHYTHERMOGRAPH

Pressure, salinity, and temperature affect sound travel through water. Increases in pressure speed up the velocity of sound, making the speed of sound higher at extreme depths where pressure is greater than on the surface. An increase in salinity also has a tendency to increase the velocity of sound in water. The effects of pressure and salinity are not as great, however, as those caused by changes in temperature.

Temperature, then, is the most important consideration to contend with in calculating variations in the speed of sound in water. Information obtained about the ocean temperature, at a given depth and time, can be used to predict what will happen to the transmitted sound beam as it travels through the water.

The bathythermograph, commonly called the BT, is an instrument for obtaining a permanent, graphical record of water temperature (in degrees Fahrenheit) against depth (feet) as it drops into the ocean.

Two types of bathythermographs are being used. The expendable and the mechanical. The expendable BTs record the readings automatically as the probe falls to the ocean depths. This is in contrast to the older mechanical BT system that requires retrieving the BT in order to obtain data recorded on a metallic coated glass slide.

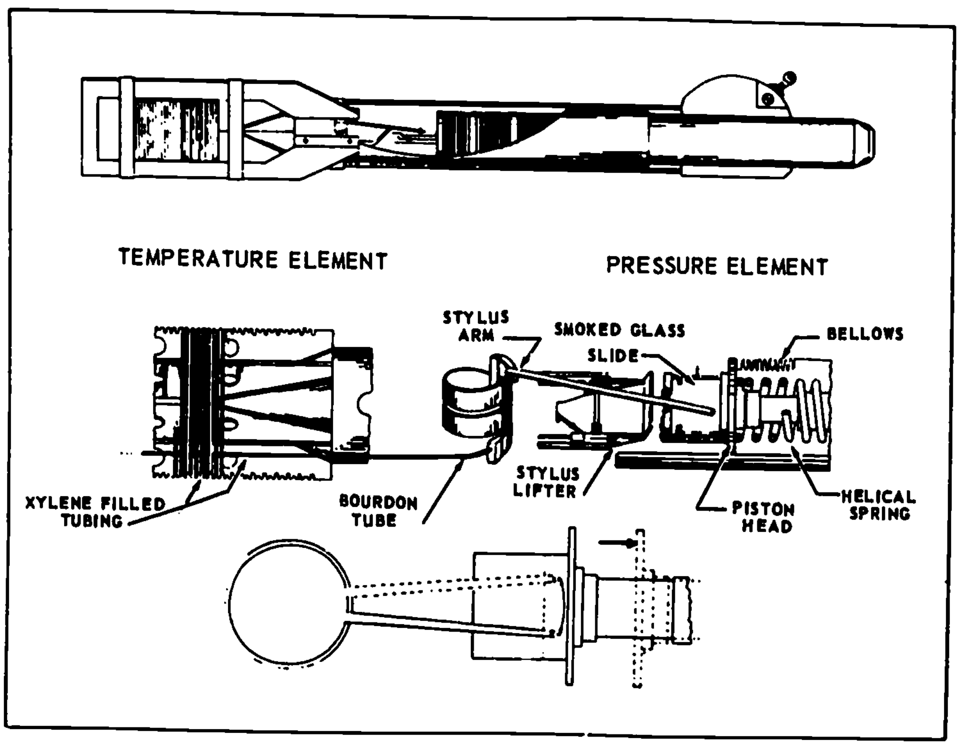
MECHANICAL BATHYTHERMOGRAPH

Mechanical bathythermographs are designed for use in measuring three different depth ranges. In general, a No. 1 designation means it is a shallow type, No. 2 means it is a medium type, and No. 3 indicates that it is a deep type BT. Table 8-2 lists the various BTs in use and gives their design depth.

The mechanical BT consists of temperature and pressure elements (fig. 8-14). The temperature element consists of about 45 to 50 feet of fine copper tubing filled with xylene.

Table 8-2.—BT Series Designations.

Series No.	Name	Maximum depth	Maximum Towing Speeds Nose Sleeve Without	With
OC-1S OC-1A/S OC-1B/S OC-1C/S	Shallow	200 feet	15 knots	22 knots
OC-2/S OC-2A/S OC-2B/S OC-2C/S	Medium	450 feet	10 knots	13 knots
OC-3/S OC-3A/S OC-3B/S OC-3C/S	Deep	900 feet	3 knots	6 knots



71.73

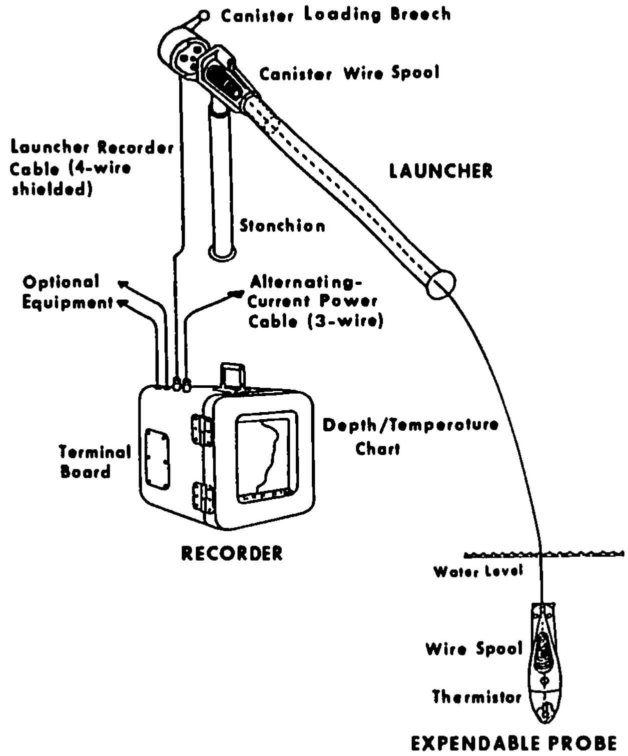
Figure 8-14.—Mechanical Bathythermograph temperature and pressure elements.

The tubing is wound around inside the tail fins of the BT, and comes into direct contact with the sea water. As the xylene expands or contracts with the changing water temperature, the pressure inside the tubing increases or decreases. This temperature change is transmitted to a Bourdon tube, a hollow brass coil spring, which carries a stylus at its free end. The movements of the Bourdon, as it expands or contracts with changes of temperature, are recorded by the stylus on a metallic-coated glass slide. The temperature range is from 28° to 90° F.

The slide is held rigidly on the end of a coil spring enclosed in a copper bellows. Water pressure, which increases in proportion to water depth, compresses the bellows as the BT sinks.

The dotted line drawings in the lower portion of figure 8-14 illustrate the action of the stylus moving left on the slide with a decrease in temperature and the bellows being compressed to the right (arrow) as depth increases. Increase in depth pulls the slide toward the nose of the BT, at right angles to the direction in which the stylus moves to record temperature. When the BT is raised toward the surface, the spring expands the bellows to its original shape. Thus, the trace scratched on the plated surface of the slide is a combined record of temperature and pressure, the pressure being proportionate to depth.

The mechanical type bathythermograph is being replaced by the expendable bathythermograph as they become available.



71.126
Figure 8-15.—Expendable Bathythermograph Set AN/SSQ-56.

EXPENDABLE BATHYTHERMOGRAPH AN/SSQ-56

The expendable bathythermograph AN/SSQ-56 (fig. 8-15) consists of an expendable probe, a launcher, and a recorder. The expendable probe contains a thermistor connected to a spool of fine wire. The wire is dereeled as the probe drops vertically through the water. The other end of the wire is wound on a second spool mounted within a probe canister aboard ship. As the ship moves ahead, this wire is also dereeled. The dual spooling technique allows the probe to free-fall from the exact point of sea-surface entry without being affected by the moving ship or sea state.

The nose of the probe is weighted and the entire unit is spin-stabilized to assure a known rate of descent upon launching. Changes in resistance of the thermistor due to temperature changes in the water are transmitted by the trailing wire to the shipboard recorder. Since the rate of descent of the probe is known, depth can be read directly from the vertical scale on the recorder. After the probe passes 1500 feet, its full scope of wire will be exhausted and the probe sinks to the bottom of the sea.

The chart type recorder is programmed to convert time and thermistor resistance into depth and temperature in units of feet and degrees Fahrenheit, or meters and degrees Centigrade. A continuous temperature/depth profile is traced on a 6-inch portion of the chart as the expendable probe descends.

The recorder has a completely automatic program, which is initiated by inserting a probe and closing the breech of the probe launching device. This procedure completes a circuit between the probe and the recorder, locking the servo in the center scale position and driving the chart for a few seconds. The chart drive then stops. It starts again when the probe is released and enters the water completing a seawater trigger circuit to begin the measurement cycle. After 90 seconds, the temperature depth profile has been recorded and the chart drive stops, indicating completion of the cycle. The launcher is then ready for reloading.

CHAPTER 9

ELECTRONIC NAVIGATIONAL AIDS

Basically, electronic navigation is a form of piloting. Piloting is that branch of navigation in which a ship's position is obtained by referring to visible objects on the earth whose locations are known. This reference usually consists of bearing and distance of a single object, cross bearings on two or more objects, or two bearings on the same objects with an interval between them.

Position in electronic navigation is determined in practically the same way that it is in piloting. There is one important difference, however. The objects by which the ship's position is determined need not be visible from the ship. Instead, their bearings (and in most instances their ranges) are obtained by electronic means—usually radio.

The advantages of piloting by radio are obvious. A ship's position may be fixed electronically in fog or thick weather that otherwise would make it impossible to obtain visual bearings. Moreover, it may be determined from stations located far beyond the range of even clear-weather visibility.

This chapter will deal with electronic navigation by Loran, Shoran, Omega, SINS, Satellite, and Tacan.

LORAN NAVIGATION SYSTEM

The long-range navigation (loran) system provides a means of obtaining accurate navigational fixes from pulsed radio signals radiated by shore-based transmitters. Depending on the mode of loran operation and the time of day or night, fixes are possible at distances up to 3000 nautical miles from the transmitting stations.

The loran system comprises two subsystems, or modes of operation, called loran A and loran C. Because loran A is the basic mode of operation, it is used as the vehicle for explaining the loran principle of operation. Loran C is a refinement of loran A, differing from the basic mode mainly in operating frequency and coding of signals employed. It has a much greater distance range than loran A.

LORAN PRINCIPLE

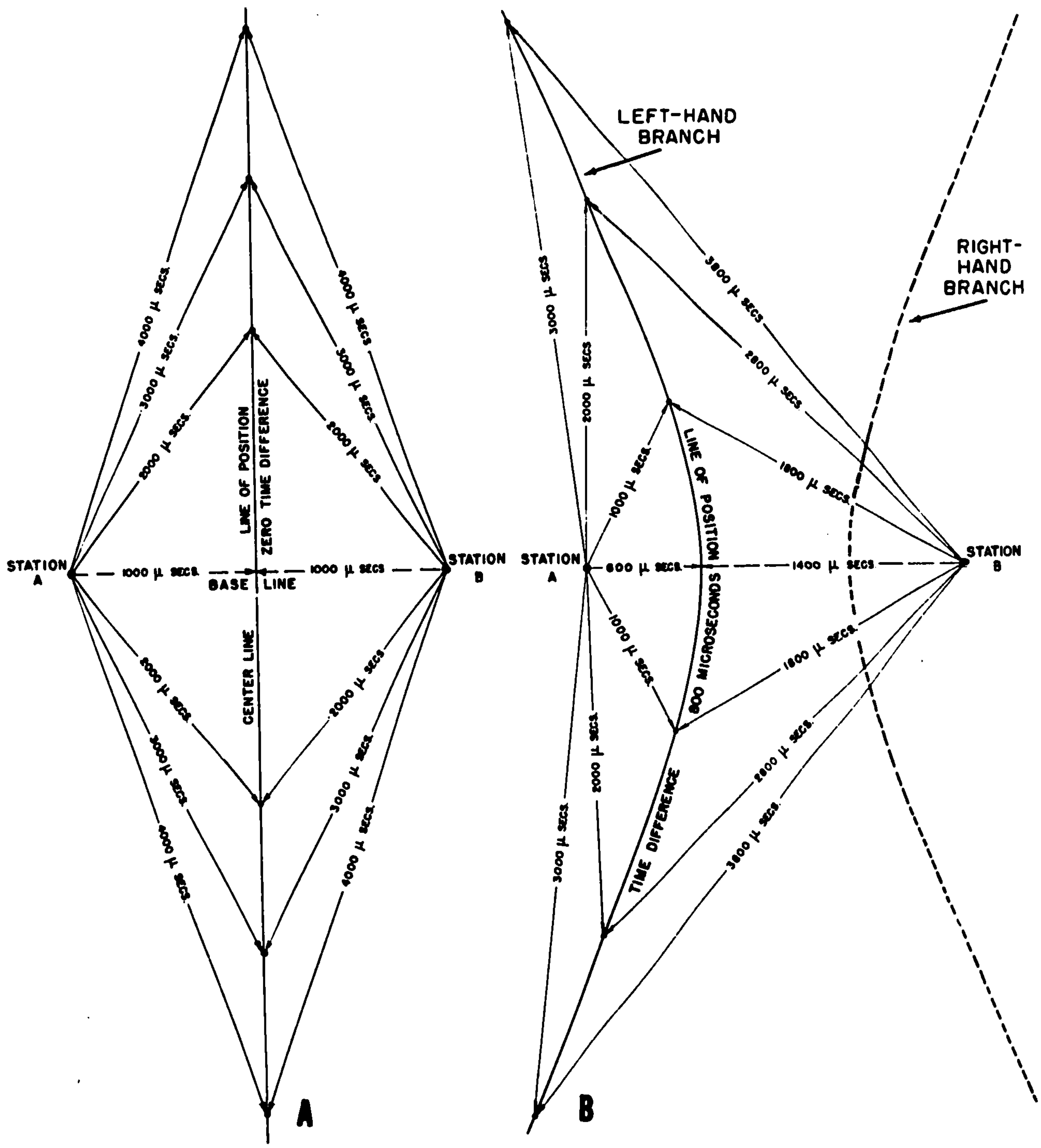
The principle of loran is illustrated in figure 9-1. If part A, stations A and B are pulsed simultaneously, the two pulses arrive at any point on the center line at the same time. This is evident from the geometry of the figure; and an observer, with the proper receiving equipment, could tell if he was 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 equipment will indicate a time difference of 800μs; 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 his 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 800 μs. The line of constant time difference is then the right-hand branch of the hyperbola, and appears as the dotted curve in figure 9-1B.

(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



12.34(120C)

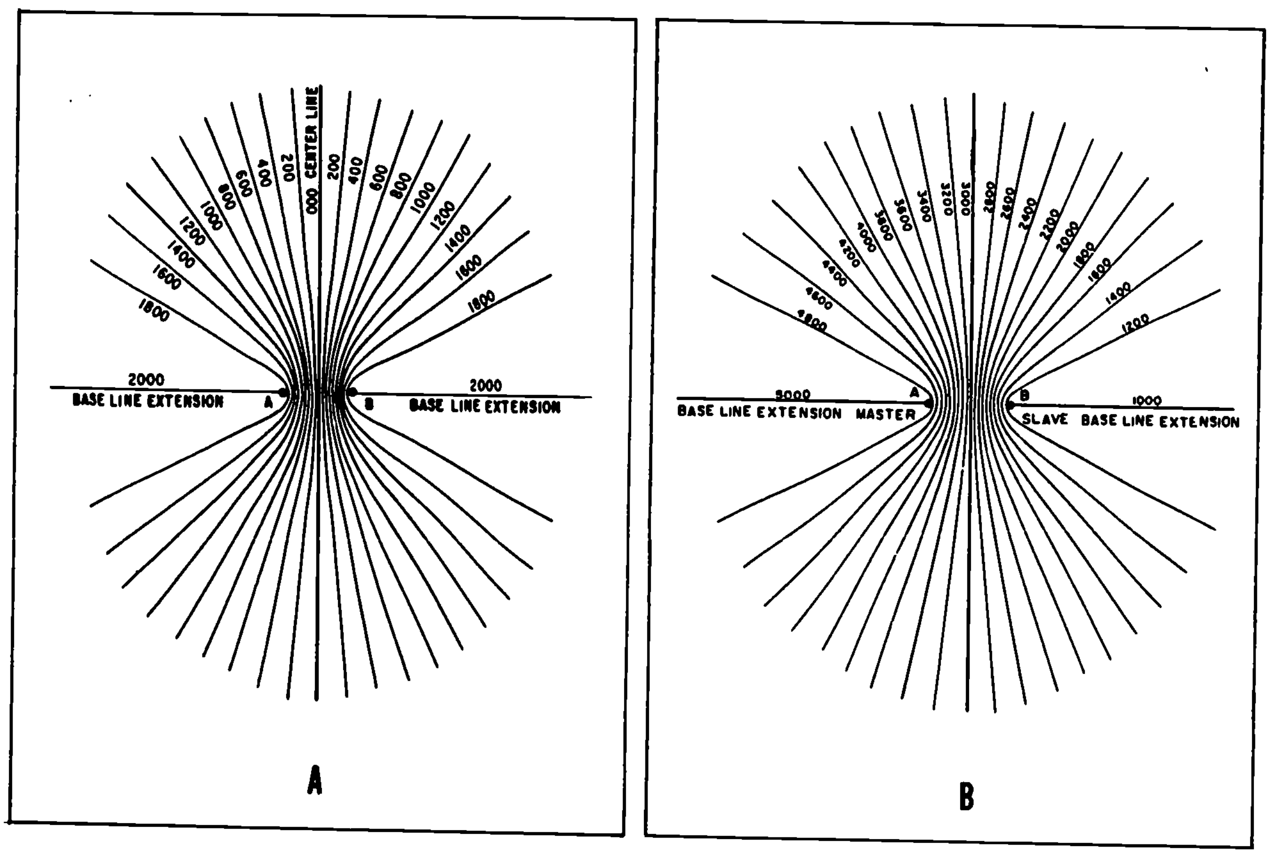
Figure 9-1.—Principle of loran simplified.

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 9-2A. 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. 9-2B) 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



70.17

Figure 9-2.—Loran lines of position.

cathode-ray-tube presentation at the loran indicator.

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 9-2B, 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 kHz, respectively. The BASIC PRR is either 25 Hz (the LOW, or L, rate) or 33-1/3 Hz (the HIGH, or H, rate). A third basic recurrence rate of 20 Hz (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 9-3 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 kHz; a low basic PRR of 25 Hz; a specific PRR of 6, corresponding to 25-6/16 Hz; and a time difference of 2500 μs.

For loran C operation, a master and two slave signals are transmitted on a carrier frequency of 100 kHz. These signals are multiple-group transmissions, identified as master or slave signals by the number of pulses transmitted in each group. The master group transmission is comprised of nine phase-coded pulses. The pulses are separated from one another by either 1000 or 500 μs, except that the ninth pulse is separated from the eighth by approximately 600 μs. The slave group transmission is comprised of eight pulses, each separated from the others by either 1000 or 500 μs to conform to the master station transmission. Phase coding is a method of changing the radiofrequency of each pulse relative to the frequency of the carrier. The phase is varied within each group of pulses in accordance with a prescribed program.

Loran C operation has capabilities for single or double rate reception. Single rate reception provides maximum time difference readings of 30,000 (H), 40,000 (L), and 50,000 (S) microseconds. Double rate reception extends the time difference readings to 60,000 (SH), 80,000 (SL), and 100,000 (SS) microseconds. For single rate reception, basic repetition rates are 16 2/3, 12 1/2, and 10 groups per second; for double rate reception, 33 1/3, 25, and 20 groups per second.

The advantage of loran C over loran A is due to the characteristics of the transmission and the lower operating frequency. Greater power output results from using group pulsing instead of single pulsing. The lower operating frequency permits greater distances with the available power output. Measurement of the phase relationship between the pulses and the carrier contributes to accurate fixes at greater distances. In addition, a fix may be made in one operation without changing the selected channel, the basic repetition rate, or the specific repetition rate.

The instrument used for measuring the small periods of time that elapse between the

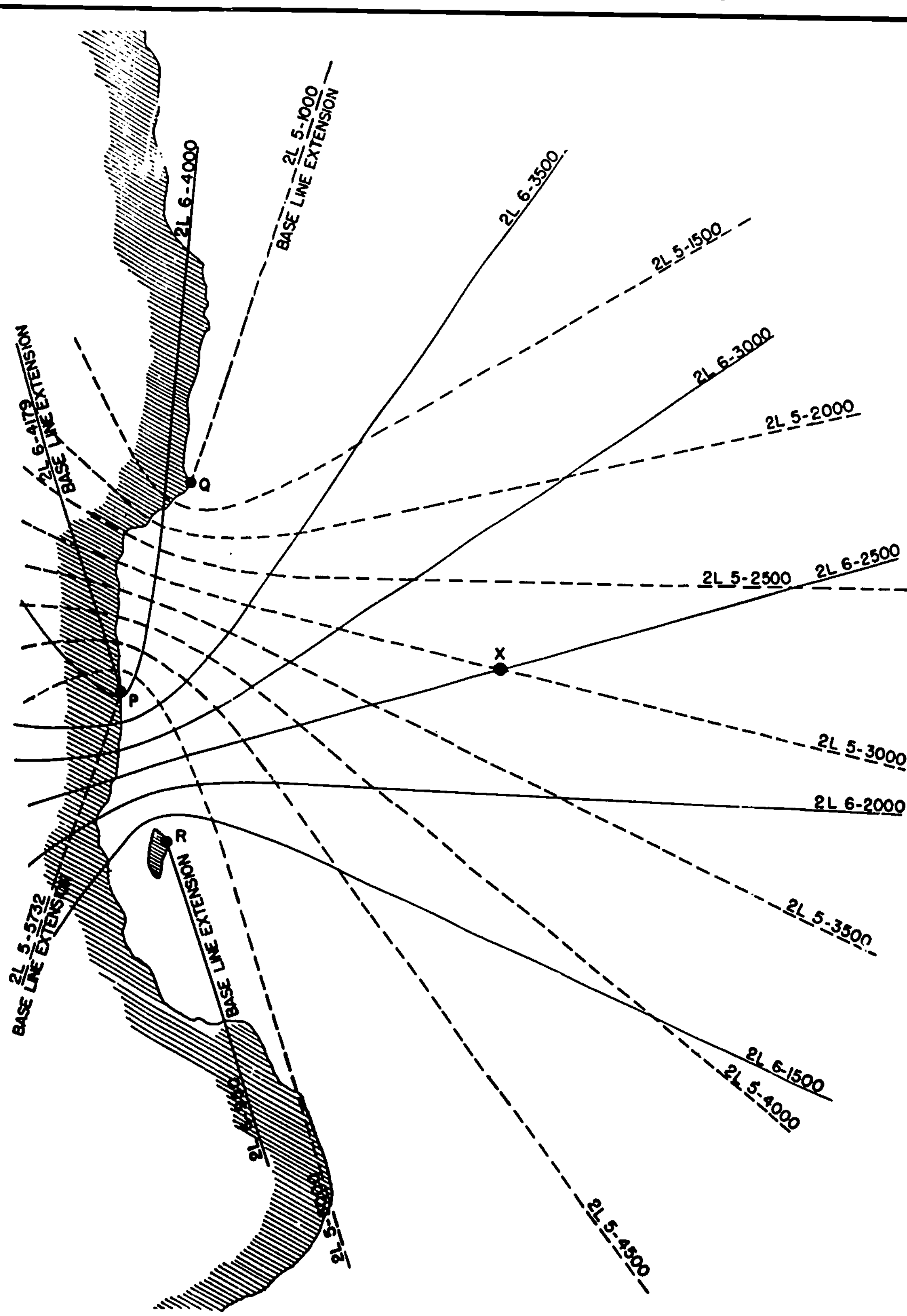
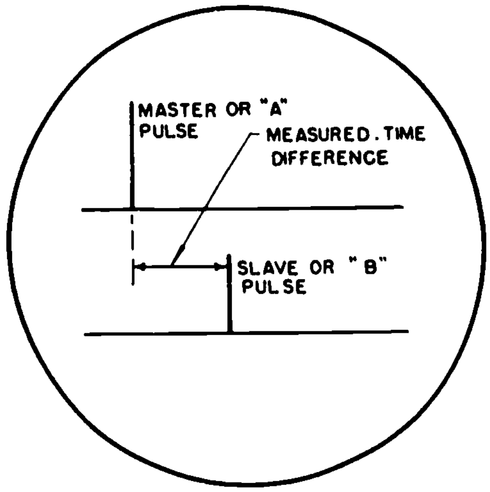


Figure 9-3.—Obtaining a fix with one master and two slave stations.

70.18

arrival of signals from the loran transmitting stations is a combination radio receiver and video indicator. The receiver accepts the RF pulses, converts them to videopulses, and sends the video pulses to the indicator for display on the face of a small cathode-ray tube.

The master and slave pulses appear on two horizontal traces, as in figure 9-4. With the



109.22
Figure 9-4.—Traces on a loran indicator.

two signals aligned properly, the time difference between their reception is read from timing markers displayed on the scope or from revolution type counters on the front panel of the receiving set. Because the measuring process is quite lengthy and varies from equipment to equipment, it is not discussed in detail in this text.

LORAN EQUIPMENTS

A loran set aboard ship is a receiving set or indicator that displays the pulses from loran transmitting stations ashore. Earlier models have a separate receiver and indicator while later models have a receiver set with a built-in indicator.

Loran Receiving Set Model DAS-4

Perhaps the oldest loran receiving set still installed aboard ships in the active fleet is the model DAS-4 (fig. 9-5).

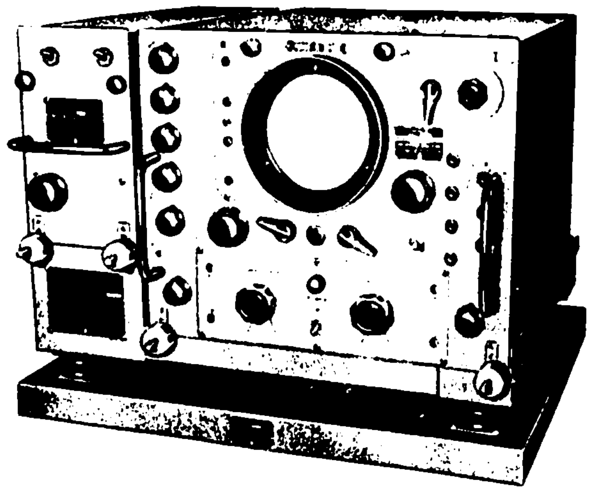


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Figure 9-5.—Loran A Receiver DAS-4.

This set, consisting of a receiver unit and an indicator unit, is capable of receiving loran A signals only.

The receiver (left-hand unit in the illustration) is a conventional superheterodyne receiver that covers the frequency range 1700 to 2000 kHz. It has no variable tuning. Instead, it is preset to four different frequencies, corresponding to the four loran A channels. Channels are selected by means of a switch located on the front panel of the receiver.

The indicator unit contains the circuitry necessary for measuring the difference in time of arrival of the pulses from a pair of loran transmitting stations. By manipulating the front panel controls (in the manner prescribed in the operating instructions accompanying the equipment), the received pulses and the timing markers are seen on the face of the scope. Interpretation of the timing markers results in a time difference measurement that is correct to 1 μs.

Loran Receiving Set AN/SPN-7( )

The AN/SPN-7( ), (fig. 9-6) is another loran A receiving set. Like the DAS-4, the receiver portion of this set is a crystal-controlled superheterodyne receiver that is preset to the four loran A frequencies. The indicator

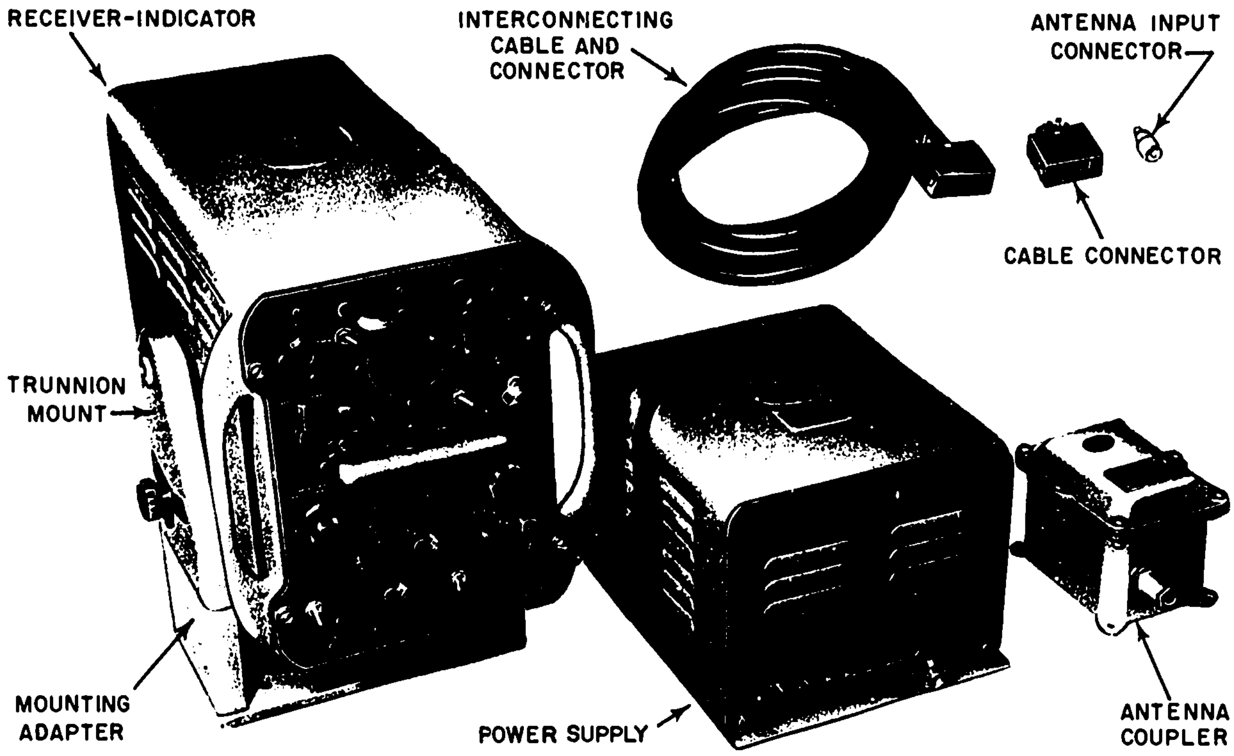

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Figure 9-6.—Loran A Receiver AN/SPN-7( ).

portion is an accurate timing device that measures the time difference in arrival of the signals from the loran transmitters.

The receiver-indicator accepts the loran signals from the transmitting stations and presents the two signals on the scope. When the two signals are matched properly, the time difference in their arrival is indicated directly on a revolution type counter and a dial. Thus, time measurements are simplified, and inaccuracies that could result from misinterpretation of timing markers are eliminated.

Loran Receiving Sets AN/UPN-12( ) and AN/UPN-15( )

Originally designed for loran A operation only, the AN/UPN-12( ) receiving set was modified to accommodate both loran A and loran C signals. Modification is accomplished by adding a small receiver-control unit and associated components to the existing AN/UPN-12( ) set. When so modified, the nomenclature of the receiving set is changed from AN/UPN-12( ) to AN/UPN-15( ). The AN/UPN-15( ) is shown in figure 9-7.

When functioning as a loran C receiver-indicator, the set utilizes the signals received by the receiver-control unit mounted atop the main chassis. This unit contains a 100 kHz radio receiver of the tuned radiofrequency type. The controls that affect its operation as a loran C receiver are on the front panel of the unit.

With the equipment set for loran A operation, the 100 kHz receiver is isolated from the set and the four-channel superheterodyne receiver in the main chassis is used to receive the loran signals.

