DOCUMENT RESUME

ED 220 621 CE 033 479

TITLE Military Curriculum Materials for Vocational and Technical Education. Communications Technician, 5-3A

INSTITUTION Naval Education and Training Command, Pensacola, Fla.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.

PUB DATE [82]

NOTE 269p.

EDRS PRICE MF01/PC11 Plus Postage.

DESCRIPTORS Autoinstructional Aids; Behavioral Objectives; *Communications; *Communications Satellites; Correspondence Study; Course Descriptions; *Electronic Equipment; *Equipment Maintenance; First Aid; High Schools; Individual Instruction; Pacing; Postsecondary Education; *Safety; Secondary Education; Textbooks; Trade and Industrial Education; Workbooks

IDENTIFIERS *Antennas; Communications Occupations; Military Curriculum Project; *Wave Propagation

ABSTRACT

These assignments and text for a secondary-postsecondary level correspondence course in electronic communications comprise one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. Purpose of the individualized, self-paced course is to provide students with background information, including fundamentals of communications, communications medium and equipment, and maintenance and safety. Six assignments containing multiple choice questions cover these topics: (1) Communications Basics; (2) Satellite Communications, Wave Propagation and Antennas; (3) Wave Propagation and Antennas (continued), Communication Transmitters and Receivers, Facilities Control Operations; (4) Facilities Control Operations (continued); and (5, 6) Maintenance and Safety. The seven chapters of the text are Communications Basics, Satellite Communications, Wave Propagation and Antennas, Communication Transmitters and Receivers, Facilities Control Operations, End Terminal Equipment, and Maintenance and Safety. Appendixes include operating procedures for various equipment, American Standard Code for Information Interchange, and information on the metric system. An index is provided. (YLB)

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COMMUNICATIONS TECHNICIAN

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

Agriculture	Food Service
Aviation	Health
Building & Construction Trades	Heating & Air Conditioning
Clerical Occupations	Machine Shop
Communications	Management & Supervision
Drafting	Meteorology & Navigation
Electronics	Photography
Engine Mechanics	Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

Developed by:

United States Navy PENSACOLA

Development and Review Dates

1975

Occupational Area:

Communications

Cost: $4.75

Print Pages: 234

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

Basic Electronics

Target Audiences:

Grades 10-adult

Organization of Materials:

Lesson sheets with objectives, assignments, and review exercises; text

Type of Instruction:

Individualized, self-paced

Type of Materials:		No. of Pages:	Average Completion Time:
Communications Technician			
Assignment 3 —	Communication Basics	20	Flexible
Assignment 4 —	Satellite Communications; Wave Propagation and Antennas	27	Flexible
Assignment 5 —	Wave Propagation and Antennas (continued); Communication Transmitters and Receivers; and Facilities Control Operations	37	Flexible
Assignment 6 —	Facilities Control Operations (continued); and End Terminal Equipment	38	Flexible
Assignment 10 —	Maintenance and Safety	16	Flexible
Assignment 11 —	Maintenance and Safety (continued)	48	Flexible
Exercises		45	

Supplementary Materials Required:

None

Expires July 1, 1978

Course Description:

This course was designed to provide the student with background information on electronic communications. It discusses the fundamentals of communications, communication medium and equipment, and maintenance and safety. The text is used as an introduction to many courses and includes information on military procedures and equipment as well as basic information.

The course consist of eleven assignments with objectives, readings, and review exercises. Five of those deal with military procedures and equipment almost exclusively, so they were deleted. The remaining six assignments are described below.

Assignment 3 — *Communications Basics* describes various types and operations of electrical, visual, and sound communication; explains the characteristics of the radiophone, facsimile, radiotelegraph, and teletypewriter; describes frequency bands; identifies applications of frequency spectrum for long distance communication; covers the capabilities, functions, and operations of switched networks; and identifies the characteristics of transmission systems, and carriers. This assignment describes the process of modulation and identifies the operational characteristics and uses of single sideband, microwave and scatter transmissions.

Assignment 4 — *Satellite Communications; Wave Propagation and Antennas* describes communication satellite systems and identifies specific satellite and earth terminal characteristics; explains the role of satellite communications and identifies advantages and limitations. Characteristics of electromagnetic waves and factors affecting wave propagation are also covered.

Assignment 5 — *Wave Propagation and Antennas (continued); Communication Transmitters and Receivers; Facilities Control Operations* provides additional characteristics of electromagnetic waves and factors affecting wave propagation; identifies the principles and characteristics of communications transmitting and receiving equipment; describes the purpose of communications systems; determines the various stages of signal flow of a secure communication system; and describes features common to all switchboard operations.

Assignment 6 — *Facilities Control Operations (continued)* identifies the uses, functions, and characteristics of key converters and converter-comparator groups; describes the methods of diversity operation; covers the purpose, operating principles and components of a multiplex system; and determines the purpose of and the basic installation requirements for distribution frames and patching facilities. The functions of the different types of patch cords of a patch panel and characteristics of the patch panel are identified. Digital signals, DC teletypewriter circuits, and distortion are discussed.

Assignment 10 — *Maintenance and Safety* explains various types and levels of equipment maintenance; describes maintenance tasks, cleaning procedures, and care of electronics equipment and air filters; describes care and preventive maintenance requirements for teletypewriters, typewriters, headphones, and microphones; and discusses safety precautions.

Assignment 11 — *Maintenance and Safety (continued)* covers safety precautions and procedures to follow when working on electrical equipment, the causes and effects of electric shock, the hazards presented by electronic equipment operating at high frequencies, and the safety precautions to follow in handling cathode ray tubes and cleaning electronic equipment.

Each assignment is organized around learning objectives, readings, and exercises. No answers are provided for the exercises. The course is designed for student self-study in basic and some advanced communication principles.

COURSE OBJECTIVE

While completing this course, the student will demonstrate his understanding of course materials by correctly answering items on the following subjects: scope and responsibilities of the Communications Technician O rating; individual and command security principles; emergency destruction procedures and devices used by Naval Security Group activities; the mission, policy, and various organizations of Naval Communications; variations of the ionosphere and how they affect radio frequencies; different antenna configurations and how they are used; the functions of communication transmitters, receivers, and terminal equipments; the operation of a secure teletype communications system; the basic message format and the rules of preparation for AUTODIN and DSSCS; communication dividion administration including types and accountability of publications; and first aid.

5-3

MODIFICATIONS

Assignments 1 & 2 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Assignment 3

Introduction to Naval Communications (continued); Communication Basics

Textbook pages 66 through 88

Learning Objective: Recognize the types and operation of electrical, visual, and sound communication used in the Navy.

3-5. In order to ensure maximum contribution to the mission of the command, the communicator should

1. qualify as a specialist in electronics
2. possess an understanding of the communication facilities he uses
3. be familiar with the limitations and capabilities of selected communication systems
4. thoroughly understand communication theory of specific types of equipment

3-6. What are the 3 types of telecommunications used in the Navy?

1. Electrical, signals, sound
2. Visual, sound, signs
3. Electrical, visual, sound
4. Electrical, visual, images

3-7. What is/are the means of communicating electrically?

1. Radio
2. Wire
3. A physical path between sender and receiver
4. Both (1) and (2)

3-8. Which statement below is true concerning radio?

1. Radio uses electromagnetic waves carried by electrical conductors
2. Radio uses electromagnetic waves not guided by a physical path between sender and receiver
3. Radio is the Navy's least important means of communications
4. The means of communicating electrically are exclusively by radio

3-9. What is the main advantage of radiotelegraphy?

1. The relatively high speed of transmission
2. The requirement for not as many experienced operators
3. Reliability
4. None of the above

3-10. Because of its directness, convenience and ease of operation, ________ is one of the most useful military communication methods.
1. radiotelephone
2. radiotelegraph
3. teletypewriter
4. facsimile

For items 3-11 through 3-14, select from column B the electrical telecommunications system described in column A.

A. Description	B. System
3-11. A reliable manual communicating system	1. Radiotelephone
	2. Facsimile
3-12. Used mainly for high speed automatic communications	3. Radiotelegraph
	4. Teletypewriter
3-13. Valuable for short range tactical communications	
3-14. Process used to transmit photographs and charts	

3-15. Visual communications are normally more secure than radio.

3-16. Which visual communication system is the principal means of transmitting brief tactical messages between ships in company?
1. Radiotelephone
2. Flashing light
3. Flaghoist
4. Semaphore

3-17. Which of the following methods of visual communication is the most secure?
1. Flashing light
2. Directional flashing light
3. Non directional lights
4. Directional infrared

3-18. What is the best visual signal substitute for handling administrative traffic when radio silence is imposed?
1. Directional flashing light
2. Flaghoist
3. Non-directional lights
4. Semaphore

3-19. Which sound communication system is not used by ships for transmission of emergency warning signals?
1. Sirens
2. Acoustics
3. Whistles
4. Bells

3-20. Sea talk is used for which of the following purposes?
1. Radiotelephone
2. CW
3. Both (1) and (2) above
4. Sonar only

3-21. Use of pyrotechnics is normally limited to CW communications.

3-22. What is the principle regulating body for radio communications worldwide?
1. ITU
2. FCC
3. Office of Emergency Planning
4. COMNAVTELECOMM

Learning Objective: Recognize the frequency bands and identify the application of the frequency spectrum for long distance communications.

3-23. Which of the following statements is true concerning U.S. frequency management?
1. The president has delegated authority for assignment of radio frequencies used by non-government agencies to the Director of Telecommunications Management
2. The FCC is responsible to Congress for regulating frequency use by U.S. Government activities
3. The assignment of all frequencies used by any component of the Navy is the responsibility of CNO
4. The FCC is responsible for regulating frequencies used by the Federal Government agencies

3-24. A frequency of 75,000 KHz could be expressed as
1. 7,500 MHz
2. 750 MHz
3. 75 MHz
4. 7 GHz

7

3-25. Primary reliance and application of the VLF range may be expected for
1. broadcast of standard time and frequency signals
2. operation of synchronous crypto devices
3. operation of single sideband transmissions
4. communications to a large number of satellites

3-26. The distribution of standard frequency and time signals is essential for which of the following?
1. Tracking space vehicles
2. World wide clock synchronization
3. Radio navigational aids
4. Each of the above situations

3-27. The difference in frequency between 13 megacycles and 12,000 kilocycles is
1. 1,000 cycles
2. 100 kilocycles
3. 10 megacycles
4. 1 megacycles

3-28. What frequency band includes the International Distress frequency?
1. HF
2. MF
3. LF
4. VLF

3-29. Which frequency band relies principally on ground waves and is used for moderately long distance over water in its lower portion and commercial broadcasting in its middle portion?
1. LF
2. ULF
3. MF
4. HF

3-30. Which frequency band would cease to exist if the ionized layers above the earth disappeared?
1. MF
2. HF
3. VHF
4. UHF

3-31. What technique increased the capacity of the Navy's assigned portion of the HF spectrum?
1. Use of single-sideband equipment
2. Application of independent sideband
3. Satellite communications
4. Both (1) and (2) above

3-32. What is the primary factor which permits reliable point to point service of HF communications?
1. Large, high gain antennas aimed at opposite terminals of each link
2. Path length and direction are variable
3. Omnidirectional antennas
4. Several frequencies are usually assigned

3-33. Application of Ship-to-Shore communications in the HF band require shipboard antennas to be
1. omnidirectional as possible
2. rotatable high gain type
3. rhombic
4. large, efficient HF antennas

3-34. Which type of service within the HF band normally always provides frequency diversity transmissions so that the terminal can choose the best frequency for the path at the time?
1. Point-to-point
2. Ship-to-shore
3. Ground-to-air
4. Fleet broadcast

3-35. Which frequency band(s) under normal conditions have line of sight characteristics?
1. MF and below
2. VHF and UHF
3. UHF and SHF only
4. EHF only

Learning Objective: Determine the difference between Strategic and Tactical Communications and identify the modes of operation.

3-36. Use of which type of communication is usually limited to a specific area of operation and is used to direct or report the movement of specific forces?
1. Strategic communications
2. Tactical communications
3. Duplex communications
4. Simplex communications

3-37. AUTOVON, AUTODIN and DSSCS could be considered as strategic communications systems.

3-38. A path between two or more points, capable of providing channels for the transmission of intelligence is identified as a
1. communication channel
2. tactical net
3. mode of operation
4. braodcast net

3-39. When a terminal must wait to receive an in-progress message before it can transmit, the technical arrangement could be termed
1. Simplex
2. Semi-duplex
3. Half-duplex
4. Full Duplex

3-40. The primary means of transmitting messages to the fleet from shore stations is by the
1. point-to-point method
2. receipt method
3. intercept method
4. broadcast method

3-41. How do fleet units determine if they have received all of the messages transmitted on a specific fleet broadcast?
1. By checking sequential serial numbers to ensure none is missing
2. By requesting verification of the number of messages sent
3. By keeping two receivers on the line at all times
4. By visiting NAVCOMMSTAs when in port

3-42. One of the chief advantages of broadcast transmission over intercept is its
1. assurance that messages have been received
2. ability to verify messages and to make corrections
3. power to reach ships as well as shore installations
4. capacity to handle heavy traffic more rapidly

3-43. Which of the following statements is true concerning broadcast operation?
1. All ships copy only certain messages on the broadcast schedule which they are guarding
2. This method allows the fleet to preserve radio silence
3. Lower precedence messages may not be interrupted to transmit a message of higher precedence
4. Broadcast reception is possible by choice of two frequencies

---

Learning Objective: Recognize the capabilities, functions, operations of the switched networks.

3-44. What capability is provided to subscribers of normal AUTOVON service?
1. The ability to communicate with other subscribers on a world-wide basis
2. The ability to preempt high precedence traffic
3. Immediate connection with predesignated distant installations
4. Conference capability on a random basis

3-45. By which method may local command voice communication systems be connected to AUTOVON?
1. Manually operated switchboards
2. Automatic dialing exchanges
3. Local private branch exchanges
4. Each of the above

3-46. What is the purpose of Automatic Secure Voice Communications?
1. To reduce message delivery time and delay
2. To eliminate the need of switchboard operators
3. To provide a telephone network for the exchange of classified information over officially designated approved circuitry
4. To provide a radio network for the exchange of classified information over officially designated frequencies

3-47. An important function of the ASC in the AUTODIN system is to
1. provide direct dialing service
2. prevent outside signal interference
3. detect and correct message errors
4. convert analog signals for transmission

3-48. The AUTODIN system is revolutionizing communications because it has resulted in a decrease in the
1. number of messages being sent
2. length of messages
3. number of skilled technicians required
4. manual handling of messages

3-49. The primary reason DSSCS came into existence was to
1. form a single automated network for SI communications
2. provide two separate systems within AUTODIN
3. ensure strict physical separation of all DSSCS and AUTODIN traffic
4. integrate the CRITICOMM and AUTODIN into a single automated network

3-50. Considering the AUTODIN/DSSCS high speed environment, which statement below is correct concerning movement of traffic?
1. All input subscribers send messages at 100 WPM to an ASC
2. Prior to forwarding a message, the ASC must receive each message in its entirety
3. The output of a given message is simultaneous with its input
4. Because a station is connected to an ASC, does not necessarily mean it will benefit from the high speed environment

3-51. Which communication network exists in support of only designated Navy requirements?
1. HICOM
2. AUTODIN
3. AUTOSEVECOM
4. AUTOVON

3-52. Commands afloat can communicate via voice with commands ashore using the ship/shore radiotelephone service known as
1. AUTODIN
2. AUTOVON
3. NORATS
4. DSSCS

Learning Objective: Identify transmission systems, and the characteristics of a carrier.

3-53. A subsystem whose information carrying bandwidth is limited to 4 voice channels or fewer would be classified as a
1. microwave system
2. narrowband system
3. FPTS system
4. wideband system

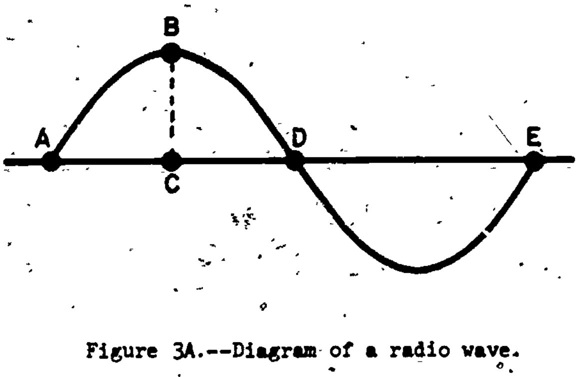

Figure 3A.--Diagram of a radio wave.

3-54. A complete cycle of a wave is represented in figure 3A by the distance
1. AC
2. AD
3. AE
4. BC

3-55. The frequency of a wave is the number of Hertz that occur in one
1. period
2. cycle
3. phase
4. second

3-56. The maximum value of a radio waves' energy measurement is a measurement of the waves'
1. frequency
2. instantaneous amplitude
3. peak amplitude
4. amplitude

3-57. The (A. frequency/wavelengths) and the (B. period/phase) of a carrier wave can be varied to produce an intelligence carrying signal.
1. A. frequency; B. period
2. A. frequency; B. phase
3. A. wavelengths; B. period
4. A. wavelengths; B. phase

Learning Objective: Describe the process of modulation and identify the operational characteristics and uses of single sideband, microwave and scatter transmission.

3-58. On which of the following emission modes does the intelligence carrying signal vary the carrier frequency?
1. CW
2. A-M
3. F-M
4. P-M

3-59. The space on a frequency spectrum that is occupied by a carrier and its associated sidebands is called a/an
1. upper sideband
2. channel
3. bandwidth
4. circuit

3-60. What is the carrier frequency of an amplitude modulated signal which has its upper sideband on 15,000 KHz and is being modulated by a 2000 Hertz note?
1. 14,998 KHz
2. 13,000 KHz
3. 14,996 KHz
4. 17,000 KHz

3-61. In the system of single-sideband suppressed carrier, at what point is the carrier suppressed?
1. At the transmitter before modulation is accomplished
2. After it reaches the power amplifier stage of the transmitter
3. At the receiver before the demodulation process
4. At the transmitter after modulation is accomplished

3-62. Which type of emission provides for using less power and a smaller frequency bandwidth?
1. SSB
2. LSB
3. A-M
4. P-M

3-63. Which of the following statements concerning SSB is correct?
1. ISB transmission is used to make up for the lack of essential channels that can be provided by SSB
2. SSB is used on all long-haul teletype circuits
3. Voice over-wire circuits between NAVCOMSTAs always use SSB.
4. ISB suppresses the carrier and filter out a sideband, in SSB only the carrier is suppressed

3-64. Which procedure conserves the frequency spectrum, saves manpower, and prevents overloading ship-shore circuits?
1. Frequency division multiplex
2. Task group net utilizing one ship as a guardship from which traffic can be relayed ashore
3. Electronic crypto devices on circuits used to send classified messages eliminating manual encryption
4. Time division multiplex

3-65. What is the most common type of communication link presently in use?
1. CW
2. AM
3. PM
4. SSB

3-66. A single sideband teletype circuit which has an electronic crypto device that automatically encrypts prior to transmission and decrypts after transmission is referred to as
1. a broadcast circuit
2. a point-to-point circuit
3. a covered circuit
4. an open circuit

3-67. How many teletype channels are available in each of the four 3-KHz audio channels of an ISB circuit when frequency division multiplex equipment is used?
1. 4
2. 8
3. 16
4. 52

3-68. Which components of the modulated signal are suppressed to produce the ISB signal?
1. The upper sideband only
2. The lower sideband only
3. Both sidebands
4. The carrier only

3-69. Long haul communications that use a microwave transmission system are made possible by
1. aiming the transmitting and receiving antennas at the same point in space with 300 miles separating the two antennas
2. forming chain of repeater stations from initial transmitting station to final receiving station
3. using wire cable transmission lines
4. using coaxial cable transmission lines

3-70. One of the limitations of microwave radio is its
1. high power requirements
2. low reliability
3. use of a large part of the frequency spectrum
4. narrow bandwidth

3-71. What method of transmission is most economical in areas where construction and maintenance are a problem?
1. Forward Propagation Tropospheric Scatter (FPTS)
2. Openwire landlines
3. Coaxial cable
4. Forward Propagation Ionospheric Scatter (FPIS)

Learning Objective: Identify the various types and uses of landlines.

3-72. The type of line used for short haul teletype circuits or keying a transmitter is a/an
1. direct current (D-C) landline
2. audio frequency landline
3. wire cables
4. coaxial cable

3-73. One pair of (A. audio frequency/direct current) landlines are capable of carrying up to 16 teletype channels and are considered to be in the (B. wideband/narrowband) system.

1. A. audio frequency; B. wideband
2. A. audio frequency; B. narrowband
3. A. direct current; B. wideband
4. A. direct current; B. narrowband

3-74. Why is air or nitrogen gas introduced under pressure into coaxial cable in spaces between tubes and wires?

1. Keeps out moisture
2. Aids in detecting any damage
3. Prevents crosstalk between various circuits in the cable
4. For the reasons stated in (1) and (2) above

3-75. What is/are the advantage(s) of underground wire cable?

1. They are less susceptible to sabotage
2. They are less vulnerable to storms
3. They eliminate unsightly congestion especially in cities
4. Each of the above

Assignment 4

Satellite Communications; Wave Propagation and Antennas

Textbook pages 90 through 117

Learning Objective: Describe a communication satellite system and identify specific satellite and earth terminal characteristics.

4-1. What does the Navy expect to accomplish by use of communication satellites?
1. Replace existing conventional transmission media
2. Lower procurement and development costs for future communication networks
3. Meet longhaul communication demands for previously inaccessible areas
4. Control military operations with greater reliability and security

4-2. How will the overall performance of the Phase II DSCS be enhanced over the capability provided in the IDCSP?
1. Phase II DSCS provides for a greatly increased effective radiated power
2. Phase II DSCS utilizes wide-beam antennas
3. Phase II satellites are deployed in non-synchronous orbit
4. Each of the above

4-3. Which characteristic best describes a passive satellite?
1. It acts as a repeater
2. The signal strength of a passive satellite is far superior to any other satellite
3. A passive satellite merely reflects radio signals back to earth
4. A passive satellite will amplify the receiver signal before retransmitting it back to earth

4-4. The inclination of an orbit is classified as
1. either elliptical or circular
2. synchronous
3. asynchronous
4. inclined, polar or equatorial

4-5. If the period of an orbit is identical to that of the earth it is referred to as a/an ________ orbit.
1. synchronous
2. special
3. asynchronous
4. circular

4-6. How many earth terminals can use a satellite at one time with the present operational military communication satellite system?
1. 2
2. 3
3. 4
4. 5

In items 4-7 through 4-9, select from column B the parameters that are described in column A.

	A. Description	B. Parameter
4-7.	Orbit of a satellite nearest the center of the earth	1. Angle of inclination
4-8.	Orbit in any plane not coincident with the equatorial plane	2. Perigee
		3. Apogee
4-9.	Orbit of a satellite at the greatest distance from the center of the earth	4. Polar

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4-10. A satellite orbit with an angle of inclination of near 90 degrees is referred to as a/an _______ orbit.
1. equatorial
2. circular
3. elliptical
4. polar

4-11. When (A. two/three) satellites are used to provide coverage over most of the earth's surface, they would be placed in (B. near synchronous/synchronous) orbits.
1. A. two; B. synchronous
2. A. two; B. near synchronous
3. A. three; B. near synchronous
4. A. three; B. synchronous

4-12. In which type of orbit will a satellite appear to be stationary?
1. Synchronous equatorial
2. Near synchronous
3. Medium altitude
4. Polar

4-13. Which power source is considered a practical choice for satellites?
1. Solar cells
2. Storage batteries
3. A combination of solar cells and storage batteries
4. Sunlight and energy

4-14. What development in satellite communications improved back-up power during eclipses?
1. An increase of solar cells mounted on the surface of the satellite
2. Installation of nuclear power sources
3. Installation of a nickel cadmium battery
4. Exposing solar cells to the sun continuously

4-15. Why is satellite orientation in space so important?
1. To meet the requirements of spin stabilization
2. It is a primary factor used for back-up power
3. To ensure that sunlight converging on the solar cells is converted to electrical power
4. Because it is essential that the maximum number of the solar cells be exposed to the sun and that the satellite antenna be visible to appropriate earth terminals

4-16. A small part of the total radiated energy of spin stabilized satellites is directed toward the earth by onboard
1. antennas that radiate in all directions around the spin axis
2. solar cells around the periphery of the satellite
3. pulsed radial jets
4. axial jets

4-17. What type antennas will support earth communications between facilities outside the narrow beam coverage in Phase II DSCS?
1. Four high gain antennas
2. Two horn antennas
3. Omnidirectional antennas
4. High gain directional antennas

4-18. What is gained by satellite earth terminals being located in areas remote from the users?
1. Less transmitter power is required
2. Greater security
3. Reduction in the number of antennas
4. Reduction in RF interference

For items 4-19 through 4-21, select from column B the antenna that is described in column A.

	A. Descriptions	B. Antennas
4-19.	Uses a parabolic antenna 60 feet in diameter	1. AN/TSC-54
4-20.	Uses a parabolic antenna 40 feet in diameter	2. AN/FSC-9
4-21.	Uses a cluster of 4 parabolic antennas	3. AN/MSC-46
		4. AN/SSC-3

4-22. Why is it essential that all earth terminals have a combination of high powered transmitters and highly directional, high gain antennas?
1. To overcome the up-link limitations
2. To ensure signals are strong enough to be detected by the satellite
3. To permit down-link operating conditions within the satellite
4. Both 1 and 2 above

4-23. What unit equipment is installed in communications satellites to allow changing of the spin axis or permit monitoring of the operating conditions within a satellite?
1. Exciter/modulator
2. Power amplifier
3. Telemetry
4. Axial jets

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4-24. Which earth terminal(s) is/are transportable, and can normally be assembled or dismantled in less than two hours by a well trained experienced crew?
1. AN/MSC-46
2. AN/TSC-54
3. AN/FSC-9
4. Both 2 and 3 above

4-25. The earth terminal designed for use as the shipboard link is designated
1. AN/SSC-6
2. AN/SSC-2
3. AN/TSC-54
4. AN/MSC-46

4-26. The extent of difficulty in acquiring and tracking a satellite is determined largely by the
1. earth terminal antenna
2. satellite's orbital parameters
3. slow relative motion of the satellite
4. relatively rapid change in position

4-27. Why is it more difficult to acquire and track satellites in elliptical orbits?
1. Because the satellite is stationary
2. Because of the slow movement of the satellite
3. Because of the requirement to keep the narrow-beam antenna pointed toward the satellite
4. Because of the rapid changes in position

4-28. Information showing the calculated positions of a satellite at regular intervals of time is called a/an ______ table.
1. ephemeris
2. acquisition
3. prediction
4. parameter

4-29. The only important local coordinate of position to acquire radio contact with a satellite is
1. velocity and elevation
2. velocity and bearing
3. elevation and bearing
4. direction and velocity

4-30. What must be taken into consideration in order to make best use of satellites?
1. Failure of electronic equipment
2. No satellite in common view of certain pairs of ground stations for minutes or hours at a time
3. Varying and contingent needs of users
4. Each of the above

4-31. The (A. Navy Satellite Operation Center/Naval Telecommunications Command) allocates Navy assigned operating time to (B. CAMS/CALS) which in turn designate pairs of earth terminals to use the assigned time.
1. A. Navy Satellite Operation Center; B. CAMS
2. A. Navy Satellite Operation Center; B. CALS
3. A. Naval Telecommunications Command; B. CAMS
4. A. Naval Telecommunications Command; B. CALS

4-32. A satellite in a ____________ orbit particularly places severe requirements on the acquisition system by a ground system equipped with large antennas.
1. equatorial or polar
2. medium altitude or elliptical
3. elliptical or polar
4. synchronous or near synchronous

4-33. What characteristic of a satellite effects the down-link frequency?
1. Antenna point data
2. Orbital geometry
3. Acquisition system
4. Bearing and elevation

4-34. Satellites in (A. near synchronous/elliptical) orbit experience the (B. largest/smallest) frequency variations.
1. A. near synchronous; B. largest
2. A. near synchronous; B. smallest
3. A. elliptical; B. largest
4. A. elliptical; B. smallest

4-35. The antenna pointing information that is generated by comparing the direction of the antenna axis with the direction from which an actual satellite signal is received is referred to as
1. frequency control
2. timing control
3. automatic tracking
4. programmed tracking

4-36. Since uncertainties, such as poor atmospheric and ionospheric bending of radio wave exist, automatic tracking is considered unsatisfactory and not used.

4-37. Which of the following functions represents minimum satellite outage time?
1. Slewing the earth terminal antennas
2. Acquiring the satellite signal
3. Checking for circuit continuity
4. All of the above

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4-38. Which statement below identifies the reason a satellite may not be available and adds to outage time.
1. Unsatisfactory programmed tracking
2. Two or more earth terminals occupy the common volume of the link terminal antenna
3. Bunching of satellites with gaps
4. Drift velocities of earth terminals

Learning Objective: Recognize the role of satellite communications and identify the advantages and limitations.

4-39. Which of the following links is NOT considered a conventional means of communications?
1. Satellite
2. HF radio
3. Tropospheric scatter
4. Microwave

4-40. What application of satellite communication resources offers more reliable communications and is less subject to detection?
1. Contingency operations
2. Command and control
3. Tactical
4. DCS long distance

4-41. Which of the following is/are considered unique advantages of satellite communications?
1. Satellite links are affected by propagation abnormalities only part of the time
2. Satellites offer greater reliability and flexibility
3. Satellite links are capable of covering greater range with the numerous repeater stations
4. Each of the above

4-42. The reliability of active satellite communication systems is dependent primarily upon which of the following considerations?
1. The equipment employed
2. The skill of the operating and maintenance personnel
3. Reflection or refraction of satellite frequencies
4. Both 1 and 2 above

4-43. What is the RF channel capability of the Phase I satellite on the down link?
1. One
2. Two
3. Four
4. Unlimited channel capability

4-44. Which statement below best describes the advantage of satellite communications in terms of flexibility?
1. Certain earth terminals are housed in vans and can be transported to remote areas
2. Military satellite communications are capable of handling hundreds of voice channels
3. The antenna group of any earth terminal can be mounted on a ship's weather deck
4. A high degree of protection to jamming is afforded by the highly directional antennas at earth terminals

4-45. What determines the limitations of a satellite communications system?
1. The satellite's technical characteristics
2. The satellites orbital parameters
3. The satellites low gain antennas
4. Both 1 and 2 above

Learning Objective: Identify characteristics of electromagnetic waves and factors affecting wave propagation. (This objective continued in assignment 5.)

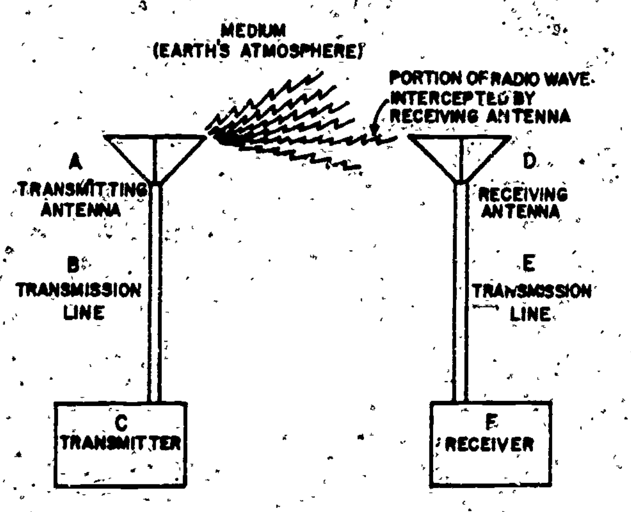

Figure 4A.--Basic Radio Communication System

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4-46. Which component(s) in figure 4A generate(s) energy in the form of electromagnetic waves?
1. A
2. A & B
3. C
4. B & C

4-47. How many miles can a radio wave travel in one second?
1. 1,860
2. 18,600
3. 186,000
4. 186,000,000

4-48. The ability of a receiver to amplify weak signals is a measure of its
1. selectivity
2. sensitivity
3. antenna configuration
4. field strength

4-49. Which of the following conditions may cause an unintelligible signal?
1. Interfering signals
2. Noise
3. Transmission line losses
4. Each of the above

4-50. Which type of wave is most satisfactory for long distance communications?
1. Sky wave
2. Ground wave
3. Surface wave
4. Ground reflected wave

4-51. Radio ground waves follow the curvature of the earth because of the affect of
1. absorption
2. diffraction
3. reflection
4. refraction

4-52. The phenomenon where part of the energy of a radio wave will change direction from the line of sight path when it passes the edge of an object is known as
1. refraction
2. diffraction
3. eddy currents
4. attenuation

4-53. What are the requirements for utilizing ground waves for long range communications?
1. High frequency & high power
2. High frequency & low power
3. Low frequency & high power
4. Low frequency & low power

4-54. Eddy currents are set up by an induced voltage in the earth caused by the passage of
1. sky waves
2. ground waves
3. space waves
4. increased energy

4-55. What part of the energy radiated by an antenna passes through the troposphere and is acted on by the ionosphere?
1. Sky wave
2. Ground wave
3. Surface wave
4. Space wave

4-56. Which of the following situations affect the quality and distance of electronic transmissions?
1. The rotation of the sun on its axis
2. The annual course of the sun around the earth
3. The development of sun spots
4. The number of ions present in the ionosphere

4-57. The number of layers in the ionosphere, their heights and their ionization (electron) density vary
1. with the number of ions present
2. with the amount of air present
3. with the strength of radiation from the sun
4. both geographically and with time

4-58. The sky wave portion of a long distance transmission at 15 MHz during daylight would most likely be reflected by the
1. D layer
2. E layer
3. F1 layer
4. F2 layer

4-59. The frequency of occurrence and degree of ionization of sporadic E vary significantly according to
1. physical processes that produce it
2. its opaqueness
3. latitude
4. ionospheric storms

4-60. Which of the following characteristics could result from partially reflecting sporadic E?
1. Serious multipath interference
2. Favorable long-distance transmission at very high frequencies
3. Short distance transmission to locations that would ordinarily be in a skip zone
4. Each of the above

4-61. The most highly ionized of all layers and the most important for HF communications, is the
1. D layer
2. E layer
3. F1 layer
4. F2 layer

4-62. Which of the following characteristics is true concerning the ionosphere?
1. It acts as a conductor
2. It absorbs energy in specific amounts from the electronic wave
3. It refracts ground waves back to the earth
4. The ionosphere does by defraction what water does to a beam of light

4-63. Which of the following conditions depends on the amount of refraction?
1. The angle at which the sky wave strikes the ionosphere
2. The frequency of the wave
3. The ion density
4. All of the above

4-64. The highest frequency that can be sent directly upward and be returned to earth by the ionospheric is known as the __________ for that layer.
1. maximum usable frequency
2. critical frequency
3. vertical frequency
4. refractive frequency

4-65. The selection of maximum usable frequencies (MUF), for fixed distance transmissions at specified times depends upon
1. atmospheric temperature
2. ionospheric ionization
3. tropospheric humidity
4. stratospheric pressure

4-66. The highest frequency that will be returned to earth at the desired location is known as the
1. low refraction frequency
2. maximum specified frequency
3. maximum usable frequency
4. frequency of optimum traffic

4-67. The distance from the transmitter to the nearest point at which the refracted waves return to earth is called the
1. skip distance
2. skip zone
3. ground wave range
4. area of best reception

4-68. The distance between the farthest point that the gound wave extends from the transmitter and the first point where the sky wave is returned by refraction from the ionosphere is called the
1. area of best reception
2. skip distance
3. skip zone
4. saturation area

4-69. Which of the following conditions is considered a major problem in electronic reception?
1. Random variation in wave polarization
2. Selection of a FOT too close to the MUF
3. Irregular variations of the ionosphere
4. Fading

4-70. What is one method of overcoming the problem of a received signal that varies in intensity over a relatively short period of time?
1. Diversity reception
2. Combine the audio outputs
3. Feed two separate receivers
4. Place two antennas a wavelength apart

4-71. What causes ducting?
1. Ionospheric storms
2. Temperature inversion
3. Frequency fluctuations
4. Low cloudy masses

4-72. What propagation technique may be employed to extend UHF transmissions beyond the horizon?
1. Tropospheric scatter
2. Ground reflection
3. Atmospheric refraction
4. Ionospheric scatter

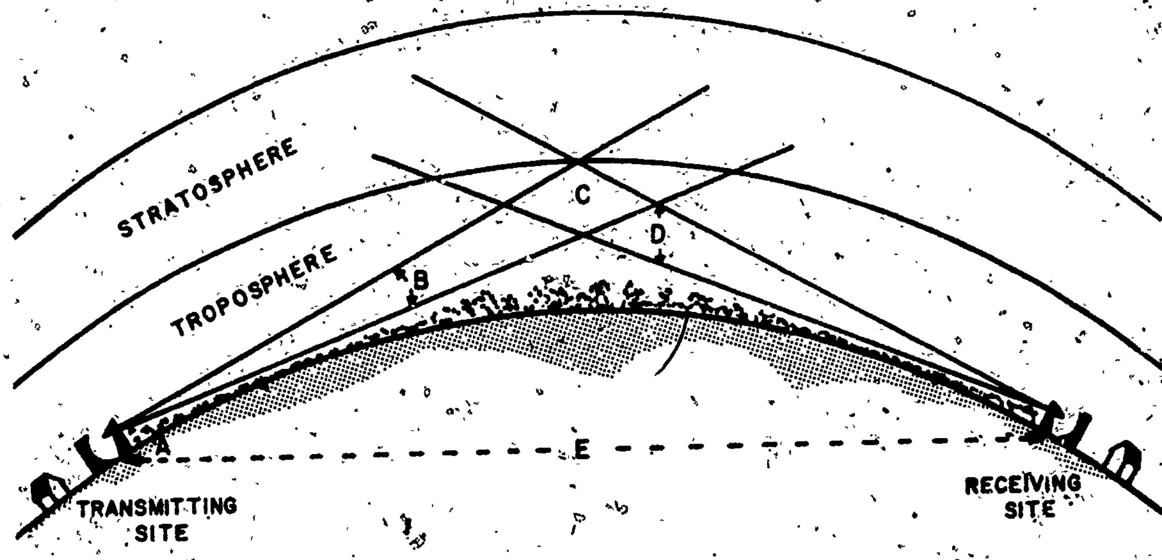

Figure 4B.-Scatter Propagation.

4-73. What effect will an increase in the angle represented by point B of figure 4B have on the received signal?
1. The received signal will increase
2. The received signal will decrease
3. The received signal will not be affected
4. It is not possible to determine what effect this will have on the received signal

4-74. The tropospheric scatter signal often is characterized by very rapid fading caused by
1. turbulence in the atmosphere
2. the angle of the transmitted beam
3. multipath propagation
4. extreme path lengths

4-75. Which of the following conditions affect the selection of frequencies for communication in the MF/HF band?
1. Propagation conditions
2. Frequency availabilities
3. Frequency authorization
4. Each of the above

Assignment 5

Wave Propagation and Antennas (continued); Communication Transmitters and Receivers; Facilities Control Operations

Textbook pages 117 through 154

Learning Objective (continued): Identify characteristics of electromagnetic waves and factors affecting wave propagation.

5-1. The key to frequency selection, regardless of the time of day or night, is the condition of the (A. troposphere/ionosphere) (B. over/midway between) the two stations.
1. A. troposphere; B. over
2. A. troposphere; B. midway between
3. A. ionosphere; B. over
4. A. ionosphere; B. midway between

5-2. Wavelength of a radio wave is commonly expressed in
1. inches
2. feet
3. meters
4. miles

5-3. The position of an antenna with respect to the earth is termed the
1. radiation pattern
2. horizontal or vertical polarization
3. magnetic field
4. electric field

5-4. The two types of antenna polarization give about the same field intensity when they are located at least one wavelength above the earth.

5-5. If an antenna's radiation pattern is altered so that it radiates in only one direction, it is said to be
1. unidirectional
2. bidirectional
3. semidirectional
4. omnidirectional

5-6. What device is used for transmitting or guiding electrical energy from one point to another?
1. transmitter
2. receiver
3. antenna
4. transmission line

5-7. An RF transmission line will transfer energy more efficiently at
1. higher frequencies
2. the frequency for which the line is designed
3. relatively low frequencies
4. medium frequencies

5-8. A "dipole" is best characterized as being a/an ________ antenna.
1. quarter wave
2. half wave
3. long wire
4. unidirectional

5-9. The quarter-wave antenna, often used where space is limited, is also known as a/an ________ antenna.
1. Vee
2. Hertz
3. long wire
4. Marconi

5-10. The most commonly used antenna for naval HF point-to-point communications is the
1. terminated Vee
2. conical monopole
3. broadband sleeve
4. horizontal rhombic

5-11. The performance of a rhombic antenna may be improved by which of the following methods, if any?
1. By using more than a single wire to form each leg
2. By adding a second wire and spacing them horizontally 10 feet apart
3. By reducing the vertical length of each leg
4. None of the above will add to the performance

5-12. Which of the following types of communications is not a primary application of the Sleeve Antenna?
1. Ship/shore/ship
2. Broadcast
3. Point-to-point
4. Ground/air/ground

5-13. Which of the following types of shore station antennas are also installed on ships?
1. Rhombic and conical monopole
2. Rhombic and sleeve
3. Sleeve and conical monopole
4. Rhombic, sleeve and conical monopole

5-14. On what frequency ranges is a wire transmitting antenna designed to operate aboard ship?
1. Low and medium
2. Medium and high
3. High and very high
4. Very high and ultra high

5-15. The wire that is used for wire antennas aboard ship differs from that used for shore installations in that shipboard antenna wire
1. is physically longer
2. has a larger diameter
3. has a smaller diameter
4. is made of solid, unstranded copper

5-16. What is the best location for a receiving antenna aboard ship?
1. As near the transmitting antenna as possible
2. As far from the transmitting antenna as possible
3. Near the center of the ship
4. Away from all vertical projections

5-17. What is the designed frequency range of the inverted cone antenna?
1. VLF only
2. LF only
3. VHF only
4. The entire HF spectrum

5-18. Which of the following antennas are used in transportable communication systems and in laboratory and shop installations?
1. Whip antenna
2. Sleeve antenna
3. Parabolic antenna
4. Yagi antenna

5-19. What is the usual length of HF whip antennas?
1. 21 feet
2. 28 feet
3. 35 feet
4. 40 feet

5-20. Why are whip antennas so widely used?
1. They are inexpensive
2. They require minimal space
3. They are simple to install
4. Each of the above reasons

5-21. For reliable communications, it is necessary for all tropospheric scatter systems to employ
1. long wire antenna systems
2. line of sight transmissions
3. on-off keying
4. diversity reception

5-22. What method of diversity reception employs the technique of illuminating two different scatter volumes in the tropposphere?
1. Circular diversity
2. Angle diversity
3. Space diversity
4. Frequency diversity

5-23. Which of the following antennas operate over an extremely wide frequency range?
1. Sleeve
2. Log periodic
3. Conical monopole
4. Parabolic

5-24. What is a distinct advantage of the rotatable version of the LPA compared to the fixed LPA?
1. The ability to rotate the array 360 degrees
2. The RLPA can be mounted on steel towers or utility poles
3. The physical form of the RLPA requires less antenna area
4. The RLPA can be used in ship/shore/ship or in point-to-point communications

5-25. How many concentric circles make up the Wullenweber antenna array?
1. Two
2. Three
3. Four
4. Five

5-26. What action do you take to restore communications when one of the high frequency antennas aboard your ship is severely damaged during heavy weather?
1. Perform emergency repairs to and reinstall the damaged antenna
2. Install a temporary, emergency antenna
3. Remove the end of the transmission line from the damaged antenna and connect it to the nearest undamaged antenna
4. Connect an insulator to one end of the damaged antenna and raise the antenna away from the deck

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5-27. Which end of an emergency antenna is attached to the equipment transmission line and when?
1. The insulator end, before the antenna has been hoisted and secured
2. The insulator end, after the antenna has been hoisted and secured
3. The alligator lug end, before the antenna has been hoisted and secured
4. The alligator lug end, after the antenna has been hoisted and secured

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Learning Objective: Recognize the principles and characteristics of communications transmitting and receiving equipment.

5-28. What is the purpose of a receiver?
1. To receive and verify the audio-frequency signal
2. To reject undesired frequencies, select desired signal and convert it to intelligible output
3. To supply a small potential to the antenna for the purpose of receiving voice transmissions from an AM transmitter
4. To provide the signals necessary to modulate an RF carrier

5-29. Which of the following type of radio communications was used first?
1. Continuous wave (CW)
2. Complitude modulated (AM)
3. Frequency modulated (FM)
4. Single sideband (SSB)

5-30. Which of the following characteristics is considered an advantage of CW transmission?
1. Wide bandwith
2. High degree of intelligibility
3. Short range operation
4. Each of the above

5-31. The part of a transmitter that generates basic radio frequency (RF) energy is the
1. buffer
2. oscillator
3. power supply
4. power amplifier

5-32. The unit that amplifies the oscillator signal and isolates the oscillator from the amplifier stages is called the
1. buffer
2. protector
3. isolator
4. multiplier

5-33. What part of a transmitter supplies RF energy which is radiated by a transmitting antenna?
1. Power supply
2. Buffer
3. Oscillator
4. Power amplifier

5-34. One of the basic differences between low and high power transmitters is the number of ________ stages.
1. oscillator
2. buffer
3. amplifier
4. preamplifier

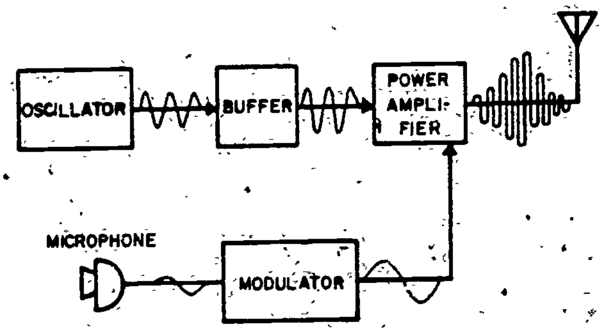

Figure 5A - AM radiotelephone transmitter block diagram.

5-35. Which component of the transmitter in figure 5A converts the audio (sound) input into corresponding electrical energy?
1. Oscillator
2. Buffer
3. Microphone
4. Modulator

5-36. On amplitude modulation, what situation listed below occurs if the modulating signal is absent?
1. A continuous RF carrier is radiated by the antenna
2. The carrier is suppressed
3. The RF carrier is varied
4. The RF carrier passes only to the buffer stage

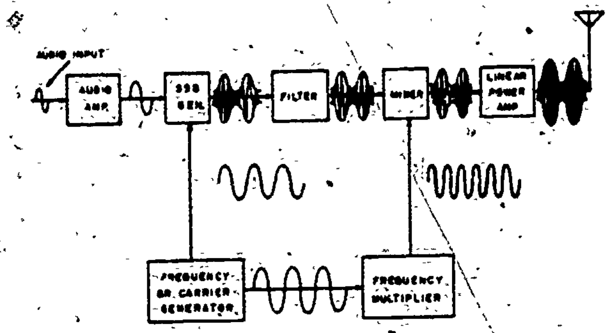

Figure 5B - SSB transmitter block diagram.

5-37. Which component of the transmitter in figure 5B combines the audio input from the frequency generator to produce the two sidebands, and then suppresses the carrier?
1. Audio amplifier
2. SSB Generator
3. Mixer
4. Frequency multiplier

5-38. What is the definition of "harmonic"?
1. A spurious and undesirable radiation caused by faulty equipment
2. A phenomenon that allows radio waves of certain frequencies to be detected randomly throughout the frequency spectrum
3. An exact multiple of a fundamental
4. A thinly-ground crystal used to generate a particular frequency

● Information for items 5-39 and 5-40: The fundamental frequency of a radio-frequency (R-F) oscillator is 15 kHz.

5-39. The R-F oscillator generates a true fourth harmonic at a frequency of
1. 30 kHz
2. 45 kHz
3. 60 kHz
4. 75 kHz

5-40. What is likely to be the highest true harmonic frequency generated by the R-F oscillator at a significant energy level?
1. 30 kHz
2. 45 kHz
3. 60 kHz
4. 75 kHz

5-41. What is the second harmonic of the fundamental frequency 4350 kHz?
1. 2175 kHz
2. 4350 kHz
3. 8700 kHz
4. 13050 kHz

5-42. Which of the following communication devices is designed to use some of the same electronic circuits for transmitting and receiving to achieve equipment compactness?
1. Transmitter-receivers
2. Transceivers
3. Converter-comparators
4. Modulator-demodulators

5-43. The AN/FRT-39 is a general purpose radio communications transmitter capable of providing (A)_______ output throughout a frequency range of 2 to (B)________ megacycles.
1. (A) 10 Kw (B) 28
2. (A) 10 Kw (B) 32
3. (A) 100 Kw (B) 28
4. (A) 100 Kw (B) 32

5-44. The intermediate power amplifier section of the AN/FRT-40 consists of the modified _________ of the AN/FRT-39.
1. power amplifier stage
2. antenna tuning controls
3. power-amplifier stage and antenna tuning controls
4. relay and indicator control panel

5-45. The principle function of the AN/FRT-39 is to provide long range communications by the ________ type of operation.
1. CW
2. frequency-shift carrier
3. independent sideband
4. single-sideband

5-46. Which of the following operating requirements is the principal basis for selecting the AN/URC-32 for installation aboard a particular ship?
1. FM communicaiton
2. Long range communication
3. Short range communication
4. Low power input

5-47. What is the maximum power output rating of the AN/WRC-1 transmitter?
1. 75 watts
2. 100 watts
3. 125 watts
4. 500 watts

5-48. In addition to having an interconnection box, the AN/WRC-1 radio set consists of a
1. transmitter and a receiver
2. transmitter, a receiver, and an R-F amplifier
3. transceiver and a sideband generator
4. transceiver, a sideband generator, and an R-F amplifier

5-49. So that an antenna can be tuned without causing unwanted radiation, a (A. remote control unit/dummy antenna) is connected to the (B. output of the transmitter/transmission line).
1. A. remote control unit;
   B. output of the transmitter
2. A. remote control unit;
   B. transmission line
3. A. dummy antenna;
   B. output of the transmitter
4. A. dummy antenna;
   B. transmission line

5-50. A beat frequency oscillator is required for all receivers which are receiving
1. A-M transmissions
2. F-M transmissions
3. P-M transmissions
4. CW transmissions

5-51. The antenna of a receiver extracts only a small amount of electromagnetic energy --a signal voltage that is measured in terms of a few
1. microvolts
2. millivolts
3. volts
4. dozen volts

5-52. The measure of a receiver's effectiveness in amplifying weak signals is known as
1. selectivity
2. sensitivity
3. capture ratio
4. stability

5-53. The selectivity of a receiver is a measure of its ability to
1. receive desired signals and reject all others
2. amplify weak signals
3. receive distant stations
4. perform all of the above functions

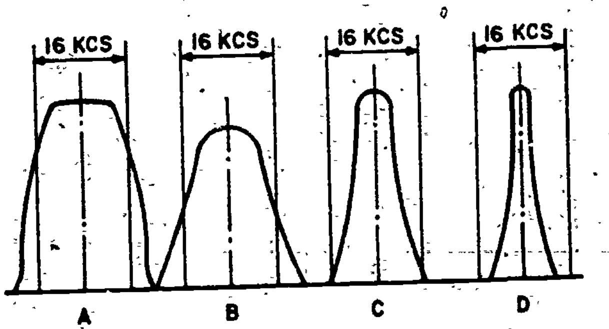

Figure 5C--Bandwidth Characteristics of four types of receivers

5-54. The two bandwidths in figure 5C that are most characteristic of commercial broadcast receivers are lettered
1. A and B
2. A and D
3. B and C
4. B and D

5-55. Which of the receivers whose bandwidth is shown in figure 5C is tuned the sharpest?
1. A
2. B
3. C
4. D

5-56. The process in a radio receiver which combines an amplified R-F signal with the output of a local oscillator is called
1. modulation
2. hetrodyning
3. detection
4. reproduction

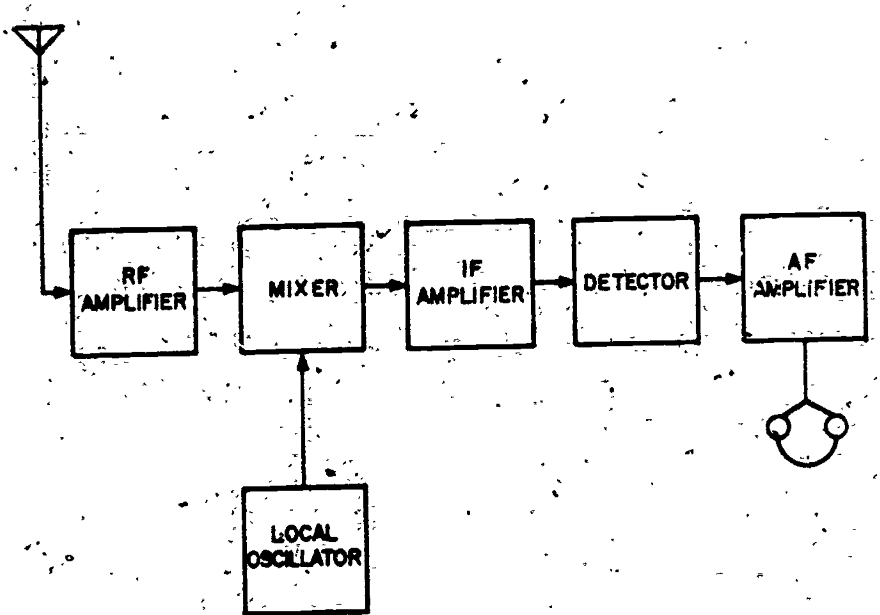

Figure 5D - Block diagram of a superheterodyne receiver.

5-57. The mixer-oscillator stage of the receiver in figure 5D acts to
1. remove audio modulation in the intermediate-frequency (i-f) signal
2. convert the radio-frequency (r-f) signal to a fixed intermediate-frequency (i-f)
3. filter out the intermediate-frequency (i-f) carrier
4. select the radio-frequency (r-f) of the desired frequency

5-58. The radio receiver R-390A/URR provides reception of which of the following signal modes?
1. CW
2. FSK
3. SSB
4. Each of the above modes

5-59. Which mode of operation requires use of the CV 591?
1. CW
2. FSK
3. SSB
4. MCW

5-60. Which system named below is used primarily for the reception of multichannel radio teletypewriter transmissions?
1. Audio space diversity system
2. Space diversity radio teletypewriter
3. Single-side-band radio teletypewriter
4. CW

5-61. What frequency range is the R-1051/URR capable of receiving?
1. 2 MHz to 32 MHz
2. 2 MHz to 30 MHz
3. 115 MHz to 156 MHz
4. 225 MHz to 400 MHz

5-62. Which of the following receivers is a solid state, general purpose HF receiver intended primarily for operation in fixed stations?
1. R-1051/URR
2. R-1401A/G
3. R-1414/URR
4. AN/SRR-19A

5-63. Which characteristic below is available with the R-1414/URR receiver, but is not available with the R-390A/URR receiver?
1. Reduced size
2. Cooler operation
3. A digital electronic frequency counter display
4. Each of the above

5-64. Superior frequency stability is an important feature of the
1. AN/SRR-19A
2. R-390A/URR
3. R-1414/URR
4. CV-591A/URR

5-65. How does the CVA-591A/URR single-sideband converter, used in conjunction with a standard communications receiver, simplify the tuning of single-sideband signals?
1. Final tuning is done at the converter, not the receiver
2. Continuous tuning is done at the converter
3. The converter may be used with a remote control system
4. All operational controls are located on the front panel

Learning Objective: Recognize the responsibilities of personnel assigned to perform duties in facilities.

5-66. FCO is one of the primary operations within the NAVSECGRU Communications Center because
1. the facilities controller must be highly qualified
2. the facilities controller coordinates restoration of circuits with commercial circuit suppliers
3. message traffic flow is dependent upon the quality of the circuits
4. of the various sophisticated equipments that must be maintained

5-67. Which person(s) would normally perform facilities control function at a small station?
1. Communication Supervisor
2. Communication Operator
3. Maintenance Personnel
4. Each of the above

5-68. Fundamental responsibilities of the facilities controller change from station to station.

5-69. Which of the following functions would the facilities controller most likely perform?
1. Frequency changes
2. Equipment performance tests
3. Equipment installation
4. Either 1 or 2 above

Learning Objective: Recognize the purpose of any communication system.

5-70. Which of the following factors, if any, determines the communication system provided every ship or station?
1. Mission
2. Allowance dictated by COMNAVSECGRU
3. Size of the activity
4. None of the above

5-71. What is the primary function of any communication system?
1. The availability of an information source
2. The necessity of a communications link
3. The efficient transmission and reception of information
4. To provide a signal path between two stations

Learning Objective: Determine the various stages of a signal flow of a secure communication system.

5-72. The incoming signal normally enters the NAVSECGRU facilities control space at the ______ stage.
1. audio distribution
2. DC distribution
3. conversion
4. end terminal devices

5-73. Immediately following encryption, the teletype signal is fed to the
1. red patch panel
2. black patch panel
3. multiplex equipment
4. receiver

Learning Objective: Indicate features common to all switchboard operations.

5-74. Which of the features listed below is common to all receiver switchboard installations?
1. Knobs are installed in the off position
2. Receivers are always connected to the vertical rows of switches
3. Remote stations are always connected to the horizontal rows of switches
4. Each of the above

5-75. What position of each rotary switch of the transmitter transfer switchboard is provided for connections to an additional switchboard to control extra transmitters?
1. 18
2. 19
3. 20
4. 21

Assignment 6

Facilities Control Operations (continued; End Terminal Equipment

Textbook pages 155 through 193

Learning Objective: Recognize the uses, functions, and characteristics of keyer/converters and converter-comparator groups.

6-1. The keyer and converter in a radio teletype system are always incorporated in one-piece of equipment.