The indicator unit of the set displays either loran A or loran C signals. When the received pulses are aligned as prescribed for the particular mode of operation, time difference readings

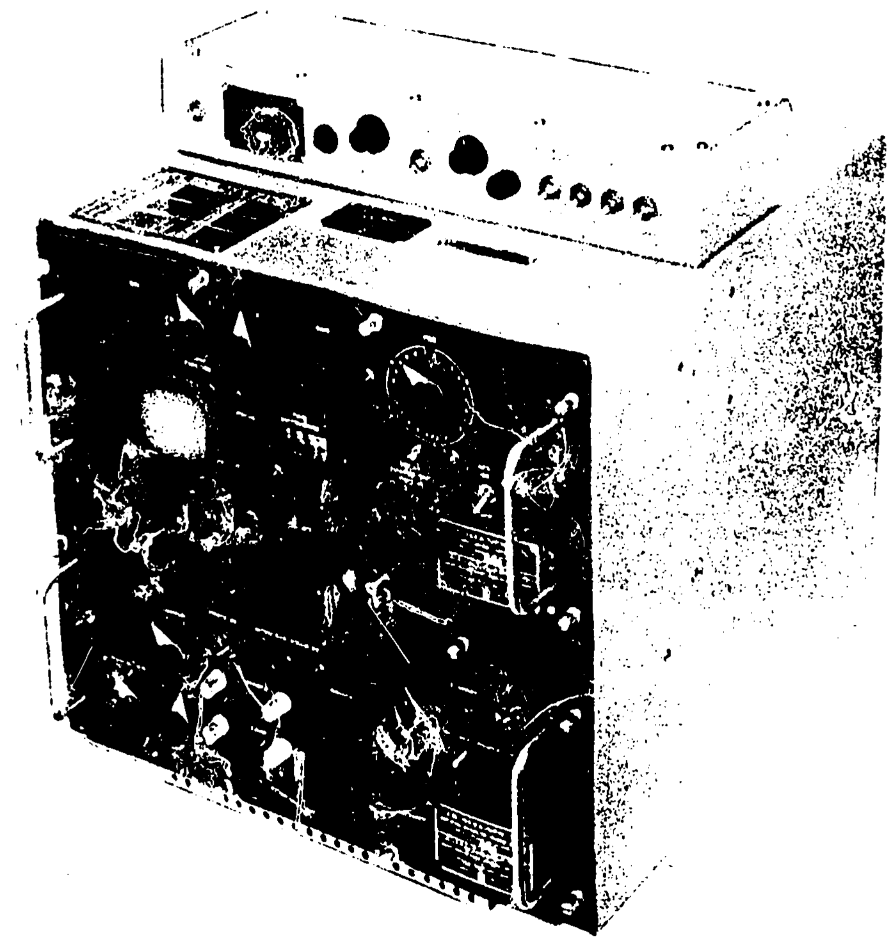

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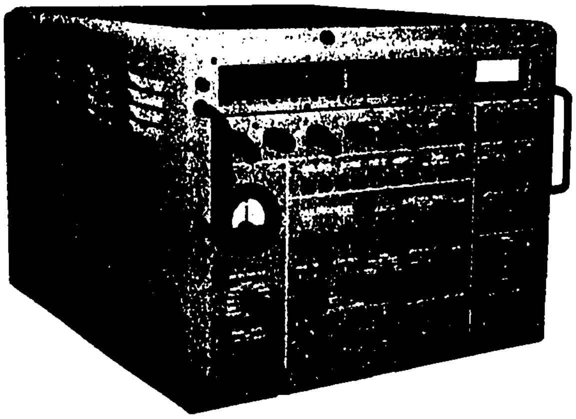
Figure 9-7.—Loran C Receiver AN/UPN-15( ).

are taken from a counter. By taking a second reading from a different set of loran stations and referring to loran charts and tables the geographic position of the ship is determined.

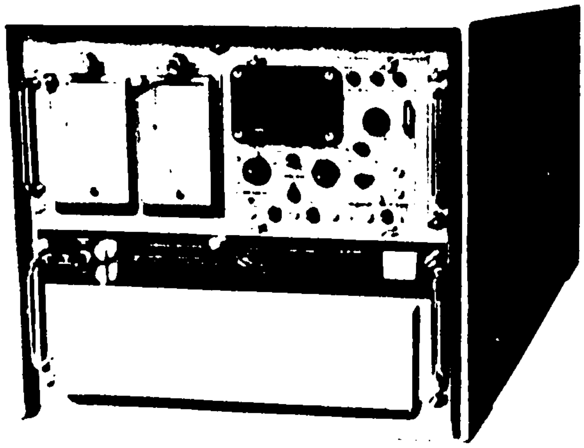
Loran Receiving Sets AN/SPN-31,-32,-38

Loran receivers of this series operate in the Loran C mode. We will discuss the AN/SPN-38 (fig. 9-8) as a representative type of the series. The receiver displays precise long range navigation time-difference measurements or Loran signals automatically and continuously to 0.05μs accuracy.

The system provides visual and electrical outputs which can be used to operate computer and recorder navigational equipments. A three-inch rectangular display indicator is located in the upper right-hand corner of the receiver. Loran video and RF signals are displayed in both slow and fast CRT sweeps. The CRT also serves as a testing oscilloscope for diagnostic mantenance of the receiver. A signal produces simulated output signals for periodic



120.48(120C)
Figure 9-8.—Loran C Receiver AN/SPN-38.



120.48
Figure 9-9.—Omega Receiver AN/SRN-12.

performance checks and serves as test equipment for the receiver.

The AN/SPN-38 automatically searches out loran signals, locks on, and synchronizes with the ground wave. The two time difference measurements between each slave signal and master signal are read out on nixie tube displays from digital logic circuits.

OMEGA NAVIGATION SYSTEM

The Omega System is an outgrowth of the loran A and loran C systems. The system, presently being installed, will provide eight position-fixing transmitting stations located around the earth to accommodate land vehicles, aircraft, ships and submarines (at moderate antenna depths). The system has been made possible by recently uncovered facts concerning the propagation of very low-frequency radio signals over substantial distances.

The Omega Navigation Receiver AN/SRN-12 (fig. 9-9) is a single frequency, phase-locked superheterodyne receiver with a whip antenna and coupler for the reception of Omega navigational signals. The receiver operates in the VLF (10 to 14 kHz) range to provide a position readout in hyperbolic coordinates.

The fundamental measurement performed by the receiver is the relative phase comparisons (phase angles) of the VLF signals. The navigator can determine the line of position generated by any convenient pair of stations and then cross it with one or more lines derived from another pair or pairs of stations. He may make readings on four or five lines of position, but usually will choose the two pairs that jointly give the greatest precision at his particular location. After the selection of the two pairs (a minimum of 3 transmitters) the operation of the receiver is automatic in the tracking of these signals, until the operator modifies his choice of pairs, or until he arrives at his destination. The indication of position lines is continuous and may be recorded for the convenience of the navigator.

SHORAN

Shoran (short range navigation) was developed during World War II to permit bombing through undercast. It provided such great accuracy that it has since been further developed for surveying. It usually operates at frequencies between 230-310 MHz. Thus, it is limited to line-of-sight ranges. Shoran permits accuracies up to about 50 feet for a fix.

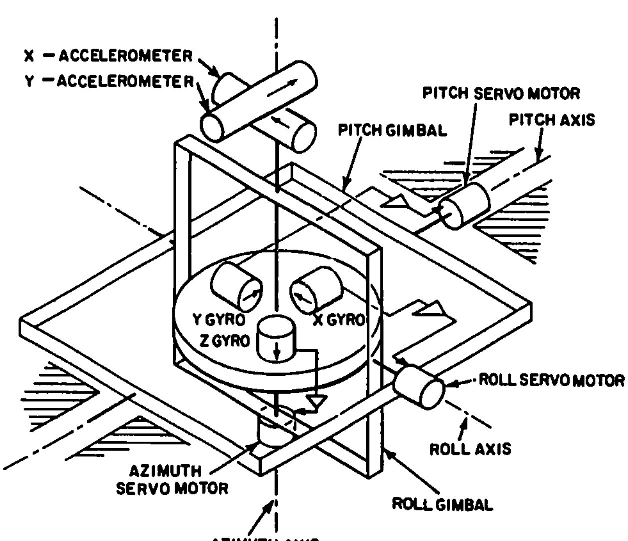
The basic principle of Shoran is as follows. Signals from one's own ship or aircraft automatically trigger two fixed beacon transmitters located ashore at some known distance apart. The signals emitted by these transmitters are received and displayed on an indicator scope aboard. The two distances in the form of pips on the scope are continually available permitting rapid determination of position. When measuring and plotting these two ranges on a chart, the point of intersection is the fix. Charts that show a number of concentric circles centered upon each beacon permits approximate positions to be plotted by inspection.

Shoran using a medium frequency of 1900 kHz was developed for use aboard ship to cover distances of several hundred miles from shore.

SHIPS INERTIAL NAVIGATION SYSTEM

Ships Inertial Navigation System (SINS) is a method of navigation by dead reckoning, which measures speed and heading and uses these measurements to compute position change from an initial position fix. This method is in contrast to the loran and omega system methods which fixed the ship's position by measuring position relative to some known object.

The basic components of an inertial navigation system (fig. 9-10) are the accelerometers, gyroscopes, servosystems, and computers (not shown). An accelerometer is a device which measures changes in speed or direction. Its output is usually in the form of a voltage proportional to the acceleration to which it is subjected. A set of two accelerometers are mounted on a gyro-stabilized platform in order to keep them in a horizontal position despite changes in the ship's movements. The accelerometers are attached to the platform by means of an equatorial mount (gimbal) whose vertical axis is aligned parallel to the earth's polar axis. This permits the N-S accelerometer to be aligned along a longitude meridian, while the E-W accelerometer is aligned along a latitude meridian.



162.55

Figure 9-10.—Stable platform with inertial components.

A three-gyro-stabilized platform is maintained in the horizontal position regardless of the pitch, roll, and yaw of the ship. When the ship's heading changes, the gyro signals will cause servosystem motors to operate to keep the platform stabilized. High-performance servosystems are needed to maintain the platform stabilized to the required accuracy.

The self-contain navigation system continuously computes latitude and longitude by accurately sensing the accelerations of the vehicle with respect to the earth's surface. A computer capable of converting distance traveled into corresponding changes in latitude and longitude is needed.

The system is expensive and its accuracy will decrease with time. A good coverage of the inertial system is found in ET3&2, NavPers 10195.

SATELLITE NAVIGATION SYSTEM

Satellite Navigation was thought feasible after observation of Russia's first artificial earth satellite, Sputnik I. Scientists listened to the beep generated by Sputnik as it passed by and noted the Doppler-like shift in the received radio frequency signals. Doppler effect is an apparent change in a received frequency because of relative motion between the transmitter and receiver. If the distance between the transmitter and receiver is decreasing, the received frequency is higher than that which is actually transmitted; if the distance is increasing, the received frequency is lower than that transmitted. It was later demonstrated that accurate measurement of this doppler shift pattern would permit the determination of a satellite orbit. From this successfully proved technique it was further reasoned that, working from a known satellite orbit, a listener could determine his position on the surface of the earth from an observed doppler pattern. From this point followed the first successful satellite launch in April 1960, and the U.S. Navy Navigation Satellite System became an all-weather, highly accurate, fully operational navigation aid, that enables navigators to obtain accurate navigation fixes from the data collected during a single pass of an orbiting satellite.

NAVIGATION SYSTEM DESCRIPTION

The Navy navigation system (fig. 9-11), is a worldwide, all-weather system of high accuracy which enables navigators to obtain fixes approximately every two hours, day and night. It consists of four earth-orbiting satellites, four tracking stations, two injection stations, the U. S. Naval Observatory, a computing center, and shipboard navigational equipment.

Satellites

Four satellites (only two shown in fig. 9-12) are placed 45 latitudinal degrees apart in separate circular polar orbits longitudinally around the earth, at known altitudes. (The altitude of the satellites is between 500 and 700 nautical miles.) The earth rotates inside these satellite orbits. Each time the satellite makes a pass over the earth (about every 108 minutes) its orbital position seems to have moved farther westward. This is due to the rotation of the earth. Externally, the satellite is octagonal in shape (fig. 9-13). It has four solar cell vanes which are shaped like a windmill and used to generate DC electrical power. The satellite's directional antennas point earthward at all times since they have been stabilized in the earth's gravitational field.

Internally, the satellite is made up of a number of all-transistorized systems. These include

1. A command receiver and identification code facility for ground station communications.
2. A telemetering system for transmitting measured results to receiver sets located on the earth.
3. A digital memory system for storing two types of information:

a. The fixed parameters for all data it transmits that doesn't change, such as the synchronization and identification signals, and the fixed parameters transmitted from ground station to the satellite every twelve to sixteen hours giving information describing all four of the satellite's nominal orbits.

b. The variable parameters transmitted from the satellite to the earth receivers every two minutes giving information describing the fine structure in the satellite's nominal orbits, thereby keeping its time and location up-dated.

4. Two harmonically related transmitters (one for a standby unit) for sending out two different phase-modulated radiofrequency carrier waves.
5. Dual frequency systems, one at 400 MHz and the other at 150 MHz, used to minimize the effects of ionospheric refraction.
6. An ultrastable transformer oscillator for making accurate doppler-shift measurements. (The transformer oscillator is an arrangement of transformers and switching transistors.)
7. A digital clock for transmitting precise time information.
8. Battery power supplies for receiving, storing, and releasing electrical energy for operating the electrical powered equipment.

Tracking Stations

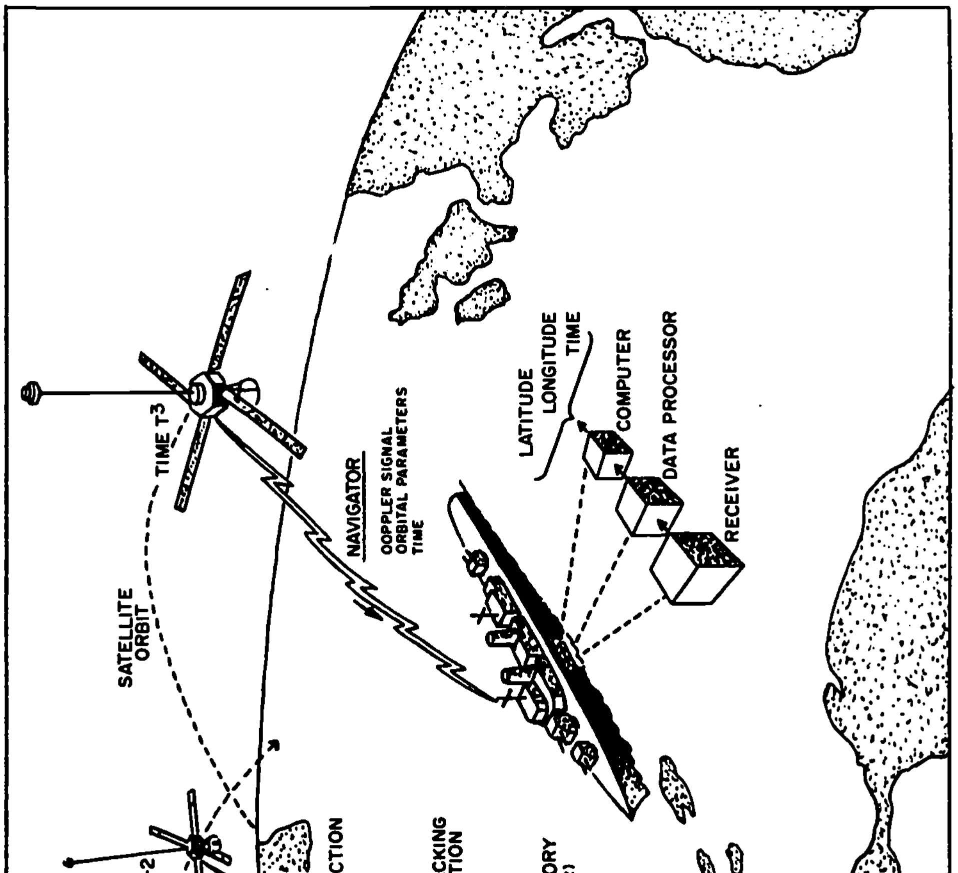
Four tracking stations, spaced to monitor the four polar circling navigational satellites, are located one in each of the States of Hawaii, California, Minnesota, and Maine. The purpose is to determine accurately the present and future orbits of each satellite. These stations having radio receiving and data processing equipment, will digitize and send the orbital and time information via control center to the computing center.

Naval Observatory

The Naval Observatory controls satellite transmission of the two-minute interval time period to an accuracy of one-millisecond of the even integer of universal time (UT-2). It accomplishes this by receiving the digital memory signals from the satellite during each pass and comparing them to the observatory's data processing equipment. The time and orbital information is sent to the control center.

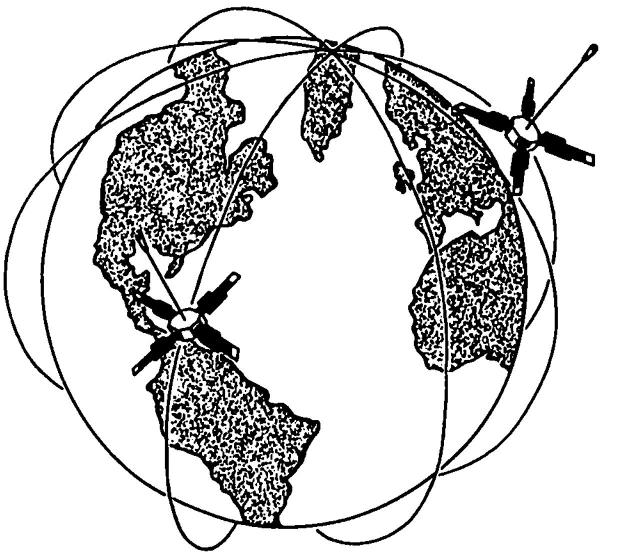
Control Center

All satellite data is routed through the control center which acts as a switching central



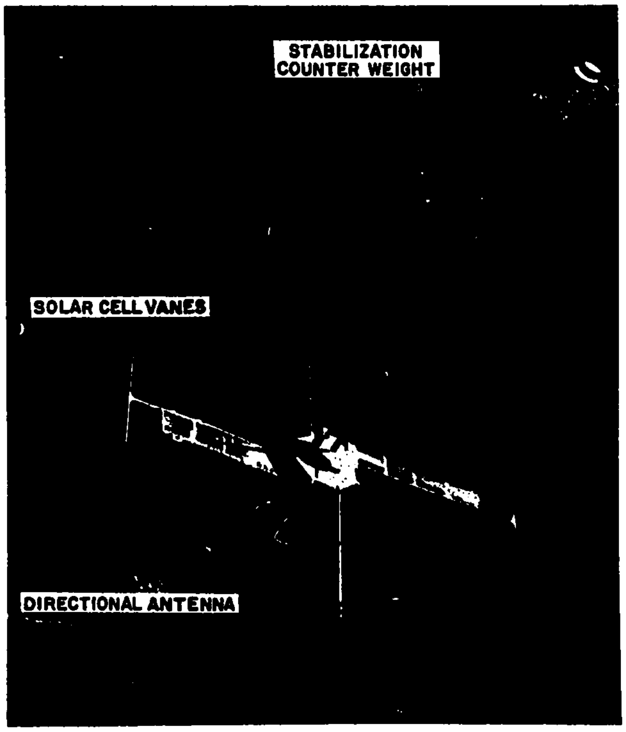
162.58

Figure 9-11. —Navy navigation satellite system.



162.59

Figure 9-12.—Four polar orbits with 45° nodes.



120.95

Figure 9-13.—Navigation satellite.

for monitoring data to and from the Central Computer Center.

Central Computing Center

The Central Computing Center continuously accepts data inputs on the satellites from the four Tracking Stations and the Naval Observatory. Periodically, to obtain fixed orbital parameters for a satellite, the Central Computing Center computes an orbit for each satellite that best fits the doppler curves obtained from all Tracking Stations. Then using the computed orbital shape, the central computing center extrapolates the position of the satellite at each even two minutes in universal time for the next 12 to 16 hours, subsequent to data injection. These data together with data on the nominal shape of the orbits of the other three satellites, commands and time correction data for the satellite and antenna-pointing orders for the Injection Station antennas are supplied to the Injection Stations via the Control Center.

Injection Stations

The Injection Stations, after receiving and verifying the incoming message from the Central Computing Center, store the message until it is needed for transmission to the satellite. As soon as the receiving equipment at the Injection Station receives and locks on the satellite's signals, the Injection Station reads the injection data and commands from storage and transmits them to the satellite. Transmission to the satellite is on a frequency different from those frequencies used by the satellite, and the bit rate is much higher; therefore, injection is completed in a matter of seconds. Once data injection is complete, the satellite continues to transmit at the normal two-minute intervals.

Shipboard Navigation System

The final link in the satellite navigation system is the shipboard navigation system and the one you, as a naval officer, will be most concerned with.

The satellite is continuously transmitting messages. These phase-modulated data on two different radio frequency carrier waves are at two-minute intervals and start precisely on the even minute mark. This permits the navigator to check on any error in the ship's chronometer.

The satellite is continually up-dating itself giving its orbital latitude and longitude coordinates and signaling this information earthward.

The area in the sky where accurate satellite readings can be taken is between 10° and 70° above the horizon (fig. 9-14). The reception pattern is like a large donut in the sky with the hole overhead. When a satellite is passing overhead it has very little doppler frequency shift since the satellite and ship are closely paralleling each other. Since the navigation principle is based on measuring the doppler shift, any area above the 70° mark is avoided.

A minimum of 6 full minutes, or 3 complete simultaneous satellite messages (at 2-minute intervals) is required to calculate a navigation fix. Additional periods of received satellite transmissions will increase the accuracy of these computations. A satellite pass may last for as long as 16 minutes (eight 2-minute periods). Passes suitable for use in obtaining a navigational fix will generally occur at least every two hours since four earth-circling satellites are in orbit for this purpose.

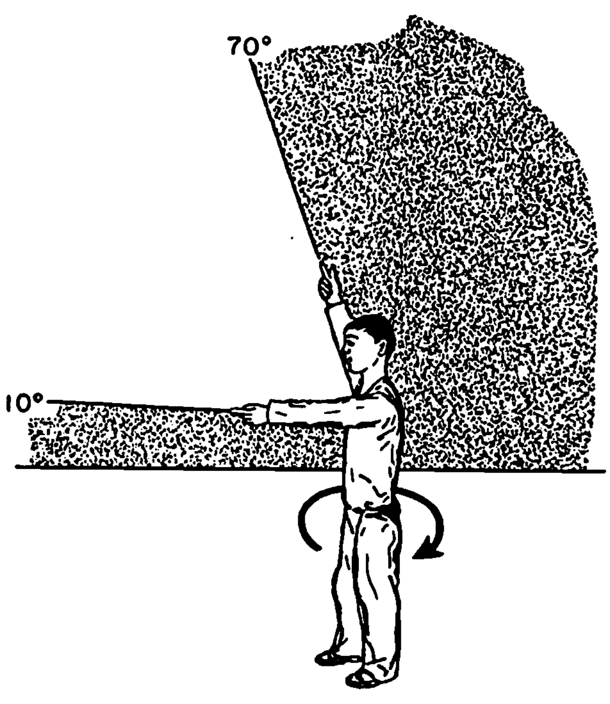


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Figure 9-14.—Determining satellites accurate calculation areas.

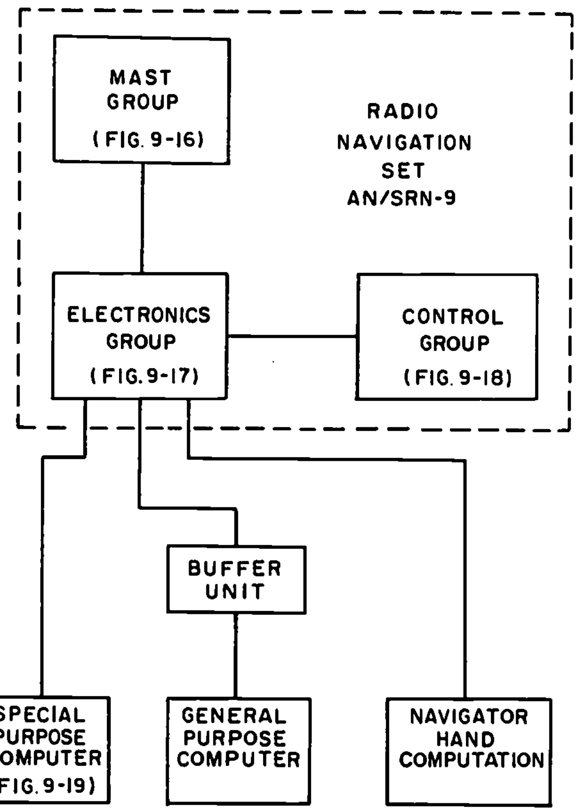

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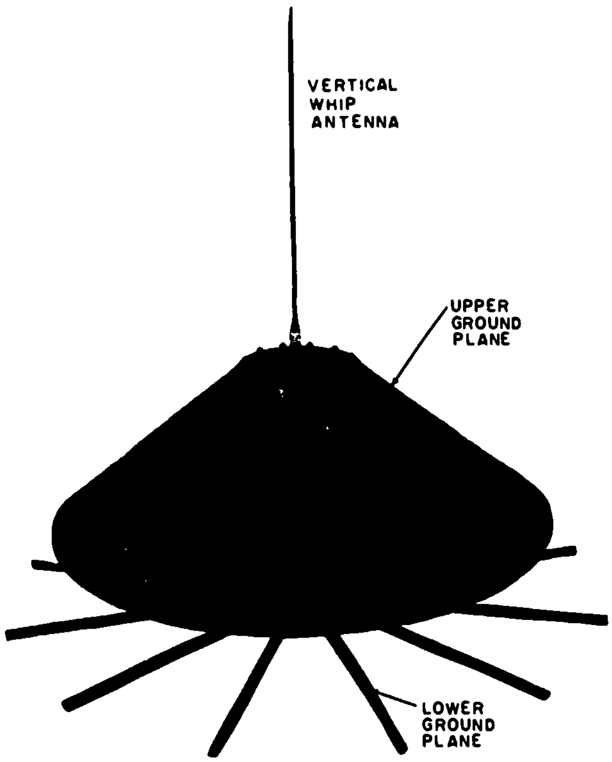
Figure 9-15.—Shipboard navigation system, block diagram.

RADIO NAVIGATION SET AN/SRN-9

Radio Navigation Set AN/SRN-9 (fig. 9-15), represented in the dotted lines in the block diagram, consists of a mast group, electronics group, and a control group. The radio navigation set reduces the satellite data to a form which is suitable for navigational computations.

The output of the AN/SRN-9 is sent to the computing system. There are three methods of computation: the Special Purpose Computer CP-827 (XN-1), the general purpose computer (which requires a buffer unit) or by navigator hand computation.



162.64(120C)
Figure 9-16.—The mast group.

Mast Group

The mast group (fig. 9-16) receives, separates, and amplifies the two modulated incoming carriers from the satellite. The dual-frequency vertical whip antenna receives both the 400 MHz and 150 MHz satellite signals. A housing assembly inside the mast group, containing all the electronic circuits, will separate the signals and amplify each separately. The upper ground plane lowers the angle of radiation to establish a good antenna pattern. The lower ground plane has 12 radial rods at the base to isolate the mast group from any of the ship's hull effects and thus preserves the antenna pattern.

Electronic Group

The electronics group (fig. 9-17) consists of a receiver unit, data processor unit, and a power supply unit. This group receives, prepares, and records doppler data, satellite data, timing information, and refraction correction data for suitable navigation computations by the computer.

THE RECEIVER UNIT.—The Receiver Unit is the phase-modulation decoder for the coded binary signal received from the satellite. The oscillator in this receiver must be very stable. In case of temporary power failure, the oscillator requires a warmup period of 10 hours for each hour the power is off up to a maximum total of 72 hours. This amount of time is required for the frequency to stabilize sufficiently for high-accuracy navigation. Readings can be made immediately after power is restored, but accuracy will be decreased. It is recommended that the standby battery be kept in good condition to assure continuous power to the oscillator unit in event the ship looses its power supply. The battery connector (not shown in fig. 9-17) is located on the side of the electronic group.

THE DATA PROCESSOR UNIT.—The Data Processor Unit is located in the top drawer of the electronics group (fig. 9-17). It combines and processes the timing signals, satellite orbit parameters, and the doppler counts. This output information goes to the computer and the control group for printout.

THE POWER SUPPLY.—The Power Supply requirements for the radio navigation set is 115 ±10 VAC, 60 ±6 Hz with a maximum of 220 watts.

Control Group

The control group (fig. 9-18) performs the switching functions and is manually operated by the navigator. In the TRACK position of the main control switch, the control group automatically searches for, locks on, and tracks the satellite. The entire navigation fix is printed out, monitored, and controlled from the control group. The digital printer prints out the coordinate position of the ship.

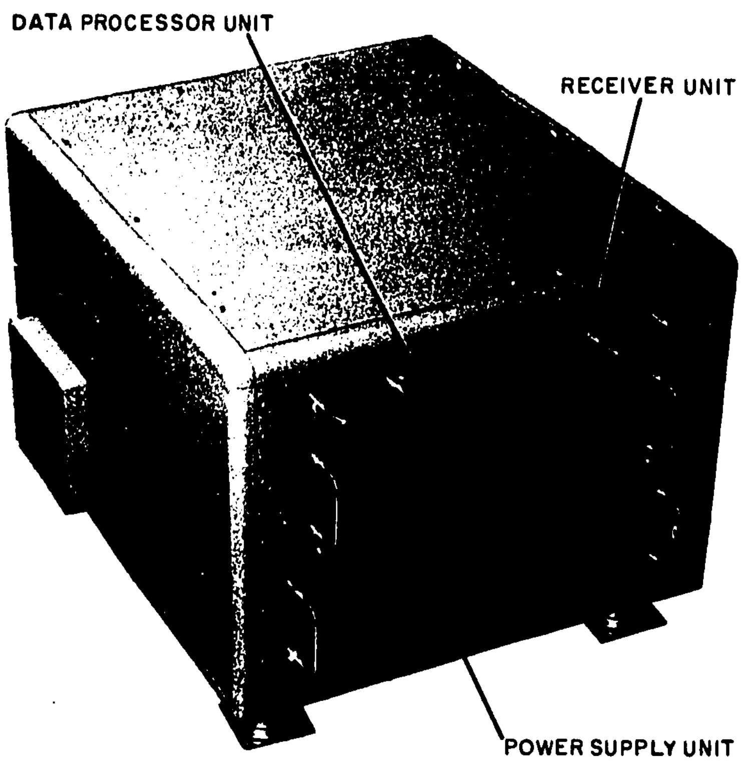


Figure 9-17.—Electronics group. 162.66

Computer

The computer uses the satellite's position data and the ship's position data to compute a fix in longitude, latitude, and coincident time. We have discussed the satellite data supplied by Radio Navigation Set AN/SRN-9. The navigator will calculate and enter into the computer the ship's heading and speed, water (currents) direction and speed, estimated ship's position, antenna height, and the time-of-day accurate to within ±15 minutes. These entries are made at the end of the satellite pass. Information is always rejected if the time is less than a 2-minute period or is otherwise invalid.

THE SPECIAL PURPOSE COMPUTER.—The Special Purpose Computer CP-827/SRN-9 (fig. 9-19) monitors all operations of the Navy's satellite navigation program. The two top drawers hold the electronic logic card circuits. The middle drawer also has the controls and indicators. The bottom drawer contains the 115 ±10 VAC 60 Hz single-phase power supply and the tape reader. The front panel of the

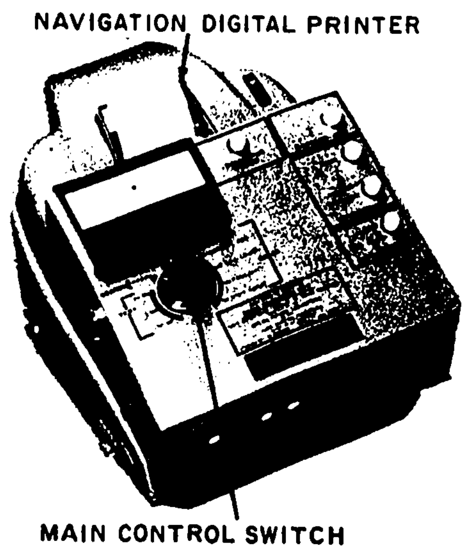


Figure 9-18.—Control group. 162.73

Test Device (fig. 9-20), is equipped with neon indicators to give a visual display of the contents of all the registers and the sequence events as they occur in the computer.