6-2. What is the function of the converter in the frequency shift system?
1. Convert mark and space impulses into fixed-frequency ac
2. Convert the audio signal into dc mark and space teletype signals.
3. Convert mark and space impulses into audio tones
4. Convert variable frequency ac into mark and space impulses

6-3. A device used to convert teletypewriter mark and space signals into carrier frequency shift signals is called a
1. keyer
2. converter
3. repeater
4. transformer

Learning Objective: Identify the methods of diversity operation.

6-4. Usually, space diversity reception is employed only at shore stations because
1. transmissions are limited to line-of-sight distances
2. fading occurs in transmissions at sea
3. the antennas must be spaced some distance apart
4. great power is required

6-5. What method of reception is commonly used aboard ships to copy fleet broadcasts?
1. Multichannel
2. Multihop
3. Space diversity
4. Frequency diversity

6-6. What component in a diversity reception system selects the better of two receiver teletypewriter pulses?
1. Antenna
2. Comparator
3. Converter
4. Patch panel

Learning Objective: Determine the purpose, operating principles and components of a multiplex system.

6-7. Multiplexing can be defined as a system for sending
1. messages to a multitude of stations at the same time
2. two or more signals simultaneously over a single RF channel
3. repeat messages, such as distress signals
4. messages through a multigraph

6-8. The purpose of a multiplex system is to
1. increase the speed of teletype messages
2. reduce the number of teletypewriters required in the communications network
3. increase the message-handling capacity of radio communication or teletypewriter channels
4. eliminate the keyer/converter equipment in the teletypewriter installation

6-9. How does time-division multiplexing (TDM) differ from frequency-division multiplexing (FDM)?
1. TDM separates signal samples by filtering; FDM separates signal frequencies by synchronized switching
2. TDM separates signal samples by synchronized switching; FDM separates signal frequencies by filtering
3. TDM separates signal frequencies by filtering; FDM separates signal samples by synchronized switching
4. TDM separates signal frequencies by synchronized switching; FDM separates signal samples by filtering

6-10. What is the maximum number of channels that may be handled by the AN/FCC-69 and AN/FCC-70 Telegraph Terminal?
1. 2
2. 6
3. 16
4. 32

6-11. The (A. AN/FCC-69; AN/FCC-70) demultiplexes a composite signal and operates on the principle of (B. frequency division; time division).
1. A. AN/FCC-69; B. frequency division
2. A. AN/FCC-69; B. time division
3. A. AN/FCC-70; B. frequency division
4. A. AN/FCC-70; B. time division

Learning Objective: Determine the purpose of and the basic installation requirements for distribution frames and patching facilities.

6-12. What purpose do distrubution frames serve at communication stations?
1. The point of equipment interconnection
2. The interface point between the outside world and the distribution within communication building
3. The access point for operators to monitor a signal
4. Both 1 and 2 above

6-13. What does the circuit patchboard at a communication station offer the facility control operator?
1. A method of rerouting circuits
2. Permits operator to substitute equipment
3. Serves as an access point to monitor the signal
4. Each of the above

~~6-14. Maximum operational flexibility is~~ achieved by the installation of circuit patchboard and distribution frames.

6-15. What is the purpose of the Main Distribution Frame?
1. To eliminate the requirement for patching facilities on all circuits
2. To serve as a tie point between equipment and various spaces within a building
3. To terminate circuits which carry classified information
4. To serve as a division point between a communications component and the outside

6-16. What distribution frame terminates equipments and patchboards that process black (unclassified) information?
1. NDF
2. IDF
3. CIDF
4. CDF

6-17. The IDF should be physically separated from the CIDF by at least
1. 2 inches
2. 3 feet
3. 9 feet
4. 12 feet

6-18. Which of the following statements is true concerning distribution frames?
1. The MDF is built with vertical blocks terminating circuit cables entering the building
2. The IDF terminate patchboards that process classified information
3. The termination of circuits carrying classified information to the same distribution frame as those carrying unclassified information is strictly forbidden
4. A CDF is used only at large communication stations

6-19. Maximum flexibility of patching facilities is dependent upon
1. test equipment being wired into a patch panel
2. each circuit being normalled through whenever possible
3. the ingenuity and resourcefulness of the facilities controller
4. the patch panel jacks being wired in parallel to the distribution frame

6-20. Patch panel jacks are wired in (A. series; parallel) to the distribution frame so that under normal operation patch cords (B. are; are not) necessary.
1. A. series; B. are
2. A. series; B. are not
3. A. parallel; B. are
4. A. parallel; B. are not

6-21. Which statement below properly identifies the unclassified black patch panel?
1. The patch panel with the crypto transmitter input and crypto receiver output circuits
2. The patch panel with the incoming and outgoing signal
3. The patch panel with the incoming receiver and outgoing send lines
4. The patch panel wired with any send and receive device properly labeled

6-22. Which statement below is correct concerning patch panels?
1. Patch panels are wired so that any receiver device may be patched to any receiver device
2. Two send devices patched together will cause a visual and audible alarm
3. Any send device patched to a receiver device will cause a visual and audible alarm
4. Any receiver device patched to a send device will cause a visual alarm only

6-23. Which of the following items of information, if any, would appear on the circuit identification slip of a circuit terminated at a RED patch panel?
1. Terminal teletypewriter equipment
2. Line number
3. Circuit numbers
4. None of the above

6-24. What element of the patch panel jack-detail permits monitoring and analyzing the incoming or outgoing circuits without interrupting the flow of traffic?
1. Monitor jack
2. Equipment jack
3. Line jack
4. Control switch

6-25. What action would a facilities controller take if it were necessary to cut off the incoming signal flow between the equipment jack and the line on the line jack?
1. Insert a patch cord in the monitor jack
2. Insert a patch cord into the send line jack
3. Rotate the control switch to the vertical position
4. Rotate the control switch to the horizontal position

Learning Objective: Recognize the functions of the different types of patch cords of a patch panel and characteristics of the patch panel.

6-26. What portion of the jack or patch cord causes the audible and visual supervisory alarms to activate when a mispatch is made?
1. Ring
2. Tip
3. Sleeve
4. Cord

6-27. The ________ cords are usually color coded red.
1. send
2. receive
3. fortest
4. meter

6-28. The meter-button located on the end of the patch panel cord shelf is used with which of the following patch cords?
1. Test
2. Meter and scope
3. Patching
4. Each of the above

6-29. The patch cords located in the two back rows farthest away from the controller facing the patch panel are usually <u>(A. green; black)</u> in color and are wired <u>(B. TIP to TIP; RING to TIP)</u> giving straight through reproduction of any signal on two circuits.
1. A. green; B. TIP to TIP
2. A. green; B. RING to TIP
3. A. black; B. TIP to TIP
4. A. black; B. RING to TIP

6-30. Which of the following statements is correct concerning the audio patch panel?
1. The audio patch panel operates in a red (classified) environment only
2. DC to audio conversion is accomplished at the audio patch panel
3. The second section of the audio patch panel contains all the test equipment jacks
4. Equipment jacks on the audio board are connected to the MODEMS

6-31. Other than the absence of ______ in the RED patch panel, its design is electrically/mechanically the same as the BLACK patch panel.
1. equipment jacks
2. line jacks
3. monitor jacks
4. activity lamps

6-32. Which of the following statements is true concerning the "STEP" signal?
1. The STEP signal is a timed pulse emitted by the crypto transmitter
2. The STEP signal is used to synchronize the teletype keyboard/TD with the crypto equipment
3. The STEP signal activates a clutching circuit
4. Each of the above is true

Learning Objective: Recognize end terminal devices.

6-33. What do end terminal devices consist of?
1. Input and output teletype equipment
2. Modulation and demodulation devices
3. Antennas and lines
4. Either 1 or 2 above

Learning Objective: Recognize the characteristic of Digital Signals.

6-34. Signals that contain two different steps or levels are termed
1. marks
2. spaces
3. digital binary signals
4. data signals

6-35. Signals require equipments to react to MARKS which indicate a passive condition and SPACES an active condition.

6-36. How many pulses are generated for each character transmitted of the International Telegraph Alphabet No. 2 (ITA 2)?
1. 4
2. 5
3. 6
4. 7

6-37. Which units of the teletype code character synchronizes the teletype machines and signals with each other?
1. Units 6 and 7
2. Units 1 and 2
3. Units 1 and 7
4. Units 2 and 6

6-38. Which of the following characteristics of a teletypewriter signal code has zero time duration.
1. Marking
2. Spacing
3. Transition
4. Modulation rate

6-39. How is the modulation rate (signalling speed) of a teletypewriter signal determined?
1. By the uniform lengthening and shortening of each unit
2. By the duration of transition time
3. By the number of transitions per unit
4. By the number of milliseconds required to transmit each unit

6-40. Characters or symbols transmitted in the ITA-2 code are represented by a series of
1. five equal transitions
2. five equal code elements
3. 26 combinations of mark and space elements
4. short and long marking signals seperated by short and long spacing signals

6-41. Excluding functional characters, how many printed characters can be sent from a teletypewriter keyboard?
1. 26
2. 32
3. 52
4. 58

6-42. What bit of the ACII code is a check bit used to insure that an even number of marking bits is in each character transmitted?
1. Start bit
2. Stop bit
3. Parity bit
4. Synchro bit

Learning Objective: Distinguish between neutral and polar operation of DC teletypewriter circuits.

6-43. In teletypewriter operation when a circuit operates on a current and no-current basis, what term is used to designate the circuit?
1. On-Off
2. Neutral
3. Polar
4. Pulse

6-44. Which of the statements listed below concerning neutral and polar operation is correct?
1. A reading of zero on a millioneter on a polar circuit indicates a complete loss of current
2. The normal polar operation in NAVSECGRU is a 60MP negative mark condition
3. Neutral circuits are not common within DCS
4. In polar operation, current is present only during a space condition

Learning Objective: Determine the effects various types of distortion have on a teletypewriter signal.

6-45. In determining the quality of teletypewriter circuit performance, the primary consideration given to the received teletypewriter signals is that the signal elements
1. be received at precisely the correct time
2. be readable at the receiving device
3. undergo uniform lengthening and shortening during transmission
4. be uniform in length

6-46. What type of teletypewriter distortion is caused by atmospheric noise, power line induction, and dirty keying contacts?
1. Bias
2. Fortuitous
3. Characteristic
4. Carrier

6-47. An example of __________ distortion would be the repeated shortening of the fourth intelligence unit at the expense of the 2nd intelligence of a character.
1. characteristic
2. cyclic
3. carrier
4. delay

6-48. One method of preventing signal distortion on synchronous circuits is to
1. clean keying contacts
2. change the length of the transmission line
3. use the transmission delay compensator
4. adjust line relays

Learning Objective: Identify the responsibilities of a technical controller during a period of circuit outage, and describe the trouble-shooting procedures which are employed to eliminate outage.

6-49. If outage should occur on a circuit, what is the responsibility of the station having the receive side of the circuit?
1. Troubleshoot the circuit, working back to the signal source
2. Advise the sending station periodically of progress being made in efforts to restore the circuit
3. Provide the sending station with the reason for the outage, once the circuit has been restored
4. Do each of the above

6-50. What is the first step a technical control operator usually takes when a circuit trouble is reported to him?
1. Plug a printer into the monitor jack of the circuit in question and verify the trouble
2. Report the trouble to the circuit supplier
3. Plug a printer into the line jack of the circuit in question and evaluate the trouble
4. Patch a test into the equipment jack of the circuit in question

6-51. Before assuming that a relay is defective, the output distortion of the relay should be compared with the
1. distortion of the test keyer
2. output of the patch panel milliammeter
3. distortion of the input signal
4. standard of acceptable relay distortion measurements

6-52. What is the first step required of a facilities controller after verifying that the incoming signal is substandard?
1. Switch to plain language
2. Make a report to the circuit supplier
3. Notify the distant station to isolate the problem
4. Assume a defective relay is present and change equipments

Learning Objective: Recognize the functions of the Digital Data Distortion Test Set.

6-53. The need for ________ is emphasized with the trend toward higher transmission speeds and the introduction of new modes of operation in communications.
1. an efficient antenna
2. performance testing
3. better quality control
4. greater security

Learning Objective: Recognize the functions of the Digital Data Distortion Test Set.

6-54. Which unit of the Digital Data Distortion Test Set provides simulated teletype signals used to test digital data and teletype equipments?
1. SG-885 (P)/USM
2. TS-293-(P)/USM
3. OS-212/USM
4. AN/USM 329(V)

6-55. The primary difference between the AN/USM 329 (V) 1 test equipment and the AN/USM 329 (V) 2 test equipment is that the AN/USM 329 (V) 1 test equipment
1. is mounted in a cart; the USM 329 (V) 2 is rack mounted
2. is modified to accomodate only speed up to 600 bauds
3. provides a degree of long term accuracy not possible with the AN/USM 329 (V) 2
4. requires operator interpretation of distortion displayed by the front panel meter

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Learning Objective: Describe the facilities controller operational practices and recognize the contents of the various records.

6-56. How does the facilities controller address a distant station on the order wire?
1. O & 2 signals
2. Unclassified fixed station call signs
3. Unclassified routing indicators
4. Plain language designators

6-57. For the purpose of recording circuit outage, each hour of the radio day on the Circuit Performance Log is divided into
1. 5 minute segments
2. 10 minute segments
3. 15 minute segments
4. 30 minute segments

6-58. Which item of information listed below is NOT included in a circuit outage report?
1. Circuit experiencing the outage
2. Geographical location of originator
3. Reason for the outage
4. Expected time of restoration

6-59. As a minimum requirement, how often should the facilities control status board be verified?
1. Once every 12 hours
2. Once every 24 hours
3. Once every 48 hours
4. Once every watch

Learning Objective: Recognize the basic principles of teletypewriter communications.

6-60. Which of the following statements relative to model 28 teletypewriter equipment is false?
1. It requires less maintenance than older models
2. It is not practical for shipboard use due to sensitivity to vibration
3. It is lighter and less bulky than earlier equipment
4. It is not as noisy as previous types

6-61. The keyboard, typing unit, and transmitter distributor are connected in (A. parallel; series) in the signal line, but selection of these components for either individual or simultaneous operation is by the (B. selector switch; line test switch).
1. A. parallel; B. selector switch
2. A. parallel; B. line test switch
3. A. series; B. selector switch
4. A. series; B. line test switch

6-62. What component of the AN-UGC-49 teletypewriter is powered by its own motor?
1. Keyboard
2. Automatic typer
3. Perforator
4. Reperforator

6-63. Which statement concerning the Model-28 teletypewriter is correct?
1. The communication and weather keyboards contain letters and punctuation marks common to the standard typewriter
2. Its operating speeds are limited to 100 or 300 words per minute
3. Conversion from one speed to another can only be accomplished by changing the motor
4. Symbols for transmission of weather data are contained in the uppercase keys of the bottom two rows of the weather keyboard

6-64. The key on the model 28 teletypewriter keyboard that you depress to return the carriage when the transmitting station has omitted the CAR RET function is the
1. LOC CR
2. LOC LF
3. BREAK
4. RPT

6-65. The model 28 typing reperforator differs from the auxiliary typing reperforator in that the auxiliary typing reperforator
1. utilizes a different kind of typing mechanism
2. produces a different type of perforated tape
3. has no backspace mechanism
4. has its own separate motor and a separate keyer in the electronic service assembly

6-66. Which of the following best explains the function of the transmitter distributor of the AN/UGC-49?
1. Conversion
2. Perforation
3. Synchronization
4. Stabilization

6-67. Which of the AN/UGC-49 on-line modes of operation listed below, if any, causes the typing reperforator, character counter, and the transmitter distributor to be inoperable?
1. Keyboard
2. Keyboard-Tape
3. Tape
4. None of the above; the transmitter distributor is operable in all modes

6-68. Starting from the extreme left hand margin with the selector switch in the T position, if you type NOW IS THE TIME 12345 the reading on the character counter will be
1. 17
2. 19
3. 21
4. 22

6-69. In order for the TD component of the AN/UGC-49 to be operable, the selector switch must be in the K-T or T position and
1. the SEND key must be depressed
2. the operator must first transmit 5 SP 2 CR and 1 LF by keyboard
3. the BLANK key must be depressed two times to set up a receive condition on the circuit
4. the start-stop lever on the TD must be in the FREEWHEELING position

6-70. Which of the following functions will the TT 471/UGC perform?
1. Provide a page copy of messages transmitted or received
2. Punch a tape of incoming messages
3. Prepare tape for transmission
4. Provide send capability from a TD only

6-71. Which teletypewriter set does not provide capabilities for transmitting message?
1. AN/UGC-49
2. AN/UGC-50
3. AN/UGC-51
4. TT 471/UG

6-72. Which group of the AN/FGC-59 teletypewriter set is an operator working with when he is tearing off reperforated tapes, logging them in, and then placing the tapes in a grid on the send bank?
1. TT-306
2. TT-308
3. TT-309
4. TT-310

6-73. The transmitter-distributors of the (A. TT-308; TT-310) group are automatic and apply a sequential channel (B. number; designator) to each outgoing message.
1. A. TT-308; B. number
2. A. TT-308; B. designator
3. A. TT-310; B. number
4. A. TT-310; B. designator

6-74. In what order, if any, are outgoing tapes transmitted by the send bank operators?
1. According to length; a long one, then a short one
2. By precedence
3. In the order received
4. None

6-75. Which group of the AN/FGC-59 teletypewriter set provides duplicate copies of tapes being transmitted including the channel number of each transmission?
1. TT-306
2. TT-308
3. TT-309
4. TT-310

MODIFICATIONS

Pages 43 - 63 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

Learning Objective: Determine the various types and levels of equipment maintenance.

10-26. Which level of maintenance has the capability to undertake major overhaul work?
1. Organizational
2. Intermediate
3. Depot
4. Tender

10-27. Maintenance work to be accomplished by employing the services of specialists normally does NOT include
1. organizational level maintenance
2. intermediate level maintenance
3. depot level maintenance
4. civilian repair maintenance

Learning Objective: Recognize maintenance tasks that are included in preventive maintenance and the definition, goals and components of the 3-M system.

10-28. That portion of the overall concept of the maintenance of electronic equipment which consists of checks to determine if equipment is functioning properly and visual inspections for damage is referred to as
1. scheduled maintenance
2. preventive maintenance
3. controlled maintenance
4. yard maintenance

10-29. Which of the following actions would NOT be included as a part of operator maintenance?
1. Cleaning
2. Lubrication
3. Major part replacement
4. Inspection

10-30. What results from the regular functional tests and a careful record of the performance data on each equipment?
1. Complete elimination of equipment failure in ships
2. Information on the expenditure of resources in maintaining ship equipment
3. Increased operational readiness in ships
4. Self implementing maintenance schedules in ships

10-31. In the 3-M system, the 3-M stands for
1. preventive maintenance, corrective maintenance, and material control
2. maintenance, material control, and malfunction repairs
3. maintenance, material and management
4. malfunctions and material management

10-32. Which are the major components of the 3-M system?
1. Planned Maintenance Subsystem and man-hour accounting system
2. Planned Maintenance Subsystem and shipboard coordinated allowance list
3. Maintenance Data Collection Subsystem and Planned Maintenance Subsystem
4. Maintenance Data Collection Subsystem and man-hour accounting system

Use the following alternatives for items 10-33 through 10-35:
1. To define maintenance standards and prescribe procedures and management techniques used to maintain equipment
2. To specify categories of maintenance needed for various equipment and estimate the cost incurred in performing the maintenance tasks.
3. To provide information concerning equipment malfunctions and the maintenance that is performed on equipment
4. To schedule and describe maintenance tasks and list tools and materials needed to perform the maintenance

10-33. What is the function of the Planned Maintenance Subsystem?

10-34. What is the function of the Maintenance Requirement Card (MRC)?

10-35. What is the function of the Maintenance Data Collection Subsystem (MDCS)?

Learning Objective: Recognize cleaning procedures and methods for electronics equipment and the maintenance needed for air filters.

Information for items 10-36 and 10-37: You are preparing to clean the chassis of a radio transmitter.

10-36. You begin your cleaning task by
1. grounding the capacitors with a length of copper wire and rubbing all accessible contacts with emery paper
2. blowing loose dust away with a hand bellows and rubbing all accessible contacts with emery paper
3. turning off the power switches and grounding the capacitors with a shorting bar
4. turning off the power switches and blowing loose dust away with a hand bellows

10-37. What cleaning gear should you use to clean dust from the chassis of the transmitter?
1. A high pressure air hose and a dry toothbrush
2. A damp rag and a moistened toothbrush
3. A toothbrush moistened with carbon tetrachloride and a hand bellows
4. A small typewriter cleaning brush and a vacuum cleaner

10-38. In cleaning a transmitter with a vacuum cleaner, you find that the nozzle of the cleaner's hose will not reach some dust collected in an area that is particularly congested. You should move the dust to a more accessible area with the aid of a
1. hand bellows
2. small typewriter brush
3. rubber tube attached to a compressed air line
4. steel wire brush

10-39. What material must never be used to clean or repair electronic equipment?
1. Soap and water
2. Alcohol or methyl chloroform
3. Sandpaper or files
4. Emery cloth or steel wool

10-40. You should never underestimate the importance of even the most minor maintenance procedures--remember that the majority of failures to electronic equipment are traceable to
1. excessive heating due to dirty air filters
2. excessive vibration resulting from dirty shock mounting springs
3. overloading of components due to fluctuation in power
4. careless soldering techniques and sloppy troubleshooting practices

Learning Objective: Recognize the care and preventive maintenance requirement of teletypewriter, typewriters, headphones and microphones.

10-41. Preventive maintenance actions that an operator may carry out on a teletypewriter include
1. replacing damaged parts and lubricating the equipment
2. visually examining and manually testing the equipment
3. visually examining and replacing damaged parts on the equipment
4. making adjustments and replacing damaged parts on the equipment

10-42. A teletypewriter operating at (A. 60; 100) words per minute should be lubricated at (B. 2400 hour; 6 month) intervals.
1. A. 60; B. 2400 hour
2. A. 60; B. 6 month
3. A. 100; B. 2400 hour
4. A. 100; B. 6 month

10-43. What emergency maintenance may the operator of a teletypewriter perform on the equipment?
1. Lubricating and replacing damaged parts
2. Checking connections at terminal boards and checking contact spring tension
3. Replacing fuses and pilot lamps
4. Replacing damaged parts

Learning Objective: Recognize cleaning procedures and methods for electronics equipment and the maintenance needed for air filters.

Information for items 10-36 and 10-37: You are preparing to clean the chassis of a radio transmitter.

10-36. You begin your cleaning task by
1. grounding the capacitors with a length of copper wire and rubbing all accessible contacts with emery paper
2. blowing loose dust away with a hand bellows and rubbing all accessible contacts with emery paper
3. turning off the power switches and grounding the capacitors with a shorting bar
4. turning off the power switches and blowing loose dust away with a hand bellows

10-37. What cleaning gear should you use to clean dust from the chassis of the transmitter?
1. A high pressure air hose and a dry toothbrush
2. A damp rag and a moistened toothbrush
3. A toothbrush moistened with carbon tetrachloride and a hand bellows
4. A small typewriter cleaning brush and a vacuum cleaner

10-38. In cleaning a transmitter with a vacuum cleaner, you find that the nozzle of the cleaner's hose will not reach some dust collected in an area that is particularly congested. You should move the dust to a more accessible area with the aid of a
1. hand bellows
2. small typewriter brush
3. rubber tube attached to a compressed air line
4. steel wire brush

10-39. What material must never be used to clean or repair electronic equipment?
1. Soap and water
2. Alcohol or methyl chloroform
3. Sandpaper or files
4. Emery cloth or steel wool

10-40. You should never underestimate the importance of even the most minor maintenance procedures--remember that the majority of failures to electronic equipment are traceable to
1. excessive heating due to dirty air filters
2. excessive vibration resulting from dirty shock mounting springs
3. overloading of components due to fluctuation in power
4. careless soldering techniques and sloppy troubleshooting practices

Learning Objective: Recognize the care and preventive maintenance requirement of teletypewriter, typewriters, headphones and microphones.

10-41. Preventive maintenance actions that an operator may carry out on a teletypewriter include
1. replacing damaged parts and lubricating the equipment
2. visually examining and manually testing the equipment
3. visually examining and replacing damaged parts on the equipment
4. making adjustments and replacing damaged parts on the equipment

10-42. A teletypewriter operating at <u>(A. 60; 100)</u> words per minute should be lubricated at <u>(B. 2400 hour; 6 month)</u> intervals.
1. A. 60; B. 2400 hour
2. A. 60; B. 6 month
3. A. 100; B. 2400 hour
4. A. 100; B. 6 month

10-43. What emergency maintenance may the operator of a teletypewriter perform on the equipment?
1. Lubricating and replacing damaged parts
2. Checking connections at terminal boards and checking contact spring tension
3. Replacing fuses and pilot lamps
4. Replacing damaged parts

10-55. As a rule, __________ is the criterion of shock intensity.
1. current
2. voltage
3. resistance
4. impedance

10-56. A person who has suffered a severe electric shock usually shows which of the following symptoms?
1. Weak pulse
2. Burns
3. Convulsions
4. Both 1 and 2 above

10-57. CT03 Miller, is cleaning a piece of radio gear when he accidently touches a ground wire and an energized power cable. The intensity of the resulting shock knocks Miller unconscious and causes him to fall across the cable. You quickly cut off the source of power to the cable and pull Miller away from the equipment.

If you had been unable to cut off the source of power to the cable, you could have dragged Miller away from it by using
1. your hands
2. your belt
3. a length of wire
4. a damp line or loop of canvas

10-58. What is the safest and most preferred precautionary measure to be taken before starting any work on electronic circuits?
1. Deactivate all power sources
2. Strict compliance with procedures in the Naval Ships Technical Manual
3. A person qualified to render first aid for electrical shock should be standing by
4. Each of the above are equally important

10-59. To ensure that rubber matting remains effective and safe for use, it must be periodically inspected and cleaned to make certain that which of the following properties of the matting are not impaired?
1. Elastic
2. Capacitive
3. Dielectric
4. Conductive

10-60. What is the reason all repair and maintenance work on electronic equipment should be completed only by authorized persons.
1. Avoid the danger of fire
2. Prevent damage to materials
3. Minimize personnel injury
4. Each of the above

10-61. Safety precautions that electronics maintenance personnel should observe when they work with energized circuits include all of the following practices except that of
1. working with one hand only as much as possible
2. wearing a rubber glove on the hand that is not holding tools
3. keeping metal tools out of the pockets of clothing
4. using dry canvas sheets as insulation from ground

10-62. What material should you use to insulate the handles of tools to be used for work on energized circuits?
1. Friction tape
2. Varnish or enamel
3. Rubber tape
4. Cotton twine

10-63. All parts of circuit breakers are conductive.

10-64. The safest way to close a power switch is to
1. move it rapidly through the full arc of its travel
2. ease the lever or knob to a position where safe and quick action can be made, and then make the final motion positive and rapid
3. ease it as gently as possible through the full arc of its travel
4. move it rapidly to the position where it is ready to click and then ease it closed as gently as possible

10-65. Who has the authority to remove a tag from a power switch which has been locked open with the following notation on it:
"THIS CIRCUIT WAS ORDERED OPEN AND SHALL NOT BE CLOSED EXCEPT BY DIRECT ORDER OF ________."
1. Communications Watch Officer
2. The person making, or in charge of, the repairs
3. Communications Officer
4. Commanding Officer

10-66. Which safety precaution should be observed when your work requires the use of portable power tools?
1. Make sure that the on/off switch is in the ON position before inserting or removing the plug from the receptacle
2. Insert the extension cord into a live receptacle prior to connecting a portable power tool into the extension cord
3. Always unplug the extension cord from the receptacle before the cord of the portable power tool is unplugged from the extension cord
4. Do not use spliced cables under any condition

10-67. A water compound cannot be used to clean a piece of equipment. Which solvent may you use?
1. Gasoline
2. Benzine
3. Ether
4. Methyl chloroform

10-68. Which property of cathode-ray tubes (CRTs) makes them extremely hazardous?
1. Cadmium
2. Copper
3. Lead
4. Phosphor

10-69. What type energy impinging on an object in an electromagnetic field constitutes a biological hazard?
1. Absorbed energy
2. Penetration of energy
3. Reflected energy
4. Electromagnetic energy

10-70. Electromagnetic energy from a frequency in the microwave region is extreme dangerous to a human being because it causes his
1. internal temperature to heat faster than his ability to dissipate the increase.
2. bone tissues to break down through induced molecular vibration
3. nerve tissues to break down through induced high electrical energy levels
4. body to become part of a closed electrical circuit and he is shocked

10-71. Which organ(s) of the body is/are likely to be damaged by heat resulting from excessive exposure to radiation?
1. Lungs
2. Eyes
3. Gall bladder
4. Each of the above

10-72. The danger of electromagnetic (r-f) radiation causing the premature firing of rockets or missiles and the explosion of warheads, VT fuses, etc. is identified as
1. HEED (hazards to electronic explosive ordnance)
2. REED (radiation affecting electronic explosive ordnance)
3. HERO (hazards of electromagnetic radiation to ordnance)
4. RADHAZ (radiation hazards)

Use the following alternatives for item 10-73:
A. Trend towards more electroexplosive devices (EEDs) in sophisticated weapons
B. Trend towards more technicians in men-of-war
C. Trend towards higher automation in ship systems
D. Trend towards higher amounts of radiated electromagnetic energy

10-73. Which trends combine to form HERO dangers?
1. A & B
2. A & C
3. A & D
4. B & C

10-74. High voltage warning signs are posted to
1. ensure personnel safety
2. satisfy material and administrative inspections
3. identify power sources for portable tools
4. eliminate use of guards for warning personnel

Assignment 11

Maintenance and Safety (continued); Appendixes I through VI

Textbook pages 310 through 348

Learning Objective (continued): Determine safety precautions and procedures to follow when working on electrical equipment, the causes and effects of electric shock, the hazards presented by electronic equipment operating at high frequencies, and the safety precautions to follow in handling cathode ray tubes and cleaning electronic equipment.

Information for items 11-1 and 11-2: Seaman JONES is a victim of electric shock and has no heart beat. He most probably has suffered a cardiac arrest. There is complete absence of pulse at the wrist. Additionally, the pupils of his eyes are very dilated.

11-1. Unless circulation is reestablished within ______ minutes, severe brain damage could result.
1. one
2. two
3. three
4. four

11-2. Attempts to reestablish Seaman JONES' circulation should first be attempted by ______.
1. application of cardiac massage
2. mouth-to-mouth respiration
3. arm-lift
4. back pressure arm-lift

11-3. The method of artificial respiration that is most effective for an individual of any age who has stopped breathing is
1. mouth-to-mouth
2. arm-lift
3. back-pressure arm-lift
4. back pressure hip-lift

11-4. If after assuming that the victim's head and jaw are properly positioned, you are unable to obtain air exchange when administering mouth-to-mouth resuscitation, what action should you take?
1. Turn him face down and use the back pressure arm-lift method
2. Try to get him to swallow water
3. Turn him on his side and strike several sharp blows between his shoulder blades
4. Place a cloth over his mouth and breath through it

11-5. A victim of electrical shock has been removed from contact with the electric circuit, but he is unconscious and his breathing is weak and irregular. Should he be given artificial respiration and if so, at approximately what frequency?
1. No
2. Yes; 5 times per minute
3. Yes; 12 times per minute
4. Yes; 15 times per minute

Learning Objective: Recognize the procedures and extinguishing agents to use to fight electrical fires.

11-6. The first thing that you should do is to
1. close all doors in the space
2. turn off all blowers in the space
3. deenergize the equipment involved in the fire
4. secure the ventilation to the space

11-7. You send MILLER to spread the alarm. In spreading the alarm, to whom should MILLER report the fire first.
1. Commanding officer
2. Senior damage controlman
3. OOD
4. XO

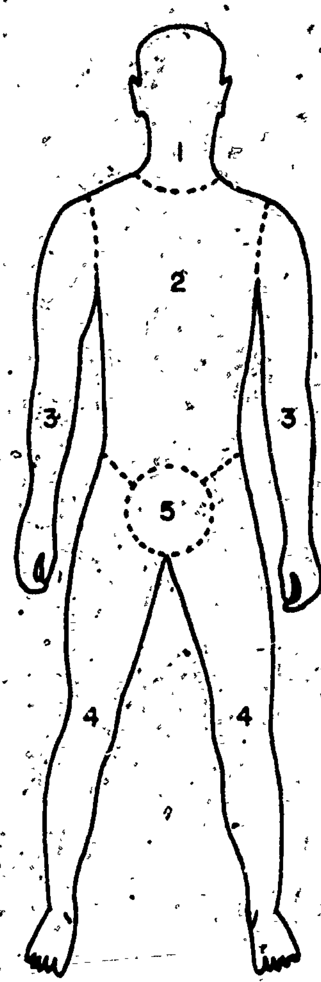
11-8. As MILLER leaves to spread the alarm you quickly grab the nearest portable carbon dioxide fire extinguisher. The extinguisher is equipped with a squeezegrip style release valve so you ready it for operation by
1. holding it erect (valve mechanism down) and squeezing the hand grip
2. holding it erect (valve mechanism up) and removing the valve locking pin
3. laying it with its side down on the deck and removing the valve locking pin
4. laying it with its side down on the deck and squeezing the hand grip

11-9. Which of the following types of firefighting equipment is best against electrical fires?
1. Fog applicator
2. Foam applicator
3. Carbon dioxide (CO_2) extinguisher
4. Fire hose

11-10. You direct the flow of carbon dioxide from the extinguisher toward the fire at a point located
1. above the tips of the highest flame
2. at the tips of the flames
3. in the middle of the flames
4. at the base of the flames

11-11. Why is there a hazard to personnel when using large quantities of carbon dioxide to fight a fire in a confined space?
1. CO_2 is poisonous in large concentrations
2. CO_2 displaces air (with its life supporting oxygen) from the space
3. CO_2 becomes explosive in large concentrations
4. CO_2 changes into deadly carbon monoxide (CO) under high temperature conditions

11-12. If carbon dioxide fails to control an electrical fire, you should apply
1. a stream of water directed at the base of the fire
2. a stream of water directed at the upper part of the flames
3. fresh water fog
4. chemical fog



LEGEND	%
1. HEAD AND NECK	9
2. ANTERIOR TRUNK	18
POSTERIOR TRUNK	18
3. ARMS	18 (9 x 2)
4. LEGS	36 (18 x 2)
5. GENITALIA AND PERINEUM	1

Figure 11A.--Computing body surface

STUDY HINT: As your textbook states, the principal factor in determining the seriousness of a burn is the extent of body area burned. To estimate the amount of skin area involved, use the "rule of nines" illustrated in figure 11A. In such calculations, you often have to estimate the percentages of partial areas involved. For example, a victim has burns covering the front of this entire left leg as well as his stomach and the front of his left arm and hand. You would estimate the total surface area burned in the following way:

Front only of entire left leg $= \frac{18}{2} = 9\%$

Stomach, approximately $= 9\%$

Front only of left arm and hand $= \frac{9}{2} = 4\ 1/2\%$

Approximate total $= 22\%$

You should remember that estimates made according to the rule of nines are only rough approximations--you do not need exact percentages of skin areas burned in order to give first aid for burns. The rule of nines is presented here only as a general guideline to use in estimating the severity of burns.

Information for items 11-13 through 11-27: You are first to arrive at the scene of a fire. You find the following casualties: POINDEXTER, whose right hand and forearm are reddened and blistered. ANDERSON, whose entire left leg exhibits symptoms of increased warmth, tenderness, and a reddish appearance. STEIN, whose face, neck, and both hands is completely destroyed and the underlying tissue is black. LAINE, whose burn on his right leg from the knee down is characterized by complete destruction of the skin, with charring and cooking of the deeper tissues.

11-13. Using the rule of nines, calculate the approximate extent of each casualty's burns.

1. POINDEXTER 6%, ANDERSON 9% STEIN 15%, LAINE 18%
2. POINDEXTER 12 1/2%, ANDERSON 15%, STEIN 18%, LAINE 12%
3. POINDEXTER 9%, ANDERSON 24%, STEIN 29%, LAINE 10%
4. POINDEXTER 4 1/2%, ANDERSON 18%, STEIN 22 1/2%, LAINE 7%

11-14. Which casualty do you consider the most seriously burned?

1. POINDEXTER
2. ANDERSON
3. STEIN
4. LAINE

11-15. From the extent of their injuries, whom can you expect to go into shock?

1. POINDEXTER and ANDERSON
2. ANDERSON and STEIN
3. STEIN and LAINE
4. ANDERSON and LAINE

11-16. Unless adequate medical treatment is rendered, whose life is endangered by his burns?

1. POINDEXTER's
2. ANDERSON's
3. STEIN's
4. LAINE's

11-17. Which casualty has first degree burns?

1. POINDEXTER
2. ANDERSON
3. STEIN
4. LAINE

11-18. Which of the following casualties would probably experience the most pain?

1. POINDEXTER and STEIN
2. ANDERSON and LAINE
3. STEIN and LAINE
4. ANDERSON and STEIN

11-19. LAINE informs you that his burns are not painful. Is this absence of pain unusual?

1. Yes; this degree of burn always causes severe pain
2. No; this degree of pain usually destroys sensory nerve endings
3. Yes; this degree of burn usually involves highly sensitive muscle tissue
4. No; this degree of burn produces severe shock which eliminates pain

For items 11-20 through 11-26, assume that the services of medical personnel cannot be obtained within the next four hours. You are to administer the necessary first aid treatment. All items necessary for treating burns are available for your use.

11-20. Your main tasks in giving first aid to the casualties are to
1. prevent infections, relieve pain. and prevent or treat shock
2. relieve pain, immobilize the burned areas, and apply antiseptics to the burns
3. prevent shock, open blisters and apply wet antiseptic dressings to the burns
4. remove foreign materials from the burns, apply hot moist packs to the burns, and prevent infections

11-21. As an emergency measure, what treatment may you give POINDEXTER, ANDERSON and LAINE to lessen the damaging effects of their burns?
1. Immersing their burned extremities in warm salt water
2. Wrapping the burned areas in a dry sheet
3. Applying a thin coating of butter to the burned areas
4. Soaking the burned areas in ice water

11-22. What is the principal danger from STEIN's burns?
1. Infection
2. Blood poisoning
3. Hemorrhage
4. Shock

11-23. In treating STEIN for shock, what exception should you make to the general procedure of shock treatment?
1. Keeping him cool
2. Giving him liquids by mouth
3. Placing him in a sitting position
4. Giving him 1/4 grain of morphine

11-24. You can help to prevent infection of STEIN's burns by
1. wearing a mask and using sterile techniques as much as possible
2. wearing rubber gloves and applying antiseptics to the burns
3. applying compresses soaked with iodine to the burns
4. applying a thick coating of bacitracin to the burns

11-25. As a dressing for STEIN's burns, you apply
1. sterile petrolatum gauze covered in turn by fluffs of gauze and a large padded dressing
2. iodine and seal the burns with adhesive tape
3. a wet antiseptic compress covered with a large sterile dressing
4. sterile absorbent cotton held in place by a thin sterile bandage

11-26. After you dress STEIN's burns, the correct precaution you should take regarding the dressing is to
1. keep the dressing wet with a solution of zephiran chloride
2. remove the dressing for a period of 30 minutes every two hours
3. see that the dressing is undisturbed until medical assistance arrives
4. apply a fresh dressing every hour

11-27. Which of the following treatments should you have given STEIN had you expected medical assistance within two hours?
1. Applying petrolatum to the burns on his face and neck and immersing his arms in ice water
2. Covering the burned areas with a sterile wrapping and treating him for shock
3. Cleaning the burned areas with soap and water and applying sterile dry gauze dressing
4. Leaving the burned areas open and dry and treating him for shock

11-28. Before giving morphine to relieve a burned patient's pain, you should make certain that he is free of
1. internal injuries
2. head injuries
3. severe bleeding
4. broken bones

11-29. The correct first aid procedure regarding foreign material that is adhering to a severely burned area is to
1. remove it carefully, using sterile technique
2. soak it loose with warm salt water
3. cleanse the area with soap and water
4. leave it alone

11-30. As first aid treatment for a thermal burn of the eye, you put into the eye a few drops of
1. olive oil or clean mineral oil
2. clean mineral oil or diluted vinegar
3. diluted vinegar or warm salt water
4. warm salt water or boric acid

Learning Objective: Recognize the location of the controls on the front panel and the operating procedure for the representative radio receiver, R-390A/URR.

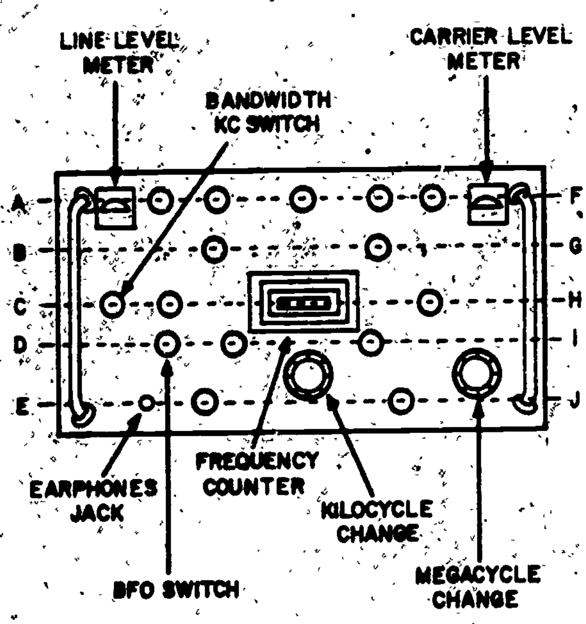


Figure 11B.—Diagram of the front panel of the R-390A/URR radio receiver.

11-31. Which controls are located along line AF of figure 11B?
1. Line meter control, line gain control, antenna trimmer control, break in switch, and audio response control
2. Line meter control, line gain control, antenna trimmer control, AGC, and limiter control
3. Line meter control, antenna trimmer control, function switch, limiter control, and dial lock
4. Limiter control, AGC, dial lock, line gain control, and function switch

11-32. What two controls of the receiver are located on line BG of figure 11B?
1. Break in switch and function switch
2. Audio response control and zero adjust control
3. Audio response control and break switch
4. BFO switch and zero adjust control

11-33. Close to the frequency indicator dial on line DI of figure 11B are the two controls of the receiver named
1. local gain control and RF gain control
2. dial lock and zero adjust control
3. dial lock and RF gain control
4. zero adjust and local gain control

11-34. Where are the BFO pitch, local gain, RF gain and function controls located in figure 11B?
1. BF pitch and local gain controls on line CH, RF gain and function controls on line EJ
2. Function and RF gain controls on line CH, local gain and BFO pitch controls on line EJ
3. BFO pitch and function controls on line CH, local gain and RF gain controls on line EJ
4. RF gain and function controls on line EJ, local gain and BFO pitch controls on line CH

11-35. To energize the filament supply voltages without supplying plate supply voltages to the tubes of the receiver, you set the
1. function switch to its MDC position
2. function switch to its STANDBY position
3. break in switch to its ON position
4. BFO switch to its ON position

Information for items 11-36 and 11-37: You are preparing to verify that the reading of the tuning dial corresponds to the frequency received by the R-390A/URR radio.

11-36. To which of the following frequencies may you tune the receiver in order to calibrate it?
1. 700 kHz
2. 725 kHz
3. 750 kHz
4. 777 kHz

11-37. You activate the stable crystal oscillator that supplies the calibrating signal to the receiver by
1. setting the function switch to its CAL position
2. turning the BFO switch to its ON position
3. setting the function switch to its MGC position
4. setting the BFO switch to its ON position and the BFO pitch control to its +2 position

---

In items 11-38 through 11-40, select from column B the control of the R-390A/URR receiver that causes the action in column A.

	A. ACTIONS	B. CONTROLS
11-38.	Adjusting the tuned circuits of the r-f portion to change the selectivity of the receiver.	1. Local gain
11-39.	Controlling the level of the output to the phone jack.	2. Break in
11-40.	Activating circuits that allow the receiver to be used with a transmitter.	3. Bandwidth KC
		4. Antenna trim

11-41. You adjust the level of the audio output used to operate terminal equipment by adjusting the front panel control labeled
1. line gain
2. local gain
3. RF gain
4. audio response

11-42. What are typical settings of the limiter control if you are monitoring voice signals and fsk-modulated signals respectively?
1. Voice and fsk, 2 or 3
2. Voice 2 or 3, fsk 8 or 9
3. Voice 8 or 9, fsk 2 or 3
4. Voice and fsk, 8 or 9

11-43. Which meters of the receiver help you in making tape recordings (TR), in adjusting the antenna trimmer (AT), and in tuning to the exact frequency that gives the strongest signal (T)?
1. Carrier level meter (TR)(AT), line level meter (T)
2. Carrier level meter (AT)(T), line level meter (TR)
3. Line level meter (TR)(AT), carrier level meter (T)
4. Line level meter (TR)(T), carrier level meter (AT)

Learning Objective: Recognize the uses, functions and characteristics of the Converter Comparator Group AN/URA-17C.

11-44. The AN/URA-17 is capable of how many separate modes of operations?
1. One; diversity
2. One; single receiver
3. Two; dual receiver and diversity
4. Two; single receiver and diversity

11-45. What aspect of converter operation is most important to achieve good communications?
1. Allowing at least 10 minutes for the equipment to warm up
2. Adjust controls in rear of equipment
3. Proper tuning of the receiver feeding the converter
4. Study visual presentation of signal on oscilloscope

45

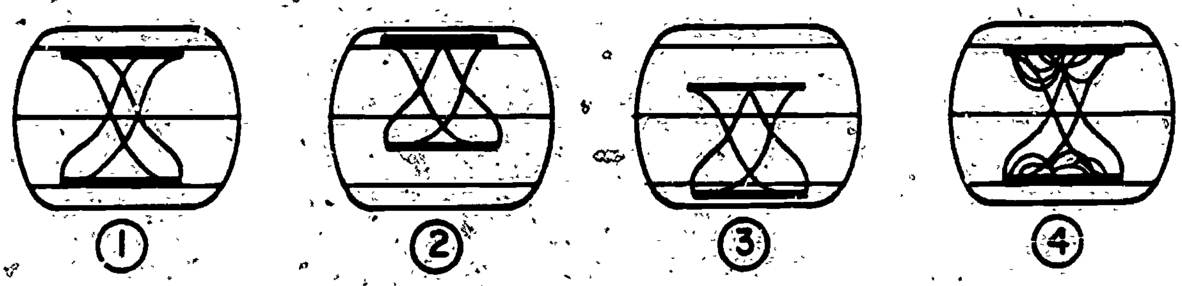


Figure IIC.—Diagram of monitor oscilloscope patterns for frequency shift converters. (1.239.3 revised)

11-46. Which scope pattern of Figure A-II-1 illustrates a correctly tuned signal?
1. 1
2. 2 and 3
3. 1 and 4
4. 4

11-47. The function control switch of the AN/URA-17 converter is in the ________ position if the input signal from the teletype printer is removed.
1. SINGLE
2. TUNE
3. DIVERSITY
4. DUAL

11-48. The (A. POLARITY; FUNCTION) switch of the AN/URA-17 should be adjusted to the (B. NORMAL; REVERSE) position if the teletype printer is garbling.
1. A. POLARITY; B. NORMAL
2. A. POLARITY; B. REVERSE
3. A. FUNCTION; B. NORMAL
4. A. FUNCTION; B. REVERSE

Learning Objective: Determine the functions and controls of the ASCII code and how they apply to Model 40 data terminals.

11-49. Why was the ASCII Code developed?
1. Accomplish data transmissions
2. Provide for additional symbols
3. Furnish parity checking
4. Each of the above

11-50. Which ASCII control displays the symbol and moves the cursor to start of next line, and causes printer to print next character at start of next line?
1. HT
2. NL
3. LF
4. CR

11-51. Which Escape sequence moves the cursor up one line?
1. ESC 0
2. ESC 1
3. ESC 7
4. ESC B

Learning Objective: Recognize the function of the Digital Data Distortion Test Set AN/USM-329(V).

11-52. Which signal generator switch selects the signal pattern?
1. CODE LEVEL
2. CHARACTER RELEASE
3. DISTORTION SELECT
4. OUTPUT

11-53. The signal lamp of the signal generator glows continuously whenever the signal is at a
1. mark level
2. steady mark
3. space level
4. steady space

11-54. What type of maintenance can an operator perform on signal generator equipment?
1. Preventive maintenance
2. Replacement of the lamps and fuses
3. Replace tubes
4. Each of the above

11-55. Which statement is TRUE regarding operation of the Analyzer-Oscilloscope?
1. The FOCUS control displays Digital Waveform
2. The Oscilloscope is capable of measuring distortion
3. Separate operation of the oscilloscope is not recommended
4. The CRT selects synchronizing signals for oscilloscope sweep

11-56. Which control of the Analyzer selects baud rate from 37.5 to 4800 of internal time base?
1. RATE switch
2. TIME BASE switch
3. INPUT switch
4. POLARITY switch

Learning Objective: Identify the meaning of operating signals.

In items 11-57 through 11-61, select from column B the operating signal which serves the purpose described in column A.

	A. Purposes	B. Operating signals
11-57.	Receiving garbled traffic.	1. ZFH (1) (2)
		2. ZAR (1) (2)
11-58.	This is my second request.	3. ZBK (1) (2)
11-59.	Message not received.	4. ZEC (1) (2)
11-60.	Receiving message clear.	
11-61.	Message unidentified, give amplifying data.	

11-62. Which operating signal would most likely be used if a message is being passed for comment?
1. ZIA
2. QRK-5
3. ZFH-3
4. ZFI

11-63. What operating signal would be used to request information on a date time group?
1. ZII-1
2. ZII-2
3. ZDK
4. ZNB

Learning Objective: Identify DSSCS operating signals.

11-64. Which operating signal is part of the message format indicating the start of text?
1. ZPO
2. ZEM
3. ZRJ
4. ZYO

11-65. Which operating signal is used on those messages requiring computer processing?
1. ZPO
2. ZNZ-1
3. ZCA
4. ZYH

11-66. The use of which operating signal must be limited to conditions of urgency?
1. ZZR
2. ZZS
3. ZYH
4. ZRJ

PREFACE

The *Communication Technician O 3 & 2*, is written for enlisted personnel of the United States Navy and Naval Reserve whose duties require them to have a knowledge of the fundamentals of communications. The primary objective of this Rate Training Manual and Nonresident Career Course (RTM/NRCC) is to enhance the degree of effectiveness and quality of communications.

This Rate Training Manual and Nonresident Career Course provides a summarization of the various functions of communications and the processes that support these functions. The opening chapters provide general information concerning the CTO rating, security and organization. This is followed by a study of communication theory which includes a discussion of modulation, the frequency spectrum, communication links, transmission systems, and wave propagation. This coverage will be very helpful to the reader since message traffic flow is dependent upon the quality of circuits and equipments provided.

You will note a broad area of this manual describes message preparation and formats. Although large numbers of messages are processed, transmitted and received via sophisticated automated equipments, the key to the system is the care with which you prepare the message.

The concluding chapters cover the mission of each NAVSECGRU communication division and a number of standard practices dealing with maintenance and safety.

The subject matter presented in each chapter is supported by references to publications and directives that provide more specific information.

Those who work in communications know how frequently procedures and publications change. This Rate Training Manual and Nonresident Career Course was up to date when published, and it will, from time to time, be revised. Between revisions some obsolescence is unavoidable. For this reason it is suggested that you use official communication publications as much as possible in your study for advancement and refresher training.

Designed for individual study and not formal classroom instruction, the RTM provides subject matter that relates directly to the occupational qualifications of the Communication Technician O rating. The NRCC provides the usual way of satisfying the requirements for completing the RTM. The set of assignments in the NRCC includes learning objectives and supporting items designed to lead students through the RTM.

This training manual and nonresident career course was prepared by the Naval Technical Training Center, Corry Station, Pensacola, Florida, for the Chief of Naval Education and Training. Technical assistance was provided by the Headquarters, Naval Security Group Command and the Naval Education and Training Program Development Center, Pensacola.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

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

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

WE SERVE WITH HONOR

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

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

Our responsibilities sober us; our adversities strengthen us.

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

THE FUTURE OF THE NAVY

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

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

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

Never have our opportunities and our responsibilities been greater.

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MODIFICATIONS

Chapters 1-4 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 5

COMMUNICATION BASICS

Every naval command afloat and ashore is assigned a mission and supporting tasks that may vary from combat operations to support of the fighting forces. In each case the communication requirements of the command are derived from its mission and tasks.

In order to ensure maximum contribution to the mission of the command, the communicator should possess an understanding of the communication facilities he uses. Communication equipment today is becoming increasingly more complex and, although you will not be required to qualify as a specialist in electronics, you should be familiar with the communication methods, principles of operation, and the limitations and capabilities of selected systems used in communicating between distant points.

The objective of this chapter is to present certain basic concepts in communications in which the communicator should be, at a minimum, aware and conversant. The subject of communication theory and the functioning of specific types of equipment will be discussed later in this manual. The information presented in this chapter will provide a basis for understanding these subjects.

TELECOMMUNICATIONS

The term telecommunication refers to communication over a distance and includes any transmission, emission, or reception of signs, signals, writings, images, and sounds; or intelligence of any nature by visual means, oral means, wire radio, or other electromagnetic systems. Telecommunications used in the Navy are of three types: electrical, visual and sound.

ELECTRICAL

The means of communicating electrically are by radio and wire. The former uses electromagnetic waves not guided by a physical path between sender and receiver, whereas wire uses electromagnetic waves carried by electrical conductors that connect the sending and receiving equipments.

Radio is the Navy's most important effective means by which the activities of widespread naval forces can be continuously coordinated.

Radiotelegraph

Radiotelegraph (continuous wave or CW telegraphy) is a system for transmitting signals by using a wave of radiofrequency (r-f) energy. The radio operator separates the continuously transmitted wave into dots and dashes, based on the Morse code, by opening and closing a telegraphic handkey.

Radio telegraphy was the first means of radio communication of military and commercial importance. Although there have been many advances in the field of radio since Marconi succeeded in sending his first "wireless" message, radiotelegraph still is used as a means of communication to, from, and among widely separated units of the Navy.

The relatively slow speed of transmission and the requirement for many experienced operators are the major disadvantages of radiotelegraph. The main advantage is reliability. The need for a thinking person at both sending and receiving stations provides a degree of intelligibility not present in automated systems.

Radiotelephone

Radiotelephone is one of the most useful military communication methods. Because of its directness, convenience, and ease of operation, radiotelephone is used by ships, aircraft, and shore stations for ship-to-shore, shore-to-ship, ship-to-ship, air-to-ship, ship-to-air, and air-to-ground communications. Modern modes of operation make it possible to communicate around the world by radiotelephone. One of the most important uses of radiotelephone is short-range tactical communications. Its capability of transmitting voice signals enables the responsible officer to talk directly with the officer in tactical command and with other ships. Little delay results while a message is prepared for transmission, and acknowledgements can be returned instantly. Radiotelephone equipment for tactical use usually is operated on frequencies that are high enough to have line-of-sight characteristics; that is, the waves do not follow the curvature of the earth. These characteristics limit the usual range of radiotelephone from 20 to 25 miles. Radiotelephone procedure can be learned easily by persons with no other training in communications.

Radiotelephone also has disadvantages. Transmissions may be unreadable because of static, enemy interference, or high local noise level caused by shouts, gunfire, and bomb or shell bursts. Wave propagation characteristics of radiotelephone frequencies sometimes are unpredictable, and transmissions may be heard from great distances. Most radiotelephone messages are in plain language, and if information is to be kept from the enemy, users must keep their messages short, stick to the proper procedures, and be careful of what they say.

Teletypewriter

Teletypewriter (TTY) signals may be transmitted by either landline (wire), cable, or radio. The landline TTY is utilized both by the military services and by commercial communication companies. Radioteletypewriter (RATT), either single- or multi-channel, is used mainly for high speed automatic communications across ocean areas. The teletypewriter unit is equipped with a keyboard similar to a typewriter. When the operator presses a key, a sequence of signals is transmitted. At receiving stations, the signals are fed into terminal equipments that type the message automatically.

The RATT mode of transmission/reception is rapidly becoming more efficient and reliable for communications between ships and ship-to-shore. Additionally, all ships so equipped copy fleet broadcast messages on radioteletypewriters. The speed of clearing message traffic on radioteletype circuits depends on the equipment in use. Normal speed of operation is 100 words per minute, but may be faster or slower. The use of RATT has brought about a considerable saving in manpower.

Facsimile

Facsimile (FAX) is the process used to transmit photographs, charts, and other graphic information electronically. The image to be transmitted is scanned by a photoelectric cell, and electrical variations in the cell output, corresponding to the light and dark areas being scanned, are transmitted to the receiver. At the receiver, the signal operates a recorder that reproduces the picture. The FAX signals may be transmitted either by landline or radio.

Facsimile transmissions suffer distortion from all of the common sources of interference experienced with ordinary radiotelegraph and radioteletypewriter. However, certain characteristics of facsimile transmission make it less susceptible to complete loss of intelligence. For example, a picture will be downgraded by any noise bursts, since facsimile recording is a continuous recording of signals coming from a receiver. However, because the machine scans material at the rate of approximately 100 lines per inch, each line is only 1/100th of an inch high. Therefore, if a noise burst interfers with the signal, it will distort a line only 1/100th of an inch high, leaving the image still readable. Under similar circumstances on a conventional circuit (teletype), such distortion could cause a portion of the page copy to be unreadable.

Facsimile transmission is not intended to be a replacement for teletypewriter and other generally employed methods of transmission; rather, it is an important supplement to rapid communication, providing a means of handling certain types of graphic and pictorial intelligence by rapid communication methods.

VISUAL

Visual communications are generally the preferred means for communicating at short range, weather conditions permitting. In reliability and convenience, visual communications often are the equal of radio and under certain circumstances are more secure than radio. For example, omnidirectional radio transmissions may be intercepted by many undesired listeners, whereas unidirectional visual signaling is limited to those positioned along the line of sight.