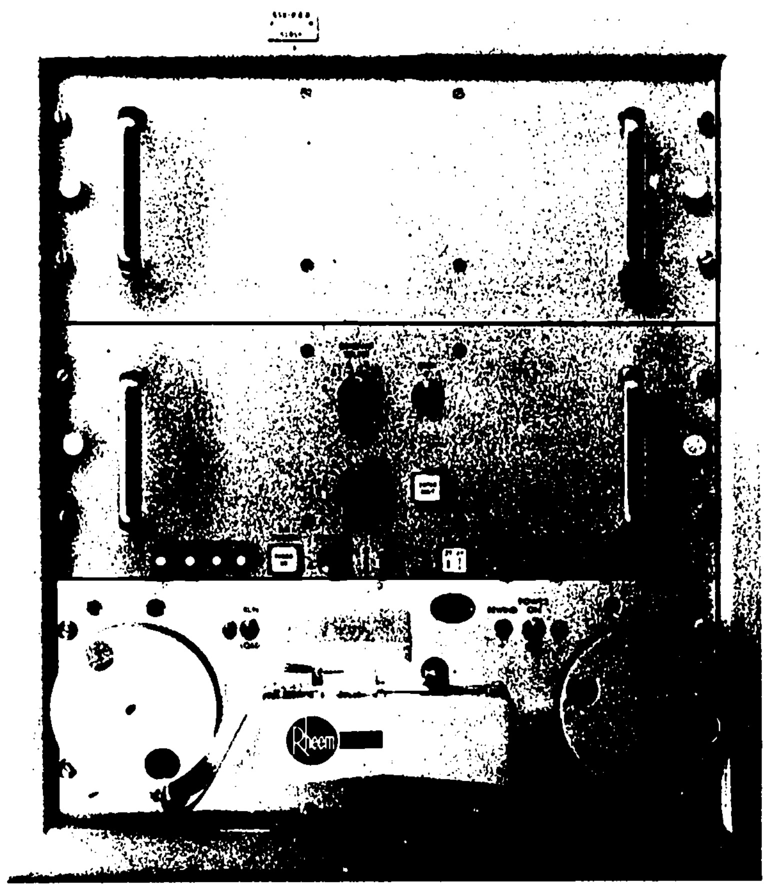
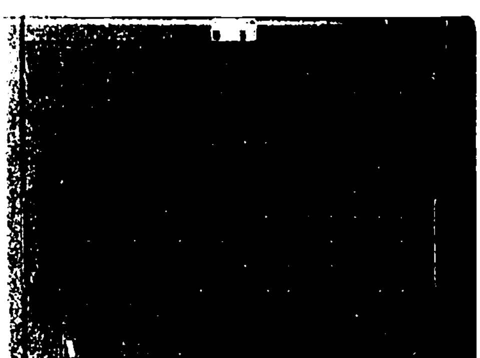


Figure 9-19.—Digital Computer CP-827/SRN-9. 162.74



162.80
Figure 9-20.—Test Device CP-827/SRN-9.

The computer readout is located in the electronics control group (fig. 9-18). A partial sampling of the output printed data is shown in figure 9-21. Some of the information that has been extracted is the doppler count, time of fix, latitude and longitude, and the offset frequency.

THE GENERAL PURPOSE COMPUTER.—The General Purpose Computer may be used, but a buffer unit is necessary to process and convert information into the appropriate computer format. The availability and time sharing of a general purpose computer makes this a less desirable choice since it may be required for tactical data processing systems, etc.

HAND COMPUTATION.—Hand Computation using the printed data available from the control group printer of the AN/SRN-9 may be made to obtain a position fix. The complexity of such calculations, however, leads to hours of computation time and an almost certain probability of human error.

Message No. 4

```
    3 4 8 3 5 7 9
-+1 1 0 6 7 0 7 3
-+1 2 0 6 9 1 0 6
-+1 3 0 6 7 1 4 0
-+1 4 0 6 2 1 7 5
-+0 0 0 5 4 2 0 7
-+0 1 0 4 3 2 3 5
-+0 2 0 2 9 2 5 8
-+0 3 0 1 4 2 7 4
```

Readout	Units	Title and Symbol
++1 2 8 1.0 8 1 5	Minutes	Time of Perigee (t_p)
+ .4 2 7 5 8 1 7	Deg/Min	Mean Satellite Motion - 3 ($\dot{M}$ - 3)
+ 3 2 0.2 0 3 4	Degrees	Argument of Perigee ($\emptyset_p$)
+ .0 0 2 1 4 3 1	Deg/Min	Argument of Perigee Change Rate ($\vert\dot{\emptyset}\vert$)
+ 0.0 1 1 1 1 5	None	Eccentricity
+ 0 7 3 7 4.0 1	Kilom.	Orbit Semi Major Axis (A_o)
+ 2 1 1.8 4 8 2	Degrees	Right Ascension of the Ascending Node (ω_N)
- .0 0 0 0 6 3 6	Deg/Min	Right Ascension Change Rate ($\dot{\omega}_N$)
+ 0.0 1 5 7 0 7	None	Cosine of the Inclination Angle
+ 1 3 4.2 8 0 2	Degrees	Right Ascension of Greenwich at Time of Perigee (ω_G)
+ 0.9 9 9 8 7 7	None	Sine of the Inclination Angle
3 9 7 7 4 9 2.	Hertz	(Doppler Count)

```
+ 0 7 3 7 4 0 1
+ 2 1 1 8 4 8 2
- 0 0 0 0 6 3 6
+ 1 3 4 2 8 0 2

              *   Time of Fix (GMT)  (Twenty hundred hours twenty-six minutes)
      2 0 2 6 *
              *

+ 0 3 8 5 9 9 9
            9 9
- 0 7 5 5 9 9 9     Initial Estimates
            9 7
+ 3 1 9 9 9 9 9
```

```
+ 0 3 9 0 9 7 7
            8 2
- 0 7 6 5 3 8 3     Second Iteration
            4 8
+ 3 1 9 6 2 1 9

+ 0 3 9 0 9 7 7                  Latitude:  39° 09.7782' North
            8 2
- 0 7 6 5 3 8 3     Fix Result   Longitude:  76° 53.8350' West
            5 0
+ 3 1 9 6 2 1 9                  Offset Frequency:  31,962.19 Hertz
              *
              *
```

120.97

Figure 9-21.—Printer readout navigation information.

INTEGRATED DOPPLER NAVIGATION

The navigational fix computed by Radio Navigation Set AN/SRN-9 is based on the shift in frequency (doppler frequency shift) that occurs whenever the relative distance between a transmitter and a receiver is changing. Such changes occur whenever a transmitting satellite passes within radio range of a receiver on earth and is due to the motion of the satellite in its orbit, the motion of the navigator on the surface of the earth, and the rotation of the earth about its axis. (You may choose to review the doppler effect in chapter five.)

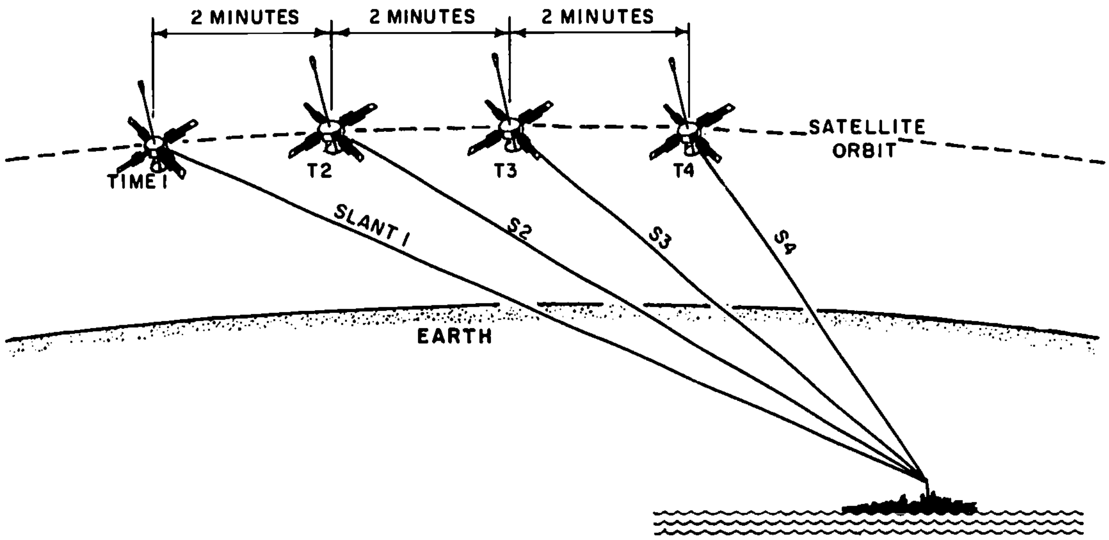


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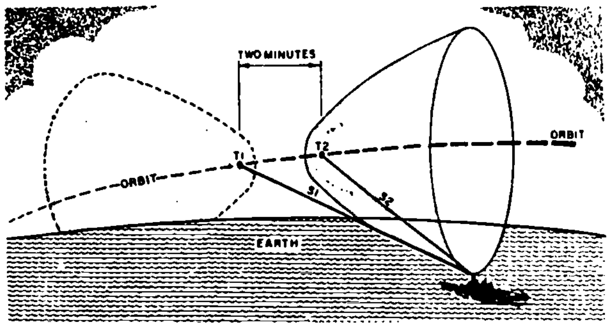
Figure 9-22.—Integrated doppler measurement.

As previously stated, the satellite message describes the orbital position of the satellite every two minutes on the even minute. To obtain a navigational fix, it is necessary only to determine the ship's location relative to the known satellite positions. The Radio Navigation Set AN/SRN-9 utilizes a so-called integrated doppler measurement for this purpose. Figure 9-22 illustrates four positions of the satellite in its orbit for arbitrary times shown as T1 through T4. The slant range from ship to satellite is given by S1 through S4. It is evident that the number of wavelengths of the transmitted signal en route at time T1 along S1 is greater than at time T2 along S2, which is the reason for the doppler frequency shift. As the satellite approaches, additional cycles must be received to account for a reduction in the number of wavelengths along the propagation path. Every positive doppler cycle received means the satellite has moved one wavelength closer. This is a very precise measurement because at 400 MHz a wavelength is only 3/4 meter long.

The principle of satellite navigation involves establishing a fix at the intersection of two or more hyperbolas of revolution. A hyperbola of revolution in satellite navigation (fig. 9-23)



120.99

Figure 9-23.—Principle of satellite navigation, hyperbola of revolution.

is a three-dimension geometric figure as compared to the two-dimension figure used in loran navigation (fig. 9-1B). Using the known positions of the satellite at T1 and T2 as foci and rotating a hyperbola (on the axes which will align with the satellite's orbit) establishes a hyperbola of revolution.

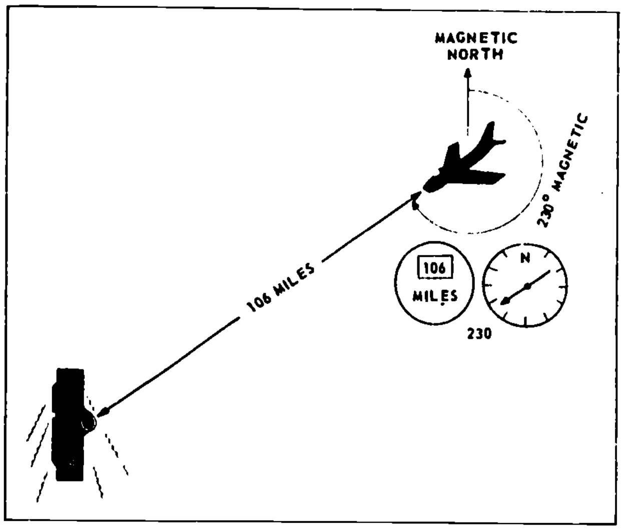
The hyperbola of revolution is electronically established when satellite positions at T1 and T2 are known and the integrated doppler measurement (being the count of the number of doppler cycles received between T1 and T2) has determined the direct measure of the total change in slant range during the two-minute time interval. The receiver must be on some surface defined by this measured slant range DIFFERENCE between these two points. The ship will be located, therefore, somewhere along the curve defined by the intersection of this hyperboloid and the earth's surface. This does not establish the location of the earth's surface nor does it tell upon which of the two branches of the hyperboloid the ship will lie. It does, however, establish electronically the shape of the hyperbola of revolution used.

The next doppler count (between T2 and T3) will define a second curve, and the intersection of these curves (not illustrated) gives the navigational fix.

In actual practice, two factors complicate this simple explanation. First, the doppler signal which is counted consists of the doppler frequency plus a fixed, but not very accurately known, bias frequency which is the inherent variations of frequency differences between the transmitter oscillator in the satellite and the receiver oscillator aboard ship. Therefore, a third doppler count is required in order to solve for the three variables—latitude, longitude, and bias frequency. This means that integral doppler counts for at least three two-minute intervals must be used (and preferably more than three) in order to determine the three unknowns. The second complication is the motion of the ship during the satellite pass. To account for this, the best estimate of a ship's motion must be entered into the navigational computation along with the doppler counts and the satellite message.

TACAN NAVIGATION SYSTEM

Tactical air navigation (tacan), is an electronic polar coordinate system that enables an aircraft pilot to read—instantaneously and continuously—the distance and bearing of a radio beacon transmitter installed on a ship or at a ground station. In aircraft equipped with tacan receiving equipment, an azimuth indicator shows the position of the transmitting sources in degrees of magnetic bearing from the aircraft. Also, the distance in nautical miles to the same reference point is registered as a numerical indication, similar to that of an automobile odometer. (Fig. 9-24) In the



32.73

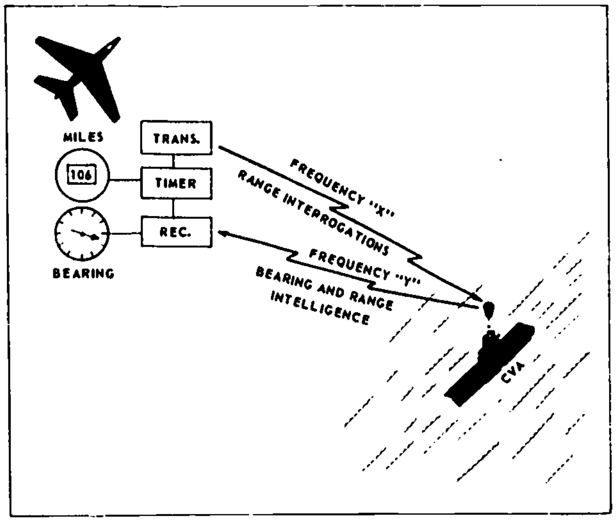
Figure 9-24.—Tacan polar coordinate presentation data.

illustration, the aircraft is 106 miles from the carrier, and the ship is on a magnetic bearing of approximately 230° from the aircraft.

To provide for a large number of transmitting stations, the system operates on 126 selectable channels. No two stations within interference distance of each other are assigned the same channel. The pilot can switch channels to select any tacan transmitter within range.

To aid the pilot in identifying 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 radio frequencies are employed, as indicated in figure 9-25. One frequency (Y)



70.16
Figure 9-25.—Dual-frequency transmission.

is used for transmissions to the aircraft; another frequency (X) is used for transmissions from the aircraft. The surface-to-air frequency carries bearing and range intelligence as well as 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 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 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.

The shipboard end of the system is the AN/SRN-6( ) (discussed in the next topic) or its older counterpart, the AN/URN-3( ). The airborne installation is a combination transmitter-receiver-indicator, such as the AN/ARN-21( ).

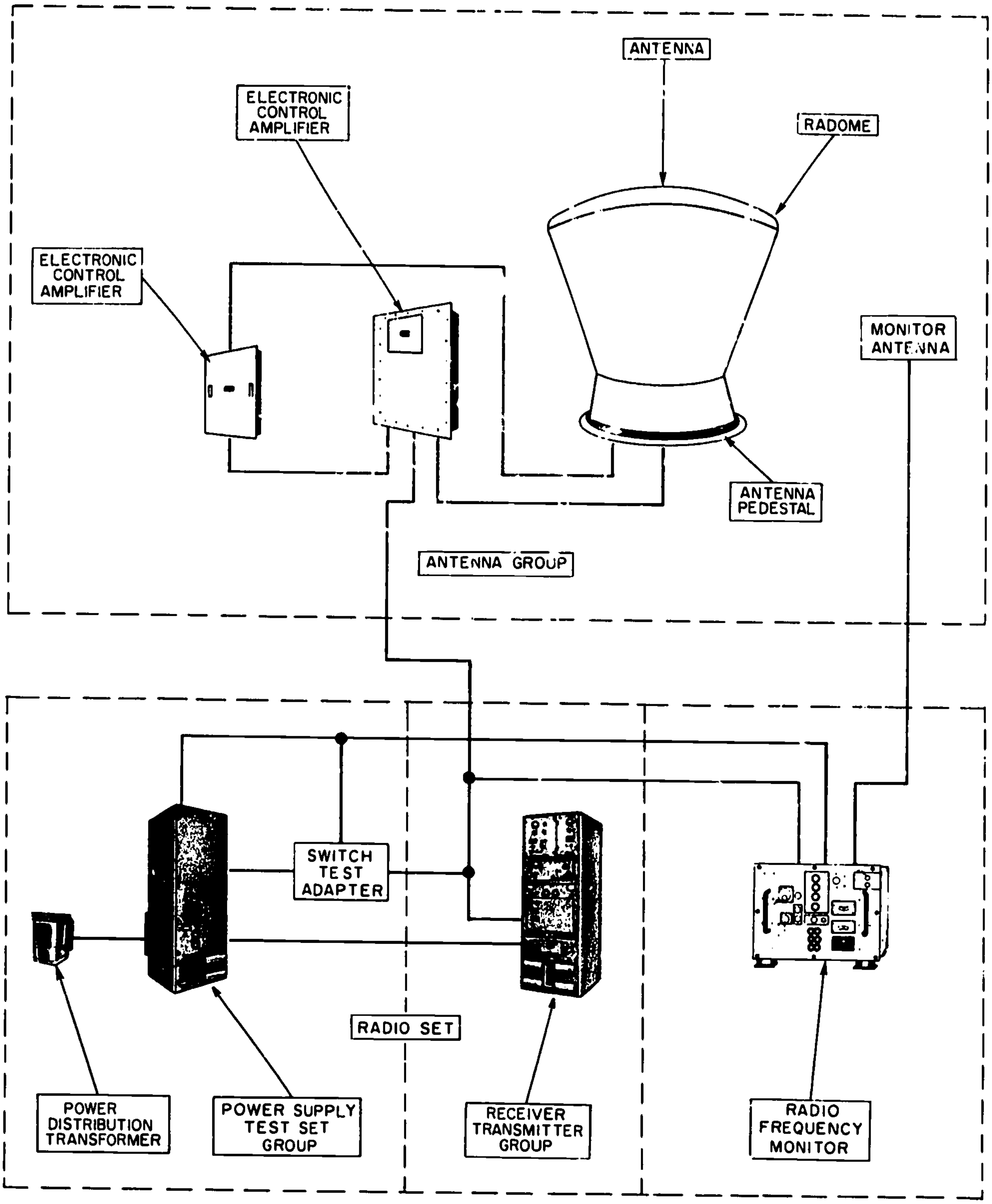
TACAN RADIO SET AN/SRN-6( )

Radio set AN/SRN-6( ) is replacing the AN/URN-3 as tacan radio sets on board ship. The AN/SRN-6( ) system (fig. 9-26) 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 MHz. Transmission of information also takes place on 126 channel frequencies in the ranges of 962 to 1024 MHz and 1151 to 1213 MHz.

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 MHz inclusive, and receive at frequencies between 1025 and 1087 MHz. High-band installations transmit in the range of 1151 to 1213 MHz, and receive in the range of 1088 to 1150 MHz.

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 MHz above the frequency used for transmitting in the same channel.



32.72

Figure 9-26.—Radio Beacon AN/SRN-6 major components.

CHAPTER 10

INTRODUCTION TO DIGITAL COMPUTERS

The Navy's reliance on computer technology has greatly increased in recent years because of the ability of computing systems to provide fast and accurate analysis of logistical and tactical operations. Computing systems are highly reliable and can perform several operations simultaneously.

Computers are divided into two general types, analog computers and digital computers. The analog computer is one which solves problems by translating physical conditions; such as flow, temperature, pressure, angular position, and size of displacement into equivalent electrical quantities. These electrical measurements are continually being updated as the physical values change.

The gasoline gage on an automobile is one type of analog computer. The liquid in the gasoline tank operates a float which, in turn, physically controls the amount of battery current flowing through a rheostat mounted at the tank. The amount of current is proportional to the amount of gasoline in the tank and positions your gasoline gage to a position on the scale indicator which indicates the approximate amout of gasoline in the tank. Thus an analog computer gives an approximate solution in a continuous form, whereas a digital computer gives exact data solutions of discrete values.

The digital computer is one which solves problems by repeated high speed use of the fundamental arithmetic process of addition, subtaction, multiplication, or division inbinary, decimal or any pre-determined notation. The digital computer uses increments (digits) to express distinct quantities.

An example of a digital computer is a cash register. Certain specific digits are entered at the console and stored, and upon request, a digital output representing the sum (or difference) is printed out. Other digital computers include the abacus, desk calculator, punchcard machine, and the modern electronic computer. The coverage in this text will be devoted to the digital computer.

Digital electronic computers are classified as special-purpose or general-purpose computers. The special-purpose computer is designed to handle a specific type of data processing task as exacting and as efficiently as possible. A general-purpose computer is designed to handle a variety of data processing tasks in which its adaptability, storage capacity and speed are adequate.

Some of the more common places where computers are used (mostly ashore but some afloat) are in command activities, operation centers, communications, finance, medical, weather, supply, maintenance, oceanography, weapon systems, and Naval Tactical Data Systems.

BASIC COMPUTER

The oldest and still most common data processor is man. In fact, man is still the most efficient data processor if size, mass, and power consumption are used as the criteria. The input to the human data processor is mostly through the eyes and ears. His memory (brain) stores data to be processed and the instructions for processing the data. His brain also functions as the arithmetic and logic element and as the control element. The output can be verbal, written, a physical action or a decision not to act.

Taken in perspective, the human being is the most versatile data processor. He has the ability to interpret his instructions in such a way that they will cover situations that were not explicit in the original form of the instructions. This, by the way, is not an ability inherent in the electronic data processor.

Although man is a versatile data processor, he has some rather serious shortcomings.

His memory capacity is rather limited (on a given subject). He is also unreliable. When called upon to remember large quantities of data, he has an annoying tendency to forget details. His calculating ability is quite limited. The average person, using only his mind, is unable to perform a series of simple calculations. Unaided, man is rather slow in performing the simplest data processing operation.

In addition, man is unreliable when performing repetitious operations. Most data processing operations are repetitious, i.e., the same basic operation is performed many times using different pieces of data. Man's ability to think tends to interfere with his performance of these boring operations. Thus, although man is a remarkable data processor, he needs some auxiliary equipment if he is to be part of an efficient data processing system.

The basic computer (fig. 10-1) is made up of a central processing unit and the input/output devices. Data processing equipments have five functions associated with them: input, storage, control, arithmetic, and output. The computer's input section introduces data into the system. Once interpreted, the information is sent to a control section where it is further directed according to programmed instructions. As specified, the data is sent to storage or memory, a high-speed device able to read in and read out data in a few millionths of a second. Data in storage can be used over and over, or can be used only once and replaced. If the computer is so instructed, the data can be directed to the processor or arithmetic section. It is here that the computer really computes; adding, subtracting, and comparing numbers. The organized results are transferable to an output section for the creation of records and reports, or to produce new media for further processing needs.

CENTRAL PROCESSING UNIT

The basic sections of a digital computer are shown in figure 10-1. The three center blocks (arithmetic logic, memory, and control units) comprise what is generally referred to as the Central Processing Unit or central data processor.

Control Unit

The control section is comparable to a telephone exchange. It directs the operations of the computer under the direct influence of a sequence of instructions called the "program". The instructions are comparable to the phone numbers dialed into a telephone exchange and cause certain switches and control lines to be energized.

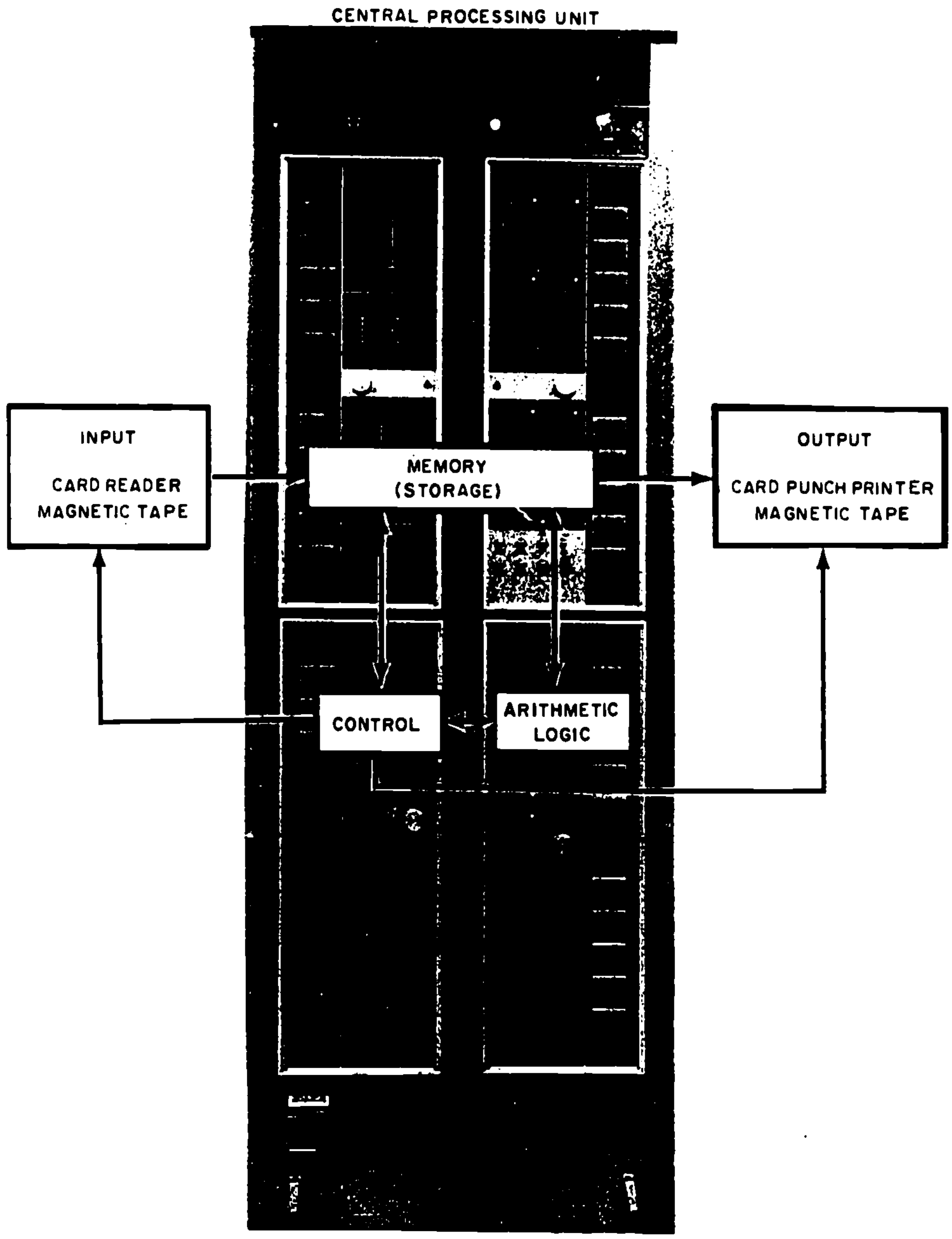
The program may be stored in the internal circuits of the computer or it may be read instruction-by-instruction from external media. The internally stored program type of computer, generally referred to only as a "stored program" computer, is the most practical type to use when speed and fully automatic operation are desired.

In addition to the command which tells the computer what to do, the control unit also dictates how and when each specific operation is to be performed. It is also active in initiating circuits which locate any information stored in the computer and in moving this information to the point where the actual manipulation or modification is to be accomplished.

In the stored program computer, the control unit reads an instruction from the memory section (as instructed by the program). The information read into the control unit from memory is in the form of voltage levels that make up a "binary word," and represents a specific operation that is to be performed. The location of the data to be operated on is generally a part of the instruction, and energizes circuitry which causes the specified operation (add, subtract, compare, etc.) to be executed. Subsequently, the control unit reads the next instruction or jumps as directed, (explained later) to find the next instruction to execute.

The four major types of instructions are: (1) transfer; (2) arithmetic; (3) logic; (4) control. Transfer commands are those whose basic function is to transfer data from one location to another. One of the locations is an address in memory and the other is either a register or an input/output device. Arithmetic instructions are those which combine two pieces of data to form a single piece of data using one of the arithmetic operations. In some types of computers, one of the pieces of data is in a location specified by the address contained in an instruction, and the other is already in a register (usually the accumulator). The results are usually left in the accumulator.

Logic instructions make the digital computer into a system which is more than a high speed



120.100.2

Figure 10-1.—Representative digital computer.

adding machine. By using logic instructions the programmer may instruct the system on various alternate sequences through the program. For example through the use of logic instructions, a computer being used for maintenance inventory will have one sequence to follow if the number of a given item on hand is greater than the order amount and another sequence to follow if the number on hand is smaller than the order amount. The choice of which sequence to use will be made by the control unit under the influence of the logic instruction. Logic instructions provide the computer with the ability to make decisions based on the result of previously generated data.

Control instructions are those which are used to send commands to devices which are not under direct command of the control unit, such as input/output units. The address contained in the instruction does not specify a location in memory but is usually a code group specifying an action required of a particular piece of equipment.

In a single address computer, i.e., where each instruction refers to only one address or operand, the instructions are normally taken from the memory in sequential order. If one instruction comes from a certain location, say X, the next instruction is usually taken from location X + 1. However, the execution of a logic instruction may produce a result which dictates that the next instruction is to be taken from an address as specified in a portion of the logic instruction. For example, the logic instruction may cause certain operations in the computer to determine if the content of a given register in the arithmetic section is negative. If the answer is "yes," the location of the next instruction is that specified in an address section of the logic instruction. If the answer is "no," the next instruction would be taken from the next sequential location in the memory.

Every computer provides circuitry for a variety of logic instructions for choosing alternate instruction sequences if certain desirable or undesirable conditions exist. The ability to "branch" at key points is the special feature of the computer that makes it able to perform such diverse tasks as missile control, accounting, or tactical air plotting.

Arithmetic Unit

The arithmetic unit of the computer is the section in which arithmetic and logic operations are performed on the input or stored data. The arithmetic operations performed in this unit include adding, subtracting, multiplying, dividing, counting, shifting, complementing, and comparing.

All arithmetic operations can be reduced to any one of four arithmetic processes; addition, subtraction, multiplication, ordivision. In most computers, multiplication involves a series of additions; and division, a series of subtractions.

The arithmetic unit contains several registers; units which can store one "word" of computer data. This group of registers generally include D, X, and Q registers (so named for identification purposes only), and a unit called an "accumulator" (A register). During an arithmetic process, the D, X, and Q registers temporarily hold or store the numbers being used in the operation, called "operands". The accumulator stores the result of the operation. The control unit instructs the arithmetic unit to perform the specified arithmetic operation (as requested in the instruction); transfers the necessary information into the D, X, and Q registers from memory (discussed later); and controls the storage of the results in the accumulator or in some specific location in memory.

The arithmetic unit also makes comparisons and produces "yes" or "no" or "go-no-go" outputs as a result. The computer may be programmed so that a "yes" or "go" result advances the computer units to perform the next step in the program, whereas a "no" or "no-go" instruction may cause the computer to jump several programmed steps. A computer may also be programmed so that a "no" result at a certain point in the program will cause the computer to stop and await instructions from a keyboard or other input device.

Generally information delivered to the control unit represents instructions, whereas information routed to the arithmetic unit represents data. Frequently it is necessary to modify an instruction. This instruction may have been used in one form in one step of the program but must be altered for a subsequent step. In such cases, the instruction is delivered to the arithmetic unit where it is altered by addition-to or subtraction-from another number in the accumulator. The resultant modified instruction is again stored in the memory unit for use later in the program.

Memory Unit

In most digital computers the storage or memory section is constructed of small magnetic cores, each capable of representing an "ON" ("1") or "OFF" ("0") condition. A system of these cores arranged in a matrix can store any computer word which is represented in binary form.

All computers must contain facilities to store computer words or instructions (which are intelligible to the computer) until these instructions or words are needed in the performance of the computer calculations. Before the stored program type computer can begin to operate on its input data, it is first necessary to store, in memory, a sequence of instructions and all figures, numbers, and any other data which are to be used in the calculations. The process by which these instructions and data are read into the computer is called "loading."

Actually the first step in loading instructions and data into a computer is to manually place enough instructions into memory by using the console or keyboard so that these instructions can be used to bring in more instructions as desired. In this manner a few instructions are used to "bootstrap" more instructions. Some computers make use of an auxiliary (wired) memory which permanently stores the "bootstrap program," thereby making manual loading unnecessary.

The memory (or storage) section of a computer is essentially an electronically operated file cabinet. It is actually a large number (generally between 1 and 40 thousand) of storage locations; each referred to as a storage address or register. Every computer word which is read into the computer during the loading process is stored or filed in a specific storage address and is almost instantly accessible.

Input/Output Unit

Input and output devices are similar in operation but perform opposite functions. It is through the use of these devices that the computer is able to communicate with the outside world.

Input data may be in any one of three forms: it may be fed in manually from a keyboard or console; from instruments or sensors; or from a source on which data has previously been stored in a form intelligible to the computer.