Visual signaling systems include flaghoist, flashing light, and semaphore.

Flaghoist

The Navy uses flaghoist signaling mainly to convey tactical and informational messages of reasonable length during daylight between ships that are in close company. Flaghoist is considered one of the best ways to ensure uniform execution of maneuvers. In signaling by flaghoist the U. S. Navy and allied navies use international alphabet flags, numeral pennants, and four repeaters, plus a set of special meaning flags and pennants, and ten numeral flags that are not part of the international system. Each flag and pennant has a name; various flags have particular meanings; and almost all hoists are coded signals.

Flaghoist signaling is the most rapid and accurate visual method when ships are within signaling distance in daytime. It normally is the primary tactical maneuvering method of transmission between surface units whenever visibility conditions permit. Signals are repeated by the addressee, thus providing a sure check on the accuracy of reception. Texts of messages which may be conveyed directly by flaghoist are limited by meanings contained in the signal books employed.

Flashing Light

Flashing light is a visual telegraphic system that utilizes visible or infrared light beams; it may be directional or nondirectional.

A directional flashing light is pointed and trained so as to be visible only by the addressee of the message. This method makes use of installed signal searchlights, on which the operator opens and closes the light shutter to form dots and dashes, and portable lights, in which the source of light is switched on and off to form the Morse code characters.

Nondirectional (omnidirectional) lights are located above the superstructure on the yardarm. Because the light beams are visible in every direction from the ship, this method of communicating is suitable for messages destined for several addressees.

In time of war, flashing light communications carried on after dark usually utilize infrared beams that are not visible unless viewed through a special receiver. As a general rule, infrared is the most secure means of visual communications. Directional infrared uses the standard signal searchlights fitted with special filters. For omnidirectional signaling, yardarms are fitted with infrared blinker lamps.

Semaphore

Semaphore is a communication medium by which a signalman with two hand flags, moves his arms through various positions to represent letters, numerals, and special signs.

Semaphore and flashing light can be used interchangeably for many purposes, but semaphore is more rapid for short distance transmission in clear daylight and may be used to send messages to several addresses at once if they are in suitable positions. Because of its speed, semaphore is better adapted to the sending of long messages than are other visual methods. When radio silence is imposed, semaphore is the best substitute for handling administrative traffic. It is more secure than a light or radio because there is less chance for interception by unauthorized persons.

SOUND

Sound communication systems include whistles, sirens, bells, and acoustics. The first three are used by ships for transmission of emergency warning signals such as air raid alerts, for navigational signals prescribed by the Rules of the Road; and in wartime for communications between ships in convoy.

Provision is made in many search sonar (underwater sound) equipments to permit their use for CW transmission. The term acoustic communications, however, usually pertains to an underwater sonar communication equipment called Sea Talk. Sea Talk (frequently referred to as Gertrude) may be used for either radiotelephone or CW communications. The range of transmission varies with the condition of the sea and the relative noise output of the ship. Under the most favorable conditions, communications may take place between ships at ranges in the vicinity of 12,000 yards.

PYROTECHNICS

Pyrotechnics for signaling are, for the most part, of the "fireworks" variety. Common sources are colored shell bursts (parachute flares), aircraft parachute flares, roman candles, and float-type flares.

The meaning of a pyrotechnic signal depends on the color instead of the type of pyrotechnic employed.

The authorized use of pyrotechnics for communications is, in general, limited to emergency signals.

RADIO FREQUENCY SPECTRUM

The rapid growth in the quantity and complexity of communication-electronics equipments and the increased international requirements for radio frequencies have placed unprecedented demands upon the radio frequency spectrum. These demands include such service applications as communications (fixed, mobile, broadcast, space); location and ranging (radar, beacons, radio-navigation); identification; standard time and frequency transmissions; and industrial, medical, and other scientific uses.

The need for worldwide regulation and conservation of this limited resource is easily recognized. Therefore, frequency regulations exist on an international as well as a national and agency level.

The International Telecommunications Union (ITU) functions as the principle regulating body for radio communications all over the world. It establishes and promulgates the international allocation of, and regulations for the use of, the radio frequency spectrum. These regulations have treaty status and, upon adoption by a country, become the law of the land. Each nation regulates its own stations within the broad limits set by international agreement.

In the United States, the basis for U. S. frequency management is derived from the Communications Act of 1934 as amended. Under this act, the Federal Communications Commission (FCC) is responsible to Congress for regulating frequency use by U.S. non-Government activities and the President is responsible for regulating use by Federal Government agencies. The President has delegated the authority for assignment and control of radio frequency resources used by Government agencies to the Director of Telecommunications Management under the Office of Emergency Planning.

The allocation, assignment, and protection of all frequencies used by any component of the Navy are the responsibility of COMNAVTELCOMM. Detailed execution of the responsibility is vested in a frequency management office, organizationally within the Naval Telecommunications Command. Authority for any use of the radio frequency spectrum must be obtained from COMNAVTELCOMM.

FREQUENCY BANDS

In 1967, the U. S. Navy adopted the term Hertz to designate units of frequency per second. If a frequency was formerly 10 cycles per second, it is now referred to as 10 Hertz (Hz). Because units of radio-frequencies become so large numerically, they are counted in terms of thousands, millions, billions and trillions of Hertz, using appropriate prefixes from the metric system: kilo, mega, giga, and tera. The latter two, giga and tera, as yet have limited application in naval communications. A Kilohertz is 1 thousand Hertz and is abbreviated kHz; a megahertz is 1 million Hertz, abbreviated MHz, and so on. A frequency of 15,000 Hertz, for example, is expressed as 15 kHz. When the number of kilohertz becomes too large, megahertz are substituted to simplify the figure. Thus, 82,000 kHz is expressed as 82 MHz and so on.

Frequencies are divided into eight bands as shown in TABLE 5-1. The propagation of radio waves varies widely at different frequencies throughout the radio spectrum as will be explained in Chapter 7. This provides a choice of frequencies best suited for various types of communications as discussed in the following paragraphs.

VLF COMMUNICATIONS

The pace of progress and world developments—political, geographical, technological and military—have broadened the Navy's commitments for communications to cover the face of the earth. New sea frontiers to the north have opened a four-million square mile ice-covered ocean of strategic importance. The requirement for positive control of U. S. Navy forces operating in new and expanded areas has dictated an urgent need for additional communication capacity, range, and reliability for the Navy's command responsibilities. This need has been confirmed through fleet exercises The need has been particularly great in the North Atlantic, and the newly opened Arctic Ocean. High frequency circuits which are subject to numerous outages from auroral and polar disturbances prevented reliable communications from previously existing U. S. Naval Radio Stations. Very low frequency (VLF) transmissions provide a highly reliable path for communications in these northern latitudes, as well as over and under all oceans and seas of the world. VLF traffic reached a peak in the early twenties when it was the only means of long distance wireless communications. After this period, many commercial VLF stations were abandoned in favor of high frequency (HF), due partly to the lower cost of HF equipment. At present, practically all VLF transmitters are used for fleet communications or navigation. In this connection, the U. S. Navy has been using VLF

Table 5-1.—Radio Frequency Spectrum

FREQUENCY	DESCRIPTION	ABBREVIATION
30GHz-300GHz	extremely high frequency	EHF
3GHz-30GHz	super high frequency	SHF
300MHz-3GHz	ultra high frequency	UHF
30MHz-300MHz	very high frequency	VHF
3MHz-30MHz	high frequency	HF
300kHz-3MHz	medium frequency	MF
30kHz-300kHz	low frequency	LF
3kHz-30kHz	very low frequency	VLF

31.20

for general broadcasting to ships at sea for many decades. The dependability of reception is such that no confirmation of the received message is normally required.

Recent history has shown an increase of all radio traffic and this is especially true of VLF. Such an increase may be expected again, not only for naval communications, but for communications to large numbers of satellites and as a backup to short wave communications blacked out by nuclear activity. The strong reliance placed on VLF by the world's navies for crucial communications is good evidence of VLF reliability during hostilities.

Secondary applications of the VLF range include the worldwide transmission of standard frequency and time signals. The requirement for the distribution of standard frequency and time signals with the highest accuracy over long distances has become increasingly important in many fields of science. It is essential for the tracking of space vehicles, worldwide clock synchronization and oscillator calibration, international comparisons of atomic frequency standards, radio navigational aids, astronomy, national standardizing laboratories, and communication systems.

Experiments over the last few years have shown the benefits of VLF for the broadcast of standard time and frequency signals with more than adequate precision for the operation of synchronous crypto devices, decoding devices and single sideband transmissions.

LF COMMUNICATION

The low-frequency band occupies only a very small part of the radio frequency spectrum. Nevertheless, this small band of frequencies has been used for communication since the advent of radio. Although the historical significance of the low frequency band is well known, the great extent of present usage of this band is not generally appreciated.

In the history of radio communications, the low-frequency transmitting installations of the pioneering era were characterized by their large physical size and by their high construction and maintenance costs. Moreover, then, as now, signal reception at low frequencies was seriously hampered by atmospheric noise, particularly at low geographical latitudes. In addition the increasing demand for radio communications soon resulted in serious congestion of transmissions within the development of the high frequency "beamed" systems. About 1924, it was found that the high frequencies offered an attractive solution to many long-distance communication problems, and the use of the low frequencies became considered as outmoded. Nevertheless, propagation factors peculiar to the low-frequency band have resulted in their continued use for radio communication. In particular, the reception of low frequency waves is not so seriously affected during periods of ionospheric disturbance when communications at the high frequencies is disrupted. Because of this, there is a particular interest in the application of low frequencies at northern latitudes. Since the initial use of radio for communication purposes, considerable advances have been made in improving both the efficiency and the quality of communications by the application of communications theory, radio wave propagation studies, and new techniques.

The Navy requirement to provide the best possible communications to the fleet requires it to operate on all frequency bands, engage in constant research to improve its existing capabilities and utilize new systems and developments as they become operationally reliable (proven systems).

In the past the Fleet Broadcast System provided ships at sea with low frequency (LF) communications via CW telegraph transmissions. As technology advanced, the system was converted to single channel radio teletype transmissions. Today LF communication also operates as a segment of the Fleet Multichannel Broadcast System providing eight channels of Frequency Division Multiplex teletype traffic on each transmission.

MF COMMUNICATION

The medium frequency band covers the part of the radio frequency spectrum from 300 kHz to 3 MHz. Included in this range are the International Distress frequency 500 kHz (to monitor) and approximately 484 kHz to respond from shore stations (Coast Guard).

Every ship has a receiver and a transmitter set for these emergency frequencies; when at sea, the receiver is continuously monitored and the transmitter is usually in the standby position. Ashore, the receiver and transmitter configuration is usually affiliated with search and rescue organizations, which are generally located near the coast.

There are occasions when the 500 kHz frequency is used for calling another station. Since all Navy and Merchant ships must monitor this frequency, it is sometimes convenient (when the sender does not know what other frequency the receiver is monitoring) to send a short message stating what frequency the receiver should turn to for further communications. The only restriction is that no call-up transmissions are permitted during the periods 15-18 minutes and 45-48 minutes past the hour, every hour of the day. These periods of time are commonly referred to as silent periods and are required by law to permit the frequency to be clear of all but emergency communication.

Only the upper and lower ends of the MF band have naval use because of the commercial broadcast band extending from 535 to 1605 kHz. Frequencies in the lower portion of the MF band (300 to 500 kHz) are used primarily for ground wave transmission for moderately long distances over water and moderate to short distances over land. Transmission in the upper MF band is generally limited to short haul (400 miles), reliable, point to point circuits.

HF COMMUNICATIONS

The Navy began using high frequencies for radio communications around World War I when a few communication systems were operated on frequencies near 3 MHz. In view of the extensive present day use of high frequencies for long distance communications, it seems curious now that those Navy systems were intended for very short range communications of a few miles. The general belief at the time was that frequencies above 1.5 MHz were useless for communication purposes.

One of the prominent features of high frequency long-distance communication is the variable nature of the propagation medium. Successful transmission of HF signals over long distances is dependent upon refraction of radio waves by layers of the ionosphere, discussed in Chapter 7. The height and density of these layers, formed primarily by ultraviolet radiation from the sun, vary significantly with the time of day, season of the year, and the eleven year cycle of sunspot activity. Because of these variations, it is generally necessary to use more than a single frequency, sometimes up to four or five, to maintain communications on a circuit.

In spite of the difficulties encountered with HF propagation, the economic and technical advantages of using high frequencies have led to rapid expansion of the use of the HF band. Ultimately, as the number of users increased, use of the HF spectrum approached saturation.

The HF band is shared by many users, both foreign and domestic, and only portions scattered throughout the band are allocated to the military services. In common with other agencies, Navy requirements have grown so as to severely tax the capacity of the Navy's assigned portion of the HF spectrum. The use of single-sideband equipment and the application of independent sideband techniques have increased the capacity, but not enough to catch up with the demand. Some predict that satellite communications (discussed in Chapter 6) will eventually relieve congestion in the HF band and that, for some types of service, it will replace HF for long-distance communications. Nevertheless, it appears that the HF spectrum will continue to be in high demand for some time.

Naval communications within the HF band can be grouped into four general types of services: point-to-point, ship-to-shore, ground-to-air, and fleet broadcast. Some of these services involve ships and aircraft which present special problems because of their physical characteristics and mobility. Generally, the less than optimum HF performance of these mobile terminals is at least partially offset by powerful transmitters and sensitive receiving systems at the shore terminals.

Point-to-Point Communications

Point-to-point systems are those established to communicate over long-distance trunks or links between fixed terminals. Generally, sufficient real estate is acquired at the terminals to permit the use of large, high gain antennas, aimed at opposite terminals of each link. This increases the effective radiated power and the sensitivity of the receiving system, and it also reduces susceptibility of a circuit to interference. With the path length and direction fixed, accommodation of the other propagation variables is simplified and highly reliable communications can be achieved.

Ship-to-Shore Communications

This application of the HF band is more difficult than the point-to-point case, since one terminal, the ship, is mobile. In this case the path length and direction are variable. At the ship terminal the limited space and other restrictions prohibit installation of large, efficient HF antennas. Because of the mobility of ships, shipboard antennas are designed to be as nearly omnidirectional as possible.

The constraints are not as severe at the shore terminal where there is sufficient space for more efficient omnidirectional antennas or arrays designed for area coverage. Moreover, at the shore terminal a rotatable, high-gain antenna or one of the fixed point-to-point antennas may be used under appropriate circumstances. For example, a rhombic antenna may serve admirably for long-haul ship-to-shore communications when the ship is at a distance such that its operating area is within the coverage of the antenna at that distance.

Several frequencies are usually assigned for each circuit so that the best frequency can be chosen, for the propagation path conditions, between the shore terminal and the ship's location.

Ground-to-Air Communications

The application of HF radio to communications between the ground and airborne aircraft is similar to the ship-to-shore case, except the aircraft terminal changes position much more rapidly than does a ship. Transmitter power and antenna restrictions imposed by the airframe design limit the effectiveness of the airborne HF radio terminal. All major circuit improvements must be made by the application of suitable techniques at the ground terminal. For example, higher powered transmitters, lower noise receiving installations, and more efficient antennas can be used on the ground.

Fleet Broadcasts

As the name implies, this type of service involves broadcast area coverage from shore based transmitters to ships at sea. Messages addressed to a ship in a designated broadcast area are delivered by various means to the appropriate fleet broadcast station where they are broadcast for pickup by the ships. To overcome the propagation difficulties, the same information is broadcast simultaneously on several frequencies. That is, most fleet broadcasts are frequency-diversity transmissions providing the terminal to choose the best frequency for the path conditions at the time.

VHF AND ABOVE

Frequencies above 30 megahertz are not normally refracted by the ionosphere, nor is ground wave range appreciable; hence, service is confined to distances approximately within the line of sight. A significant exception to this general principle is the increased range made possible through the employment of tropospheric scatter techniques. Forward propagation by tropospheric scatter (FPTS) (discussed in more detail later in this chapter) has proven feasible up to several thousand megahertz. Certain atmospheric and ionospheric conditions can also cause normal line of sight range to be extended at times. Frequencies at the lower end of this band are capable of overcoming the shielding effects of hills and structures to some degree but as the frequency is increased the shielding effect becomes more pronounced. Reception is notably free from atmospheric and man-made static. The VHF and UFH bands are known as "line of sight" transmission bands. That is to say, the transmitting antenna is in a direct line with the receiving antenna; it is not over the horizon. The "line of sight" characteristic makes the bands ideal for utilizing the VHF for amphibious operations (beach landing from sea craft) and the UHF for tactical voice transmissions (maneuvering of ships traveling together). The SHF band is used for radar and satellite communications whereas the EHF band is in the experimental stage and not in active use by the Navy.

COMMUNICATION LINKS

A complex of links forms a major communications system. The Naval Communication System is broken down into two groups: strategic and tactical.

Strategic communications are generally global in nature and are operated on a common user or special purpose basis. While a strategic system may be confined within a specified area or limited to a specific type of traffic, the configuration is such that inter-operation with other strategic systems is possible when desired or required. For example, Autovon, Autodin and DSSCS.

Tactical communications usually are limited to a specific area of operations and are used to direct or report the movement of specific forces. Some tactical nets are utilized only for operational traffic; others may be used for operational and administrative traffic. For instance, the task force and task group nets and air control nets ordinarily are employed for operational traffic. Ship-to-shore nets and broadcast nets can serve both types of traffic.

MODES OF OPERATION

Communication links have numerous modes of operation. In this discussion, modes of operation can be identified as a link or path between two or more points, capable of providing one or more channels for the transmission of intelligence. The five most prominent modes of operations plus their standard abbreviations are as follows: Simplex (SX), Half Duplex (HDX), Semiduplex (SDX), Duplex (FDX), and Broadcast (BCST).

Simplex (SX)

A single channel or frequency used to exchange information between two or more terminals, but not simultaneously. All may receive concurrently, but only one may send at a time.

Half Duplex (HDX)

A unidirectional flow of information between terminals. Technical arrangements may permit transmission in either direction, but not simultaneously. This term then, must be qualified to show S/O (send only), R/O (receive only), S/R (send or receive).

Semi-duplex (SDX)

A technical arrangement wherein one terminal is simplex configured and the other full duplex using two channels or frequencies. A clarifying example would be a ship with only one keyboard/printer or one COMSEC device terminated full duplex with a NAVCOMMSTA.

Duplex (FDX)

A method of operation in which telecommunications between stations may take place simultaneously in both directions. The term "full duplex" is synonymous with "duplex."

Broadcast (BCST)

Broadcast is that type of operation in which one station emits information on one or more channels, which may be received by more than one station and/or unit. There is no provision for receipt or reply in a broadcast system; however, special arrangements may require reply at a later time by other means. Broadcasts are the primary means of delivering message traffic to the fleet. Units copying a broadcast are not required to receipt for messages received and can therefore maintain radio silence while still receiving essential traffic.

There are three ways in which radio traffic is sent to the fleet: broadcast, intercept, and receipt. The first two are "do not answer" methods, while the third, as its name implies, requires a receipt from the addressee (addee) for each message. Broadcast and intercept methods allow the fleet to preserve radio silence, which is a great advantage from the standpoint of security. By the intercept method, a shore radio station transmits messages to another shore station which repeats them back. Ships intercept and copy all traffic.

Broadcast is preferable to intercept chiefly because it is faster. It is the method by which nearly all fleet traffic is handled, and it utilizes all four systems of radio communications: radiotelegraph, radio-telephone, radio-teletypewriter, and facsimile.

There is some similarity between civilian and naval broadcasts. Just as commercial stations in the broadcast band transmit programs to radio receivers in the homes in their communities, Navy communication stations broadcast messages to fleet units in their particular geographic areas. The term "broadcast," in fact, originated in naval communications.

The resemblance between Navy and commercial stations ceases here, however. Information broadcast by naval communications stations is contained in chronologically numbered messages addressed to the ships. The messages are copied by the fleet units, which check the serial numbers to ensure that they have a complete file.

Fleet broadcasts follow regular schedules. Messages are placed on the schedules in order of precedence. If a message of higher precedence is given to a transmitter station while a lower-precedence message is being transmitted, the latter message may be interrupted to transmit the message of higher precedence.

All ships copy all messages appearing on the broadcast schedule which they are guarding.

To ensure reception of these very important broadcasts, they normally are transmitted on several frequencies to allow a choice for best reception, considering the time of day or night and the atmospheric conditions.

SWITCHED NETWORKS

As discussed in the previous chapter, the Defense Communications System (DCS) is composed of all world-wide, long-haul, government-owned and leased point-to-point circuits, trunks, terminals, switching centers, control facilities, and tributaries of military departments and other defense activities. In essence the DCS combines into a single system those elements that make up the Navy's Naval Communications System, the Army's STARCOMM, and the Air Force's AIRCOM.

The switched networks discussed in this section, AUTOVON, AUTOSEVOCOM, AUTODIN and DSSCS, are part of the DCS, and are managed by the Defense Communications Agency (DCA). These DCS Switched Networks should not be confused with the HICOM (High Command) and NORATS (Navy Operational Radio and Telephone Switchboard) nets, mentioned later in this section which support only designated Navy requirements.

Automatic Voice Network (AUTOVON)

The DCS AUTOVON offers rapid, direct interconnection of DOD and certain other Government installations. AUTOVON is intended to be a single, worldwide, general-purpose direct dialing system. Its goal is to complete connections between two points anywhere in the world in about 2 seconds and to complete regular connections with pushbutton speed.

The AUTOVON system is comprised of several installations comparable in function to commercial telephone exchanges. An installation is referred to as an AUTOVON switch, or simply switch. Within individual areas are local command, control, and administrative voice communication systems. The systems can be connected into the world wide AUTOVON through manually operated telephone switchboards, or automatic dial exchanges, by provision of direct in or out dialing capabilities.

Normal AUTOVON service makes it possible for subscribing stations to call other stations on a worldwide basis for day-to-day nonpreemptive traffic. Depending on the type of service available in each locality, AUTOVON calls may be accomplished either by direct dialing or through a local operator. Where users require priority calls to be made, they place the call with their local operator or the AUTOVON dial service assistance operator. More detailed information on AUTOVON can be found in JANAP 137.

Automatic Secure Voice Communications (AUTOSEVOCOM)

AUTOSEVOCOM is a worldwide, switched telephone network whose purpose is to provide authorized users with a means for exchanging classified information over COMSEC circuitry or officially designated as approved circuitry. The system consists of both manual and automated networks lined together to form a single system.

Interface arrangements are necessary to overcome differences in the security equipment and transmission modes between circuit switches and/or subscriber terminals of one system to the other. There are two types of switches in the AUTOSEVOCOM system:

(1) Switches that provide users with an automatically switched secure voice capability.
(2) Switches that require the assistance of an operator.

The interface service provided by switchboard operators is in addition to normal switch service provided for their locally connected subscribers. Additionally, some naval communications stations are equipped to extend AUTOSEVOCOM service to shipboard users.

A telephone directory published periodically contains subscriber listings, general instructions for placing calls, and trouble-reporting procedures. Additionally, JANAP 138 contains complete operating instructions on AUTOSEVOCOM.

Automatic Digital Network (AUTODIN)

The DCS AUTODIN is a fully automatic digital data switching system capable of handling any type of information in digital form. The system consists of high-speed, electronic, solid state switching centers, various types of data and teletype subscriber terminals, and interconnecting transmission media.

AUTODIN is intended to afford instantaneous, error-free, and secure communications around the world to several thousand directly connected subscriber terminals. Daily capacity of the system is in the neighborhood of 5 million average-length messages.

Interconnection of AUTODIN switching centers is accomplished through a network of high-frequency radio channels, submarine cables, microwave and tropospheric channels, and a variety of wire lines. These transmission medias are available from existing DCS transmission resources, AUTOVON, and from commercial communication facilities.

Backbone of the AUTODIN system is the AUTODIN switching center (ASC). Basic functions of the ASC are to accept, store, and retransmit digital messages from one location to another, automatically detect and correct errors, and accomplish alternate routing. Each switching center has a high degree of reliability resulting from duplicate major units, which can be activated with a minimum of disrupted service. The current status of an ASC can be checked at any moment by obtaining a printout of exactly how many messages, by precedence (required speed of transmission) and destination, are in the center.

Each overseas ASC is capable of recognizing and routing 921 non-relay routing indicators (routing indicators of five or more characters). This total includes 215 collective routing indicators (encompassing more than one addressee) and 512 relay (four letter) routing indicators.

The whole concept of AUTODIN is to reduce manual handling of messages to a minimum by the use of automated equipment; to reduce message delivery times and delay anywhere in the world to a matter of seconds (in essence, real-time) rather than in minutes or hours.

More information on AUTODIN equipments and message format will be covered in later chapters of this manual. Operating procedures for AUTODIN can be found in JANAP 128.

Defense Special Security Communications System (DSSCS)

The Defense Special Security Communications System (DSSCS) was established by the Deputy Secretary of Defense on 4 November 1964. The purpose of the DSSCS was to integrate the Critical Intelligence Communications (CRITICOMM) and Special Intelligence Communications (SPINTCOMM) networks into a single automated communications network. In effect, the integration of DSSCS subscribers into AUTODIN provides two separate systems within AUTODIN, one system for Special Intelligence (SI) message traffic and the other for the AUTODIN common user. While the AUTODIN and DSSCS traffic is intermixed within AUTODIN ASC and on inter-ASC trunks, strict physical separation of all DSSCS and AUTODIN input and output terminal facilities is maintained. Each ASC Patch and Test Facility (PTF) is configured with a unique Yellow Patch bay isolated from the standard Red Patch bay to insure that DSSCS access lines/COMSEC equipment and other subscriber access lines/COMSEC equipment cannot be interconnected.

Although the above explanation is primarily devoted to high speed operations, many Navy stations continue to operate low speed, 100 WPM, circuits. However, most of these stations are also connected to an ASC to benefit from the automated external high speed environment. As an example, one input subscriber could send a message at 100 WPM to an ASC. The ASC, in turn, could pass this traffic to another ASC at 1300 WPM or to another subscriber at 200 WPM. The output of a given message is not simultaneous with its input. Each message must be received in its entirety in the "store" position of the ASC before forwarding of that message can begin.

It should also be noted, a number of circuits terminating at Navy SI communications centers (e.g., Ship/Shore, Command/Control, Broadcasts, etc.,) remains active to support designated Navy requirements and has not been integrated into AUTODIN/DSSCS.

High Command (HICOM) Network

The HICOM network provides a voice link between CNO, the Fleet Commanders in Chief, and subordinate commands ashore, afloat and airborne. CNO is the master control station; the FLTCINCS are area network control stations. All NAVCOMMSTAs are members.

In cases where a fleet unit is suffering communications difficulties with normal channels, HICOM can be used on a not-to-interfere basis for restoration coordination, as nearly all NAVCOMMSTAs guard their respective area nets.

Navy Operational Radio and Telephone Switchboard (NORATS)

The NORATS meets the need for an interface between Navy tactical voice systems of the operating forces and the various fixed telephone services ashore, so that the tactical voice can be extended to shore-based operational commands. NORATS provides a common terminal point in the Fleet Center of each communication station where installed for all ship-to-shore voice circuits and all applicable local shore telephone systems and extensions. A combined HICOM/NORATS console exists at certain NAVCOMMSTAs.

TRANSMISSION SYSTEMS

Transmission systems are classed either "narrowband" or "wideband." These terms refer to the bandwidth of a transmission system and the number of channels utilized in transmitting messages—in other words, the information-carrying capacity of a transmission system.

Narrowband transmission systems consist of a group of facilities (or subsystems) whose information-carrying bandwidth is 4 voice channels or fewer. Narrowband systems include high frequency radio (single sideband and independent sideband) and landlines.

Wideband transmission systems consist of a group of transmission facilities having an information-carrying bandwidth of more than 4 voice channels, regardless of transmission means or frequency utilized. Bandwidth and number of voice channels used depend on the type of system. Links carrying 1800 voice channels through a single transmitter and receiver are available. Included in wideband systems are forward propagation tropospheric scatter (FPTS), microwave, and cable systems.

In the past and to a large degree in the present, narrowband systems are (and have been) the main link between communication facilities. Although wideband systems are more desirable than narrowband systems, their usage is limited because of an over-crowded frequency spectrum. As technical advances in equipment and systems are devised and economical use of the frequency spectrum is solved, increased use of wideband systems is expected.

TRANSMISSION OF INFORMATION BY RADIO

To convey a message between distant points a message carrier is required. Since the majority of the Navy's communications is to and from fleet units, the only practical and ideal message carrier for transmitting information to these units is through space by electromagnetic waves, commonly called "radio waves." The speed of transmission through the space medium from the transmitting antenna to the receiving antenna is approximately 186,000 miles per second.

In this section we will discuss how electromagnetic waves are produced, and the process of modulation, by which the message is attached to an electromagnetic-wave message carrier. Later in this manual we will deal with radio wave propagation and antennas.

CARRIER CHARACTERISTICS

The r-f (radio frequency) signal used to transmit intelligence from one point to another is called the carrier. It consists of an electromagnetic wave having amplitude, frequency, and phase. If the voltage variations of an r-f signal are graphed in respect to time, the result is a waveform such as that in figure 5-1. The unmodulated carrier is a sine wave that

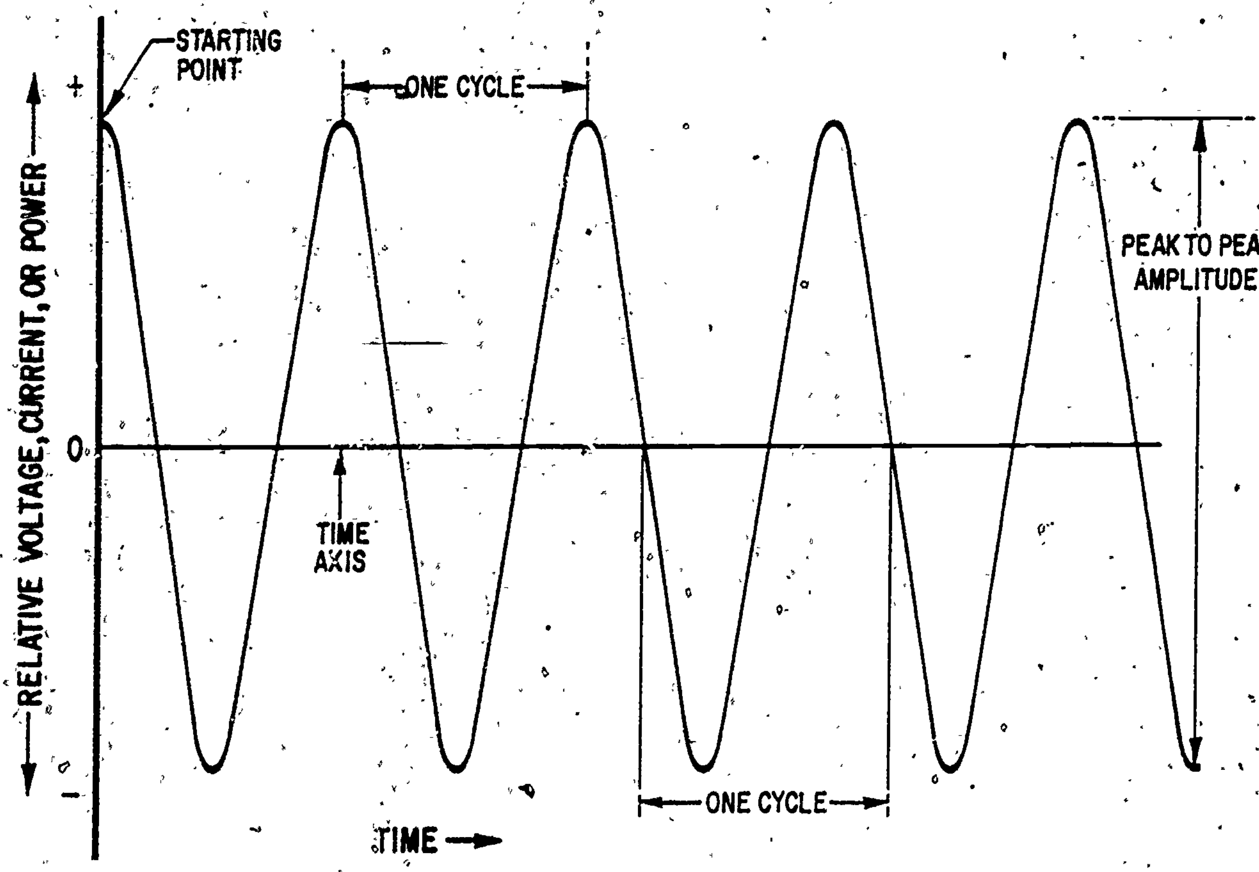

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Figure 5-1.—Graph of Typical Unmodulated Carrier.

repeats itself in definite intervals of time. It swings first in the positive and then in the negative direction about the time axis and represents changes in the amplitude of the wave. This action is similar to that of alternating current in a wire, where these swings represent reversals in the direction of current flow.

Perhaps the simplest approach to an understanding of the sinewave and its characteristics is to consider a rotating vector used to generate a sinewave. In actual practice, sinewaves are generated by electrical devices designed for that purpose.

Assume that a vector, as shown in figure 5-2A, is lying in a horizontal plane and pointing to the right. A line divided into increments representing time lies to the right of the vector.

If the vector in figure 5-2A were rotated, a certain angle would exist between its starting position and its position at any given instant. If the SINE (a trigonometric function not discussed here) of the angles formed by the vector at a series of regular intervals is plotted along the time base, the resultant curve will be in the shape of a sinewave.

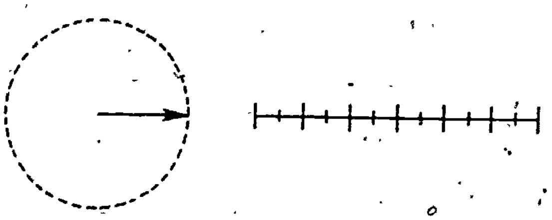

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Figure 5-2A.—A Vector and a Time base.

Looking at figure 5-2B, assume that in one time increment the vector rotates counterclockwise from its rest position at 0 degrees to the 30 degree position. This is plotted along the time base by placing one dot at 0 and other dot above the 1, directly across from the point of the vector to advance another 30 degrees, to the 60 degree position. The new position of the vector is plotted along the time base by placing a dot above the 2, directly across

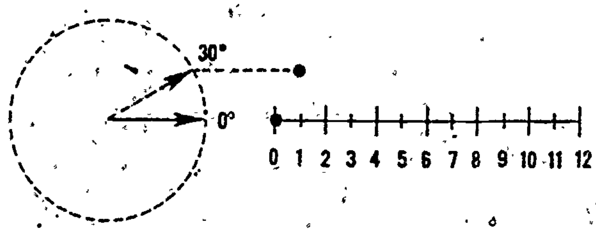

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Figure 5-2B.—Vector after 30 degrees rotation.

from the point of the vector as before. The procedure is repeated for every 30 degrees of rotation until the vector has completed one full revolution of 360 degrees and returned to its original point, as shown in figure 5-2C. A continuous line drawn through the successive points plotted will be in the shape of one repetition of a sinewave: this single repetition is known as one CYCLE of the sinewave. It can be seen that if the time base were extended and a second revolution of the vector plotted there would be two cycles of the sinewave. Note that the 360 degree point of one cycle coincides with the beginning, or 0 degrees, point of the following cycle.

If you study figure 5-2C for a moment, several important characteristics of sinewaves can be seen:

a. Rotating the vector at a constant rate of travel through one 360 degree cycle takes a specific amount of time, equal to the elapsed

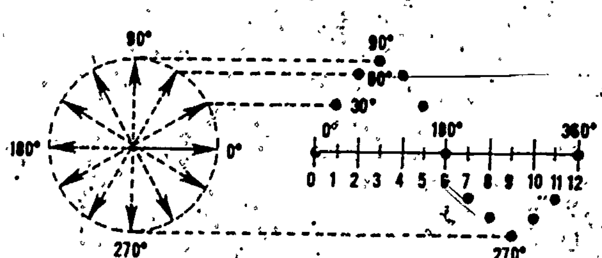

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Figure 5-2C.—Plot of Sinewave after 360 degrees Vector rotation.

time between the beginning and end of one cycle of the resultant sinewave. The time required is referred to as the PERIOD of the cycle. If the vector makes one revolution per second, a cycle of the sinewave will have a period of on second. If the rate of rotation is increased to one thousand revolutions per second, each cycle of the resultant sinewave will then have a period of one-thousandth of a second (one millisecond).

b. The faster the vector rotates the faster sinewaves are generated. The number of cycles that are completed in one second is referred to as the FREQUENCY of the wave. If the vector makes one revolution per second, the completed sinewave has a frequency of one cycle per second (1 Hz). If the rate of rotation is increased to one thousand revolutions per second, the frequency of the sinewave will be one thousand cycles per second (1 kHz).

c. The magnitude of the sinewave, normally some value of voltage or current, can be seen to vary above and below the time base. The value at any given point along the line is called the INSTANTANEOUS AMPLITUDE; the maximum value above or below the line is referred to as PEAK AMPLITUDE. Generally, the value is considered to be positive above the line, negative below the line, and zero at the points equating to 0, 180, and 360 degrees of vector rotation.

d. When it's desired to indicate how much of a cycle has been completed at a given instant, we refer to its PHASE, which is stated in degrees. At time increment 1 in figure 5-2C, there has been 30 degrees of the cycle completed: therefore, the phase is 30 degrees. Likewise at time 2, the phase is 60 degrees, and at time 3 it is 90 degrees. Each of these phase conditions corresponds to the angle between the starting point the vector and its instantaneous position at the time increments stated.

INTRODUCTION TO MODULATION

Simple sinewaves cannot convey information because they do not vary from their normal state. In order to carry information there must be some variation in frequency, phase or amplitude according to the intelligence to be conveyed. Even those waves that contain the necessary variations are useless unless they can be transmitted to their intended destination. When circumstances dictate that intelligence waves reach a distant point without the use of telephone cables, they must be radiated in the form of radio waves.

As produced at their source, information waves are generally of such low frequencies that their wavelengths (wavelength discussed in chapter 7) are too long to be efficiently radiated by practical antenna systems. The frequencies of the human voice encountered on standard broadcast transmissions, for instance, range only from about 100 to 5,000 Hz. The wavelength at 5,000 Hz would be over 37 miles, and at 100 Hz it would be 1863 miles. Obviously, it would not be practical to construct antennas designed to operate at such wavelengths.

The solution to the problem is to translate the information wave up into a higher part of the frequency spectrum where wavelengths are compatible with practical antenna sizes. This frequency translation is accomplished by the process of modulation. Actually the process of varying any one of the three characteristics (amplitude, phase or frequency) is called modulation. Generally, modulation of a carrier is named for the wave characteristic that is altered by the modulation process.

Amplitude Modulation

In amplitude modulation, the peak-to-peak amplitude of the carrier is varied in accordance with the intelligence to be transmitted. For example, the voice picked up by a microphone is converted into an a-f (audio-frequency) electrical signal which controls the peak-to-peak amplitude of the carrier. A single sound at the microphone modulates the carrier, with the result shown in figure 5-3. The carrier peaks are no longer constant in amplitude because they follow the instantaneous changes in the amplitude of the a-f signal. When the a-f signal swings in the positive direction, the carrier peaks are increased accordingly. When the a-f signal swings in the negative direction, the carrier peaks are decreased. Therefore, the instantaneous amplitude of the a-f modulating

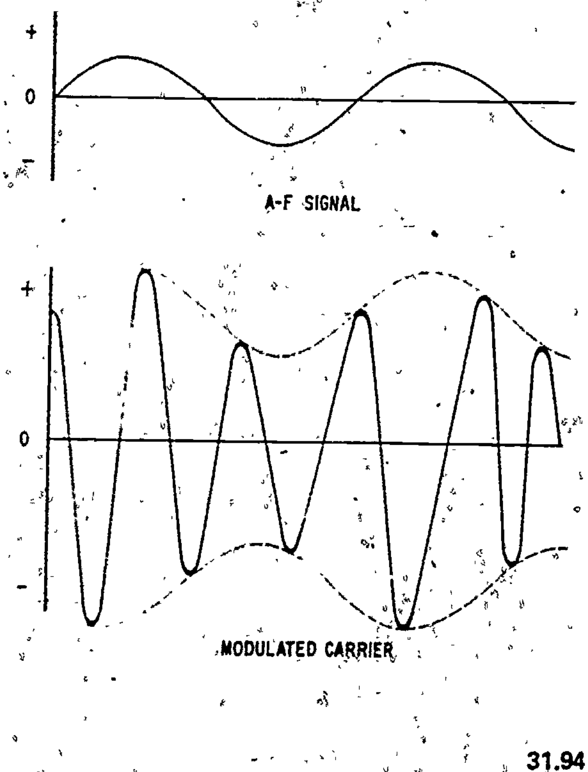

Figure 5-3.—Effect of a-f Signal on Carrier in Amplitude Modulation.

signal determines the peak-to-peak amplitude of the modulated carrier.

Frequency Modulation and Phase Modulation

Besides its amplitude, the carrier wave has two other characteristics that can be varied to produce an intelligence-carrying signal. These are its frequency and its phase. The process of varying the frequency in accordance with the audiofrequencies of voice or music is called frequency modulation (f-m), and the process of varying the phase is phase modulation (p-m). These two types of modulation are closely related. When f-m is used, the phase of the carrier wave is affected. Similarly, when p-m is used, the carrier frequency is affected.

The primary advantages of f-m are improved fidelity and increased freedom from static. Because of these qualities, it is of considerable use in commercial broadcasting, but its shortcomings, including frequency extravagance and short range on available frequencies, have severely limited its naval communication applications. The Navy has, however, found f-m satisfactory for other purposes, among them altimeters and some radars.

SIDEBANDS AND BANDWIDTH

When an r-f carrier is modulated by a single audio note, two additional frequencies are produced. One is the upper frequency, which equals the sum of the frequency of the carrier and the frequency of the audio note. The other frequency is the lower one, which equals the difference between the frequencies of the carrier and the audio note. The one higher than the carrier frequency is the UPPER SIDE FREQUENCY; the one lower than the carrier frequency is the LOWER SIDE FREQUENCY. When the modulating signal is made up of complex tones, as in speech or music, each individual frequency component of the modulating signal produces its own upper and lower side frequencies. These side frequencies occupy a band of frequencies lying between the carrier frequency, plus and minus the highest modulating frequency. The bands of frequencies containing the side frequencies are called SIDEBANDS. The sideband that includes the sum of the carrier and the modulating frequencies is known as the UPPER SIDEBAND (USB). The band containing the difference of the carrier and the modulating frequencies is known as the LOWER SIDEBAND (LSB). The space a carrier and its associated sidebands occupy in a frequency spectrum is called a channel. The width of the channel (called BANDWIDTH) is equal to twice the highest modulating frequency. For example, if a 5000-kc carrier is modulated by a band of frequencies ranging from 200 to 5000 cycles (0.2 to 5 kc), the upper sideband extends from 5000.2 to 5005 kc, and the lower sideband extends from 4999.8 to 4995 kc. The bandwidth is then 4995 to 5005, or 10 kc. The bandwidth is twice the value of the highest modulating frequency, which is 5 kc. This is illustrated in figure 5-4.

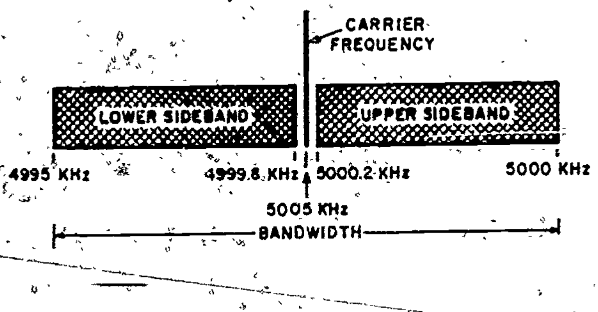

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Figure 5-4.—Sidebands Produced by Amplitude Modulation.

Single Sideband

A mode of radio emission that has become increasingly important to the communicator is single sideband (SSB). Single sideband is not a new term in the history of communications. It has been used extensively by the shore communication system for many years. The congestion in the medium and high frequency bands and recent developments that have reduced the physical sizes of equipments have given a new impetus to the advantages of using SSB in fleet communications.

Following is a brief introduction to the technique of SSB.

In our study of sidebands, we learned that modulation of the carrier produces a complex signal consisting of three individual waves: the original carrier, plus two identical sidebands, each carrying the same intelligence. Naturally, this appears to be an uneconomical means of transmission. By eliminating the carrier and one of the sidebands, the same intelligence can be transmitted at a saving in power and frequency bandwidth.

Suppressed Carrier

In SSB, the carrier itself is suppressed (or eliminated) at the transmitter, so that sideband frequencies are produced but the carrier is reduced to a minimum. This reduction or elimination usually is the most difficult or troublesome aspect in understanding SSB suppressed carrier. In single sideband suppressed carrier, there is no carrier present in the transmitted signal. It is eliminated after modulation is accomplished, and reinserted at the receiver for the demodulation process. All r-f energy appearing at the transmitter output is concentrated in the sideband energy or "talk power."

After eliminating the carrier, the upper and lower sidebands remain. If one of the two sidebands is filtered out before it reaches the power amplifier stage of the transmitter, however, the same intelligence can be transmitted on the remaining sideband. All power is then transmitted in one sideband, instead of being divided between the carrier and both sidebands, as in conventional a/m. This provision amounts to an increase in power for the wanted sideband. Equally important, the bandwidth required for SSB voice circuits is approximately half that needed for conventional a/m. (See figure 5-5).

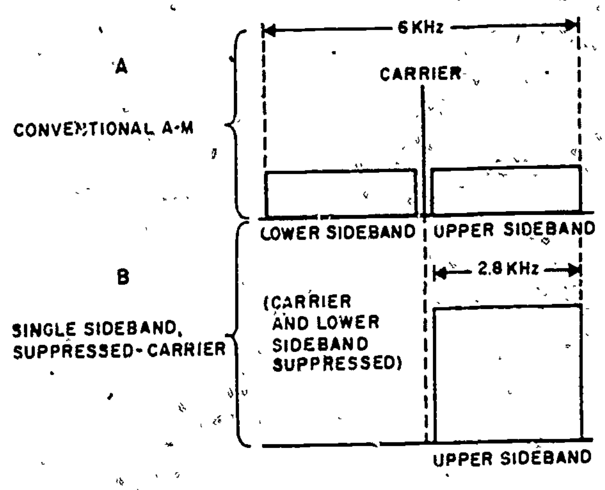

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Figure 5-5.—Comparison of Bandwidths of Conventional a-m and SSB Voice Channels.

SINGLE SIDEBAND TRANSMISSION

Single sideband (SSB) transmission is the most common communications link used today. Some of the SSB application in naval communications is described in the following paragraphs.

SSB Voice Circuits

The high command (HICOM) net uses SSB as a means of communication between fleet commanders, and fleet commanders use it for communication with their subordinates and adjacent commands.

Whenever special voice circuits are necessary, either between shore activities or ships and shore activities, SSB is selected because it is less susceptible to atmospheric interference than is amplitude modulation. Often, SSB is used for voice order-wire circuits between NAVCOMMSTAs.

SSB Teletype Circuits

With few exceptions, SSB is used on all existing long-haul (great distance) teletype circuits. It is also used on ship-shore circuits, as well as on ship-shore teletype circuits. Most of these systems are now covered circuits; that is, an electronic cryptodevice on both ends of the circuit automatically encrypts and decrypts message traffic. These devices are used on point-to-point, ship-shore, ship-ship and broadcast circuits.

POINT-TO-POINT TELETYPE CIRCUITS.–Most point-to-point, long haul circuits between naval communication stations need more channels than SSB can provide. To compensate for the deficiency, independent sideband (ISB) transmission is used. It is similar to SSB. But where SSB suppresses the carrier and filters out a sideband, in ISB only the carrier is suppressed. Both sidebands are used, and are split into two 3-kHz audio channels, as shown in figure 5-6. Each audio channel may carry different intelligence.

The use of frequency division multiplex equipment (discussed in chapter 9) permits 16 teletype channels to be put into each of the 3-kHz audio channels, giving a possible total of 64 teletype channels on one ISB circuit. Usually, only one or two audio channels are available for voice and/or facsimile, depending on the needs of participating stations.

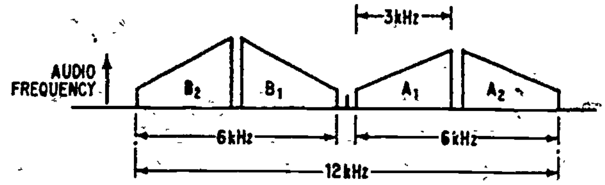

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Figure 5-6.–Radiofrequency-ISB Channel and Frequency Bandwidth.

SHIP-SHORE SSB TELETYPE CIRCUITS.–Many ships handle enough message traffic to justify ship-shore teletype circuits. Depending on traffic load, these circuits can be from one to four teletype channels on one SSB circuit. If the traffic load warrants more than one teletype channel, usually time division multiplex or frequency division multiplex (MUX) equipment is used. This equipment handles up to four incoming and four outgoing channels. One channel normally is used as an order-wire circuit for handling operator-to-operator service messages and for making frequency changes when necessary. Three remaining channels are available for handling official message traffic.

SHIP-SHIP SSB TELETYPE CIRCUITS.–Ship-to-ship SSB teletype circuits are in wide use today. Their main application is with task force or task group nets or several ships in company. By using this type of net, ships can send their outgoing messages to a guardship from which traffic can be relayed ashore. This procedure saves manpower and circuit time, prevents individual ships from overcrowding ship-shore circuits and conserves the frequency spectrum. Depending on the number and types of ships in company, the guard can be shifted to other ships from time to time. A major advantage of these circuits is that electronic cryptodevices can be used to send classified messages without the need for manual encryption. These circuits are used for incoming as well as outgoing traffic, and they can use either HF (high frequency) or UHF (ultra high frequency) signals.

MICROWAVE TRANSMISSION

Microwave is a line-of-sight radio transmission system. Line-of-sight systems are made up of one or more links having a clear path between antennas at the ends of a link. Usually frequencies used are above 900 mHz. In the Naval Communication System, three equipments currently in use are the UQ, operating between 1700 and 1850 mHz; AN/FRC-37 system, operating between 1700 and 2400 mHz; and AN/FRC-84 system, operating between 7125 and 7750 mHz. Wideband transmission, suitable for 24 to 600 voice channels, has been obtained by proper system planning.

Terrain determines the length of a single link. In actual practice, transmit and receive antennas can be separated by a slightly greater distance than the actual horizon-to-horizon line-of-sight distance, due to refraction of the microwave-beam by the atmosphere. Most systems are composed of links of 30 miles or less, except where especially favorable sites can be found. Repeater stations may be used to connect one link to another to form long chains, thereby setting up long paths for many voice channels where needed. Chains of more than 40 links, for example, cross the United States carrying voice, teletype and television signals.

Microwave links are often used for carrying signals from a portion of a naval communication station to another; from and to the transmitter and receiver sites to the main station, for example.

Microwave radio link systems have the advantage of greater flexibility, economy of operation, and almost complete independence over weather conditions. They have excellent reliability (over 99 percent), extremely wide information-carrying bandwidth, good resistance to interference, and low power requirements. Limitations are that they require a relatively large portion of the frequency spectrum, and are effective at only a short range.

Usually microwave radio is used where large channel capacity is required, links are relatively short; and where it is more difficult or costly to install cable.

SCATTER TRANSMISSION

Forward propagation scatter transmission is a point-to-point method of HF or UHF radio communications. It permits reliable multichannel telephone, teletype, and data transmission out to a range of 400 miles.

Two types of scatter systems that have been used are ionospheric and tropospheric. Because of greater capacity and reliability, only the tropospheric system is now being used.

Forward Propagation Ionospheric Scatter (FPIS)

Forward propagation ionospheric scatter (FPIS), a system using HF range, utilizes SSB or ISB. A transmitted signal is beamed at the ionosphere where it is scattered in a forward direction. A receiving antenna is beamed at the same point in space to receive the signal. Because of its limited bandwidth, relative highpower requirements, and crowded HF spectrum, this system is not used.

Forward Propagation Tropospheric Scatter (FPTS)

Numerous communication networks now in operation, extending for thousand of miles, utilize "tropo" terminals with hops of 300 miles or more. These relay hops are accomplished by using both transmitting and receiving equipment and antennas at each terminal. At the initial transmitting point, many separate telephone conversations and teletype circuits are combined into a single radio signal. A feedhorn in a tower beams the signal out toward the horizon, and thus is similar to a huge, precisely aimed searchlight. A minute reflected portion of the signal is picked up by a parabolic receiving antenna well over the horizon. There it is reamplified and sent on its way again, if necessary, for another leap over the horizon toward its destination at the other end of the circuit.

Tropo has many advantages over other methods of long-distance communications. Besides greater economy in areas where construction and maintenance present problems, it is relatively free of atmospheric interferences that affect other transmission methods.

The number of channels that can be transmitted over a given link depends on the degree of distortion the particular circuit can accept. For links that are part of long-haul telephone systems, distortion must be held to a minimum. Typical tropospheric scatter link capacities are given in the accompanying list.

Distance	No. voice channels
0-100 miles	To 252
100-200 miles	To 132
200-300 miles	To 72
Over 300 miles	12-24 (quality usually limited)

LANDLINES

Almost all landlines used by the Navy are leased. When it is determined to link one place with another, the telephone company serving the area is notified regarding the type of circuit and kind of service desired.

Depending on the type of installation, these circuits may either be d-c lines or audio lines. Patching usually is accomplished at a control center of a Navy communication station or in the communication control link (CCL) of a tributary station.

DIRECT CURRENT (D-C) LANDLINES

These lines are used for controlling different types of equipment, such as keying a transmitter, and for short-haul teletype circuits. In some instances they are used as secondary or backup circuits for primary microwave circuits that link different sites of a naval communication station. Some tributary stations of a NAVCOMMSTA may have d-c landlines as their primary teletype circuit and also may have them for remote keying COMMSTA transmitters.

AUDIOFREQUENCY LANDLINES

Audiofrequency landlines (as they appear in a CCL) are pairs of wire used for handling tone teletype equipment. One pair of lines is capable of carrying up to 16 teletype channels. Because these lines are engineered to handle a 3-kc bandpass at audiofrequencies, they are considered to be in the narrowband system.

LEASED LINES AND CIRCUITS

Telephone companies use many types of circuits and systems in handling their vast telephone and telegraph network. Each circuit is engineered to meet specifications of individual users. In general, these circuits and systems can be classified as landline types, two-wire and four-wire circuits, audio systems, and carrier systems.

Landline Types

Landline systems that carry various circuits are further broken down into four types of lines: open wire, wire cable pairs, coaxial cable, and submarine cable. All four of these lines are capable of handling all circuits and systems in use today.

WIRE CABLE PAIRS.—Use of cables came about because of unsightly congestion resulting from overhead wires, especially in cities. Underground wire cables are less vulnerable to storms and other weather conditions. During wartime they also are less susceptible to sabotage and enemy attack.

Wire cables are made up of many pairs of wires insulated in such a way as to prevent crosstalk between various circuits in the cable.

COAXIAL CABLE.—Today, nearly 30 percent of all communication services flow over a coast-to-coast coaxial cable network. This percentage is destined to increase in the future, along with usage of its newer companion, microwave (discussed later). Together, they will replace older open-wire and cable circuits. Coaxial cable falls into the wideband group of communications systems.

Modern coaxial conductors are constructed chiefly of 3/8-inch copper tubing. Exactly in the center, a No. 10 gage copper wire is held by small plastic disk insulators spaced about 1 inch apart. Both the outer conducting tube and the wire have the same center or axis, hence the name coaxial. In some types of coaxial conductors, insulation between these two conductors is made of a solid dielectric material.

Coaxial conductors are made up into cables, with eight or more coaxials arranged in a tight ring. Also contained within the cable is a number of paper or polyethylene-insulated wires used for control, maintenance, and short-distance communications. Air or nitrogen gas is introduced under pressure into coaxial cable in spaces between tubes and wires. The air or gas keeps out moisture and also aids in detecting any damage that may occur to the cable.

SUBMARINE CABLE.—Because submarine cable now reaches almost every continent, it is possible to contact nearly every part of the world without using radio as a link. Until 1956 existing telegraph cables could not carry voice circuits. Since 1956 several cables have been laid that can carry up to 128 voice channels.

The first telephone cable had external armor for strength and protection, and its flexible one-way amplifiers or repeaters were spaced about 40 miles apart. Power for these repeaters was fed from terminals. Improvements in this system increased its capacity from 36 to 48 circuits.

A newer type of cable and improved amplifiers brought circuit capacity up to 128 circuits. New cable, constructed in a manner that makes it stronger, employs two-way amplifiers spaced about 20 miles apart.

The various kinds of line facilities and apparatus described so far are, in practice, applied to developing several distinct types of long-distance circuits. Such circuits may be broadly classified as between those operating at voice frequencies and circuits that operate at higher (carrier or radio) frequencies. In the former group are ordinary two-wire circuits, which employ a single pair of open-wire cable conductors as their transmitting medium, or as is the general practice with most local and shorthaul service. These two-wire circuits are comparable to simplex or half-duplex circuits. The voice frequency group also includes the four-wire cable circuits in which a separate pair of cable conductors is used for transmission in each direction. These four-wire circuits can be compared to the Navy's full duplex circuits.

Except where coaxial cable is used, carrier circuits employ the same (or similar) kinds of wire facilities for transmission as do voice frequency circuits. Both circuits must have amplifiers or repeaters at regular intervals along the line.

It is impossible to make an unqualified statement concerning particular situations in which each type of circuit may be best applied in practice. In general, however, two-wire circuits commonly are used for relatively short distances—not more than a few hundred miles. Four-wire cable circuits are for somewhat longer distances. Landline carrier or microwave circuits ordinarily are utilized for longest distances, although their use is not limited to such application.

AUDIO SYSTEMS.—Audio systems used by telephone companies can be compared to audio lines terminating in a CCL. Each pair of lines carries a telephone conversation at the frequency of the participants, i.e., audiofrequency. By using terminal equipment, twelve 100-wpm teletype circuits can be put on one voice or audio channel.