Computers can process hundreds of thousands of computer words per second. Thus, a study of the first method (manual input) reflects the incompatibility of human-operated keyboards or keypunches to supply data at a speed which matches the electronic speed of digital computers. A high average speed for keyboard operation is 2 or 3 characters per second, which when coded to form computer words may have more than 15 to 20 binary digits. The computer is capable of reading several thousand times this amount of information per second. It is clear, therefore, that manual inputs should be minimized to make more efficient use of computer time.

Instruments are used as input sensors, and are capable of supplying several thousand samples regarding pressure, temperature, speed, etc., per second. This is equivalent to 10 or 20 thousand bits or binary digits per second. Digital computers which use these devices must be equipped with analog-digital converters to convert physical change to specific increments.

Input data which has previously been recorded on punched cards, perforated tapes, magnetic tapes or magnetic drums or disks in a form understood by the program may also be entered into the computer, this being a much faster method than entering data manually from a keyboard. The most commonly used input devices in this category are magnetic tape readers or paper tape (perforated tape) readers.

Output information is also made available in three types: human information, such as codes or symbols presented on a cathode-ray screen which are used by the operator to answer questions or make decisions; information which operates a control device such as a lever, aileron, or actuator; or information which is stored in a machine language or human language, on tapes, or printed media.

Devices which store or read-out output information include magnetic tape, punched cards, punched paper tapes, cathode-ray oscilloscopes, electric typewriters, line-at-a-time printers, and surface-at-a-time printers.

One of the main features of computers is their ability to process large amounts of data quickly. In most cases, the processing speed far exceeds the ability of input devices to supply information. One common limitation of most input devices is that each involves some mechanical operation, that is, the movement of a tape drive or card feeder. Because a mechanical movement of some part of these devices cannot take place fast enough to match electronic speeds within the computer, these input devices limit the speed of operation of the associated computer particularly in cases where successive operations are dependent upon the reception of new data from the input medium.

Several methods of speeding up mechanical operations have been devised, all of which are designed to move a smaller mass a shorter distance and with greater driving force. Many of these designs have been directed toward increasing the drive speed of magnetic tapes. Present day tape drives can pass up to 150 inches of tape per second over a tape reading head. Card readers can read between 100 and 2000 cards per minute, depending on the particular reader.

Another method of entering data into a computer which has not previously been mentioned is to link two (or more) computers together and program them to communicate with each other. This is the fastest method of entering or extracting data.

COMPUTER OPERATIONS

With an understanding of the function of the various computer sections, let us now consider a basic computer instruction and how this instruction is executed. Let the instruction be as follows:

> "Add the contents of the A register to the contents of memory address location 123 and store the results in address 456 in memory."

We will assume that the computer used is the stored program type and that all instructions, data, numbers, and symbols have been previously loaded or stored in memory at known addresses. The stored input may have been read from a magnetic tape (similar to that used with commercial tape recorders), from paper tape (similar to that used with teletype), or from punched cards.

If the instruction to be executed is the first programmed operation, energizing the start button will cause the control unit to issue an order "Read instruction." The instruction will be read into a register in the control unit where it will remain throughout the execution cycle.

Note that the mathematical operation requested in the instruction is ADD. The instruction word thus contains a code which is interpreted by the control unit as ADD.

After reading the instruction, the control unit automatically energizes circuits which will (1) read-out the contents of memory address 123, (2) transfer this information to a register (say the X register) in the arithmetic unit, and (3) perform an add X to A operation.

The ADD process is thus accomplished, being constantly monitored by the control unit to ensure that no further actions are initiated before the ADD operation is completed. The results of the ADD operation are stored in the accumulator from which, by control request, it is transferred to address 456 in memory. This ends the instruction. The control unit will read and execute the next instruction.

If the result is to be displayed at the output immediately or at a later time (as stipulated in the programmed instructions) the control unit upon receipt of the instruction will issue an order to read-out the contents of memory address 456. Because read-out (which sometimes involves printing by some electromechanical apparatus) is extremely slow as compared to computer speed, most computers use a secondary storage device called a buffer into which data is read directly from the primary (main) storage at computer speeds. When read-out is desired, the control unit enables the buffer storage to read-out all or any part of the buffer storage data. The buffer read-out is independent of the main computer operation, and in some computers only one instruction is required to start and stop the read-out process.

COMPONENTS USED IN COMPUTERS

Unlike the mechanical computer, such as adding machines and odometers which are based on the decimal (ten) digit system, modern electronic computers use components which will represent only 2 conditions. These conditions are sometimes referred to as the 1 (energized) or 0 (deenergized) states. Early computers used relays and electron tubes; now transistors and silicon or germanium diodes are used because of the higher speeds at which they can react, and too, because of their lower power consumption.

Electronic circuits used in computers are basically simple. To a large extent these circuits are of four types: the OR circuit which produces an output when one or more of its inputs are active, that is, in the one state: the AND circuit which yields an output only when all inputs are active; the flip-flop circuit which is a bistable multivibrator; and the inverter circuit which yields a high output with a low input or a low output with a high input.

COMPUTER TOOLS

Components or tools of a computer system are categorized as either hardware or software. Hardware includes all the mechanical, electrical, electronic, and magnetic devices within a computer system. Software consists of the automatic programming materials developed for the most efficient use of the hardware and is usually supplied by the manufacturer of particular systems.

Hardware.—Computer hardware falls into two categories, peripheral equipment and the central processor. PERIPHERAL EQUIPMENT includes all input and output devices associated with specific recording media such as, a card reader and punch with punched cards, or magnetic tape units with magnetic tape. This peripheral equipment can operate ON-LINE under direct control of the central processor or OFF-LINE, independently of the central processor.

As previously stated the CENTRAL PROCESSOR includes the Control, Arithmetic, and Memory units.

During ON-LINE operations, data can be transferred to and from peripheral devices and the central processor under the influence of CONTROL UNITS. These units may be free-standing, or built into either the central processor or the peripheral device, and receive their signals or instructions from the stored program.

In OFF-LINE or AUXILIARY operations, the input and output devices are used in conjunction with other peripheral devices not directly connected to the system. Since input output data conversion operations are relatively slow compared to the speed of the central processing unit, off-line operations free the computer of time-consuming procedures and provide more time for the computing and processing of data by the central processor. For example, a system's output data could be written on magnetic tape (because of its speed) and, in an off-line operation, converted to some other record form—by a slower device. This allows the computer to continue processing new data.

Software.—This consists primarily of general purpose programs that are common to many computer installations. Included among them would be assemblers and compilers which aid in producing machine language routines from a relative or nonmachine language source, plus sort, control, and other utility programs.

ELECTRONIC DATA PROCESSING EQUIPMENTS

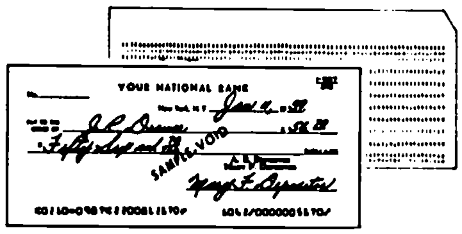
In certain respects, electronic data processing is similar to the unit record system in that punched cards may be used as input, and printed reports or punched cards may be produced as output. The unique difference lies in the manner of processing the data and the electronic equipment used in its processing applications. Whereas the unit record system required the physical movement of cards from one machine to another, the electronic system permits many processing functions to be performed in one operation. This is made possible through the use of several interconnected devices which, working together, can receive, process, and produce data in one operation without human intervention. These devices constitute an electronic data processing system.

The operations of preparing source documents, punching cards from source documents, and (for a punched card EDPS) sorting punched cards, are accomplished by the same methods used in the unit record system. However, systems using magnetic tape for input generally have punched card data transcribed onto the tape, and it in turn is sorted into a sequence acceptable for processing by the computer. Once information has been entered into the system, all classification, identification and arithmetic operations are performed automatically in one or several processing routines. This is accomplished by a set of written instructions called a PROGRAM which, when recorded onto punched cards or magnetic tape and fed into the system, controls operations automatically from start to finish.

Information used as input to an electronic data processing system may be recorded on punched cards, paper tape, magnetic tape, or magnetic ink or optically read documents, depending upon the system requirements. Similarly, output may be in the same forms with the addition of printed reports, again depending upon the system.

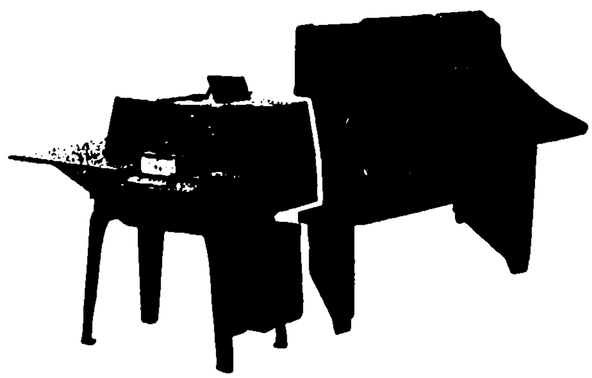
Figure 10-2 shows some of the major Electronic Data Processing (EDP) equipments presently in use.

UNIT RECORDS



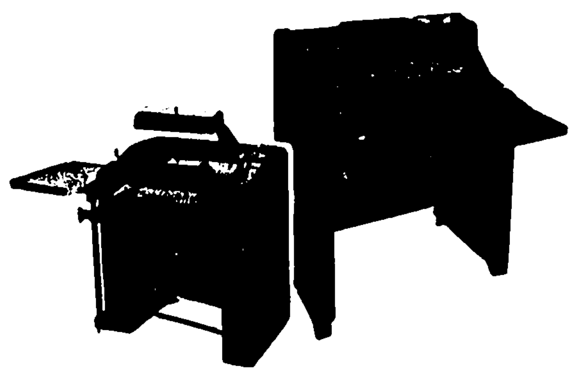
RELATED FACTS TREATED AS A UNIT, RECORDED ON INPUT MEDIA ACCEPTABLE TO A DATA PROCESSING SYSTEM.

CARD PUNCH



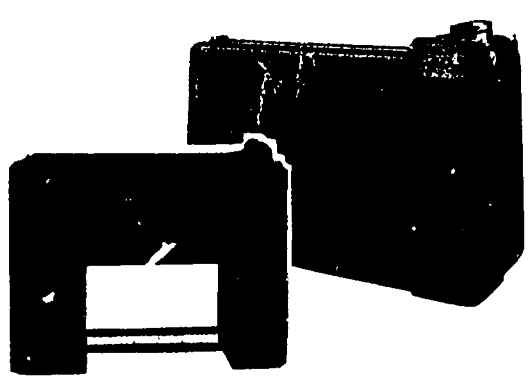
A MACHINE WHICH ALLOWS AN OPERATOR TO PUNCH DATA INTO CARDS FOR CONVEYANCE INTO OTHER MACHINES OR DEVICES. SYNONOMOUS WITH KEYPUNCH.

CARD VERIFIER



CHECKS ORIGINAL PUNCHING OF DATA IN CARDS FOR TRANSCRIPTION ERRORS.

CARD SORTERS

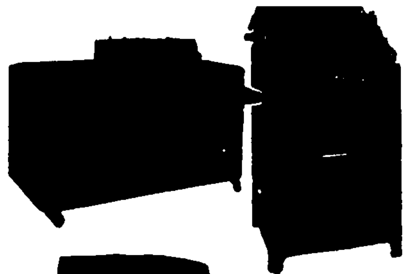


SELECTS OR ARRANGES PUNCHED CARD UNIT RECORDS IN A DESIRED SEQUENCE.

49.215.1

Figure 10-2.—Representative Electronic Data Processing Equipments.

ACCOUNTING MACHINE



PERFORMS END OF THE LINE PROCESSING OF PUNCHED CARDS THROUGH ITS ABILITY TO ADD, SUBTRACT, AND PRINT REPORTS. SYNONYMOUS WITH TAB AND TABULATOR.

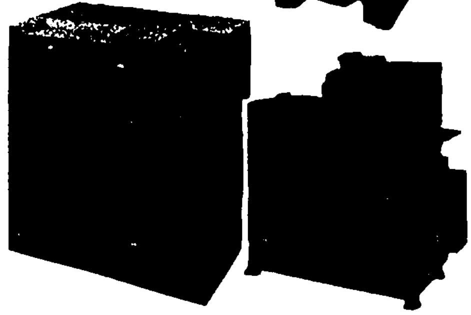
INTERPRETER

READS, INTERPRETS, AND PRINTS PUNCHED CARD DATA ON THE FACE OF A CARD.

REPRODUCER

USED PRIMARILY TO CREATE NEW FILES BY REPRODUCING ALL OR PORTIONS OF DATA FROM ONE UNIT RECORD TO ANOTHER, OR ADDING NEW INFORMATION TO EXISTING FILES.

COLLATOR



A FILING MACHINE USED TO ARRANGE OR SELECT CARDS FOR SUBSEQUENT OPERATIONS.

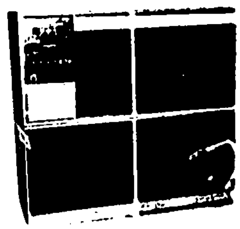
1004 CARD PROCESSOR

A SOLID-STATE ELECTRONIC PROCESSING MACHINE WITH AN EXTERNAL CONTROL PANEL, INCORPORATING CARD READING, ARITHMETIC PROCESSING, AND PRINTING FUNCTIONS.

49.215.2

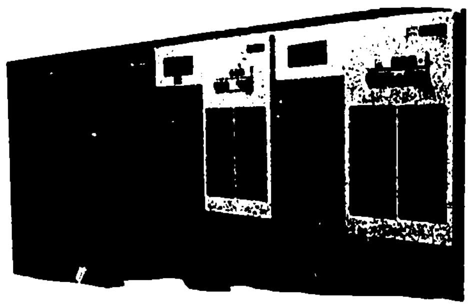
Figure 10-2.—Representative Electronic Data Processing Equipments—(Cont'd).

CENTRAL PROCESSING UNIT



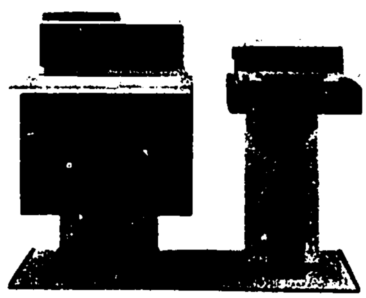
THAT PORTION OF A COMPUTER EXCLUSIVE OF PERIPHERAL EQUIPMENT THAT CONTAINS THE MAIN STORAGE, ARITHMETIC-LOGIC UNITS, AND CONTROL SECTION. SYNONOMOUS WITH CPU.

SYSTEM CONTROL UNITS



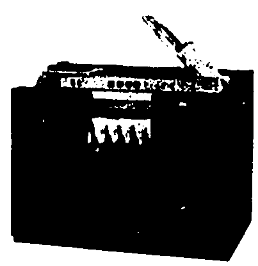
USED PRIMARILY TO CONTROL ALL OPERATIONS INCLUDING INPUT AND OUTPUT FUNCTIONS.

CONSOLE



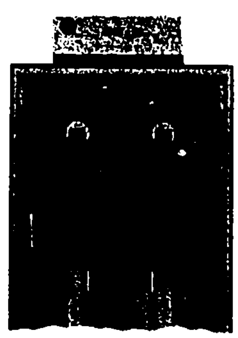
PROVIDES EXTERNAL CONTROL OF A DATA PROCESSING SYSTEM. USED MAINLY TO DETERMINE THE STATUS OF CIRCUITS, COUNTERS, PANEL REGISTERS, AND CONTENTS OF STORAGE.

CARD READ PUNCH



AN INPUT AND OUTPUT DEVICE THAT READS AND CONVERTS PUNCHED CARD DATA FOR TRANSFERENCE INTO STORAGE OR ONTO MAGNETIC TAPE; TRANSFERENCE FROM STORAGE OR MAGNETIC TAPE TO PUNCHED CARDS; CAN BE INDIVIDUAL UNITS.

MAGNETIC TAPE UNIT

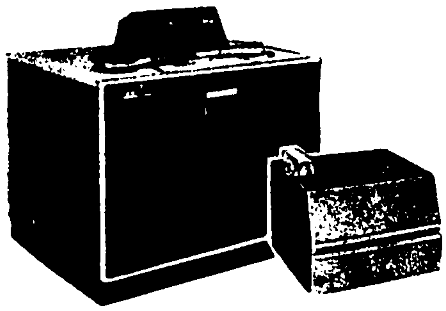


INPUT AND OUTPUT DEVICE CAPABLE OF READING AND WRITING INFORMATION (REPRESENTED BY MAGNETIC SPOTS) ON AND FROM MAGNETIC TAPE.

49.215.3

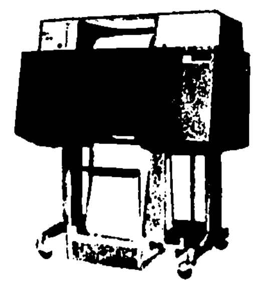
Figure 10-2.—Representative Electronic Data Processing Equipments—(Cont'd).

PAPER TAPE
READER AND
PUNCH



INPUT AND OUTPUT DEVICES WHICH CAN SENSE AND PUNCH THE HOLE PATTERNS OF PAPER TAPE, COULD BE A COMBINED UNIT.

HI-SPEED
PRINTER

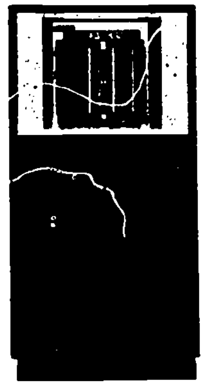


A PRINTER OUTPUT DEVICE WHICH OPERATES AT A SPEED COMPATIBLE WITH THE SPEED OF COMPUTER COMPUTATION AND PROCESSING, ENABLING IT TO OPERATE ON-LINE IF NECESSARY.

DISK STORAGE

A STORAGE DEVICE IN ADDITION TO MAIN STORAGE OF THE CPU WHEREIN DATA IS RECORDED BY MAGNETIC SPOTS ON THE SURFACE OF FLAT CIRCULAR MAGNETIC DISKS.

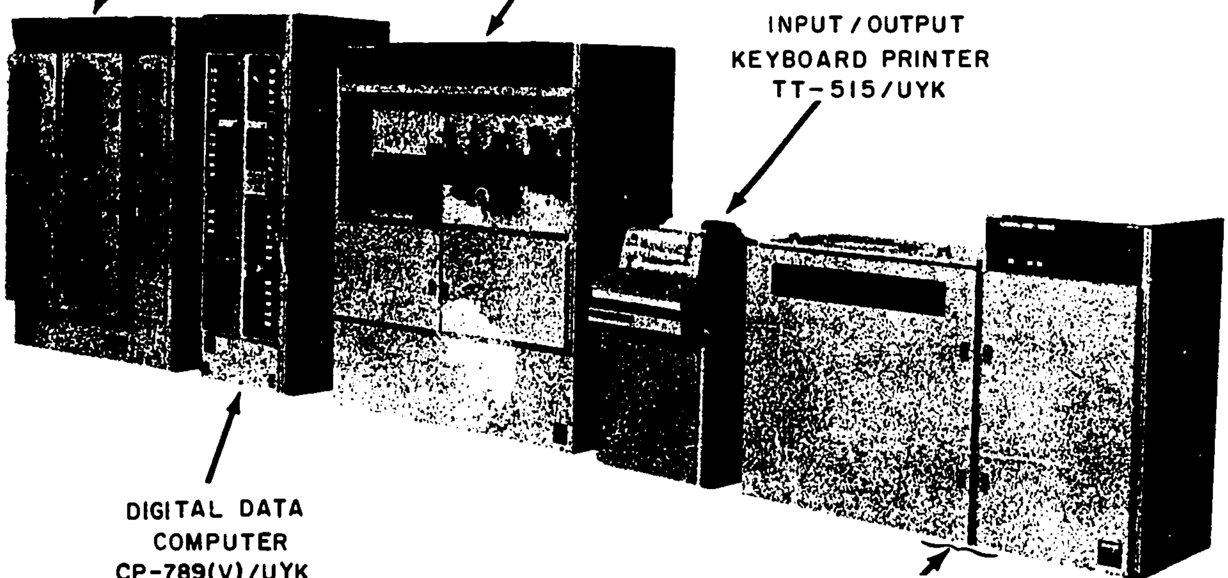
DRUM STORAGE



A STORAGE DEVICE IN ADDITION TO MAIN STORAGE OF THE CPU WHEREIN DATA IS RECORDED BY MAGNETIC SPOTS ON BANDS OR CHANNELS OF A ROTATING CYLINDER.

49.215.4

Figure 10-2.—Representative Electronic Data Processing Equipments—(Cont'd).



120.100(120C)

Figure 10-3.—Data Processing Set AN/UYK-5(V).

DATA PROCESSING SET AN/UYK-5(V)

The Data Processing Set AN/UYK-5(V) (fig. 10-3) is a general purpose processing system developed for shipboard installations of the Standard Navy Maintenance and Material Management (3M) system. It includes:

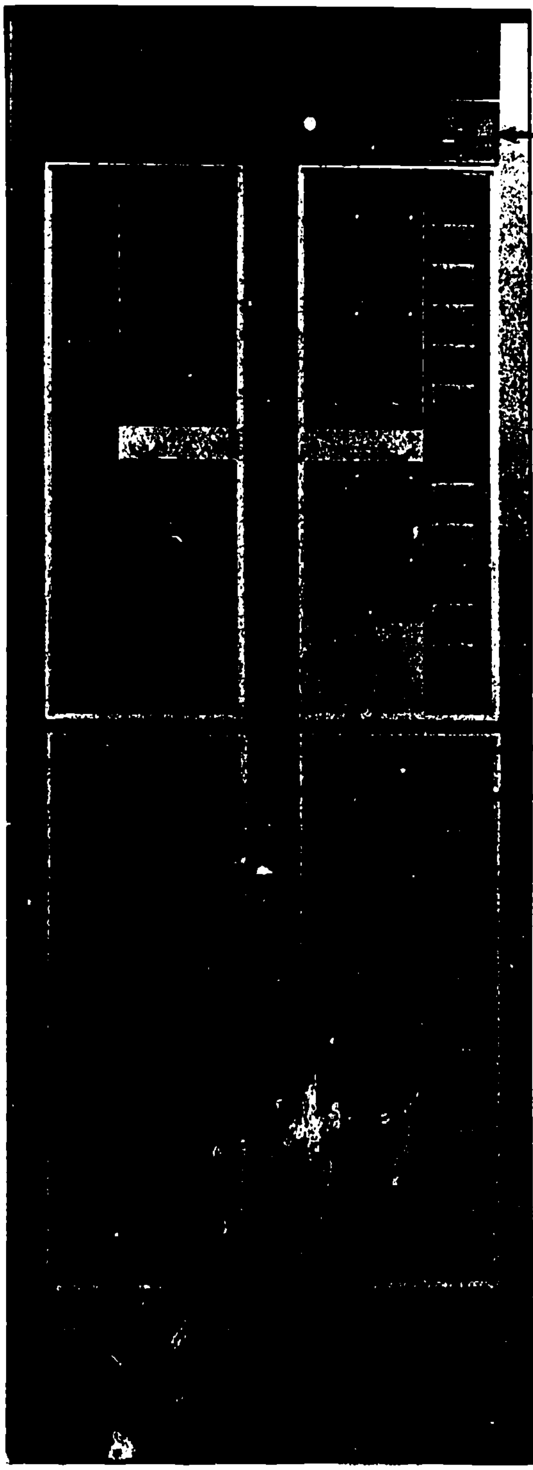
- Digital Data Computer CP-789(V)/UYK
- Digital Data Recorder-Reproducer RD-270(V)/UYK
- Card Reader-Punch-Interpreter Unit RD-293/UYK-5(V)
- Input/Output Keyboard Printer TT-515/UYK
- Data Processing Line Printer RO-302/UYK-5(V)
- Motor-Generator PU-655/U (not shown)

The handling of supplies and accounts is accomplished by a stored program type real-time digital data computer. During the execution of stored instructions from memory, the input/output section is continuously monitored and whenever any peripheral equipment connected to the computer has a request to send data to the computer or wants data from the computer, the computer program interrupts and honors the input/output request. After input or output, the computer resumes executing programmed instructions as stored in memory.

The input/output sections have four channels available. All input/output transfers are buffered under buffer control so that they do not require program attention, and will operate at the rate required by the external device.

DIGITAL DATA COMPUTER CP-789(V)/UYK

The computer (fig. 10-4) consists of a power control panel, with either four or six pull-out bays and a power supply. The upper



120.100.2

Figure 10-4.—Digital Data Computer CP-789(V)UYK.

left bay contains the input/output section logic and switches. The upper right bay (control panel 1) contains the arithmetic section logic and some of the control section logic and switches. The lower left bay contains the computer memory. The lower right bay (control panel 2) contains control section logic and switches. If six pull-out bays are present (not shown), the upper bay is empty and the lower bay contains a larger core memory. The pull-out bays extend forward to facilitate access to the printed-circuit cards, switches, and memory modules. Internal blowers cool the computer.

The computer is basically an automatic machine, however there are certain switches and controls that affect computer operation. These switches and controls provide means of selecting computer operating speed, selecting optional program jumps or stops, selecting input/output modes, and setting and clearing the registers.

DIGITAL DATA RECORDER-REPRODUCER RD-270(V)/UYK

The RD-270(V)/UYK magnetic tape unit (fig. 10-5) is a large capacity, medium speed, magnetic tape storage system. It is capable of receiving data from the computer and recording it on magnetic tape or retrieving information previously recorded on tape and transferring it to the computer. It is usually used on-line, but it may be used in an off-line mode of operation with the high speed printer. Information recorded on magnetic tape is retrieved and transferred to the high speed printer for reproduction in printed form.

Card Reader-Punch-Interpreter Set RD-293/UYK-5( )

The RD-293/UYK-5( ) (fig. 10-6) unit is a computer input/output device that provides interim storage for, and intermediate control over information transmitted between the computer and keyboard-printer, high-speed printer, and reader-punch interpreter system. The reader-punch-interpreter assembly is an on-line panel-mounted card reading, punching, and printing system. It consists of a card punch head assembly, a printer head assembly, two photoelectric reading stations, an input card hopper, two output card stackers, and the electrical mechanical and pneumatic devices necessary to select, transport, process and stack standard size 80-column cards.

Input/Output Keyboard Printer TT/515/UYK

The teletypewriter set (fig. 10-7) provides a means by which an operator can conveniently transmit information to and receive direct replies from the computer. As an input device the unit can be used for manually loading programs and other input data, for example, constants and program parameters, into the computer; for altering existing programs, portions of a program, or constants stored in the computer memory, and for initiating and terminating various computer operations. As an output device the unit can be used for printing out errors, conditions requiring decisions or operator intervention, and various types of computer output data. The control logic for the keyboard printer is incorporated in the card reader-punch-interpreter cabinet.

DATA PROCESSING LINE PRINTER RO-302/UYK-5(V)

The RO-302/UYK-5(V) is a high speed line/printer system consisting of two major sections (fig. 10-8) referred to as a printing compartment (mechanical section on left side) and electronics compartment (on right side).

The printing compartment houses a high speed line/printer mechanism which consists of a drum gate assembly, interlock, drum motor, position pickup, paper feed assembly paper interlocks, paper feed stepping motor, and paper feed magnetic pickup.

The electronics compartment consists of two power supplies, printed logic chassis, two printed-circuit card chassis and cards, two capacitor banks, fuse panel and a control circuit for the paper feed stepping motor.

The high speed line/printer can be used as an on-line computer output device which produces printed copy in alphanumeric form from binary-coded computer output data. The unit is capable of printing 64 different characters including the upper case alphabet, numerals 0 through 9, punctuation symbols, and special characters.

The high-speed printer control panel contains all the controls and indicators necessary

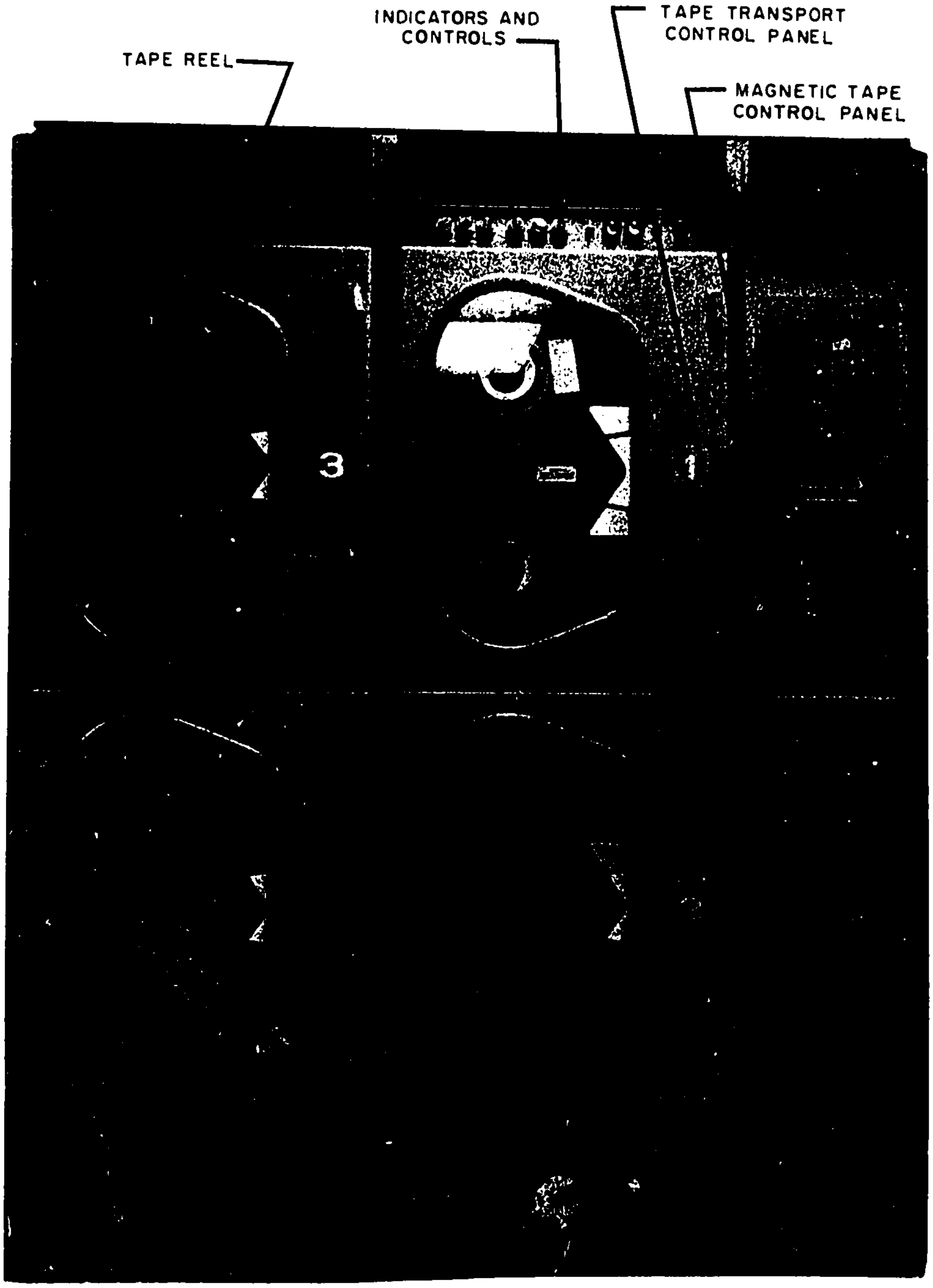


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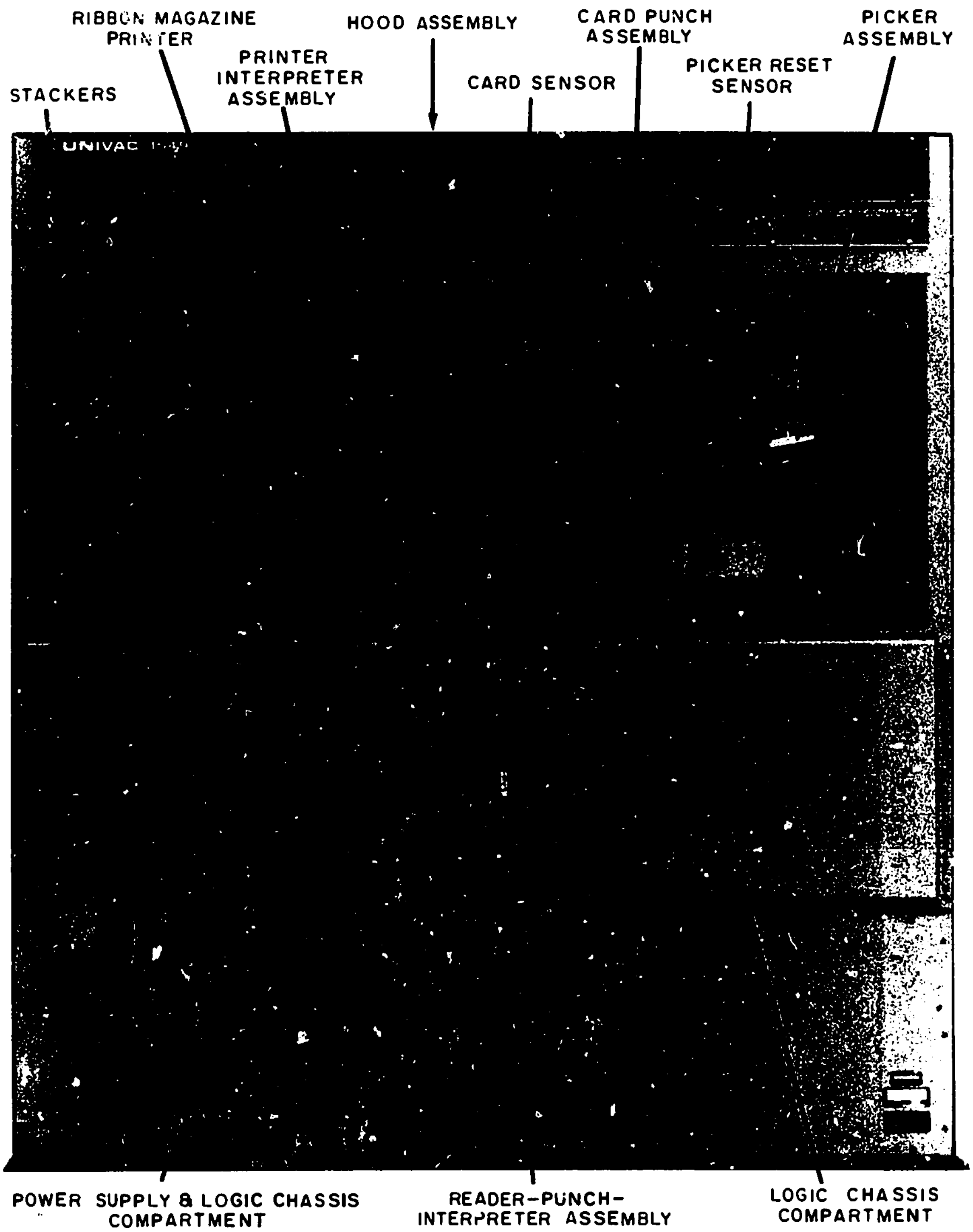
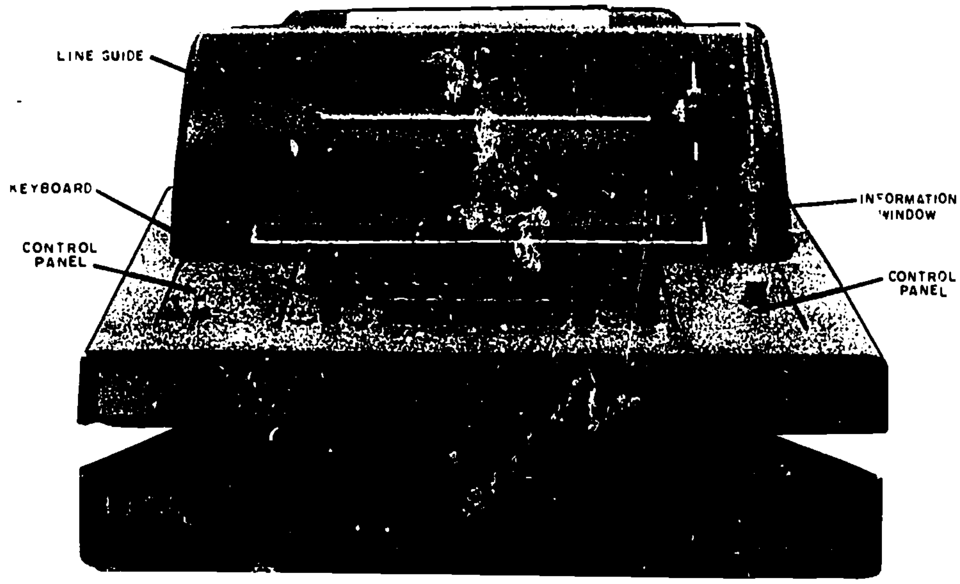
Figure 10-5.—Digital Data Recorder-Reproducer RD-270(V)/UYK.



120.100.3

Figure 10-6.—Card Reader-Punch-Interpreter Unit RD-293/UYK-5(V).



120.100.4

Figure 10-7.—Input/Output Keyboard Printer TT-515/UYK.

to operate and monitor the printer once paper and ribbon have been properly installed in the printer mechanism.

UNIFORM AUTOMATIC DATA PROCESSING SYSTEM

The Uniform Automatic Data Processing System (UADPS) is a program designed to apply electronic data processing equipment and techniques to the supply function at Navy Stock Points. The Navy Stock Point provides a large variety of items for bulk and ready issue supply support to the operating forces of the fleet and to shore based activities.

The UADPS system consists of Inventory Control Points, the Navai Supply Depot in Rhode Island, and several supply centers. The basic control points are for navy ships parts, aviation supplies, and electronic supplies.

The UADPS centers use real time random access computer operations to process incoming requisitions, receipt notices, and requests for information. Many incoming requests enter the system from dockside input/output stations.

Upon receipt of a request, inventories are are automatically checked and warehouses are notified of articles to be shipped, or where needed articles can be obtained. The system also keeps accounting and inventory records, assembles and prints management reports, and points out trouble spots for immediate attention.

DATA PROCESSING SET AN/UYK-1

The AN/UYK-1 (not shown) is a general purpose, stored program computer set designed for shipboard environment. The computer can be used with, but is not a part of, the Navy Tactical Data Systems, and with the oceangraphic and navigation systems. It computes and manipulates digital data at electronic speeds, and stores data in its magnetic core memory. The computer controls, or can be controlled by a variety of peripheral devices such as teletype machines, paper tape punches, and readers, magnetic tape transports, punched card readers, high speed printers, magnetic drums, and all components of NTDS. The computer uses 30-bit words. Magnetic core memory may contain as many as 32,768 words.

Digital Data Computer CP-642( )/USQ-20(V)

The Naval Tactical Data System (NTDS) is an automatic data system for gathering and processing data received from the ship's

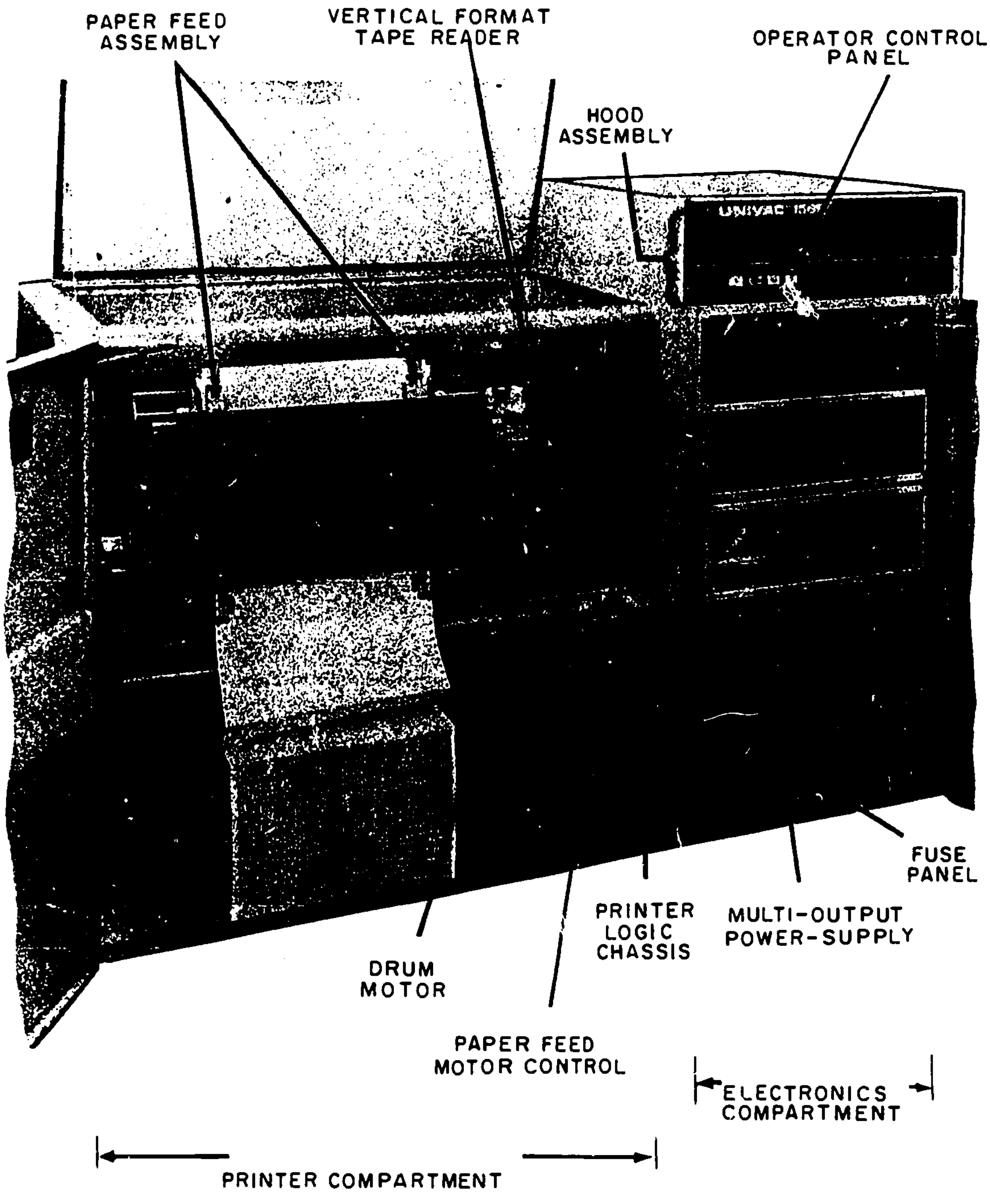


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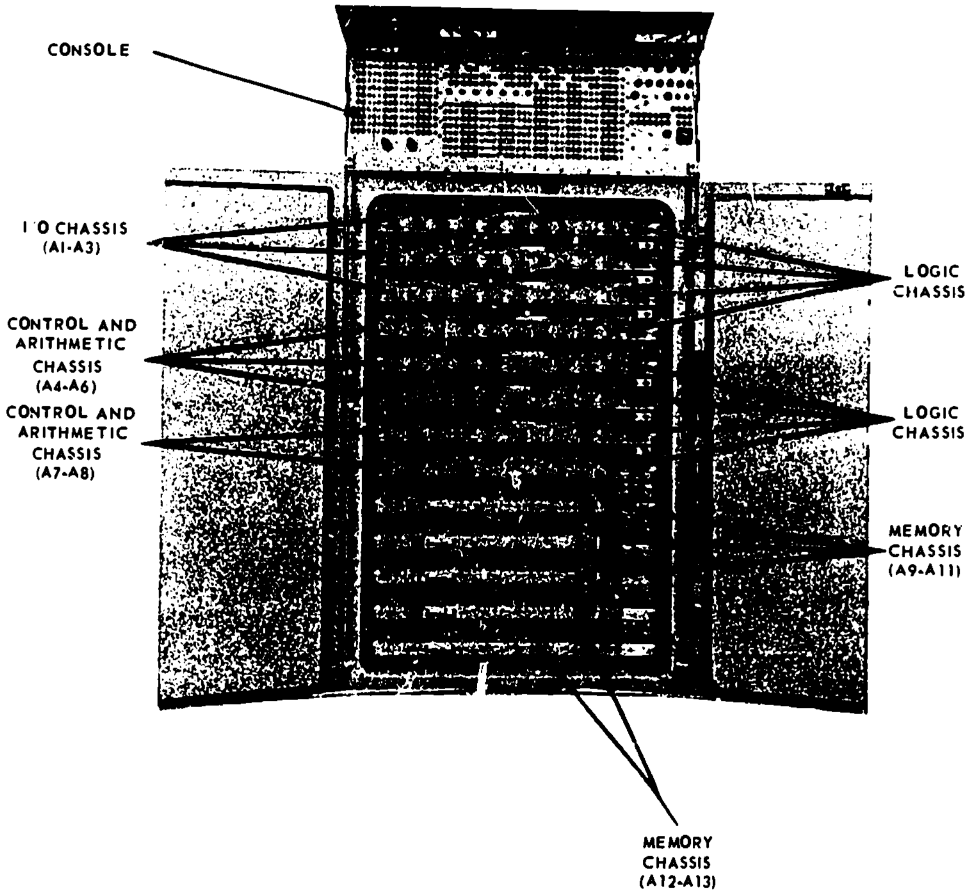
Figure 10-8.—Data Processing Line Printer RO-302/UYK-5(V).



151.93

Figure 10-9.—Digital Data Computer CP-642( )/USQ-20(V) showing major subassemblies.

sensors. It utilizes digital computers which operate in a real-time environment.

The NTDS computer CP-642( )/USQ-20 (fig. 10-9) is a general purpose, stored program computer. A list of instructions (program) is entered into the computer storage area prior to executing the problem. The program directs the computer in the execution of logical steps which ultimately produce a solution to a given problem. In addition to performing routine tasks in connection with calculating and processing the information received in the Combat Information Center, such as tracking and presenting intercept solutions, the computer can store a program to check out the NTDS equipments, or, when not needed for CIC use, it can be used to solve logistic problems.

The CP-642( )/USQ-20(V) is capable of rapid processing of large quantities of complex data. The computer performs arithmetic and logical functions by manipulating binary numbers in automatic or manual modes of operation.

The major subassemblies of the computer are of modular design, having 13 roll-out type chassis; eight of which are logic chassis used for input/output, control, and arithmetic, and five used for memory. Memory chassis are interchangeable.

Connections between the chassis are made by movable plug-racks (not shown) located on the sides of the computer and jacks mounted on the sides of the chassis. Connections between the computer and external equipment is via jacks (not shown) located on the top of the computer.

OPERATIONAL FEATURES

The major features of the computer include:

1. An internal, high-speed magnetic storage with a cycle time of eight microseconds and a capacity of 32,768 30-bit words.
2. A repertoire of 62 instructions, most of which provide for conditional program branches.
3. Average instruction execution time of 13 microseconds.
4. A word length of 30 bits.
5. Optional operation with 15-bit half words.
6. Internally stored programs.
7. Parallel, one's complement, subtractive arithmetic.
8. Single address instructions with provisions for address modification.
9. Internal 7-day real-time clock for initiating operations at desired times.
10. Twelve input and twelve output channels for rapid data exchanges with external equipment.
11. Two input and two output channels for intercomputer data transfer.
12. A 16-word auxiliary wired memory for storage of critical instructions and constants that provide the facility for automatic recovery in the event of program failure and for initial loading of programs.

Computer Console Set C-3413/USQ-20(V) is the remote console associated with the computer (fig. 10-10). Although the computer itself is basically an automatic machine, the console provides facilities for manual intervention and control of the computer. The operator has switches on the console that are used to affect the entire computer operation by injecting several modes of operation as, providing certain jump or stop conditions, controlling computer operations, and governing speed of operation. There are also controls by which a single stage can be set or an entire register can be cleared.

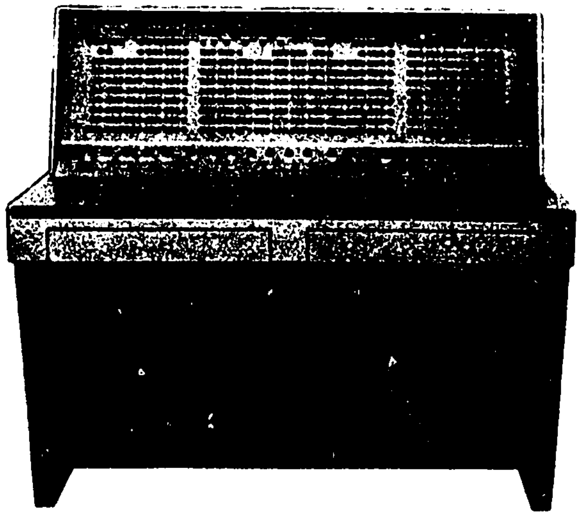


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Figure 10-10.—Computer Console Set C-3413/USQ-20(V).

CHAPTER 11

INTRODUCTION TO A SHIPBOARD WEAPONS CONTROL SYSTEM

This chapter will give you an overview of a shipboard gun and missile weapon system. The treatment is brief for several reasons. First, to describe the physical features and functioning of components of a weapon system in detail would require several volumes. Second, security requires that we describe the functions of certain equipments in very general terms. In some cases values of range, target height, target speed, and other characteristics of the target and equipment have been left out. But this chapter will provide you with the background you will need to understand the many weapons systems now in the fleet.

WEAPONS SYSTEM CONCEPT

The effective use of any weapon requires that a destructive device (usually containing an explosive) be delivered to a target—usually a moving target. To deliver the weapon accurately, we must know the location of the target, as well as its velocity and direction of motion. Many targets now travel faster than sound, and must therefore be engaged at great distances. Against such targets, a weapon is most effective when it is used as part of a weapon system. A weapon system is the combination of a weapon (or multiple weapons) and the equipment used to bring their destructive power against an enemy.

A weapons system includes:

1. Units that detect, locate, and identify the target.
2. Units that direct or aim a delivery unit.
3. Units that deliver or initiate delivery of the weapon to the target.
4. Units that will destroy the target when in contact with it or near it. These units are usually termed weapons.

DETECTING UNITS

The first steps in using a weapon system to solve the fire control problem are to detect, locate, and identify the target. Initial contact with a surface or air target may be visual, or it may be made by radar. It is difficult to detect a target visually at long range, or even at short range when visibility is poor. For that reason, targets are usually detected by search radar. Search radars, as you know, keep a large volume of space around your ship under continuous watch. They give the ship accurate information about the target's position, even when the target is hidden by fog or darkness. To determine a target's position we must know its range, its direction from the ship, and, for an air target, its elevation. Radar gives all three of these coordinates. (Radar has certain disadvantages, too. For example, it can be detected by an enemy at about 1.5 times the range at which it can pick up an enemy target.)

Optical devices are used as a source of information on slow-moving targets at relatively short range. They are useless against missiles or jet aircraft, which must be engaged while they are still beyond the range of optical instruments.

After we have detected and located a target, we must identify it. How can we identify a target that may be several hundred miles from out ship? The answer lies in a device called IFF (Identification, Friend or Foe). Radar alone cannot tell the difference between a friendly or enemy target. But the IFF equipment can challenge an unidentified target, and determine from the answer whether the target is friendly. The equipment consists of two major units—the challenging unit which asks the question, friend or foe, and the transponder which answers the question. IFF equipment is used in conjunction with search radar, and sometimes fire control radar. Briefly, this is how it works. To challenge a target you press a switch attached to the radar. The IFF transmitter will then send out a pulse of low power radio energy toward the target. If the target is friendly it will carry a transponder, which consists of a receiver and a transmitter. When the receiver picks up a challenge, it causes the transmitter to send out an answering pulse or pulses. The answer is usually a coded message. It is picked up by the challenging unit's receiver and sent to the indicator of the search radar.

CONTROL UNITS

Control units in a weapon system develop, compute, relay, and introduce data into a delivery unit, a weapon, or both. They direct, control, or guide the weapon (destructive device) to the target, and cause it to function in the desired way. These units form the heart of the weapon system.

Types of Control Units

The devices that perform the control functions include: DATA TRANSMISSION SYSTEMS that send target position information developed by the detecting units to the rest of the weapon system, and convey other data among the components of the weapon system. Examples are synchro, resolver, and potentiometer circuits.

COMPUTER DEVICES are used to process the input data from the detecting units and other sources, and put out the aiming and program instructions that cause the weapon to reach its target. Examples are rangekeepers and computers.

DISPLAY UNITS display information at various locations on the ship. These are generally electronic, electromechanical, or optical devices.

DIRECTING DEVICES are those which, with the aid of detecting devices, establish target location. Directing devices can also function to directly or indirectly control missile flight. Examples are gun and missile directors, and radar sets.

REFERENCE DEVICES are those such as stable elements, which establish reference planes and lines to stabilize lines of fire, lines of sight, and other references. These units usually are gyroscopically controlled.

DELIVERY UNITS

Broadly speaking, delivery units launch or project destructive units toward the target. Examples are guns, missile and rocket launchers, torpedo tubes, and depth charge projectors. Don't think of these devices as weapons. The term WEAPON is properly applied to the destructive unit that is launched or projected. Thus a guided missile launcher is not, strictly speaking, a weapon; the missile itself is the weapon.

To be effectively used against their targets, all weapons must either be aimed at their targets or be programmed during flight; they may require both aiming and programming. Programming is the process of setting automatic equipment to perform operations in a predetermined step-by-step manner. Aiming and programming are done at or before the time of launching, either by or through the delivery device. This function is characteristic of all delivery devices, even the simplest. Aiming the destructive device (weapon) at the target may be done simply by positioning the delivery device (a gun barrel or launcher guide arm, for example). Or it may be done without aiming the delivery device, by placing program instructions in the weapon. Some missiles are programmed to start searching for the target after the launching phase is over. Examples of other programmed functions that could be performed in the weapon are ignition of propulsion units and arming of the warhead after a designated number of seconds in flight.

Types of Delivery Devices

Two representative types of delivery devices are guns and missile launchers.

GUNS provide all the propulsion energy to their projectiles, and direct (aim) the projectiles by positioning the gun barrels.

MISSILE LAUNCHERS retain and position missiles during the initial part of the launching phase, and, by means of attachments to the launcher, feed steering, vertical reference, and program information into the missile up to the instant of launch.

DESTRUCTIVE UNIT

The end purpose of detection units, delivery units, and control units is to cause the destruction unit to intercept or pass near the target.

It is then the function of the destruction unit to destroy or inflict maximum damage on the target.

Basic Weapon Components

All weapons have these components:

1. A CONTAINER or BODY which houses the internal components. The body may have such other functions as piercing armor, breaking up into high velocity fragments when the weapon or projectile explodes, or improving the weapon's ballistic characteristics by means of fins or streamlining.

2. A DETONATING DEVICE (called a fuze, an exploder, a detonator, etc.) which initiates explosion at the proper time, and includes safety devices to prevent premature explosion.

3. A PAYLOAD which is the "reason for being" of the weapon or projectile. The payload usually consists of high explosive or nuclear material.

Weapons of some types have their own propulsion systems. The outstanding examples are guided missiles, torpedoes, and rockets. With the exception of rockets, weapons that have a propulsion system also contain guidance and control systems.

REPRESENTATIVE WEAPONS SYSTEM

Figure 11-1 depicts the major components of a representative weapons system. The equipments making up each of the four categories of functional components are enclosed in separate blocks. We will introduce and discuss the four groups of equipments in the order in which they operate to solve the fire control problem.

TARGET DETECTION, LOCATION, AND IDENTIFICATION

The first contact with an airborne target is usually made by air search radar. These radars are designed to keep a large aerial volume under nearly continuous observation. Jet aircraft travel at high speed, and may launch guided missiles against our ships from a great distance. This requires that our radar search be carried out to long range. To cover the necessary area, search radar uses a wide beam. In addition, most search radar antennas rotate as they search. Targets show up on the radar's target display indicators as alternately fading and brightening spots. It is difficult to determine target range, course, and speed from these spots. All of these factors limit the accuracy with which search radar can provide information about target position. For target information of the required accuracy, we must depend on fire control radars.

After the search radar has detected a target and determined its approximate location, the next step in the development of the fire control problem is to identify the target. The problem of recognizing and identifying a friend or foe is as old as warfare. Passwords, flag hoist signals, and even the uniforms we wear are identification devices that have been developed through the years.

In modern warfare the identification problem is urgent. Radar systems present targets in the form of spots or spikes (called echoes) on a radar screen; but friendly and enemy targets look alike on the screen. Furthermore, high speed planes and guided missiles give us very little time to slove this problem. And when friendly fighter aircraft pursue enemy planes to within weapon range of our ships, the identification problem is acute.

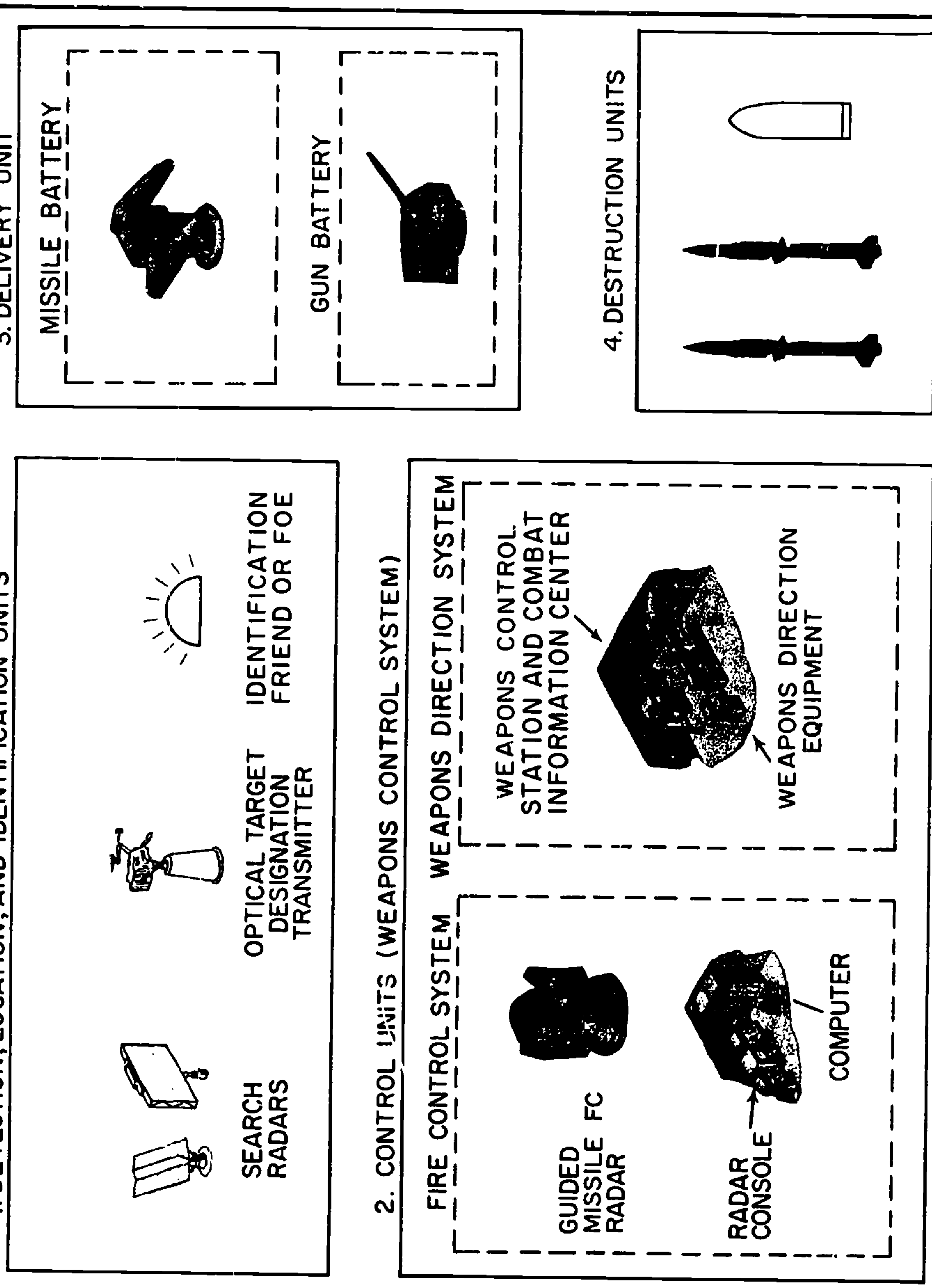
As we said before, IFF is the device we use to determine whether the target is a friend or foe. Although search radar and IFF are not part of the fire control system, they are components of your ship's weapons system.

Before we leave the subject of the major equipments that fall in the category of detection, location, and identification units, we want to emphasize that solution of the fundamental fire control problem begins with detection of a target. The next step is to locate it. And the final step in this initial phase is to identify it as friend or foe. These three steps combine to form the first phase (Phase 1) in the functioning of a weapon system. At this point you should begin to see that you must think in terms of a complete weapons system in order to understand the functioning of each individual component in the system.

Now let's consider the CONTROL UNITS in group (2) (fig 11-1).

THE WEAPON CONTROL SYSTEM

Once the air search radar detects and roughly locates the target, and the IFF equipment has determined whether it is a friend or foe, the target information from these sources



12.41

Figure 11-1. —Makeup of a weapon control system.

is sent to the equipments that we have called control units. These units include fire control radars, directors, computers, weapon direction equipment, stable elements, and many other mechanical, electrical, and electronic instruments.

Traditionally, the systems of equipment used for the control of a particular battery of guns, torpedoes, or other weapons, have been known as fire control systems. But the complexity of guided missiles has required the introduction of new fire control instruments, and new terms to describe them. In the following paragraphs we will define some of these terms.

All the units that are enclosed by the solid line in block (2) of figure 11-1 form a WEAPON CONTROL SYSTEM. A weapon control system is defined as a group of interconnected and interrelated equipments that are used to control the delivery of effective fire on selected targets. The system is composed of a WEAPON DIRECTION SYSTEM and one or more FIRE CONTROL SYSTEMS.

Weapon Direction System

A WEAPONS SYSTEM begins to function as soon as a target is detected. However, a FIRE CONTROL SYSTEM begins its functioning by determining the future target position with all possible precision, so that a line of fire can be established. Before a fire control system can establish a line of fire, certain preliminary processes must take place within the weapon system. These processes are:

1. Detection of a target by search radar or other devices
2. Identification of the target by IFF or other devices
3. Evaluation of the target
4. Designation of the target to a fire control system
5. Acquisition of the target by a fire control system

The target position and identification information obtained during the first two processes is sent to the CIC (Combat Information Center) and to the WCS (Weapon Control Station). These two organizations of equipment and personnel may be in the same compartment or in separate locations. Here, we will consider them to be in the same compartment. This compartment also contains the units that make up part of the Weapon Direction System (WDS). This particular group of equipments is known collectively as WEAPON DIRECTION EQUIPMENT (WDE). The WDE, and units that support its function, make up the Weapon Direction System of a ship.

The purpose of the WDS is to perform those functions that are required during three phases of a tactical situation. During the first phase, the equipment provides electronic means for the display of targets detected by search radars, and it provides devices for selecting and initially tracking the targets that show up on the displays. These displays are similar to the PPIs (Plan Position Indicator). Targets show up as bright pips or dots on the face of the scope.

As the tactical situation develops, and the targets get closer, the system provides means for evaluating the situation and assigning a fire control system or systems to acquire and track designated targets. This is the second phase in the tactical situation. The third and last phase requires that weapons be assigned by the WDS to the fire control system that is tracking the target. Before weapons are assigned, the tactical situation must be reevaluated.

So far in this discussion, we have introduced three new terms: evaluation, designation, and acquisition.

Target EVALUATION is concerned with these questions:

1. What does the target intend to do? Is it going to pass close to the ship for observing, or is it going to launch an attack?

2. How threatening is the target to the ship's safety? If its obvious intent is to attack, how much time does the ship have to launch a counterattack? What weapons should the ship use to repulse the target?

3. What kind of attack is the target capable of launching? If the target carries missiles, the ship must launch weapons that will reach the target before it can launch its missiles.

There are other factors involved in evaluating a tactical situation, but these sample questions should give you some idea of what the term "evaluate" means. More examples will turn up later in this chapter.

The equipment in the weapon direction system presents a complete visual picture of the tactical situation. It displays all the targets that have been detected by the search radars. Each target must be evaluated with respect to the overall defense picture. Decisions are made to bring the ship's weapons to bear on the most threatening targets. These selected targets must be assigned to the appropriate fire control systems. The assignment process includes two functions—designation and acquisition.

DESIGNATION is the step taken to assign the tracking element (director's radar or optical equipment) of a fire control system to a particular target. On the basis of target evaluation and the availability of fire control systems (some of which may be disabled, or busy with other targets), a decision is made to assign a fire control system to the target. This is usually done by pressing a button to activate circuitry that transmits target position information from the weapon direction system to the antenna positioning circuits of a radar set, or the power drives of a director. These units automatically move the radar antenna to the designated position. If the designation is inaccurate, the director must search for the target.

The searching process may last for a second or longer, depending on the accuracy of the designation information and other factors. Once the director has found the target and starts to track, it can be said that it has acquired the target.