An early development called a phantom circuit was used on open-wire lines. It enabled use of three circuits on one pair of lines. A key to proper operation of a phantom group is the precision with which line wires and coils are balanced. Any unbalance permits currents from side circuits to leak into the phantom (and vice versa). These unwanted currents make circuits noisy. In severe cases, they actually allow a conversation on one circuit to be heard on others. This phenomenon is called crosstalk.

CARRIER SYSTEMS.—Carrier systems used by telephone companies are carrier frequencies that are modulated by information to be transmitted. Various modulation means used that you are already familiar with include:

amplitude modulation (a-m) and frequency modulation (f-m).

When carrier systems were first used, cost of equipment and installations was high. For economy of use, therefore, it had to be used on long circuits, where equipment costs were less than the price of additional wires on the line.

As new techniques were developed and better equipment was built, the number of carrier systems increased. They were progressively used for shorter distances.

Many types of carrier systems are in use today. The time division multiplex process and frequency division multiplex equipment used on these carrier systems are similar to systems used by the Navy. Chapter 9 of this manual describes the complete process of time division and frequency division multiplex.

CHAPTER 6

SATELLITE COMMUNICATIONS

Experience with satellite communications has demonstrated that such systems can satisfy many military requirements for reliable, survivable, secure and cost effective telecommunications. It is almost obvious that satellites are the ideal, if not often the only solution to problems of communicating with highly mobile forces deployed worldwide. And we must not forget that satellites, if properly used, provide the sorely needed geographically independent alternate to large, fixed ground installations.

For the past fifty years, the Navy has primarily used high frequency (HF) transmission as the principal method of sending messages. In the 1970's, an era when the HF spectrum is overcrowded, when "free" frequencies are at a premium, and when HF jamming techniques are highly sophisticated, the need for new and advanced long-range transmission methods becomes readily apparent.

Communications via satellite is a natural outgrowth of modern technology and the continuing demand for greater capacity and higher quality communications. Relatively recent technical developments have made satellite communications possible.

Although the communications facilities of the various military departments have generally been able to support their requirements in the past, predictable requirements indicate that large-scale improvements will have to be made to satisfy future needs of the Department of Defense. The usage rate of both commercial and military systems has increased by at least ten percent per year over the past fifteen years, and there appears to be general agreement that this trend will continue at an accelerated rate. Centralized control of military operations, with its accompanying reliability and security requirements, has generated demands for communications with greater capacity and for long-haul communications to previously inaccessible areas. Some of these requirements can be met only by sophisticated modulation techniques and wideband, long-distance transmissions for which satellite communication is the most promising means.

DEFENSE COMMUNICATION SATELLITE PROGRAM (DCSP)

The Defense Communication Satellite Program (DCSP) was initiated by the Secretary of Defense in 1962 as an outgrowth of the Advent Program. Phase I of the program was given the title, "Initial Defense Communication Satellite Program" (IDCSP). The first satellite launch occurred in June 1966 when seven IDCSP and a gravity gradient experimental satellite were injected into random, near synchronous orbits by a single Titan III C booster. A total of 26 IDCSP satellites have been placed into orbit. The final launch consisting of eight IDCSP satellites, occurred in June 1968. As of December 1972, fourteen IDCSP satellites were still operational.

DEFENSE SATELLITE COMMUNICATION SYSTEM (DSCS) PHASE II

The Phase II Defense Satellite Communication System (DSCS PHASE II) will, over a period of time, evolve from an initial, basically all-analog communications system to an all-digital communications system. The performance capability provided by the Phase II

DSCS will vary as a function of equipment availability; that is, an extensive digital traffic capability will not be available until digital modems and baseband equipments are available. However, the overall performance of the Phase II DSCS will be greatly enhanced over the capability provided in the IDCSP (or PHASE I DSCS) through the use of the new PHASE II satellites. These satellites provide a greatly increased effective radiated power (ERP) and RF bandwidths, together with a highly flexible satellite configuration using both earth coverage and narrow beam antennas to provide a wide range of communication services and capabilities. In addition, these PHASE II satellites are deployed in synchronous orbits which eliminates the problems that currently exist with the drifting nonsynchronous PHASE I satellites.

BASIC SATELLITE COMMUNICATION SYSTEM

A satellite communication system is one that uses earth orbiting vehicles or satellites to relay radio transmissions between earth terminals. There are two types of communication satellites: active and passive. A passive satellite merely reflects radio signals back to earth. An active satellite, on the other hand, acts as a repeater; it amplifies signals received and then re-transmits them back to earth. This increases the signal strength at the receiving terminal compared to that available from a passive satellite.

A typical operational link involves an active satellite and two earth terminals. One station transmits to the satellite on a frequency called the up-link frequency, the satellite amplifies the signal, translates it to the down-link frequency, and then transmits it back to earth where the signal is picked up by the receiving terminal. This basic concept is illustrated by figure 6-1.

DESCRIPTION OF COMMUNICATION SATELLITE SYSTEM

The basic design of a satellite communication system depends to a great degree upon the parameters of the satellite's orbit. In general terms an orbit is either elliptical or circular and its inclination is classified as inclined, polar or equatorial. A special type of orbit is a synchronous orbit, one in which the period of the orbit is the same as that of the earth. An orbit which is not synchronous is called asynchronous, with a further subidentification of a near synchronous type in which the period of orbit approaches that of the earth. Orbits are discussed in more detail later in the succeeding paragraphs.

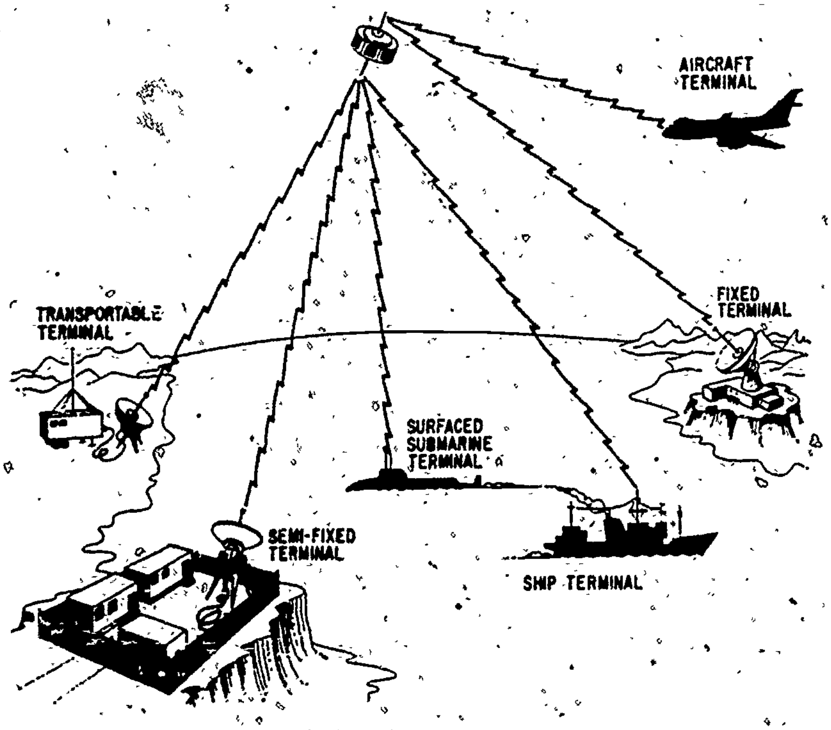
The essential basic system components of an operational communication satellite system are (1) an orbiting vehicle with a communication receiver and transmitter installed and (2) two earth terminals equipped to transmit signals to and receive signals from the satellite. The design of the overall system determines the complexity of the various components and the manner in which the system operates. With the present operational military communication satellite system only two earth terminals can use a satellite at one time, and this has led to the establishment of satellite scheduling or control facilities.

ORBIT DESCRIPTIONS

As stated previously, orbits generally are described according to the physical shape of the orbit and the angle of inclination of the plane of the orbit.

a. Physical Shape. All satellites orbit the earth in elliptical orbits that are determined by the initial launch parameters and the later deployment techniques used. (A circle is a special case of an ellipse.) The path of any satellite has the earth located at one of its foci as shown in figure 6-2.

Perigee and apogee are two of the three parameters customarily used to describe orbital data of a satellite. Perigee is defined as the point in the orbit of a satellite that is nearest to the center of the earth. Apogee is defined as the point in the orbit of a satellite at the greatest distance from the center of the earth.



31.95

Figure 6-1.—Satellite communication system.

Both distances usually are expressed from the surface of the earth in statute miles, although nautical miles usually are used for military systems.

b. Angle of Inclination. The angle of inclination is the third parameter customarily used to describe orbital data of a satellite. Most satellites orbit the earth in orbital planes which do not coincide with the earth's equatorial plane. A satellite orbiting in any plane not identical with the equatorial plane is in an inclined orbit.

The angle of inclination is the angle between the equatorial plane and the orbital plane as shown in figure 6-3.

The inclination of the orbit determines the geographic limits of the projection of the path of the satellite over the earth's surface. The greater the inclination, the greater the amount of the earth's surface that is covered by the satellite. This is shown graphically in figure 6-4.

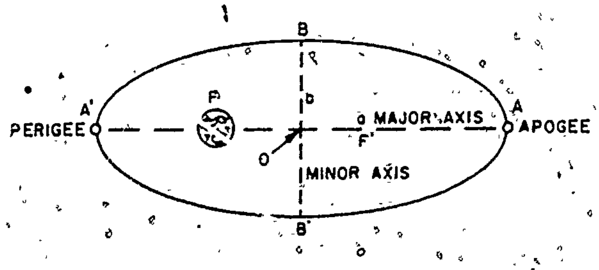


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Figure 6-2.—Elliptical satellite orbit.

c. Special Types of Inclined Orbits.

(1) Equatorial Orbit. A satellite orbiting in a plane that coincides with the earth's equatorial plane is in an equatorial orbit.

(2) Polar Orbit. A satellite orbiting in an inclined orbit with an angle of inclination of 90 degrees or near 90 degrees is in a polar orbit.

d. Circular Orbits. A circular orbit is a special type of elliptical orbit in which the major and minor axis distances are equal or

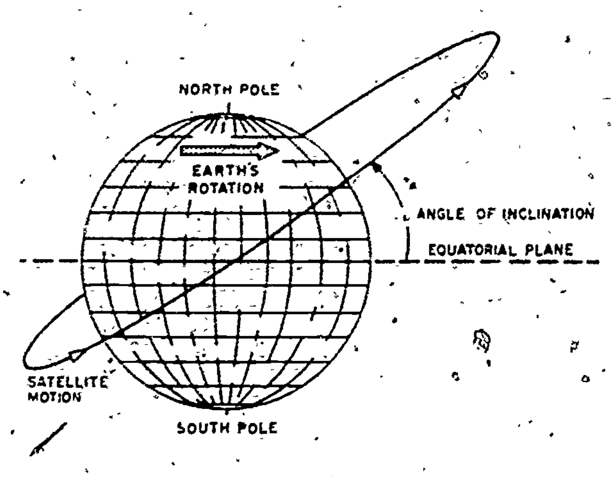

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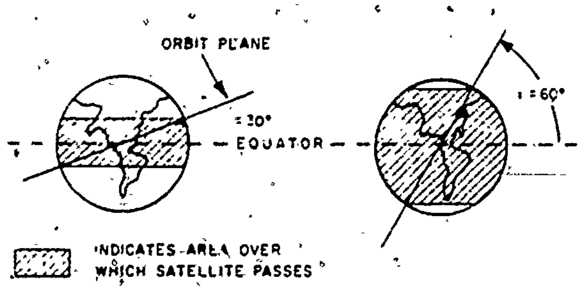
Figure 6-3.—Inclined satellite orbit.

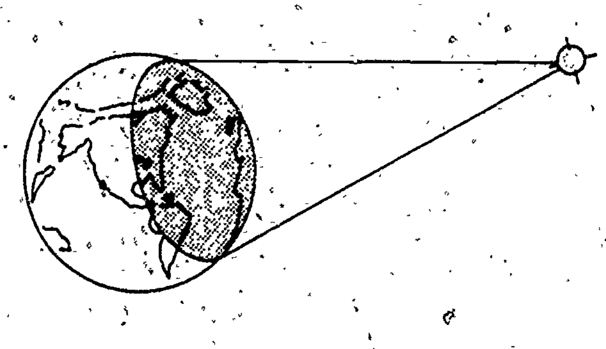


31.98
Figure 6-4.—Effect of orbit plane inclination on satellite coverage.

approximately equal. Mean height above earth, instead of perigee and apogee, is used in describing a circular orbit.

e. Special Types of Circular Orbits.

(1) Synchronous Orbit. A satellite in a circular orbit at a height of approximately 19,300 nautical miles above the earth is in a synchronous orbit. At this altitude the satellite's period of rotation is 24 hours, the same as the earth's, and the satellite orbits in synchronism with the earth's rotational motion. Although inclined and polar synchronous orbits are possible, the term synchronous, as commonly used now, refers to a synchronous equatorial orbit. In this type of orbit, satellites appear to hover motionlessly in the sky. Figure 6-5 shows



31.99
Figure 6-5.—Illumination from a synchronous satellite.

how one of these satellites can illuminate almost one-half of the earth's surface.

Three of these satellites can provide coverage over most of the earth's surface (except for the extreme north and south polar regions). A polar projection of the global coverage of such a three-satellite system is shown in figure 6-6.

(2) Near Synchronous Orbit. A satellite in a circular orbit within a few thousand miles of 19,300 nautical miles above the earth is in a near synchronous orbit. If the orbit is lower than 19,300 nautical miles, the satellite's period is less than the earth's and the satellite appears to be moving slowly around the earth from west to east. (This type of orbit is also called sub-synchronous.) If the orbit is higher than 19,300 nautical miles, the satellite's period is greater than the earth's and the satellite appears to be moving slowly around the earth from east to west. Although inclined and polar near synchronous orbits are possible, common usage of the term near synchronous implies a near synchronous equatorial orbit.

(3) Medium Altitude Orbit. A satellite in a circular orbit from approximately 2000 miles to 12,000 miles above the earth is considered to be in a medium altitude orbit. The period of a medium altitude satellite is considerably less than that of the earth, causing such satellites to appear to move rather quickly across the sky from west to east.

SATELLITE CHARACTERISTICS

Early communication satellites were limited to the diameter of the final stage of the rocket

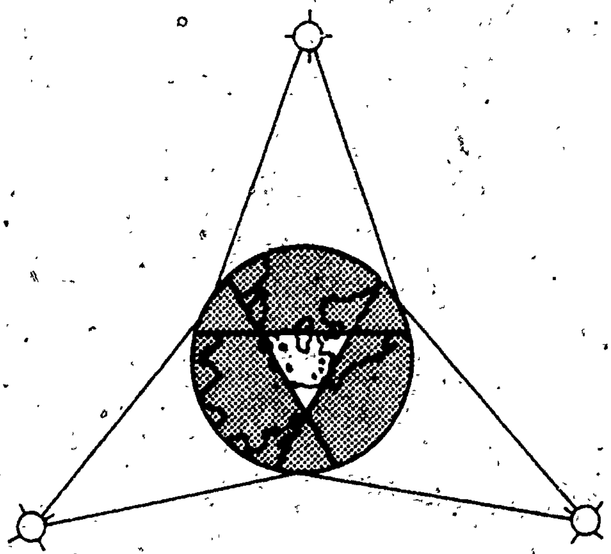


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Figure 6-6.—Worldwide synchronous satellite system viewed from above North Pole.

that was to be used for launching. Similarly, the weight was determined by the thrust of the rocket motors and the maximum weight that the rocket could lift into the desired orbit.

As early as June 1960, two satellites were successfully placed in orbit by the same launch vehicle. With the development of this multi-launch capability, additional flexibility was made available in the design options as to size, weight and number of satellites to be included in each launch.

The Phase II Defense Satellite Communication System (DSCS) will have larger and heavier satellites in synchronous equatorial orbits. Present planning indicates that two of these Phase II satellites will be injected into orbit from a single launch. Figure 6-7 is a drawing of the Phase II satellite.

Satellite Power Sources

Early communication satellites were severely limited by the lack of suitable power sources; this, in turn, severely limited the output power of the satellite transmitter. The only source of power available within early weight restrictions was a very inefficient panel of solar cells without battery backup. A major disadvantage of this type of power source is that the satellite has no power when the satellite is in eclipse. For continuous communications, this outage is unacceptable.

A combination of solar cells and storage batteries is a better prime power source for satellites. This is a practical choice at this time, even though the result is far from an ideal power source. About ten percent of the sunlight energy converging on the solar cells is converted to electrical power. Even this low efficiency is further decreased when the solar cells are bombarded by high-energy particles that are sometimes encountered in space.

The IDCSP satellites have over 8500 solar cells mounted on the surface of the satellite. Initially these cells supplied about 42 watts. No battery backup was provided.

The Phase II DSCS satellites will have about 32,000 solar cells, initially supplying about 520 watts, mounted on the surface of the satellite. A nickel cadmium battery will be used for backup power during eclipses.

Although numerous nuclear power sources have been used in space for special purposes, the state of the art has not progressed sufficiently for nuclear power sources to be competitive with the solar cell-battery combination for synchronous communication satellites. With solar cells exposed to the sun continuously (and battery backup for eclipses), the solar cell-battery installations will be lighter in weight, more efficient and less costly than existing nuclear power sources.

Satellite Orientation

Satellite orientation in space is quite important for two reasons: continuous solar cell orientation and continuous antenna orientation. Since the primary source of power in most satellites is from solar cells, it is essential that the maximum number of the solar cells be exposed to the sun at all times. Moreover, for useful communications, the satellite antenna must be visible to appropriate earth terminals. Early communication satellites used spin stabilization to meet these important requirements.

Spin stabilization operates on the principle that the direction of the spin axis of a rotating

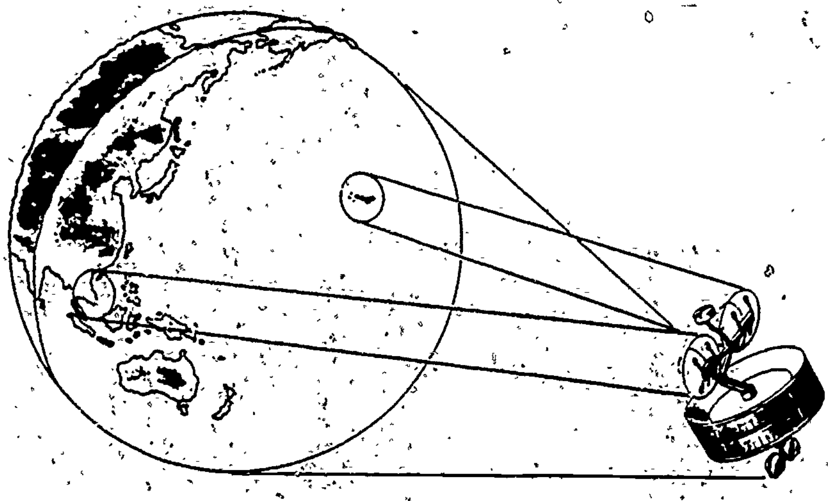

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Figure 6-7.—Phase II DSCS Satellite.

body tends to remain fixed in space. A natural example of spin stabilization is the effect of the earth's rotation in keeping its axis fixed in space. A satellite having a spin axis parallel to the earth's axis will maintain this position since both axes are fixed in space. Figure 6-8 illustrates the use of this principle with an equatorial orbit satellite to keep a doughnut-shaped antenna pattern pointing toward the earth.

Spin stabilization requires virtually no additional energy, once the system is in motion. A spin-stabilized satellite is usually constructed like a flywheel with the heavier equipment mounted in the same plane and as close to the outside surface as possible.

After orbital injection, the radial jets are pulsed to initiate spinning. The satellite spin axis is oriented to the earth's axis by means of the axial jets, which are pulsed at the proper spin phase. The velocity jets, pulsed at the proper spin phase, provide orbit position and velocity correction. (See fig. 6-9.)

By installing solar cells all around the outside surface of the spin-stabilized satellites a large number of solar cells is exposed to the sun at all times (except when the satellite is in eclipse). By installing antennas that radiate in all directions around the spin axis a small part of the total radiated energy is directed toward the earth at all times.

The Phase I "IDSCS" satellites are spin stabilized, as described above. They utilize solar cells mounted on the outside surface of the

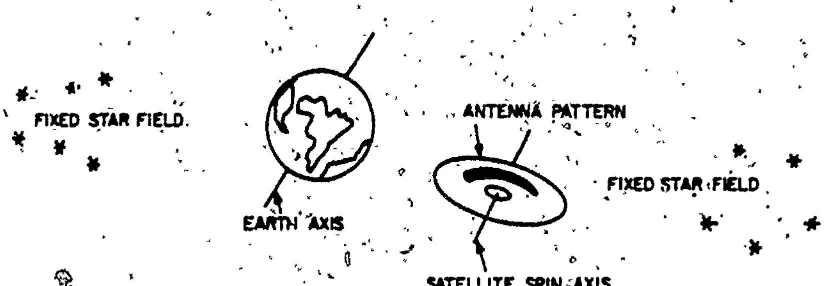

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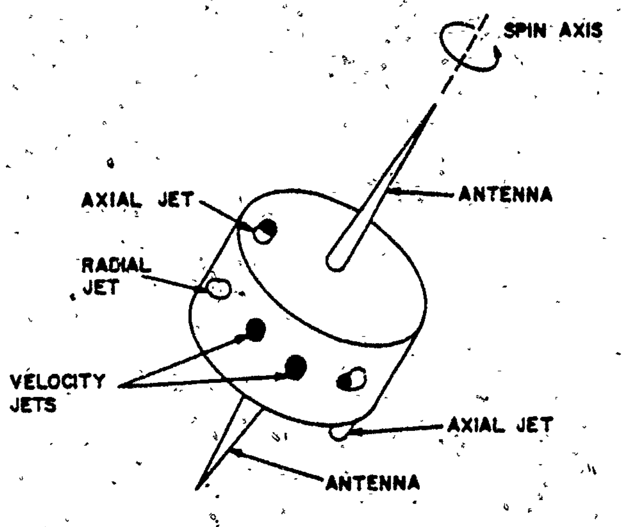
Figure 6-8.—Spin-stabilized satellite antenna pattern.



31.103
Figure 6-9.—Spin-stabilized satellite controls.

satellite and have two omnidirectional antennas installed around the spin axis.

In an effort to overcome the disadvantage of omnidirectional antennas, which radiate only a small amount of energy toward the earth, various techniques to achieve an earth-oriented antenna system have been developed and the most promising have been tested in space vehicles. The best system developed to date uses spin stabilization for orientation of the satellite with a despun inner platform for mounting controllable antennas. The satellite is constructed in two parts with both parts having radial jets. The inner part is concentric with the outer part and contains the communication antennas and the communications package. The satellite is launched and injected into orbit in the usual manner. The whole satellite is spin stabilized using the outer radial jets. After the satellite is stabilized with the desired orientation, the inner radial jets spin the inner part in the opposite direction to counter the initial spin. This results in a despun inner platform, which is stationary with respect to earth. The despun platform is oriented to such a position that the communication antennas point continuously toward the earth. This arrangement allows the use of high gain directional antennas to concentrate the majority of the radiated energy in the direction of the earth.

The Phase II DSCS satellites will use a despun platform with four high gain antennas. Two steerable narrow beam antennas will be used for communications between and within regions of high traffic density. Two horn antennas will provide for earth communications between facilities outside the narrow beam coverage. The antenna arrangement proposed for the Phase II satellites is shown in figure 6-7.

EARTH TERMINAL CHARACTERISTICS

Communication satellite earth terminals generally are located in areas remote from the actual users of these communications. This is necessary to minimize RF interference to the satellite communications. Characteristic of this remoteness is a need for interconnect links to permit communication flow to and from the users of the satellite systems. These interconnect links are usually via telephone cables or microwave radio with normal terminal equipments.

Earth terminals generally have a single large antenna, a highly sensitive receiver, a powerful transmitter, multiplex equipment, modulating-demodulating equipment, and telemetry equipment.

Antennas

Earth terminal antennas are highly directional, high gain antennas capable of transmitting and receiving signals simultaneously. Generally, large, high gain, parabolic antennas are used.

Three sizes of parabolic-type antennas are currently in use with the Phase I IDSCS earth terminals: the AN/FSC-9 uses a parabolic antenna 60 feet in diameter; the AN/MSC-46 uses a parabolic antenna 40 feet in diameter; and the AN/TSC-54 uses a cluster of 4 parabolic antennas, each 10 feet in diameter, which in combination are equivalent to a parabolic antenna 18 feet in diameter.

Receivers

All satellite communication earth terminals are equipped with specially designed, highly sensitive receivers. These highly sensitive receivers are required to overcome the down-link power limitations and to permit extraction of the desired communication information from the received signal. All of the terminals currently in use in the Phase I IDSCS system utilize specially designed preamplifiers mounted directly behind the antennas. The preamp noise temperatures vary with the sizes of the earth terminals.

Transmitters

All earth terminal transmitters generate high power signals for transmission to the communication satellites. The combination of high powered transmitters and highly directional, high gain antennas is necessary to overcome the up-link limitations and to ensure that the signals received by the satellite are strong enough to be detected by the satellite. Although various arrangements of functional components are possible in transmitters, all the transmitters in use in the Phase I IDSCS earth terminals have the same general arrangements. Each IDSCS transmitter has an exciter/modulator and a power amplifier. The modulator accepts the baseband input from the terminal equipment and modulates an IF carrier. The exciter translates the IF signal to the up-link frequency and amplifies it to the level required by the klystron of the power amplifier. The output power of the AN/FSC-9 is variable from 10 W to 20 kW: that of the AN/MSC-46 is variable from 100 W to 10 kW; and that of the AN/TSC-54 is variable from zero to 5 kW.

Telemetry Equipment

Telemetry equipment is included in all communication satellite systems to permit monitoring of the operating conditions within the satellite Telemetry can be used also for remote control of satellite operations such as energizing axial jets for changing the spin axis of the satellite. In the Phase I IDSCS system telemetry information is transmitted in the 400-MHz band and is the responsibility of the Air Force. (A normal Navy earth terminal will not have a 400-MHz capability.)

General Description of DSCS Earth Terminals

There are three types of earth terminals currently in use in the DSCS: AN/FSC-9, AN/MSC-46, and AN/TSC-54. The two AN/FSC-9 earth terminals were built originally for the ADVENT program, were modified later for the SYNCOM program, and finally were modified for the IDCSP program. The AN/MSC-46 and AN/TSC-54 equipments were built for the IDCSP program.

AN/FSC-9.—The AN/FSC-9 terminals are permanent installations located at Fort Dix, New Jersey, and Camp Roberts, California. They are used as the principal terminals for communication links to Europe and to the Pacific respectively. A 60-foot parabolic antenna is mounted on a 60-foot steel antenna tower on a concrete foundation 30 feet deep and 84 feet in diameter. The antenna mount includes a bridge superstructure that acts as a counterweight and serves as a housing for electronic equipment. The estimated weight of the antenna is 190 tons. A 200-foot covered passageway connects the antenna to a 6000-square foot operations building. An AN/FSC-9 is shown in figure 6-10.

AN/MSC-46.—The AN/MSC-46 is a transportable communication satellite terminal that is housed in three vans. A rigid radome (not supplied with the terminal) is usually installed over the antenna. Power is furnished by three diesel generators (supplied as a part of AN/MSC-46 of 100 kW each, or local commercial power may be used if available. The complete terminal, including the disassembled antenna, weighs 114,000 pounds but it can be transported by three C-130E aircraft. After arrival on site, the terminal can be assembled by a crew of eight trained men. An AN/MSC-46 antenna with its pedestal is shown in figure 6-11.

AN/TSC-54.—The AN/TSC-54, the smallest of the Phase I IDSCS earth terminals, is a highly transportable communication satellite terminal.