ACQUISITION by the tracking device is the process of accepting a designation, acquiring the target, and starting to track it. A target is acquired when the radar has "gated" it, or the crosshairs in the director sights are on it.

In the preceding discussion we indicated that the WDS was further subdivided into the weapons direction equipment, and other equipment related to the overall function of the weapons direction system. In the following articles we shall take up the units that make up the weapons direction system.

REPRESENTATIVE WEAPONS DIRECTION EQUIPMENT

The weapon direction equipment (WDE) includes displays and controls for the evaluation of target data, and for the selection and engagement of targets so as to ensure the most effective use of the gun and missile batteries. A typical WDE conists of one or more TARGET SELECTION and TRACKING consoles, a DIRECTOR ASSIGNMENT console, a WEAPON assignment console, and the necessary cabinets to house power supplies and computer units.

Target Selection and Tracking Console

Figure 11-2 shows a representative target selection and tracking console. Regardless of the mark or modification, they all have the same general function. The console is used for

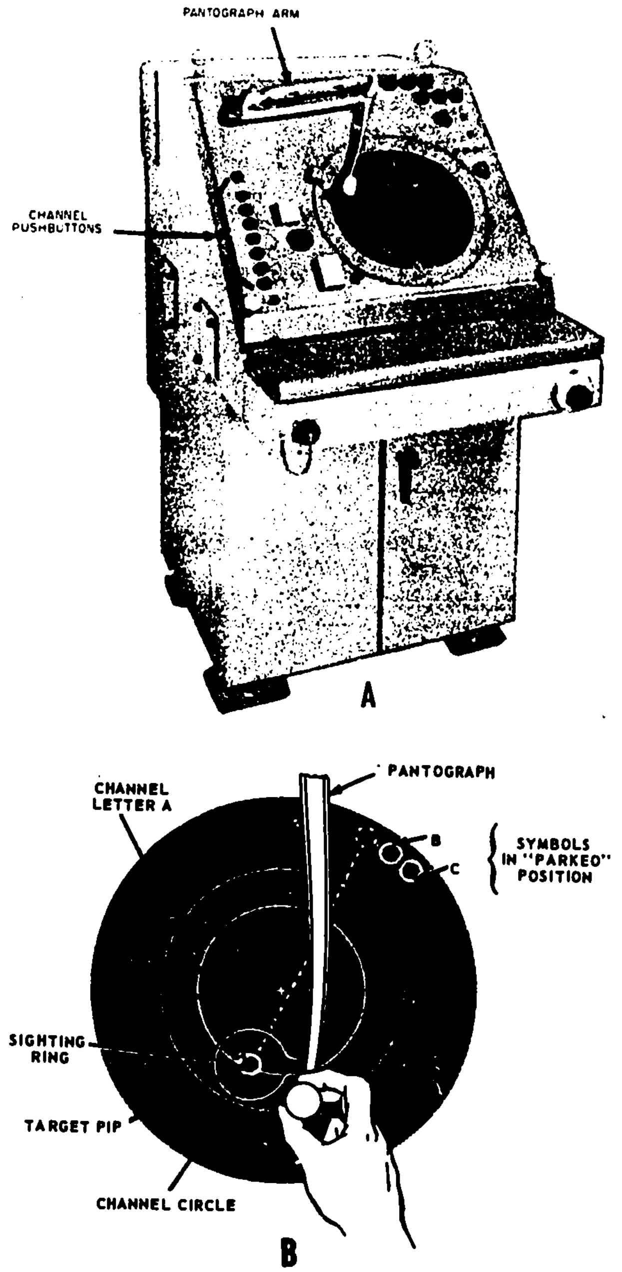


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Figure 11-2.—A. Representative target selection and tracking console. B. Scope display.

selecting and tracking targets detected by search radars. The principal indicator is a PPI that displays the true bearing and slant range of targets picked up by a selected search radar. The primary controls are a pantograph arm for selecting and tracking targets, and pushbuttons for assigning targets to tracking channels. Other controls are provided for selecting various search radars for the PPI display, for selecting the range scale, and for inserting target position and height data into the tracking channels.

Targets are displayed on the scope as radar video (pips). To select a target and assign it to a tracking channel, you position the pantograph sighting ring over the target pip and then press a channel button. Pressing the button gains electrical access to that channel, and simultaneously causes an identifying channel letter to appear next to the target pip. Successive corrections of pantograph position develop target course and speed in the tracking channels.

Director Assignment Console

The primary purpose of this console is to provide the information display and controls required to assign fire control systems to the targets being tracked by the target selection and tracking console operator, when it is determined that a specific target or targets should be engaged. Figure 11-3 shows the panel layout of the director assignment console for our basic WDE. Two plots are provided on the face of the console—a plan plot on the left, and a multipurpose plot on the right.

The plan plot shows three range rings, and indicates true bearing with north at the top. Each target being tracked by the target selection and tracking console appears on the display as a letter, corresponding to the tracking channel from which it originates. The figure shows that tracking channels A, B, and C are tracking three separate targets. The straight line associated with target A indicates the course of this target. The number 1 indicates the position of the director in the fire control system. If the weapon control system had more than one fire control system, these additional systems would have associated numerals. A ship's heading marker, and radial clearance lines on either side of it, are presented electronically and rotate when the ship changes course. The sector between the two clearance lines indicates the region into which we may not launch missiles because of danger of striking the ship's superstructure.

The multipurpose plot is used primarily for making time comparisons. These comparisons help the operator to decide which of several targets to designate to a director, and to plan the future handling of targets that cannot be assigned immediately. Once the director acquires the target and begins to track it, the fire control system is busy. During this time the operator, with the aid of the information displayed on the plot, can decide which target is next in line for assignment.

The multipurpose plot also indicates the speed and height of targets in the tracking channels. As you can see in figure 11-3, it is divided into three vertical lines—each line representing a tracking channel. All changes in indications take place vertically, and you can read the values indicated as you would read a thermometer.

The vertical lines show, for each target, the time within which the radar set must be assigned and a missile fired in order to intercept the target before it can reach its Estimated Weapon Release Range (EWRR). The EWRR will vary depending on the type of payload the enemy is carrying and on how accurate you guess what the payload is. For example, if you guess that the target's payload is an air-to-surface beam-rider missile, the EWRR might be on the order of 25,000 yards. At the left of the plot you can read how much time you have to assign the target, solve the problem, and load and fire a missile salvo, to intercept the target before it can release its missiles. This points up the need for quick evaluation. In conjunction with the plan plot, the multipurpose plot provides the necessary information to speed up this process. It relieves the operator of the necessity of remembering how much average time each component in the weapon system requires to perform its function under varying conditions.

The scale used to measure assignment time is also used with the height line. The height line is a short horizontal bar which moves up and down the vertical channel line as target altitude changes (fig 11-3). In this case the number (not shown in the figure) represents thousands of feet. To the right of the display is a target speed scale (marked knots) which is used in conjunction with the speed circle. The speed circle rides up and down to indicate target speed.

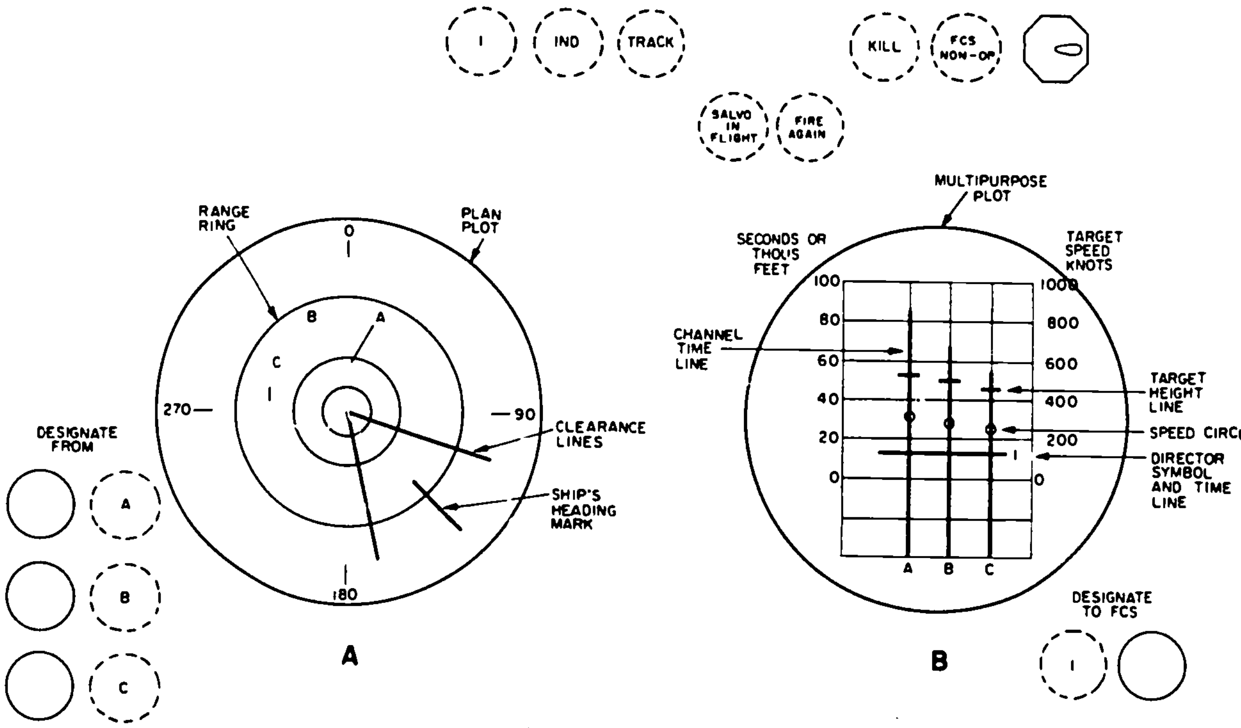

Figure 11-3.—Director assignment console display. 12.43

The long horizontal line shown in this plot represents busy time for the fire control system. When the system is not acquiring or tracking, the time line and director symbol number rest at zero time. But when the director is assigned a target, the time line and symbol move up to indicate the time during which the director will be busy with that target; they slowly move down as time elapses. After a missile salvo is launched, the line and symbol continue to move downward until they reach zero. The missile should have intercepted the target, and the fire control system is free to be assigned a new target.

Above the two display plots is a field of lamps relating to the gun and missile fire control system. The lamp with the numeral 1 in it is called the BUSY lamp. (If our weapon control system had more than one fire control system, each of them would be represented by a different lamp and number.) The BUSY lamp is lighted whenever the director is assigned the target. The IND lamp is lighted when the director is operating INDependently of the weapon direction equipment. The TRACK lamp indicates that the assigned target is gated and is being tracked. The KILL lamp lights when a target has been destroyed. The observation of the kill is usually visual.

The FCS NON-OP lamp indicates that some part of the fire control systems is not in operation. When missiles are launched, the SALVO-IN-FLIGHT lamp lights. If another salvo is ordered to be fired, the FIRE-AGAIN lamp lights to indicate that this order has been sent to the weapon assignment console, but that the salvo has not yet been fired.

The pushbuttons at the left labelled DESIGNATE FROM, and the pushbutton at the right labelled DESIGNATE TO FCS, are used in making assignments of a director to one of the three tracking channels. The operator makes the assignments by simultaneously pressing the selected "designate from" button and the "designate to FSC" button until both lights function. This process connects the director to the selected tracking channel and slews the director automatically onto the target. At this time the repeat-back symbol, (numeral representing the FCS), moves until it is superimposed on the track channel symbol. This indicates to the director assignment console operator that the system is tracking the proper target.

Weapon Assignment Console

The Weapon Assignment Console is the connecting link between the fire control system and the weapon launcher. It displays data from the fire control system, giving the target's present and predicted intercept positions, and information from the computer indicating whether or not missile intercept is possible. It also has a summary display of launcher information.

The missile firing key is located on the weapon assignment console. Decision of whether or not to fire is made from this station.

The console has a PPI display showing a horizontal plot and true bearing, with own ship's position in the center. Around this plot is a fixed bearing ring. Radial lines from the center to the edge of the plot, generated electronically, indicate launcher unclear areas caused by ship's heading. These lines rotate with changes in ship's heading. This display is similar to the plan plot of the director assignment console.

The other indications on the cathode-ray tube display appear only while the fire control system is tracking a target. These indications are:

1. An "X" indicating target present position

2. A small circle indicating target future position at the predicted point of intercept

3. A large circle about the center, which indicates the maximum range the missile can reach at the target's predicted altitude at intercept

4. A thermometer-type display at the left-hand edge of the plot, giving the target's predicted altitude at intercept (H)

REPRESENTATIVE MISSILE FIRE CONTROL SYSTEM

In this section we will discuss the equipments that make up the fire control system of a typical guided missile ship. Look again at figure 11-1. We have assumed that the fire control system shown is capable of controlling gun and missile batteries at the same time. This is a valid assumption, because there are systems with this capability in the fleet. But for now we will separate the capabilities and consider the fire control system a missile system. The fire control computer calculates the prediction angle and uses it as an offset to the line of sight to establish the line of fire and to produce weapon orders. The orders are transmitted to the missile launcher to position it in the line of fire.

Thus the primary basic functions of the fire control system are: to acquire and track targets; to develop launcher and missile orders; to guide missiles to the target; and in some instances to detonate the missile's warhead.

Secondary functions of the system are to provide target information such as target speed, target course, range to the target, and system and weapon status information to the display units of the weapon direction system. This information is used to evaluate the tactical situation and to aid in the fire control system and weapon assignment.

The Director or Radar Set

The director or radar set can search for, detect, acquire, and track a target; and it can "capture" and guide a missile. Let's stop and consider the terms "director" and "radar set." A director may contain a radar and/or optics for tracking and ranging, and it is usually manned. A missile director has no optical tracking device or rangefinder but relies on its radar set for tracking. It is not manned in the sense that a man is located inside the antenna supporting structure. True, there is an operator in the radar control room; but his primary function is to monitor the equipment. In the rest of this discussion we will use the term "radar set," rather than director, because that name is more descriptive of the function of a missile director.

The radar set described here, and illustrated in figure 11-1, is an automatic target tracking and missile guidance radar. It normally receives target designation signals from the weapon direction equipment, via the fire control computer. The designation signals position the radar set at the designated range, bearing, and elevation. If the radar set does not acquire the target immediately the fire control computer originates a search program for the radar set to seek out the target. If the ship has more than one fire control system, designation between systems is possible. Designation from another fire control system, called "Inter-director Designation" or "IDD", is accurate and a search program is not needed. Therefore IDD does not go to the computer but through the fire control switchboard to the radar set.

When the radar set acquires the target in range, bearing, and elevation the radar set locks on the target and starts to track it. Tracking circuits within the radar set automatically keep its tracking beam on the target. Target position is continuously transmitted to the computer. The computer and the radar set working together solve for the target's rate of movement about the ship by calculations based on the line of sight movements.

The radar not only tracks the target, but also transmits radar beams to control the missile and guide it to the target. In the case of the beam-rider missile the radar set will transmit simultaneously, on a common nutation axis, three distinct beams—the tracking, capture, and guidance beams. A narrow tracking beam first acquires and tracks the target. The wideangle beam captures the missile after launch, and holds it until it enters the narrow guidance beam that guides it to the target.

Where a semiactive homing missile is used, the radar set will transmit simultaneously, on a common nutation axis, a tracking beam, and an illuminating beam. After the missile is launched it will lock on to the illuminating radar's energy reflected from the target, and home on it. If a missile whose guidance is a combination of beam-rider and semiactive homing is launched, the radar set will transmit a tracking beam and a beam-riding guidance beam and later switch on an illumination beam.

The radar set consists of two major groups of equipment: an antenna group, and a power control group. The antenna group, which is located abovedeck, consists of a pedestal upon which is mounted the antenna and the necessary electrical and mechanical components required to stabilize and position the antenna. Housed inside the mechanical structure of the antenna group are the transmitting, receiving, and associated microwave circuits. Here, too, are located the gyroscopes that space-stabilize the antenna, and thus the radar beams, to compensate for the roll and pitch of the ship.

The control and power equipment group is located belowdeck in a compartment usually called the radar room. This room contains the radar consoles used to operate, monitor, and control the radar set. Also located in the radar room are the cabinets containing the power supplies that provide the operating voltages for the various units in the radar set.

Representative Missile Computer

The representative guided missile fire control computer described here is an electromechanical type designed to operate automatically. No operating personnel are needed. It is located in the ship's plotting room, and is used with the radar set described previously.

The computer has three basic ways of operating. It can operate when designation is desired; then, after the radar set has acquired the designated target, the computer aids the radar set in tracking it As soon as the missiles have destroyed the target, the computer shifts to the air-ready method of operation. These different methods of operating are called modes. The various modes of computer operation can be briefly described as follows.

AIR-READY MODE.—In this mode the computer is energized, but is receiving no information. It generates orders only to put the radar set and launcher in predetermined air-ready positions. For example, the air-ready position of the radar set may be at zero° of train and 45° of elevation; the launcher air-ready position may be at 180° of train and zero° of elevation.

DESIGNATION MODE.—The computer goes into this mode of operation when it receives a "director assigned" signal from the director assignment console of the WDE. The computer directs the radar set to the designated target position so that the radar line of sight will point at the target. It also sends a search program to the radar set. The search program causes the radar beams to move in a preset pattern about the designated target position. The radar searches for the target, and when the target is gated the computer automatically goes into the track mode of operation.

TRACK MODE.—When the radar set acquires the target in range, bearing, and elevation, the track mode starts. The radar set then transmits an on-target signal to the computer. The computer sends signals to the radar set that cause it to drive at a rate that will keep it locked on the target. The computer determines the proper lead angles for the launcher, and transmits these quantities in the form of electrical signals. These signals drive the launcher to the proper aiming position.

Before the missiles are launched, the computer determines and transmits to the missiles quantities that move the missile gyros to their proper positions. The computer also transmits tactical data such as present target position future target position, and missile time to target intercept (time of flight) to the various display consoles of the WDE.

DELIVERY UNITS IN A REPRESENTATIVE WEAPONS SYSTEM

The delivery units of a representative weapon system are the gun and the missile launcher. In this section we will discuss only the missile launcher and the equipments associated with it.

Guided Missile Launching System

The guided missile launcher shown in figure 11-4 is part of a group of equipments that are known collectively as a Guided Missile Launching System. A guided missile launching system has three major components:

1. Guided missile launcher
2. Guided missile launcher feeder
3. Guided missile launching system control

The primary purpose of a guided missile launching system is to stow missiles until needed and then supply them to a launcher for firing. Its secondary function is to remove unfired missiles from the launcher and return them to the missile stowage area.

GUIDED MISSILE LAUNCHER.—Except for Polaris, all Navy missiles that are launched from ships use zero-length launchers. This type has one or two, usually two, launcher arms (or rails). The launcher shown in figure 11-4 is the dual-rail type. It receives and secures two complete missiles—one on each launcher arm. The launcher automatically trains and elevates in response to synchro signals (missile launcher orders) from the fire control computer. Through various devices on the launcher arms, the missiles receive warmup power before launch. Warmup power is used to bring the missile gyros up to speed, and to warm up the vacuum tubes, without taking power from the missile power supplies. Preflight information is also supplied to the weapon through contactors in the launcher arms, and the firing circuit is connected through the launcher to the missile's internal firing circuitry. The launcher can automatically return to a predetermined fixed position in which a new missile can be loaded on the launcher arm, or an unfired missile can be returned to stowage.

LAUNCHER FEEDER.—The purpose of this group of equipments (fig. 11-4) is to stow guided missiles and their boosters in magazines, to remove them from the magazines, and to load them on the launcher arms. There are several types of feeders, but they all have these two purposes.

LAUNCHING SYSTEM CONTROL.—This equipment group includes the panels used to operate the missile launching system. The power panels contain circuit breakers, overload relays, and other electrical components required by the various power drives that control the movement of the launcher, rammer, and ready-service ring. Other panels contain operating controls that are used to start the system and control its operation. These panels normally respond to orders from the WDE. For example, the WDE may send an order to ALERT the missile launching system. An ALERT light on a panel flashes, indicating to the operator that WDE wants the missile launching system's equipment put into operation. Several of the orders transmitted from the

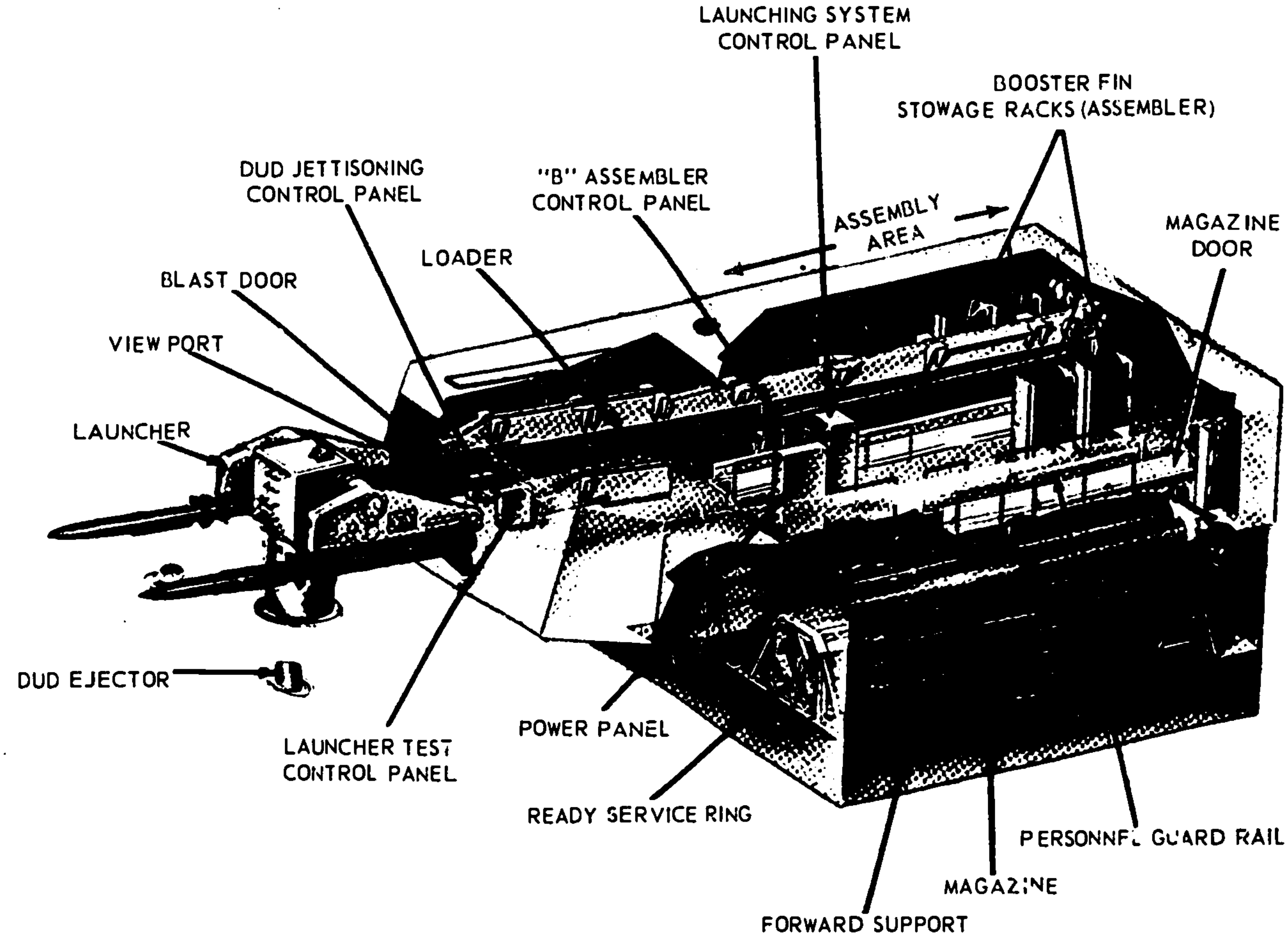

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Figure 11-4.—Representative Terrier missile launching system.

WDE to the missile launching system are of interest to the FT.

TYPES OF ORDERS.—The MISSILE SELECT order is transmitted from the WDE to the launching system to indicate the type of missile to be loaded on the launcher. There are several types of Terrier missiles. All of these types may be loaded together in a single magazine. This is called mixed loading. When the launching system has selected the type of missiles called for by the WDE, it sends back a signal indicating that the order has been carried out.

The LOAD ORDER tells the launching system to start loading a missile or missiles. A load order may be "continuous," "single," or "hold." A "continuous" order causes missiles to be continuously supplied to the launcher. This operation is similar to "rapid or continuous fire" in conventional gunnery. The "single" order causes one missile per arm to be loaded on the launcher. The "hold" order holds the launching system in a ready-to-load condition.

When the launching system receives the UNLOAD ORDER, it unloads any missiles that may be left on the launcher arms.

The INTENT-TO-LAUNCH (ITL) is similar to the conventional "commence fire" order in one respect—it is transmitted by closing a firing key. But, while the gun firing circuit is completed almost instantly when the key is closed, there is a slight delay before a missile firing circuit is completed. This delay is necessary to establish certain operating conditions in the missile, and other equipments in the weapon system. Before the missile can be fired, it must indicate that it is ready to be launched. This indication, "missile-ready-to-fire," is sent through the launching system control circuits back to the WDE. Almost every piece of equipment in the weapon system affects the operation of the firing circuit, either directly or indirectly.

DESTRUCTION UNITS IN A TYPICAL WEAPONS SYSTEM

As we mentioned earlier in this chapter, our typical weapons system is designed to control two weapons, the gun (projectile) and a guided missile. Both of these weapons have already been discussed; therefore these units will not be cover here.

GUNFIRE CONTROL SYSTEM

Here we will compare the functions of the major units in a GFCS with those in a missile fire control system, (MFCS). Since the same basic elements are present in the missile and the gun fire control problem, both types of systems will have the same major units and the primary function of the units will be the same. This is clearly illustrated by the fact that the weapon control system we just discussed can control both missile and gun batteries.

Variations between the problems and the functions of the major units are the result of the differences between the guided missile and the gun projectile. The missile is guided during its flight; hence its control problem continues after launch. On the other hand, once a gun projectile is fired the gun control problem for that round is completed. The missile, having a longer range and higher altitude capability, extends the limits of its problem beyond those of the gun problem; but this fact does not change the basic problem.

We will follow target information through a gun fire control system, starting with the initial detection of a target by the search radar. At each major unit we will point out the principal differences between it and its counterpart in a missile system.

TARGET DESIGNATION SYSTEM

The target designation system (TDS) is the connecting link between the search radar and the GFCS. The function of the search radar is the same as it is on a missile ship. Due to the limitations of the guns, particularly their range limitation, the designation equipment for a gun battery is simpler than the WDE for a missile battery. A single console with a PPI presentation is used to evaluate, track, assign, and designate targets to the GFCSs.

Guns are assigned to a GFCS by a prearranged ship's doctrine. Thus when the TDS assigns a GFCS to a target, the assignment includes the guns. Normal procedure is to commence fire as soon as the target is within effective gun range. The firing circuit is controlled within the GFCS. Thus when the director has acquired the target, the TDS has completed its job with respect to this target and GFCS. DESIGNATION TRANSMITTER, an optical target detector, can transmit target designation directly to the GFCS without going through the TDS.

If more than one FCS is installed, designation can normally be made between the systems. As you know, this method of target designation is called IDD (interdirector designation).

GUN DIRECTOR AND COMPUTER

Gun directors are manned, and normally have both optical and radar equipment to detect, locate, and track a target. The director crew can readily shift from optical to radar tracking, or vice versa. The radar transmits a single target-tracking beam. Another function of gun directors is to furnish a centralized control station and a remote firing station for the battery.

There is little to distinguish between gun and missile computers. Due to the nature of today's air targets, Anti-aircraft (AA) computers are almost fully automatic, with little or no provision for manual operation. Gun computer outputs of train, elevation, fuze, and parallax orders drive the gun to the predicted position of the line of fire. The entire problem of locating the correct line of fire is solved before the projectile is fired.

WEAPONS SYSTEM FUNCTIONING

To provide a brief review of what you have studied so far in this chapter, we list the principal steps or phases a typical weapons system goes through to accomplish its mission. The mission, of course, is to destroy the enemy or a practice target. The principal steps, in chronological order, are:

1. TARGET DETECTION. Search radars detect targets at long ranges, to allow time for the weapons system to go into action and complete its function.

2. TARGET SELECTION. The weapons direction system selects the targets that appear hostile, and that require missile and/or projectile interception, and inserts them into tracking channels. Target selection and tracking is performed by personnel assigned to the target selection and tracking console—a unit of the weapon direction equipment.

3. SEARCH RADAR TARGET TRACKING. The tracking channels (computing circuits) continuously track selected search radar targets to generate target rate of movement. This data appears as a symbol (letter) on the face of a large cathode-ray tube (scope). When the tracking channel has computed the correct target course, speed, and rate, the symbol on the scope will remain superimposed on the target echo supplied by the search radar. This computed target position and rate data is used for evaluation of the tactical situation presented to the ship, and for transmission to other units in the WDS—especially the director assignment console. Each target that is being tracked is assigned a different symbol to prevent confusion.

4. EVALUATION. The weapon system evaluates the threat of various targets, decides which should be engaged by guns and which by missiles, and decides which targets should be given priority. The evaluation is performed by personnel, but they are aided in this process by the displayed information on the various consoles in the WDE and CIC.

5. DIRECTOR ASSIGNMENT. A radar set is assigned to the target having the highest priority. When a radar set is assigned, this implies that a fire control system has been included in the assignment.

6. ACQUISITION. The assigned radar set (fire control system) gets on the target.

7. TRACKING. The fire control radar tracks the target to provide precise target position and rate data. The computer associated with the tracking radar operates on the data from the radar set to provide the solution to the fire control problem. The computer answers are supplied to the guns and launcher as synchro signals to position these units in train and elevation.

8. REEVALUATION AND WEAPON ASSIGNMENT. The target that is engaged by the fire control system is reevaluated with respect to the tactical situation (this may have changed), availability of the launcher or gun, and the range limitations of the weapons.

9. LOADING. Missiles are loaded on the launcher, and the guns are prepared for firing.

10. LAUNCHING AND FIRING. The missiles are launched at the proper time and in the proper direction. The guns are loaded and fired.

11. MISSILE GUIDANCE. The fire control radar guides each missile to the target being tracked. Gun projectiles, of course, receive no guidance.

12. TERMINAL PHASE. When a missile or projectile approaches to within lethal range of the target, a VT (variable type) or other type fuse detonates its destructive charges. This is the "moment of truth" for the weapons system.

SUMMARY

A weapons control system consists of a combination of a weapon (or multiple weapons) and the equipment used to bring their destructive power against an enemy. The system includes:

1. Units that detect, locate, and identify the target.
   a. Search radars
   b. Optical target designation transmitter
   c. IFF radar
2. Units that direct or aim a delivery unit.
   a. Gun and guided missile radar and directors.
   b. Computer devices (rangekeepers and computers)
   c. Display units (electronic, electromechanical, or optical devices)
   d. Reference devices (stable elements) to establish reference planes and lines to stabilize lines of fire and lines of sight
3. Units that deliver or initiate delivery of the weapon to the target.
   a. Guns
   b. Missile launchers
4. Units that will destroy the target when in contact with it or near it.
   a. Shells
   b. Missiles

CHAPTER 12

MISCELLANEOUS FACILITIES

Although many of the equipments discussed in this chapter operate on the radio, radar, or sonar principle, their application is so specialized that they are dealt with more appropriately as miscellaneous facilities, instead of as radio, radar, or sonar equipments. For this reason, they were not included in preceding equipment chapters.

RADIO DIRECTION FINDERS

The Radio Direction Finder (RFD) is installed aboard most ships for use in locating personnel afloat in liferafts or lifeboats equipped with radio transmitters. It also is used to obtain bearings on intercepted radio and radar signals of both known and unknown origin.

Essentially, the radio direction finder is a sensitive receiver connected to a directional antenna. Early models utilized a loop antenna that was rotated manually to the position of strongest signal reception. Bearing of the signal was read from an indicating device consisting of a pointer and an azimuth scale. Modern RDFs have antennas that are rotated at a constant speed by a motor. Bearing information is indicated on the face of a cathode-ray tube.

Range data cannot be obtained by taking a single bearing with an RDF. Usually, several bearings are taken either as rapidly as possible on several radio beacons or radio stations of known geographical location, or on a single beacon or station of known location, allowing from 10- to 30-minute intervals between bearings. Plotting these bearings gives a fix that is more or less accurate, depending on the accuracy of the bearings.

Currently, three different models of radio direction finders are installed on ships in the active fleet. They are models AN/URD-2( ), AN/URD-4( ), and AN/SRD-7( ). A combination MF/HF radio direction finder, the AN/SRD-7( ), is installed mostly on submarines.

Shipboard installations of the AN/URD-4( ) direction finder set (fig. 12-1) consist of an antenna, a receiver/power supply unit, an azimuth indicator, and a signal data converter (not shown). The set provides visual (and sometimes aural) direction-finding information from radio signals in the frequency range of 225.0 to 399.9 MHz. For surface to surface operation, the range of the equipment is approximately 20 miles; for surface to air, approximately 90 to 125 miles. Bearing accuracy is plus or minus 5°.

Tuning controls for the receiver are located on the front panel of the azimuth indicator. By setting the digit selector switches to the desired frequency, the receiver can be tuned to any one of 1750 frequencies, spaced 0.1 MHz apart. To facilitate rapid tuning, any 20 of the 1750 available frequencies may be preset on the digit selector switches. Then, the preset frequencies are selected by means of a single channel selector switch. For convenience in servicing the equipment, or for emergency operation, digit selector switches also are provided on the front panel of the receivers.

Visual information appears on the face of a cathode-ray tube in the azimuth indicator. Around the perimeter of the scope is a compass scale from which is read the signal bearing. When no signal is present, the pattern on the scope is a circle. When a signal is present, this cir[illegible] resolved into a propeller-shaped pattern [illegible] axis lies along a line indicating the signa[illegible] rce direction and a point 180° displaced [illegible] the direction of signal origin. To eliminate this ambiguity, it is necessary to cause a further change in the shape of the pattern. Placing the calibrate-sense switch in its sense position causes the propeller-shaped pattern to become a V-shaped pattern, the apex of which indicates the signal bearing.

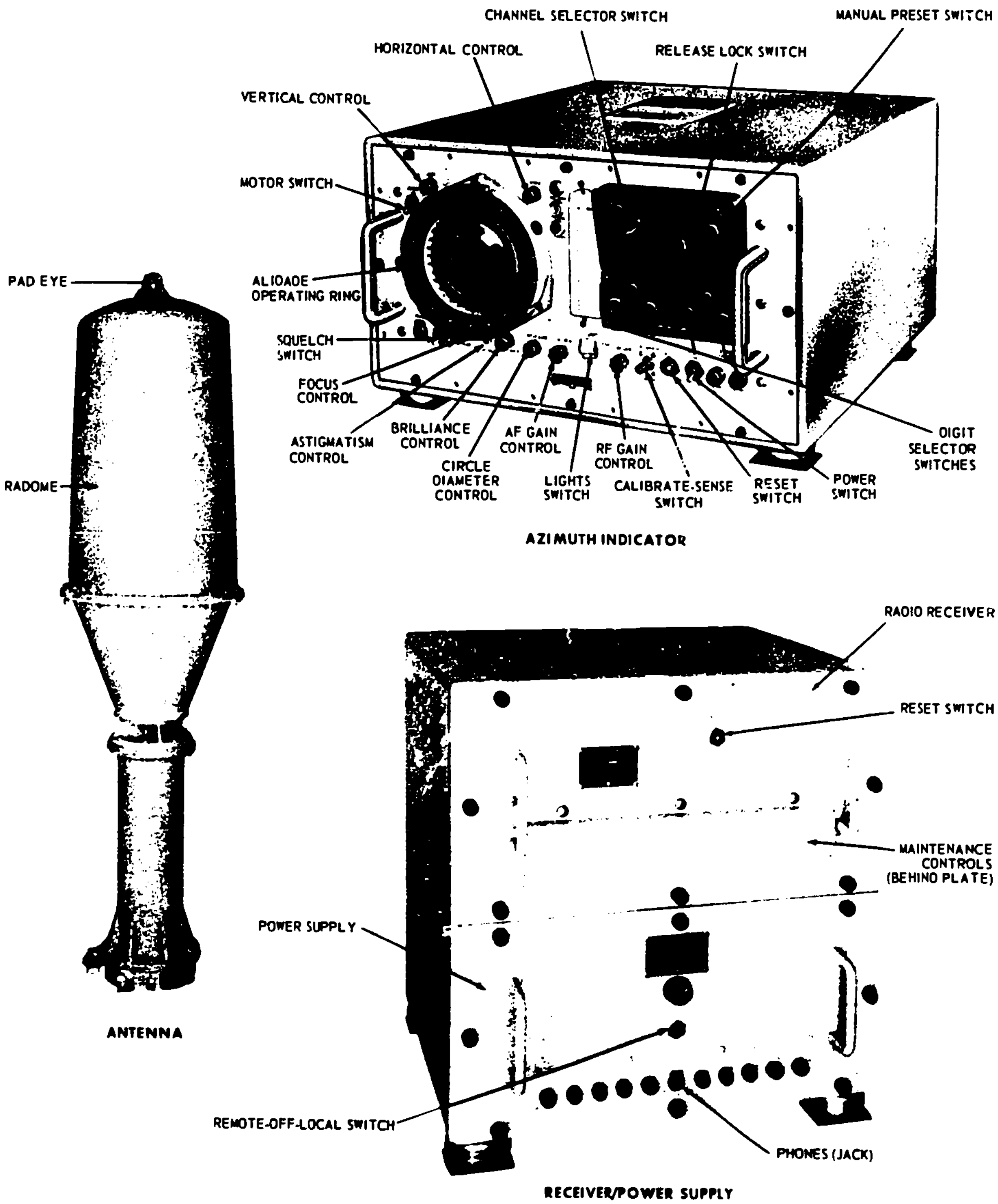

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Figure 12-1.—Radio Direction Finder Set AN/URD-4( ) major components.

The direction finder set is designed for either shipboard or shore use. When the equipment is installed on ships, the bow of the ship is used as reference or zero degree direction. Signal bearings, consequently, are relative to the ship's heading if not corrected by the action of the signal data converter. A switch, on the front panel of the azimuth indicator permits selection of either a relative bearing or a true geographical bearing of a received signal.

CLOSED-CIRCUIT TELEVISION

On larger ships closed-circuit television systems are becoming commonplace. They make it possible for shipboard personnel at remote locations to view or monitor various operations, and to exchange vital information rapidly. Although present applications of TV are limited to interior communications, it is envisioned that future applications will include intership conferences and briefings.

One closed-circuit TV system installed aboard ship is the AN/SXQ-2 (fig. 12-2). This system consists of a camera, a system control unit, an electronic equipment cabinet, and one or more viewer units. It is used principally for viewing the data displayed on the CIC plotting board at remote locations.

When the system is used to transfer tactical information from the CIC to remote stations,

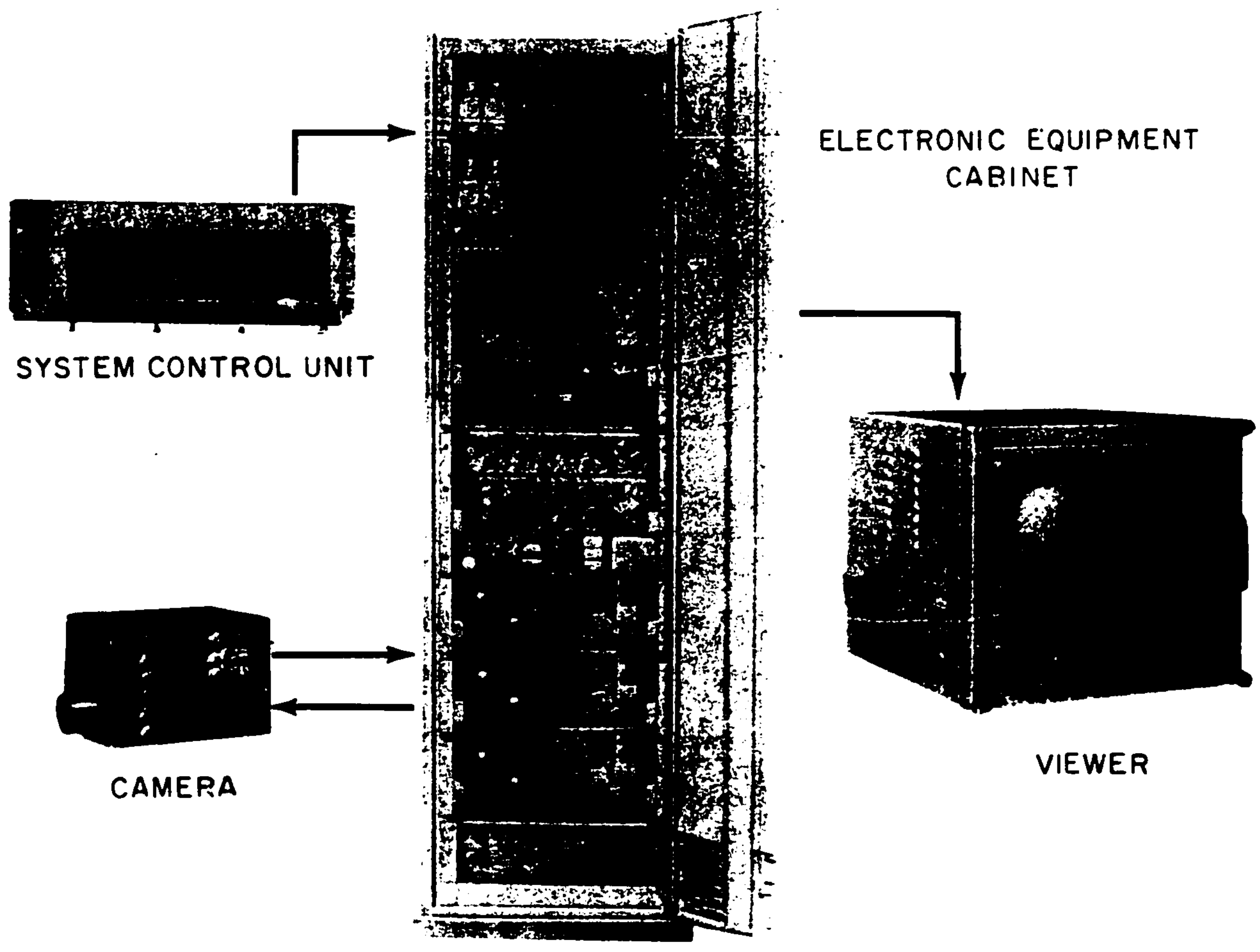

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Figure 12-2.—Television System AN/SXQ-2.

the TV camera is fastened to the overhead in the CIC so that it overlooks the plotting board. The video output of the camera is sent to a maximum of eight viewer units. From these video signals, the viewer units reproduce and display the data appearing on the plotting board. Thus, cognizant personnel are informed instantaneously and accurately of any changes in a tactical situation.

The AN/SXQ-2 system also is used aboard aircraft carriers for briefing pilots before a mission. When the system is used for this purpose, a viewer unit is installed in each readyroom. The TV camera is arranged so that it picks up the briefing officer and any pertinent charts or displays. With this arrangement, all pilots concerned are briefed in one session.

Most aircraft carriers now have a closed-circuit television system that aids the landing signal officers (LSO) in landing the aircraft. In general, the system operates in the following manner. A television camera mounted in the centerline of the flight deck spots the plane at the beginning of its landing approach, and follows it to the touchdown. A second TV camera on the carrier's superstructure then takes over. Viewer units installed at strategic locations reproduce the images picked up by the cameras. Crosshairs on the viewer screens and minute-by-minute records of time, air speed, wind velocity, and flight number on dials at the top of the screens are utilized by the LSO in talking the pilot down to a safe landing. All video and audio information, including the conversations between the pilot and the LSO, is recorded on tape. The tape thus becomes a complete record of each landing. This system is referred to as the PLAT (Pilot Landing Aid Television) system.

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 application of transmitting equipment that may be used for jamming 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.

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

Some of the foregoing information is obtained by analyzing the enemy transmission. Other data may be obtained by examining captured equipment.

Special equipment has been developed for use in analyzing RF 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.

Antijamming measures or counter-countermeasures (CCM) are used to reduce the effect of enemy jamming on our own equipment. Some of the most important CCM devices in receivers are special filters that pass only the most important parts of 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 enemy jamming transmitters from locking on the radar signal.

Several ECM equipments (or systems) are in use today. Among these equipments are the models AN/SLA-1 and -2 series, AN/SLR-2, AN/SLR-10, AN/WLR-1, AN/WLR-3, AN/ULQ-5, and AN/ULQ-6. Because of the security AN/SLR-10, AN/WLR-1, AN/WLR-3, AN/ULQ- tailed description cannot be given in this text. Further information concerning ECM and ECCM equipments may be obtained from the training manuals for the Radarman rating, or from the appropriate equipment technical manuals.

UNDERWATER TELEPHONE

The AN/UQC-1( ) sonar set, popularly known as the underwater telephone, provides CW and voice communications between surface vessels and submarines. Although its application differs, the set operates on the same principle as other sonar equipments.

The set consists of a transmitter, receiver, power supply, transducer, and remote control unit. All controls needed to operate the set are contained in the remote control unit (fig. 12-3).

To transmit by voice, a toggle switch on the front panel of the remote control unit is set to VOICE & CW RECEIVE, the microphone button is depressed and the message is spoken into the microphone. For CW transmission, the toggle switch is set to CW TRANSMIT, and the handkey is used to send the message. During either type of transmission, an output indicator on the control unit flashes each time energy is transmitted.

The range of the transmission varies with water conditions and the relative noise output of the ship. Under good conditions, communications between ships is possible at ranges up to 12,000 yards and in some instances far beyond this range. On board submarines, the range may be extended over that obtained by surface ships by the phenomenon of channeling, that is, keeping the transmission between sharp temperature gradients within the layer in which it was transmitted. If this layer extends for many miles, the range of the signal also is extended for many miles.

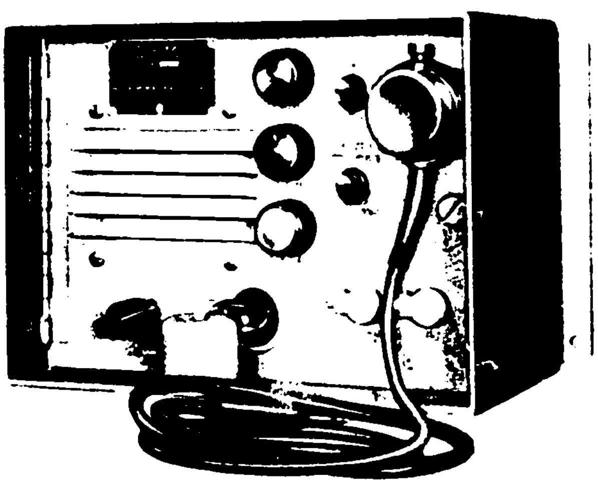

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Figure 12-3.—Remote Control Unit for AN/UQC-1( ).

COMMUNICATION CONSOLE

To centralize the control of voice communication circuits at key tactical stations, some large types of ships utilize communication console equipments such as the AN/SIC-2 (fig. 12-4). A system may comprise 1 or 2 master consoles, 16 subconsoles, 4 radio-control/terminal-unit assemblies, and 1 or 2 power supplies. The quantities of the various components may be varied to meet the requirements of the vessel on which the equipment is installed.

Each master console provides pushbutton selection of a combination of 1 to 16 radiotelephone curcuits (channels or frequencies) for both transmitting and receiving.

Selector switches and volume controls mounted on the console provide facilities for the connection of amplifiers and overhead speakers to permit monitoring any 4 of 16 radiotelephone circuits.

A selector switch provides for the selection of any 1 of 16 radiotelephone circuits for quick relay playback as recorded by a short-memory voice recorder.

An interphone system provides two-way or network communications between master consoles and subconsoles. Sixteen interphone circuits may be selected at the master console.

At each master console, facilities are provided for communications with any combination (up to 10) of 20 ship's intercom stations.

Intercom systems differ from the interphone in this manner: Interphones systems use radiotelephone handsets or headphones. Intercoms are microphone speaker systems that provide amplified voice communications between two or more stations. The intercoms are used chiefly during routine conditions when personnel are unavailable to man all the sound-powered telephone circuits. During general quarters (CONDITION ONE) and general quarters relaxed (CONDITION ONE E), they should be used only for passing emergency information.

Each master console provides facilities for monitoring or two-way communications without crosstalk on any combination of 14 sound-powered telephone circuits. Provision also is made for crossing 7 sound-powered telephone circuits, and for monitoring or transmissing on the crossed circuits.

A microphone mounted on the master console is provided for connection to the

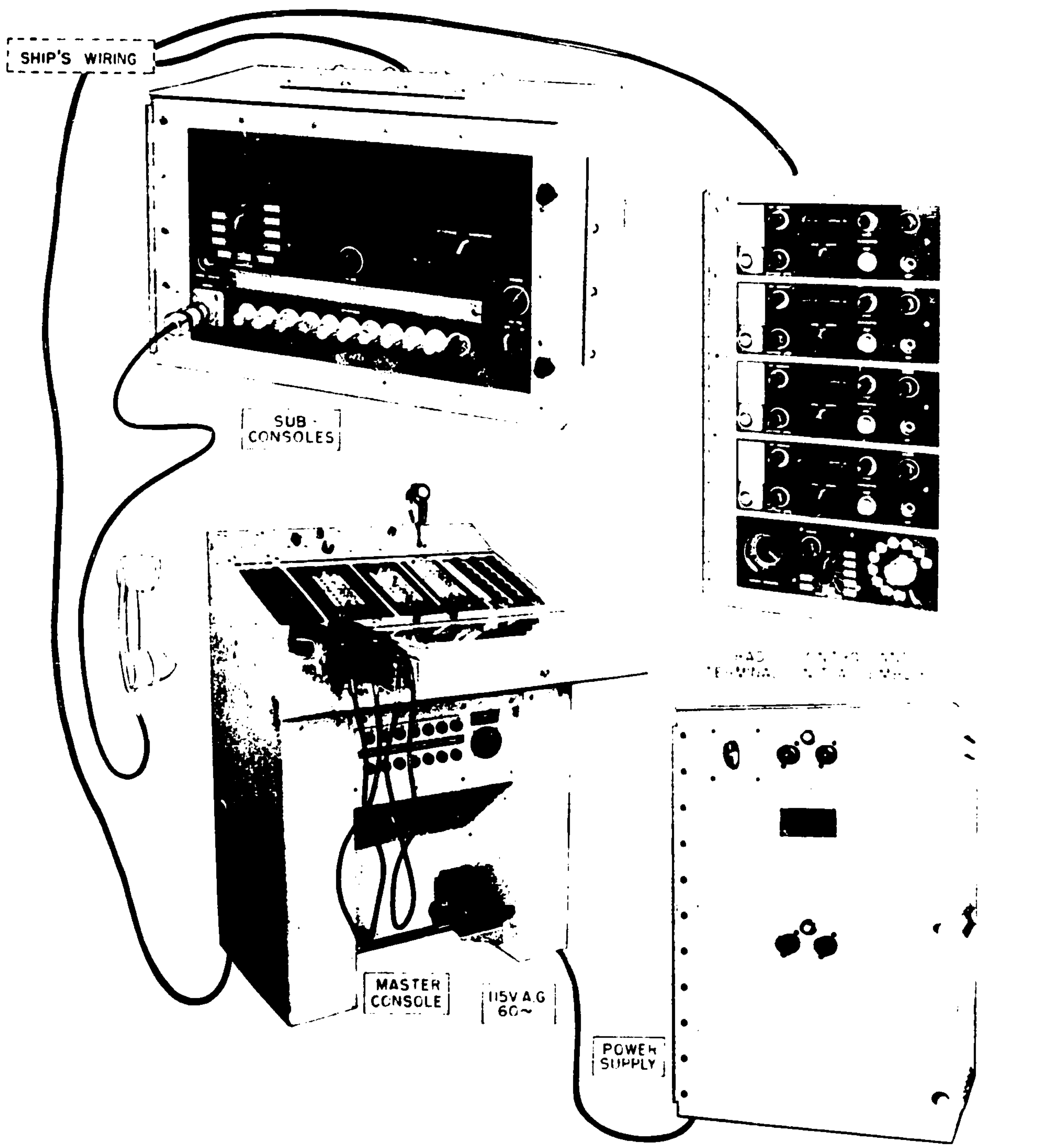

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Figure 12-4.—Communication Console AN/SIC-2.

shipboard announcing system when the communication console equipment is installed in CIC.

The subconsoles provide secondary control points for radiotelephone and interphone circuits. Each subconsole may select any 1 or 10 radio circuits for both transmitting and receiving. Two-way or network communications from the console to the master console and the other subconsoles take place over any 1 of 10 available interphone circuits. A radiotelephone jack is provided for monitoring the selected radiotelephone circuit or interphone circuit.

Normally, the master console is the CIC watch officer's station while the ship is underway. From this station, he can control as desired: radiotelephone, interphone, intercom, sound-powered telephone, and shipboard announcing circuits.

CARRIER CONTROL APPROACH (CCA) EQUIPMENT

Carrier controlled approach (CCA) equipment provides the means for guiding aircraft to safe landings under conditions approaching zero visibility. By means of radar, aircraft are detected and watched during the final approach and landing sequence. Guidance information is supplied to the pilot in the form of verbal radio instructions, or to the automatic pilot (autopilot) in the form of pulsed control signals.

Six CCA systems (or equipments) currently are installed aboard carriers in the active fleet. They are models AN/SPN-6, AN/SPN-10, AN/SPN-12, AN/SPN-35A, -35B, AN/SPN-42, AN/SPN-43.

The AN/SPN-6 CCA system displays an aircraft's position relative to an ideal approach path on offset sector PPIs. These presentations are viewed by an aircraft final controller, who transmits verbal landing instructions to the pilot. The aircraft is directed along an ideal approach path to a point where it is visible to the landing signal officer (LSO). When the aircraft is visible, the LSO operates a "contact" light that informs the controller that contact has been made and that the aircraft is being brought aboard by visual means. If the aircraft approaches to the minimum range of 200 feet from touchdown without the LSO indicating that he made contact, it is given an instrument waveoff by the final controller at the radar set.

The AN/SPN-10 is a computerized CCA system that provides precise control of aircraft during their final approach and landing. The equipment automatically acquires, controls, and lands a suitably equipped aircraft on CVA type aircraft carriers under severe ship motion, or weather conditions.

Aircraft returning to the carrier are assigned to the AN/SPN-10 system by means of an air traffic control computer. On receipt of an assignment, the system programs an optimum flight path for the aircraft. It also establishes a radar acquisition window (search area). When the assigned aircraft enters the window, it is automatically detected, locked onto, and tracked by the precision radar subsystem. The radar-derived data of the aircraft's position (flight path) are compared with the optimum flight path. As a result of this comparison, correction signals are generated to control the aircraft along the optimum flight path to touchdown.

If an unsafe flight or landing condition is indicated, the AN/SPN-10 signals a waveoff and returns control of the aircraft to the air traffic control computer. In addition, the LSO or equipment operator may initiate a waveoff sequence when, in his judgment, a safe landing cannot be accomplished. The pilot can terminate the automatic landing anytime at his discretion.

The AN/SPN-10 has two identical control channels. These channels, operating independently, provide an overall maximum system landing rate capability of one aircraft every 30 seconds, however one per minute is usually experienced. Each channel has three modes of operation: automatic, semiautomatic, and manual (voice talkdown). In all instances, the mode of operation is determined by the pilot of the landing aircraft, after which the operator will take the appropriate action to furnish the pilot with the desired control guidance.

The AN/SPN-12 is a range-rate radar set that computes, indicates, and records the speed of aircraft making a landing approach to the carrier. Both true air speed and relative speed are indicated. Thus, the LSO is supplied with accurate information on the speed of the approaching aircraft, and can wave off those attempting to land at an unsafe speed.

The AN/SPN-35, -35A is a lightweight carrier controlled approach radar designed to provide precision range azimuth, and elevation information for aircraft during the final approach phase of flight onto aircraft carriers.

Aircraft normally enter AN/SPN-35, -35A control approximately ten miles from touchdown. Under optimum weather conditions, aircraft may enter AN/SPN-35, -35A control approximately twenty-five miles from touchdown. Information presented on the indicators provides the final approach controllers with precision information as to relative azimuth, range, and elevation of the aircraft. This enables the operator to direct the pilot along a predetermined glidepath and azimuth courseline. All aircraft on the glideslope and azimuth courseline are displayed and can be controlled.

The three major modes of operation for the AN/SPN-35, -35A are as follows:

(1) Normal Mode—For normal precision approach operation the azimuth antenna scans a 30 degree sector and the elevation antenna scans 11 degrees vertically.

(2) 35 Degree Elevation Mode—The azimuth antenna scans a 30 degree sector and the elevation antenna scans 35 degrees vertically.

(3) 60 Degree Azimuth Mode—The azimuth antenna scans a 60 degree sector and the elevation antenna scans 11 degrees vertically.

The AN/SPN-35A differs from the AN/SPN-35 in that the AN/SPN-35A employs a more reliable stabilization system to compensate for pitch and roll of the carrier in order to maintain precision azimuth and elevation coverage. The AN/SPN-35A employs an electromechanical stabilization system, whereas the AN/SPN-35 utilizes the modified mechanical-hydraulic stabilization system of the AN/SPN-6 radar.

The AN/SPN-42 is a landing control central which provides an automatic landing capability for aircraft under all-weather conditions. Aircraft enter the system through an acquisition "window" approximately four miles from the carrier. From this point to touchdown the operation is completely automatic, the pilot serving only as monitor. When the aircraft enter this window, the precision radar of the AN/SPN-42 tracks the aircraft and feeds position information to the computer group via the buffer group. The stabilization group feeds ship's motion data to the computer group in a similar manner. Operating on the stabilized aircraft position data, the computer group generates control signals for holding the aircraft on a predetermined flight path. Deck motion compensation is derived by the computer group from ship's motion data and is used to modify control of the aircraft during the last twelve seconds of flight. Control signals and wave-off command are transmitted to the aircraft by way of the NTDS data link and are implemented by the autopilot and appropriate cockpit indicators. Video presentation is provided to the AN/SPN-42 console operator on a conventional GCA type radar scope.

The AN/SPN-42 has three modes of operation: automatic, semiautomatic, and manual.

(1) Automatic (Mode I): In this mode, the aircraft is acquired and controlled from the acquisition "window" to touchdown without assistance from the operator or pilot, after the pilot signals that he is ready for control. Both the Landing Signal Officer and controlling operator monitor the landing sequence and may initiate a waveoff whenever an unsafe flight or landing condition exists. The pilot may also terminate the automatic landing at his discretion.

(2) Semiautomatic (Mode II): In this mode, the control signals are generated and transmitted via data link to cross-pointers for guidance to the pilot who has complete control of the aircraft.

(3) Manual (Mode III): In this mode, the operation is similar to GCA talkdown; no data link is required, only voice communications.

The AN/SPN-42 is an improvement over the present AN/SPN-10 Landing Control Central in that it offers far greater reliability and maintainability. The AN/SPN-42 employs digital computers and solid state circuitry, resulting in a Mean Time Between Failure of approximately 250 hours in Mode I; whereas the AN/SPN-10 has a Mean Time Between Failure of 35 hours in Mode I.

The AN/SPN-43 provides azimuth and range information from a minimum range of 250 yards to a maximum range of fifty miles at altitudes from horizon to 30,000 feet. The ship's radar indicators display the information to the operators in the Carrier Air Traffic Control Center. This enables the operator to direct the aircraft along a predetermined azimuth courseline to a point approximately one quarter mile from touchdown. At night or during adverse flying weather however, control of the aircraft is transferred to the precision approach radar (AN/SPN-35) or Landing Control Central (AN/SPN-42) for guidance along the glidepath and azimuth courseline to the carrier landing ramp.

The AN/SPN-43 modifies and improves the AN/SPN-6 radar air space coverage required for carrier landing operations.

The present AN/SPN-6 radar's vertical beam width of 2 1/2 degrees is inadequate to simultaneously cover normal carrier approach and bolter/waveoff patterns. Furthermore, the AN/SPN-6 no longer provides adequate range coverage for surveillance of aircraft at high altitudes.

TARGET CONTROL SYSTEM

The AN/SRW-4( ) target control system is installed principally aboard destroyers equipped with the Drone AntiSubmarine Helicopter (DASH). The system provides positive control of the drone during all phases of flight, including takeoff and landing, by transmitting to the helicopter commands in the form of coded FM radio signals.

The system consists of duplicate transmitters, coders, antennas, and operating control positions. Selection and operation of the transmitting arrangement are accomplished by the flight controllers at the operating position. Normally, one operating position is installed in the CIC; the other position is located in the vicinity of the flight deck. By manipulating the controls at the operating control positions, the controllers send altitude, bearing, speed, and various special command signals to the drone. In the drone, the signals are accepted by a receiver and processed and applied to an Automatic Flight Control Set (AFCS). The AFCS causes the drone to execute the command signals.

The drone is started and preflighted from the deck controller's position. On signal from the CIC controller, the deck controller launches the drone and vectors it toward the target or to a holding position. He then relays to the CIC controller the altitude, speed, and heading of the drone as indicated at his control position. The controller in CIC sets these data into his operating position, and takes control of the drone when it appears on the CIC radar display. He pilots the drone throughout its mission and return to the ship. When the drone comes into view, control is transferred back to the deck controller, who executes the approach and landing.

INFRARED EQUIPMENT

Infrared equipment belongs to a family of devices which use electro-optics for communication, surveillance, detection, and navigation. Also included are image intensifying night observation devices, low level television, and lasers.

Infrared equipment is designed to create, control, or detect invisible infrared radiations. The equipment is of two types transmitting and receiving. The transmitting (source) equipment produces and directs the radiations. The receiving equipment detects and converts the radiations into either visible light for viewing purposes, or into voice or code signals for audible presentation.

Infrared devices can be used for weapon guidance, detection of enemy equipment and personnel, navigation, recognition, aircraft proximity warning, and communications. Depending on its application, the equipment is either passive or active. The active method employs both transmitting and receiving equipment, whereas the passive method requires only receiving equipment.

The infrared spectrum, which extends from the upper limits of the radio microwave region to the visible light region in the electromagnetic spectrum (fig. 12-5), is divided into three bands: near infrared, intermediate or middle infrared, and far infrared. Devices operating in the near and middle bands are used for ranging, recognition, and communications. They normally have a usable distance range of 6.5 to 10 miles. Equipment that operates in the far infrared band is used for ranging, missile guidance, and the detection and location of personnel, tanks, ships, aircraft, and the like. This equipment is usually effective at distances between 100 yards and 12 miles.

Some of the infrared devices in use in the fleet today are the blinker equipments AN/SAT-( ), and VS-18( )/SAT; the voice/tone equipments AN/SAC-4, AN/PAC-3, and AN/PAR-1; and the viewer AN/SAR-( ) equipments. A brief description of the equipment follows.

Perhaps the most widely used infrared transmitting gear is the VS-18( )/SAT hood, with filter lens. It is mounted on the standard Navy 12-inch searchlight (fig. 12-6). It blocks most of the visible light so the searchlight cannot be seen at a distance. The light is operated in the same manner as an ordinary communication searchlight. Using the same

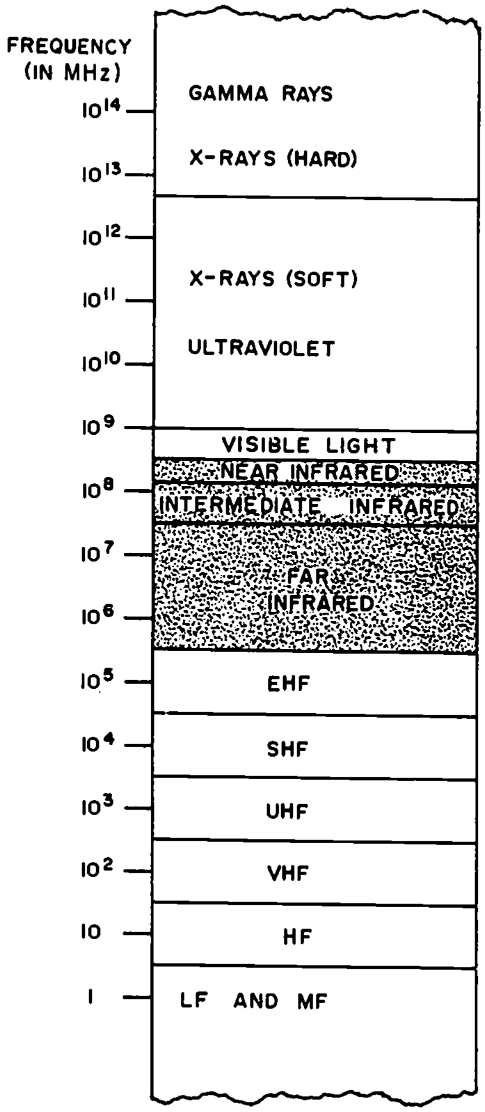

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Figure 12-5.—Electromagnetic spectrum showing infrared bands.

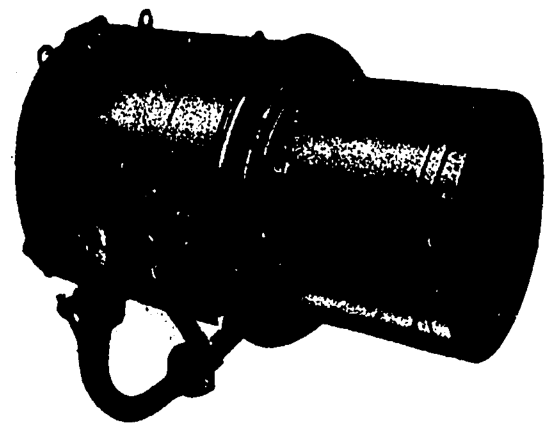

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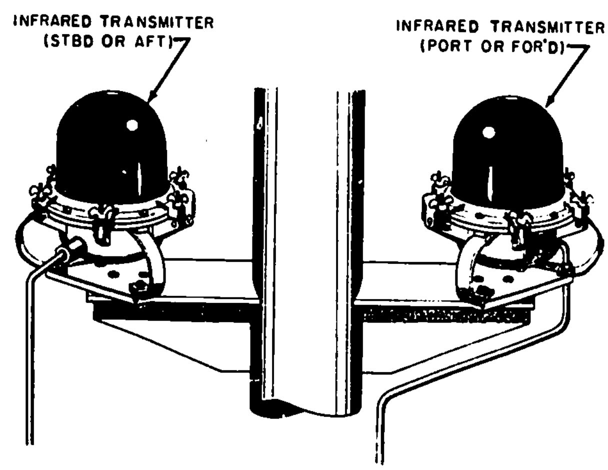
Figure 12-6.—The VS-18( )/SAT infrared hood on 12-inch searchlight.



101.6
Figure 12-7.—Infrared Yardarm Beacons AN/SAT-( ).

design, there are variations to the VS-18( )/SAT hood for use on nonmagnetic minesweepers, the 8-inch signal light, and hand signal lamps.

Another type of infrared transmitting equipment is a 360° light, which is installed in pairs on yardarms (fig. 12-7) of the majority of naval ships. These lights, designated AN/SAT-( ), are operated in the same manner as yardarm blinkers. They can be used as a steady source for "point of train" (POT) purposes, or they can be used for signaling or recognition purposes.

A third important transmitter is the X-9B small craft beacon. It is similar to the AN/SAT-2 but is smaller and powered by 24 volts from the small craft electrical system.

The voice-tone equipments are not in general use. They work by modulation of a light beam which is received and amplified by a photocell receiver.

Electronic infrared viewers convert the infrared rays to visible light. They must be used to detect signals from the VS-18( )/SAT or AN/SAT-( ), or to observe a night scene illuminated by an infrared searchlight.

The AN/SAR-4( ) viewing set (fig. 12-8) is a very old set still used in the fleet. It consists of two main units; (1) a 115 volts AC converted to a 20,000 volts DC power supply, and (2) the viewer unit which consists of a sealed housing and two interchangeable sets of lenses. The housing contains an image converter tube which produces an image of the infrared scene on a phosphorescent screen. The AN/SAR-6 viewing set (fig. 12-9) is similar to the AN/SAR-4( ) except that it has an internal battery power supply instead of a separate power unit. The AN/SAR-7( ) viewing set (not shown) is similar to the AN/SAR-6 but is smaller and lighter. The Type T-7 (AN/PAS-6) infrared metascope (not shown) is a small pocket-sized viewer used chiefly in amphibious operations. It includes an infrared flashlight which can be used for signaling, chart reading, and the like.

METEOROLOGICAL EQUIPMENT

Electronic meteorological equipments consist of a variety of equipments, each serving different purposes. Electronic devices have been developed to measure cloud heights and visibility. Others measure winds aloft, as well as temperature, pressure, and humidity in the upper air. Still others were developed as complete weather stations that report automatically by radio. By far the most sophisticated of the recent developments of electronic

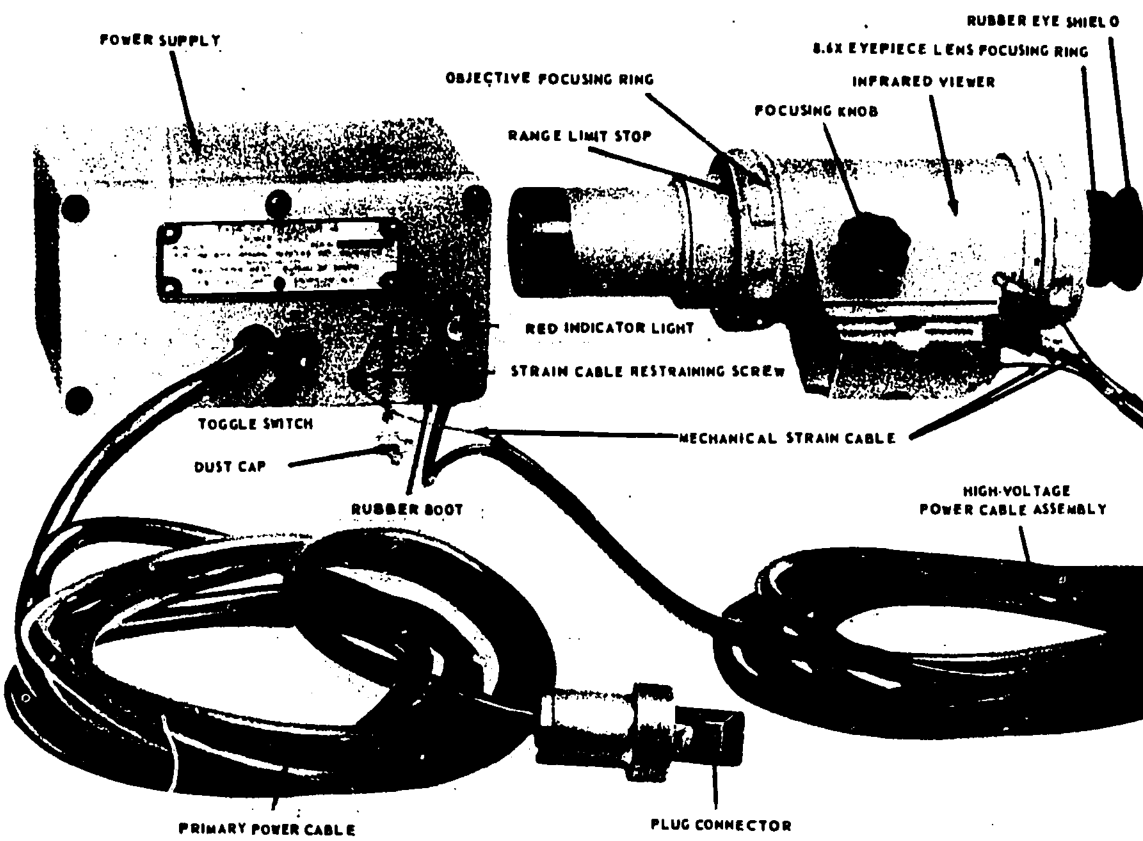


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Figure 12-8.—Electronic Infrared Receiver AN/SAR-4( ).

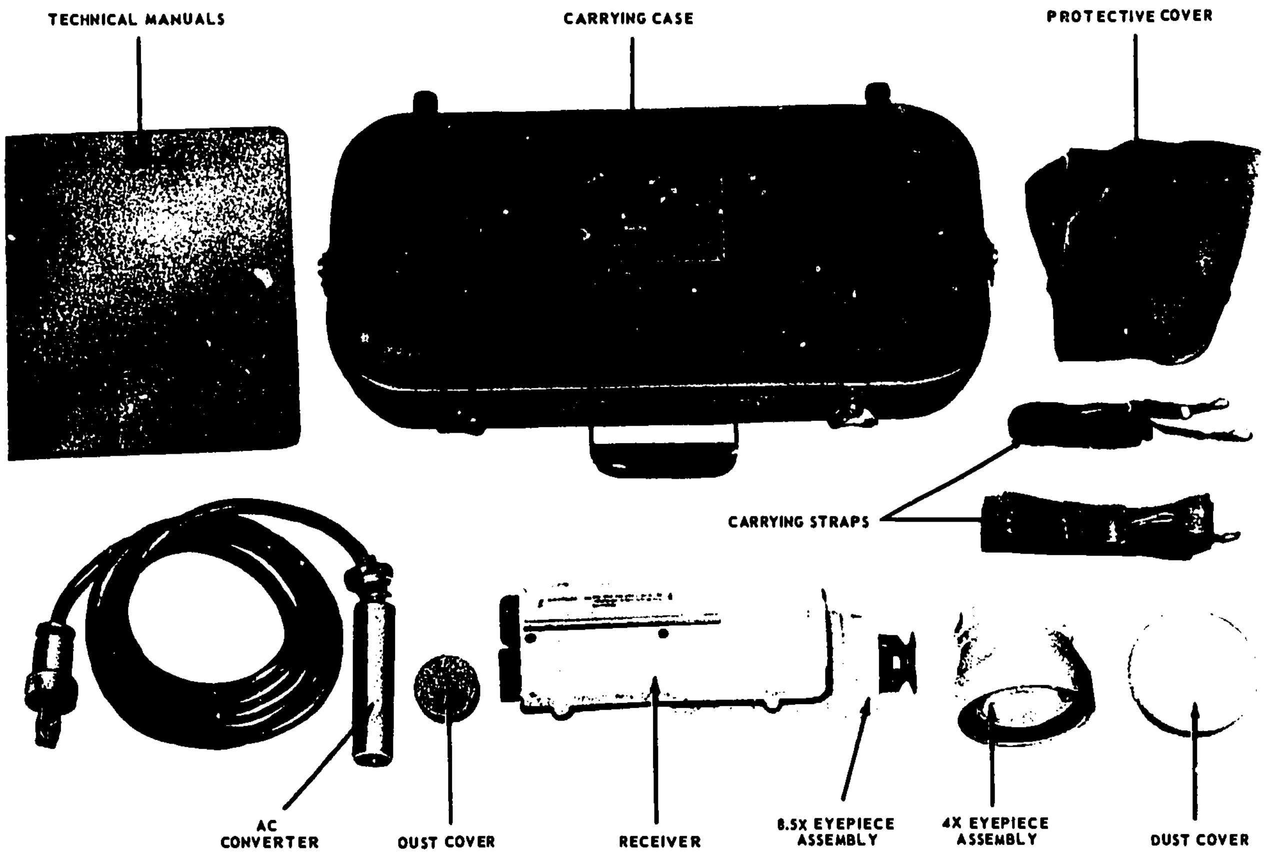

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Figure 12-9.—Electronic Infrared Receiver AN/SAR-6.

meteorological devices are the weather satellites.

Two meteorological devices that are representative of the types carried aboard naval vessels are the AN/AMT-11( ) radiosonde and the AN/SMQ-1( ) radiosonde receiving set. (Radiosondes are the flight equipment used in making upper air pressure, temperature, humidity, and, in some instances, wind observations. Depending on the type they are carried aloft by ballons or are dropped from aircraft.)

The AN/AMT-11( ) radiosonde (fig. 12-10) is an expendable scientific instrument designed to be carried aloft by a sounding balloon. During its flight, the radiosonde transmits pulse-modulated radio signals in the frequency range 395 to 406 MHz. When properly recorded and interpreted, these signals give a continuous reading of the pressure, temperature, and humidity of the atmosphere through which the instrument passes. Wind direction and velocity are measured by tracking the radiosonde with radar or radio direction finders.

Radiosonde receptor AN/SMQ-1( ) (fig. 12-11) receives, amplifies, demodulates, and graphically records the signals transmitted by the AN/AMT-11( ). The received signals are pulses of RF energy. The frequency of repetition of these pulses depends on meteorological conditions. Each pulse is approximately 250 to 275 μsec in duration, and the pulse repetition rate varies from 10 to 200 PPS. Usually, the received signal is a series of pulses at one audio rate followed by a series of pulses at a different audio rate. Each series of pulses causes the receptor to record on a chart in a certain position, as determined by the audio rate of that particular series of pulses. The order in which these different series are recorded is known and common to all radiosondes of a particular type. Thus, it is possible to interpret and evaluate the chart.

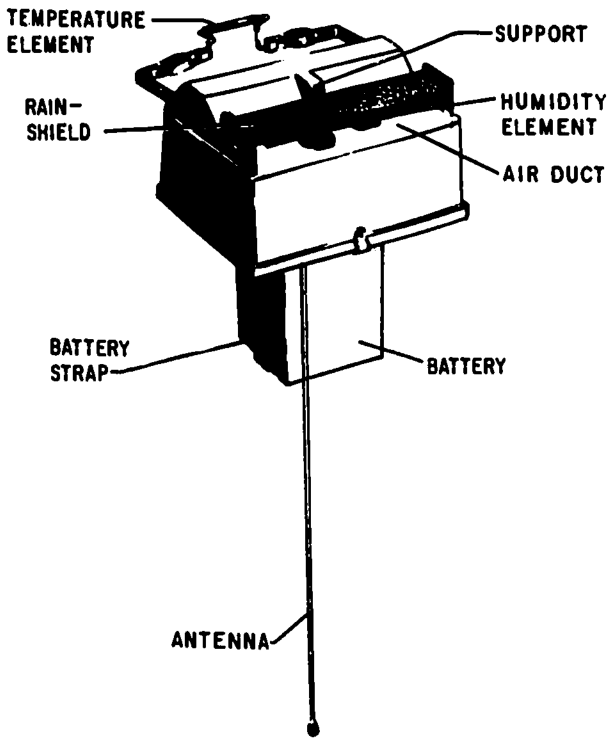

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Figure 12-10.—Radiosonde AN/AMT-11( ).

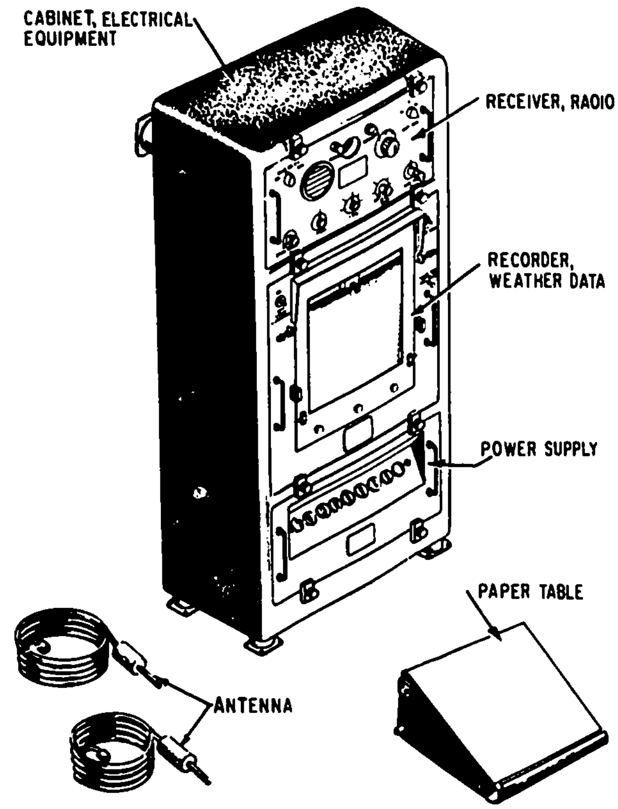

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Figure 12-11.—Radiosonde Receptor AN/SMQ-1( ).

RADIAC EQUIPMENT

An important factor in the control of danger to personnel from nuclear radiation is the determination of how much radiation has been absorbed by personnel and how much is present on the ship. Because it is impossible to see, feel, or smell radiation, special instruments have been developed to detect and measure radiation. These radiological measuring instruments are known as radiac devices. (Radiac is a short term derived from the underlined letters of the words radioactivity detection, indication, and computation.) Radiac instruments are designed to (1) detect and measure alpha, beta, gamma, and neutron radiation, (2) measure the intensity of radiation, (3) determine the extent of contamination, (4) provide information for calculating the length of time that contamination will exist in an area, and (5) protect personnel by providing means for determining the radiation dose received.

Radiac instruments are of two general types: (1) those that show how much radiation has been received over a period of time (accumulated dose); and (2) those that indicate the amount of radiation at any particular instant (dose rate). Instruments of the first type, usually called dosimeters, are used to measure the amount of radiation to which a person has been exposed during a given period of time. Equipment of the second type are radiacmeters, and are used chiefly for surveying contaminated areas, structures, or objects to determine the amount and type of radiation emitted.

Dose rate or intensity is expressed as either "roentgen per hour" or "rads per hour." The roentgen is the unit of exposure to radioactive doses of gamma and X-rays. The roentgen is being replaced by rad as the standard unit of absorbed radioactive dose. Because absorbed dose is the most critical of the two, most new detection devices are scaled to read in rads. An added factor in using rads is that the term expresses the dose from any type of radiation, whereas roentgen relates only to gamma radiation or X-rays. Due to the large number of detection devices still in use that are scaled in roentgens, roentgen is used in this text.

DOSIMETER

A typical pocket dosimeter of the self-reading type is the IM-9( )/PD. This instrument and its charging unit PP-354( )/PD are shown in figure 12-12. At one end of the dosimeter is an optical eyepiece; at the other end, a charging contact. When the dosimeter is fully charged, an indicator viewed through the eyepiece is at the zero point on a scale. As radiation penetrates the instrument, its charge is dissipated or neutralized, and the indicator moves along the scale a distance proportional to the quantity of radiation received.

By holding the dosimeter to the light and peering through the eyepiece, the total radiation dose received in milliroentgens can be read directly from the scale. The instrument measures (up to 200 milliroentgens) the X- or gamma radiation accumulated by an individual. It is used by personnel who work in contaminated areas to indicate when the accumulated maximum permissible exposure is reached.

Although a self-reading dosimeter, it requires a separate charging and adjusting device for setting the movable element on the zero of the interior scale. The charger (fig. 12-12) requires no external power source; it produces a static electrical charge when the knob on the front of the unit is rotated. This pocket-sized device, known as the PD-354( )/PD charger, can serve many types of dosimeters.

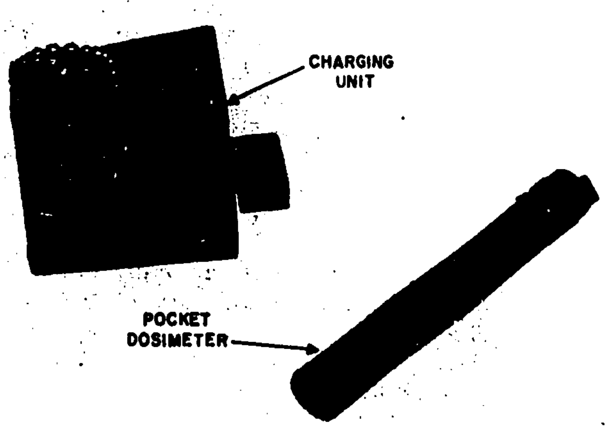

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Figure 12-12.—Pocket Dosimeter IM-9( )/PD, with charging unit PP-354( )/PD.

The high-range nonself-reading dosimeter, DT-60/PD (not shown) is for use by all ship's personnel. This dosimeter consists of a special phosphate glass housed in a moistureproof plastic case. The dosimeter is about the size of a pocket watch, weights less than an ounce, and is of sturdy construction. It will measure accumulated dose from 10 to 600 roentgens. A special instrument, CP-95/PD, is required to read it. The dose indication does not change with time (after use); therefore, the dosimeter may be reused and read repeatedly.

RATEMETER

Ratemeters used for measuring radiation intensity (dose rate) contain electronic circuits that detect the presence of radiation and indicate its intensity on a direct-reading meter. These radiac instruments are available in various sizes; some are portable, others are fixed. The ratemeters use different detection methods to measure alpha, beta, gamma, and neutron radiation. Among the various types are the AN/PDR-18, -27, -43, -45, -56, -65, -70 and the AN/SDR-1, -2. A description of some of these ratemeters follows.

The Radiac Set AN/PDR-27 (fig. 12-13) is a portable, watertight, battery-operated instrument that furnishes visual and aural indication of the detection and/or measurement of gamma and beta radiation. It has a range of 0 to 500 milliroentgens per hour (MR/HR) and is used to detect low intensity beta radiation or low intensities of beta and gamma radiations together, or detect and measure gamma radiations alone. It is used to detect low intensities of beta and/or gamma radiation, such as might be found on clothing or hands of personnel, or in moderately contaminated radioactive areas. In general, it is used for detailed monitoring of personnel, spaces, and material.

The high-range intensity meter, AN/PDR-43( ), is a "pulsed" (controlled on time) end-window Geiger-Mueller (G.M.) type, portable radiac for measuring gamma radiation and detecting beta radiation (fig. 12-14). The end-window G.M. tube and associated electronic

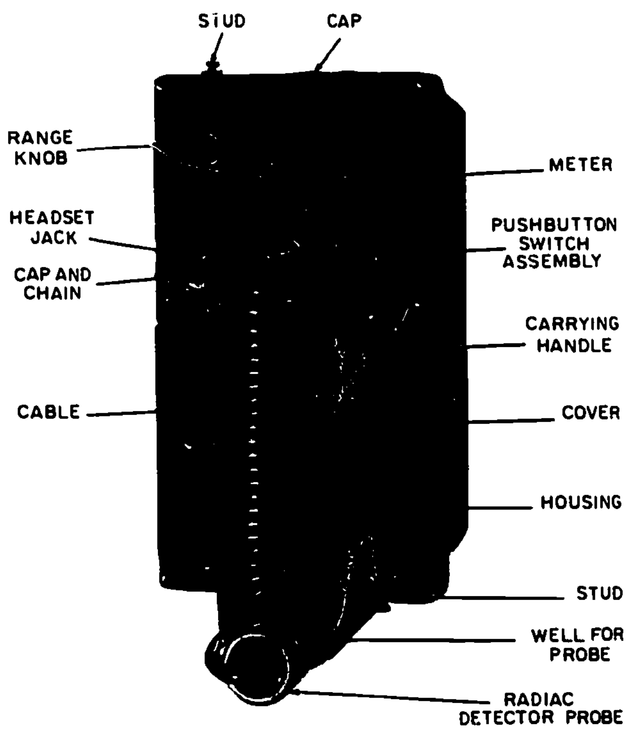

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Figure 12-13.—Radiac Set AN/PDR-27( ).

circuits are contained in a single metal case. X-ray and gamma radiation penetrates material more readily than does beta; therefore an "end window" of relatively smaller thickness compared to the remainder of the cylinder wall is used to permit beta penetrations. The gamma-intensity range scales are 0 to 5, 0 to 50, and 0 to 500 roentgens per hour. Beta-gamma radiation may be detected on these range scales by properly positioning the function selector slide (beta shield-source slide) located on the bottom of the case. A 50-microcurie source is contained on the function selector slide to check the range scales for response to radiation. The numerals on the meter face change with the position of the range selector switch. The following controls are provided; (1) a range selector switch with positions for OFF, BATT, and the three range scales; and (2) a function selector slide with OPERATION CHECK, GAMMA, and BETA positions. In the OPERATION CHECK position, the end-window of the G.M. tube is exposed to the 50 microcurie source. In the GAMMA position, only gamma radiation is detected by the G.M. tube. In the BETA position, the end-window of the G.M. tube is exposed to beta and gamma radiations.

The AN/PDR-56 (fig. 12-15) is the Navy's standard alpha survey meter. This radiac set is hand carried and is comprised of a ratemeter with an auxiliary probe, a shoulder harness, a headset, a probe handle extension, and a carrying case (fig. 12-15. The ratemeter receives pulses from the probe and converts them in a discriminator and ratemeter ciruit to a meter reading. The reading is proportional to the amount of alpha contamination as seen by the probe. The AN/PDR-56( ) detects and measures the intensity of alpha radiation in counts per minute.

The AN/PDR-65 (fig. 12-16) is a high-intensity instrument that provides gamma radiation dose and dose rate information needed for tactical decisions. It is designed primarily for fixed shipboard installation but can be used as a portable instrument. It measures gamma field intensity to 10,000 rads/hr and dose to 10,000 rads. The rate meter portion of the instrument has four sensitivity ranges: 0 - 10, 0 - 100, 0 - 1000, and 0 - 10,000. Accumulated dose is given numerically in increments of 1 rad. The radiacmeter consists principally of a detector assembly, power supply and remote control unit, remote detector mounting bracket, 200 feet of remote detector cable, and a carrying case.

The AN/PDR-65 utilizes a recycling ionization chamber detection principle with a recycling event occurring every 0.5 millirad. (A recycling ionization chamber charges and discharges like a capacitor.) A sounder with a low-range capability gives an aural indication of each recycling event. The detector assembly can operate remotely up to 500 feet from the instrument housing. Two units may be interconnected, e.g., one at a topside station and one belowdeck, so that the dose rate topside can be monitored at the readout unit belowdeck.

The AN/PDR-65 is designed for continuous operation from a 115-volt, 60-hertz circuit. For the portable mode of operation it is provided with four rechargeable nickel cadmiun C batteries.

The AN/SDR-1 and -2 are older fixed radiac systems aboard ships. They indicate field intensity of gamma radiation up to 10,000 roentgens per hour. These sets have audible alarms that ring at a rate proportional to the field intensity. The alarm may be set

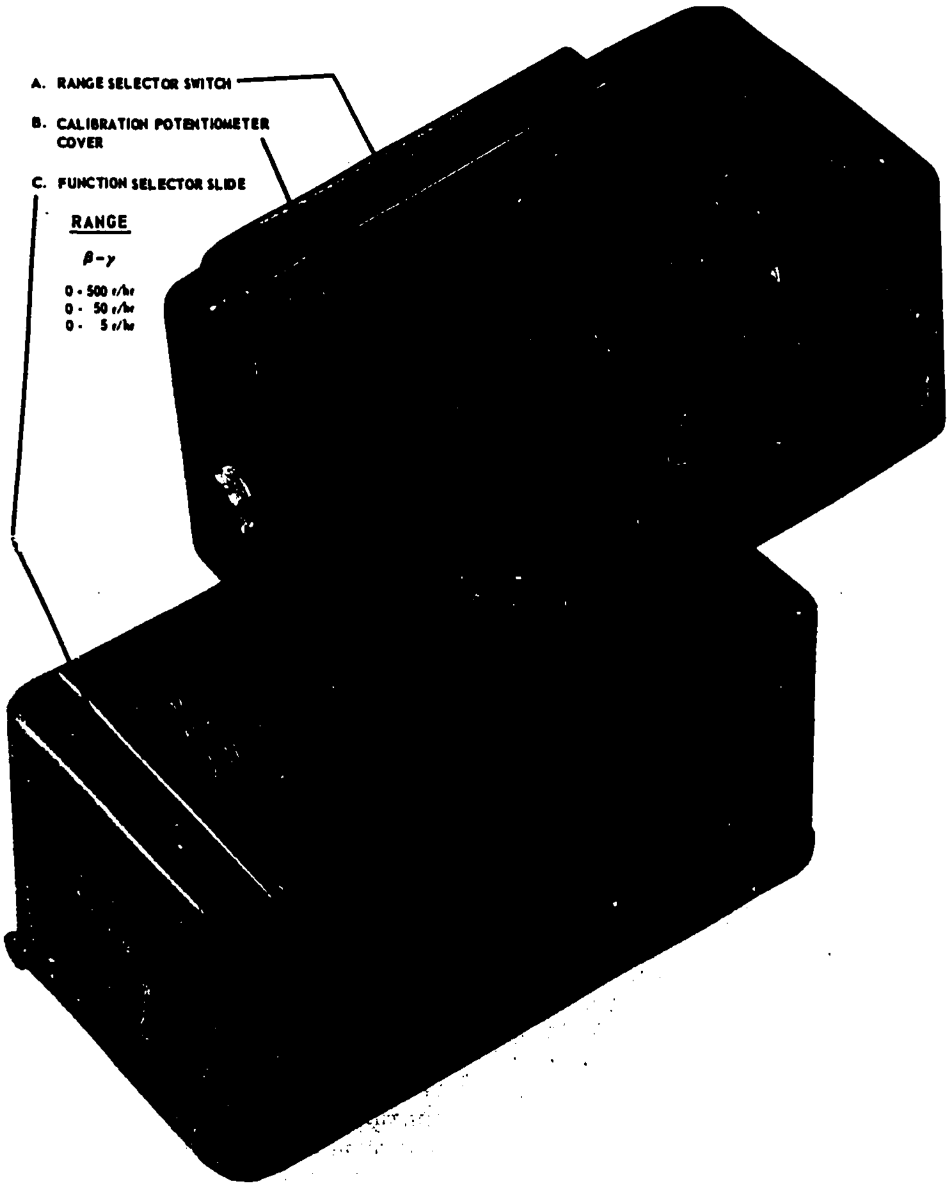

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Figure 12-14.—Radiacmeter AN/PDR-43( ).

to operate when the radiation field exceeds a preset level of intensity between 0 to 1000 milliroentgens per hour.

The systems include remote radiac indicators and a training device. The training device can simulate high-range readings for the remote indicators during field defense training exercises. The radiacmeter is designed for continuous operation from a 115-volt AC power source. It, in turn, supplies the power to all other units. If the normal power source fails, a built-in battery operates the equipment for a maximum of 50 hours. When the AC power is returned, the discharged battery commences recharging and assumes a full charge within 24 hours.

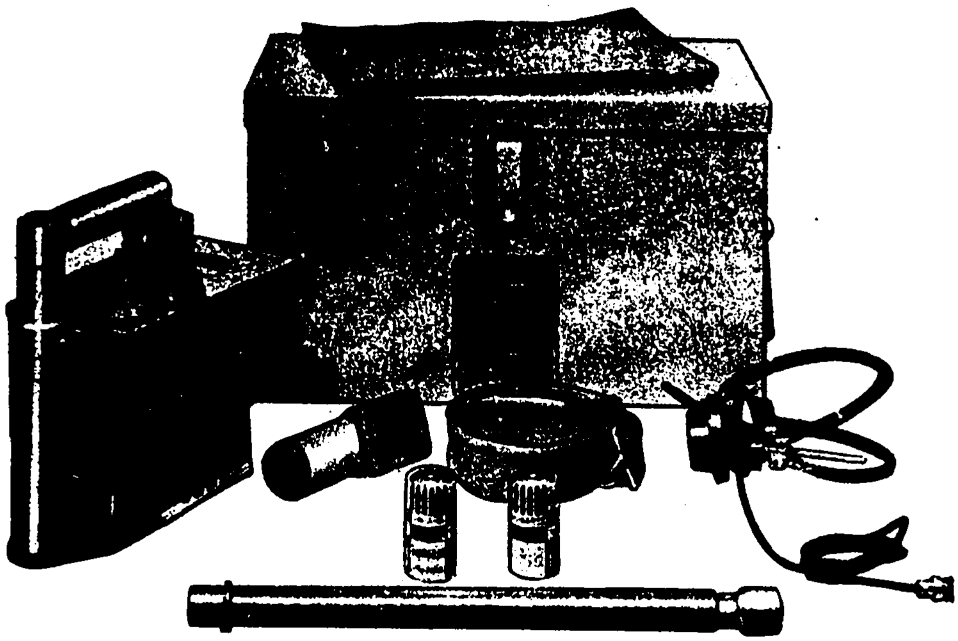

Figure 12-15.—Radiac Set AN/PDR-56. 5.184

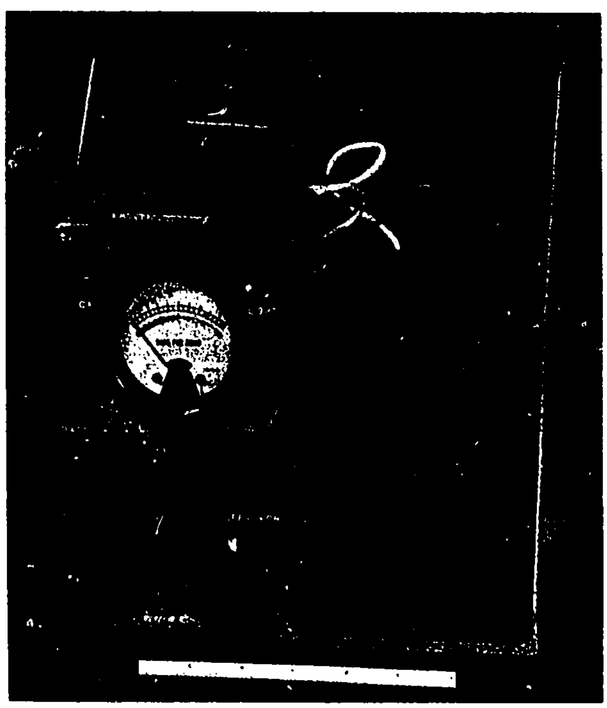

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Figure 12-16.—Radiac Set AN/PDR-65.

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