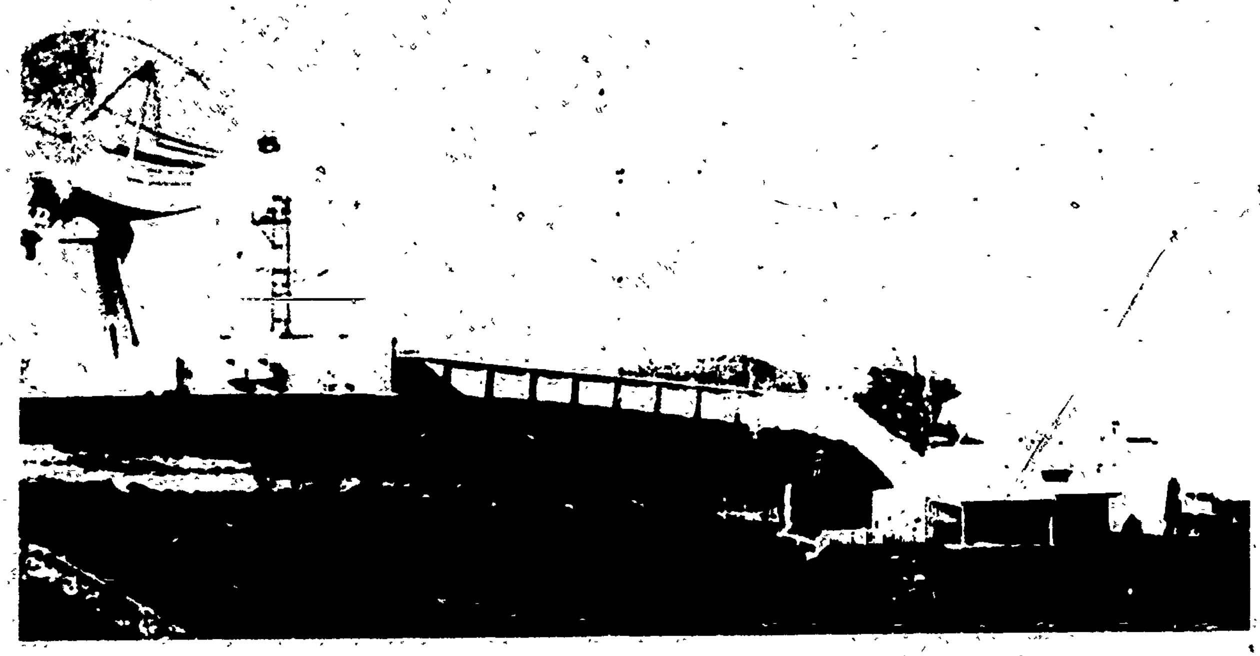


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Figure 6-10.—AN/FSC-9 satellite earth terminal.

The antenna, klystron and preamplifier are mounted on a trailer, and the remainder of the terminal equipment is in an equipment shelter. Power is supplied by a trailer-mounted diesel generator. The complete terminal weighs 19,500 pounds and can be transported by C-133E aircraft, H-37 helicopter or it can be towed by suitable trucks over unimproved terrain by attaching "goat" mobilizers (furnished with the terminal) to the equipment shelter. A well trained, experienced crew of six can set up or dismantle the AN/TSC-54 in less than two hours. A rigid radome (not supplied with the terminal) is available for semipermanent installations where required. An AN/TSC-54 is shown in Figure 6-12.

AN/SSC-6.—The AN/SSC-6 is a shipboard satellite communication earth terminal. It provides the capability for tracking a satellite and for the capability of long-range, high-speed data, voice and teletype communications signals transmitting at 7.9 to 8.4 GHz and receiving at 7.25 to 7.75 GHz. Figure 6-13 is a pictorial representation of the AN/SSC-6.

The AN/SSC-6 is a shipboard installation installed as an interim SHF capability until replaced by AN/WSC-2 terminals. The antenna group is mounted on the ship's weather deck. The servo electronics, modem, transmitter, prime power, and electronics groups are located within the ship's structure. The servo electronics, modem, and electronics groups are collocated.

The AN/SSC-6 uses a six foot diameter Cassegrain type antenna system with an automatic tracking feed system capable of tracking synchronous and near-synchronous communications satellites.

SATELLITE ACQUISITION AND TRACKING

An essential operation in establishing communications via satellite is the acquisition of the satellite by the earth terminal antenna and subsequent tracking of the satellite. Initial

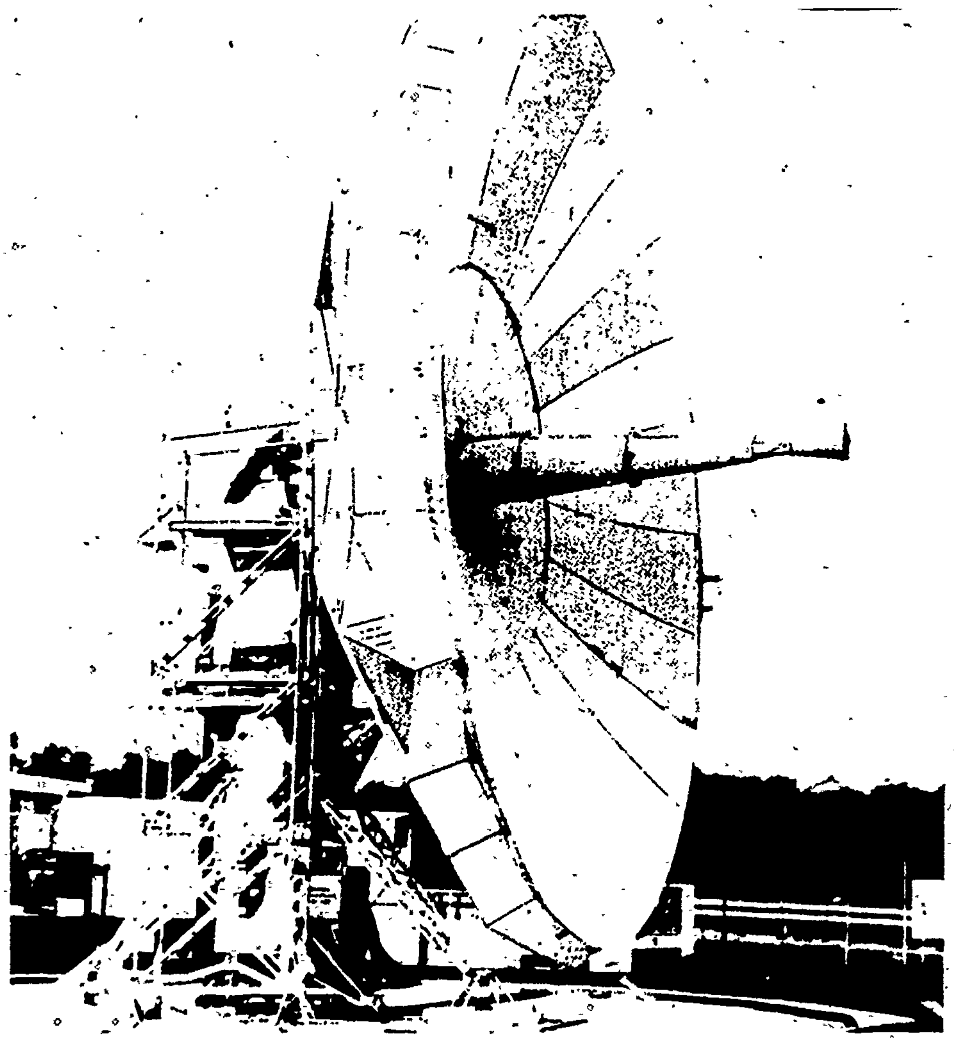

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Figure 6-11.–AN/MSC-46 antenna and pedestal.

acquisition depends upon an exact knowledge of the satellite's position which, in combination with the geographic location of the earth terminal, enables the computation of accurate antenna pointing information. The degree of difficulty in acquiring and tracking a satellite is determined largely by the satellite's orbital parameters.

Acquisition and tracking of a synchronous satellite are relatively simple because the satellite appears to be stationary. Acquisition of a near synchronous satellite is relatively simple because of the slow relative motion of the satellite; however, the satellite movement is enough that accurate tracking is required to keep the narrow beam antenna pointed toward the satellite. Satellites in medium altitude circular orbits or in elliptical orbits are more difficult to acquire and also to track because of their relatively rapid changes in position.

Orbital Prediction

In order to be able to supply antenna pointing information to earth terminals, it is necessary to know with a high degree of

31.1.06
Figure 6-12.—AN/TSC-54 satellite communication terminal.

accuracy the orbital parameters of the satellite. A table showing the calculated positions of a satellite (or any heavenly body) at regular intervals of time is called an ephemeris. The ephemeris of a satellite is calculated from its orbital parameters and a knowledge of the physical laws of motion. After the ephemeris data of a satellite are determined, it is possible to predict for any given location the apparent track of the satellite as viewed from that location.

The constants defining an orbit are initially obtained by the process of tracking. At the time launch, the rocket is tracked by radar from "lift off" to injection, and then until it passes out of sight. The recorded tracking data obtained in this way is sufficient for making rough predictions of the orbit. These predictions are made rapidly with a computer and sent to other tracking stations in other parts of the world. The other tracking stations around the world watch for the satellite during its first trip and record additional data which enables more precise predictions to be made. Thus, during the first week of orbiting, tracking stations all around the world are obtaining progressively more accurate data concerning the satellite. This data is put into a computer where corrections of earlier estimates of the orbit are made.

Once the initial predictions are complete and the satellite link becomes operational there is very little change in these calculations. The orbits will change slightly over a period of time; however, these changes are so gradual that predictions will be accurate enough to be used for weeks or even months without further corrections. When the orbits are known precisely, an ephemeris can be calculated for each satellite of the system.

Antenna Pointing

Antenna pointing instructions are derived from the ephemeris of a satellite. These instructions must, however, be computed separately for each ground station location. A satellite which bears due south of station A at an elevation of 25 degrees may simultaneously bear due southeast of station B at an elevation of 30 degrees. Antenna pointing instructions are determined by taking into consideration the orbital prediction and the latitude and longitude of each ground station.

From the standpoint of acquiring radio contact with a satellite, the only important local coordinates of position are bearing and elevation. Knowledge of the bearing and elevation of a satellite at the time planned for acquisition permits the antenna to be properly pointed.

CONTROL CENTER INFORMATION.—The use of satellites to set up particular communication links requires planning. Varying and contingent needs of users must be considered. With a limited number of either random orbit or quasi-synchronous satellites, it is possible that there may be no satellite in the common view of certain pairs of ground stations for minutes or hours at a time.

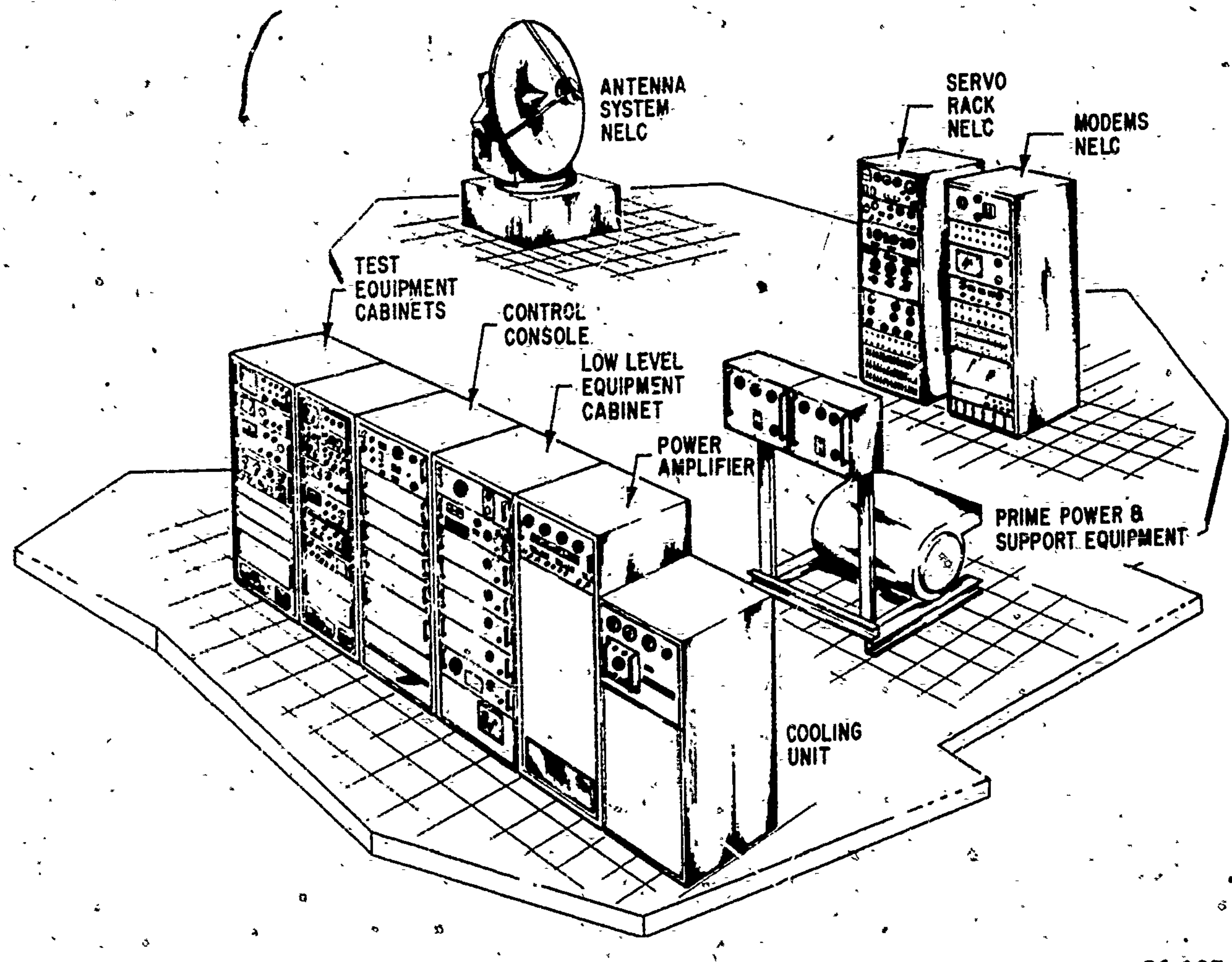


Figure 6-13.—AN/SSC-6 shipboard terminal.

Also, there may be a failure of electronic equipment. Planners must take all of these things into consideration in order to make best use of the satellites.

Antenna pointing instructions are calculated for planned satellite acquisitions and for additional acquisitions to provide reliability in event of satellite equipment malfunction. In the IDSCS a central computer in the Air Force Satellite Control Facility performs these calculations for each earth terminal location.

The Satellite Communications Control Facility, operated by the DCA, schedules operating time for the use of the various satellites by the three services. The Navy Satellite Operations Center, under the direction of the Naval Telecommunications Command, allocates Navy-assigned operating time to Communications Area Master Stations (CAMS) which in turn designate pairs of earth terminals to use the assigned time.

Acquisition

The acquisition of satellite signals by a ground station equipped with large antennas and operated at microwave frequencies places severe requirements on the acquisition system, particularly if the satellite is in a medium altitude circular orbit or in an elliptical orbit.

These requirements can be divided into two problem areas: spatial-time uncertainties and frequency variations. The spatial-time acquisition (acquisition of a signal at some point in space at some instant in time) must also involve acquisition of the signal frequency.

SPATIAL-TIME FACTOR.—Very accurate antenna point data will be available to the earth terminal from the Satellite Control Facility. However, due to equipment limitations it is necessary to conduct a small search about the predicted location of the satellite in order to make initial contact. This searching involves either manually or automatically scanning a small area around the point where the satellite appearance is predicted.

TIMING CONTROL.—Timing signals for the entire system are transmitted by the Army satellite terminal at Camp Roberts, California, to Fort Dix, New Jersey, and Helemano, Hawaii. Fort Dix retransmits these timing signals to all terminals in the Atlantic-European-African area, and Helemano transmits the signals to all Pacific sites.

FREQUENCY CONTROL.—The frequency of a radio signal received from a satellite generally is not exactly the assigned down-link frequency because of variations in the received frequency. The extent of this frequency variation is quite dependent upon the orbital geometry of the satellites. The greatest frequency variations are observed in signals from satellites in medium altitude, circular orbits and from those in elliptical orbits. The smallest frequency variations are observed in signals from satellites in near-synchronous and synchronous orbits.

Tracking

When a particular satellite has been acquired, the earth terminal antenna must continue to track that satellite for as long as it is to be used as the communication relay. Two of several methods of tracking are programmed tracking and automatic tracking.

PROGRAMMED TRACKING.—In programmed tracking the known orbital parameters of the satellite are fed into appropriate computation equipment to generate antenna pointing angles. The antenna pointing angles are fed as commands to the antenna positioning servo-mechanisms which point the antenna in the required direction. The amount of data and computation involved in using programmed tracking to point narrow beamwidth antennas is quite extensive. In addition, some deviations from calculated pointing angles arise as a result of antenna mount flexure and atmospheric and ionospheric bending of radio waves. Since these uncertainties exist, programmed tracking is not wholly satisfactory and is not used extensively.

AUTOMATIC TRACKING.—In automatic tracking, antenna pointing information is generated by comparing the direction of the antenna axis with the direction from which an actual satellite signal is received. Since automatic tracking systems track the apparent position of the satellite—that is, the direction of arrival of the radio signal—knowledge of the real position of the satellite is not required. The automatic tracking system is a servo-mechanism and, once acquisition has been accomplished, it continually generates its own pointing data, thus eliminating the requirement for data input and computation.

SATELLITE OUTAGE TIME.—The system specification for the DSCS allocates 120 seconds for slewing the earth terminal antennas, acquiring the satellite signal, and checking for circuit continuity at handover. This represents the minimum outage time. However, for several reasons a satellite may not be immediately available, and, these reasons may combine to increase the outage time. The difference of drift velocities of the Phase I IDSCS satellites will lead to bunching of satellites with gaps causing increased outage times. In addition, when two or more satellites simultaneously occupy the common volume of the link terminal antennas, they will mutually interfere and prevent reliable communication. Other factors leading to increased outage times are satellite-sun conjunction (increased noise from the sun prevents communication), satellite eclipse (absence of power from solar cells), and satellite failures. Hence, the distribution of outage times is a complicated function of time and earth-station locations.

ROLE OF SATELLITE COMMUNICATIONS

In the context of a global military communications network, satellite communication systems become subsystems adding sorely needed capacity or additional alternate routing for communications traffic. A satellite link is just one of several kinds of long-distance links that interconnect switching centers located strategically around the world to comprise the Defense Communications System (DCS) network. Satellite links are usually in parallel with links that employ the more conventional means of communication—HF radio, tropospheric scatter, ionospheric scatter, line-of-sight, microwave, and landline. Satellite links provide added capacity between various points in the network; and, since these links continue in operation under conditions that render other media operable, they make a significant contribution to the improvement of reliability. The primary purpose of the DCS is to provide long-haul, point-to-point communications capabilities to Department of Defense users. Users need only establish communications with the nearest switching center to become network subscribers and to have access to the entire DCS network. Beyond the point-to-point communications requirements there are the tactical communications requirements of the individual services. For the Navy, the potential of satellite communications for tactical (non-DCS) service is most encouraging.

TYPICAL APPLICATIONS

In the application of satellite communication resources to military communications, certain typical deployments will exploit to the maximum extent their versatility and capacity. Some such applications are:

a. DCS Long-Distance, Common-User Communication. This type of communication represents the normal employment of the satellite subsystem. This application provides additional high-capacity wide-band trunks for a variety of transmission modes and added flexibility for rerouting traffic.

b. DCS Area Common User Communication. Area communication supports large concentrations of forces engaged in operations encompassing a discrete remote area. Such service extends high-capacity, long-distance DCS trunks to a high density of potential users engaged in fluid tactical situations.

c. Contingency Operation. In this application the DCS facilities are extended to support a military operation or humanitarian effort. In this connection, the capability of the satellite subsystem can be used to advantage to support rapid deployment and to furnish reliable long-distance trunking service within a minimum time.

d. Command and Control of Widely Deployed Forces. HF communication to elements of widely deployed forces is difficult even under ideal propagation conditions. On the other hand, the capabilities of a satellite subsystem offer rapid, reliable communication between and among mutually supporting theater and fleet commanders. A satellite subsystem also possesses the necessary flexibility for system configuration without loss of contact during sudden or frequent headquarters displacement.

e. Tactical Communications. With the development of suitable antennas and equipments that can be installed in most types of ships and aircraft, satellite communications will be able to fill the requirements for various tactical communications, such as ship-to-ship, ship-to-aircraft, ship-to-shore-to-ship, and aircraft-to-ship. This type of communications will be more reliable and less subject to detection than methods presently in use.

f. Fleet Broadcast and Ship-to-Shore. Present fleet broadcasts and ship-to-shore communications rely heavily upon HF for communication over extended distances. As with tactical communications, a satellite subsystem will be more reliable and less subject to detection. This will ensure reliable long-range links between major fleet units and naval communication stations ashore and will simultaneously enhance fleet security.

ADVANTAGES OF SATELLITE COMMUNICATIONS

Satellite communications offer unique advantages over conventional transmission for long-distance service. Satellite links are unaffected by the propagation abnormalities that interfere with HF radio, are free from the high attenuation of wire or cable facilities, and are capable of spanning long distances without the numerous intervening repeater stations which are required for line-of-sight or troposcatter links. They can furnish the greater reliability and flexibility of service needed to support a military operation.

Capacity

Although existing commercial satellite communication systems are capable of handling hundreds of voice-frequency channels, the present operational military communication satellite system, the Phase I Initial Defense Satellite Communications System (IDSCS), is limited to less than a dozen voice channels per earth terminal. Four separately assigned channels, each capable of handling eleven voice channels, are available in each IDSCS satellite on both the up link and down link; however, the power limitations of the Phase I satellite on the down link prevents the use of more than two RF channels simultaneously, (one full duplex circuit). The Phase II DSCS satellites, now under contract, will have greater channel capability with a considerably wider RF bandwidth.

Reliability

Since propagation of communication satellite frequencies is not dependent upon reflection or refraction and is affected only slightly by atmospheric phenomena, the reliability of active satellite communication systems is limited, essentially, only by the reliability of the equipment employed and the skill of the operating and maintenance personnel. This improvement in reliability is a remarkable advantage for Navy communications, so long dependent upon unreliable HF propagation for most tactical communications.

Vulnerability

Within the present state of art in rocketry, destruction of an orbiting vehicle is possible; however, destruction of a single communication satellite would be quite difficult and expensive. The cost would be excessive compared to the tactical advantage gained. It would be particularly difficult to destroy an entire multiple-satellite system such as the twenty-six random-orbit satellite system currently in use in the IDSCS. The earth terminals offer a more attractive target for physical destruction, but they can be protected by the same measures that are taken to protect other vital installations.

A high degree of invulnerability to jamming is afforded by the highly directional antennas at the earth terminals and by the wide bandwidth system which can accommodate sophisticated anti-jam modulation techniques such as spread spectrum and frequency hopping.

Flexibility

Almost all of the existing operational military satellite earth terminals are housed in transportable vans that can be loaded into cargo planes and flown to remote areas. With trained crews these terminals can be put into operation in a matter of hours. Therefore, direct long-haul communications can be established quickly to remote areas nearly anywhere in the free world. (The present and proposed DSCS satellites provide slight coverage in the polar regions at latitudes greater than 70 degrees.)

LIMITATIONS

Limitations of a satellite communications system are determined by the satellite's technical characteristics and its orbital parameters. Active communication satellite systems are limited by satellite transmitter power on the down links and to a lesser extent by satellite receiver sensitivity on the up links. Early communication satellites have also been limited by low gain antennas.

Satellite Transmitter Power Limitations

The amount of power available in an active satellite is limited by the weight restrictions imposed on the satellite. Early communication satellites were limited to a few hundred pounds because of launch-vehicle payload restraints. The only feasible power source consistent with the above weight limitation is the inefficient solar cell. (Total power generation in the Phase I IDSCS satellites is less than 50 watts.) Thus the RF power output is severely limited, and a relatively weak signal is transmitted by the satellite on the down-link. The weak transmitted signal, further diminished by propagation losses, results in a very weak signal being available at the earth terminals. The level of signals received from a satellite is comparable to the combination of external atmospheric noise and internal noise of standard receivers. Consequently, special techniques must be used to permit extraction of the desired communication information from the received signal. Large, high gain antennas and special types of preamplifiers solve this problem but add complexity and size to the earth terminal. (The smallest terminal in the IDSCS has an 18-foot antenna and weighs 19,500 pounds.) Development of more efficient power sources and relaxation of weight restrictions will permit improved satellite performance and increased capacity.

Satellite Receiver Sensitivity

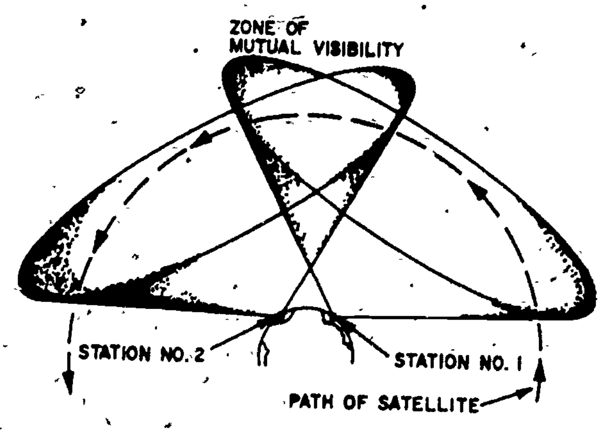
Although powerful transmitters and highly directional antennas can be used at an earth station, the spherical wavefront of the radiated signal spreads as it travels through space. The satellite antenna intercepts only a small amount of the transmitted signal power and, because of its low gain, a relatively weak signal is received at the satellite receiver. Although the strength of the signal received on the up link is not as critical as that received on the down link, careful design of the RF stage of satellite receivers is required to achieve satisfactory operations. Development of stabilized, high gain antennas and improved RF input stages in the receiver will make this problem less critical.

Satellite Availability

The availability of a satellite to act as a relay station between two earth terminals depends on the locations of the earth terminals and the orbital parameters of the satellite. All satellites, except those in a synchronous orbit, will be in view of any given pair of earth stations only part of the time. The length of time that a nonsynchronous satellite in a circular orbit will be in the zone of mutual visibility depends upon the height at which the satellite is circling. Elliptical orbits cause the satellite zone of mutual visibility between any two earth terminals to vary from orbit to orbit, but the times of mutual visibility are predictable. See figure 6-14 for an illustration of the zone of mutual visibility.

FUTURE SATELLITE COMMUNICATIONS

When satellite communications are well established and Navy ships have need for permanent terminals, a new type will be integrated into the ship and be fully compatible with other electronic systems and equipment.



31.108
Figure 6-14.—Zone of mutual visibility.

When this happens, the number of conventional transmitters and receivers aboard ship can be reduced. Communications via satellite will augment existing communications as part of the overall system for the command and control of naval forces. Satellite communications will not replace all existing means of radio communications; however, it is a major step in modernizing Navy communications and will relieve the Navy of its total dependence on HF radio transmissions, ultimately reducing the need for many HF ground stations overseas.

The survivability of reliable communications for the command and control of our strategic nuclear forces is of paramount importance to the credibility of our deterrent. For this reason the Department of Defense is engaged in the development of new communications techniques and systems, including some that are space based, to improve the survivability of our strategic communications against nuclear and electronic attack.

For more information on Satellite Communications refer to *NTP 2, Navy Satellite Operations*. This publication was designed to concisely explain the Navy's role in Phase II of the Defense Satellite Communication System and to promulgate procedures for effective, coordinated utilization of available satellite resources.

CHAPTER 7

WAVE PROPAGATION AND ANTENNAS

In the two previous chapters we studied the basic concepts of the various communications systems. Essential to communication systems is the theory of transmitting RF energy through space and the various conditions affecting its progress from the point of transmission to the point of reception.

This chapter will present in a simplified manner the basic theories involved in propagating radio waves, the characteristics of antennas designed to radiate radio waves, and the different antenna configurations utilized in communication systems.

BASIC RADIO COMMUNICATION SYSTEM

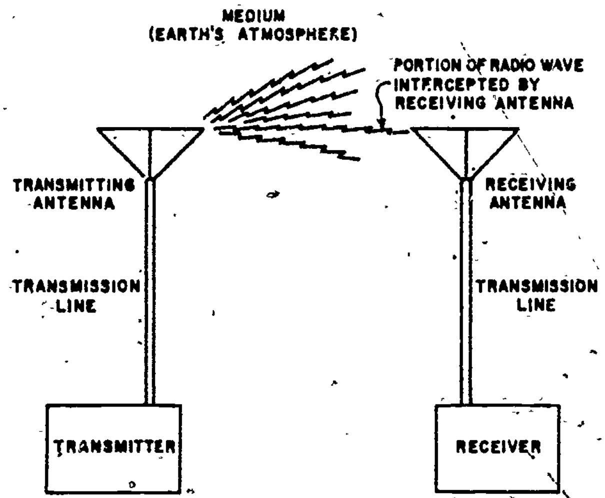
In any radio system, energy in the form of electromagnetic (radio) waves is generated by a transmitter and fed to an antenna by means of a transmission line. The antenna radiates this energy out into space at the speed of light (approximately 186,000 miles per second). Receiving antennas, placed in the path of a traveling radio wave, absorb part of the radiated energy and send it through a transmission line to a receiver. Thus, components required for successful transmission of intelligence by means of radio waves are a transmitter, a transmission line, a transmitting antenna, a medium through which radio waves travel (for example, the atmosphere surrounding the earth), a receiving antenna, another transmission line, and the receiving equipment. Figure 7-1 is a block diagram showing the arrangement of these components.

Successful communication by means of radio waves depends chiefly on the power of the transmitter, frequency used, distance between transmitter and receiver, antenna configuration, and sensitivity (ability to amplify weak signals) of the receiver. The ability of the earth's atmosphere to conduct energy to its destination, together with the nature of the terrain between sending and receiving points, may be responsible for the frequency selected. Interfering signals can make reception impossible at a desired time. Moreover, the amount of noise present and transmission line losses may combine to make unintelligible an otherwise good signal.

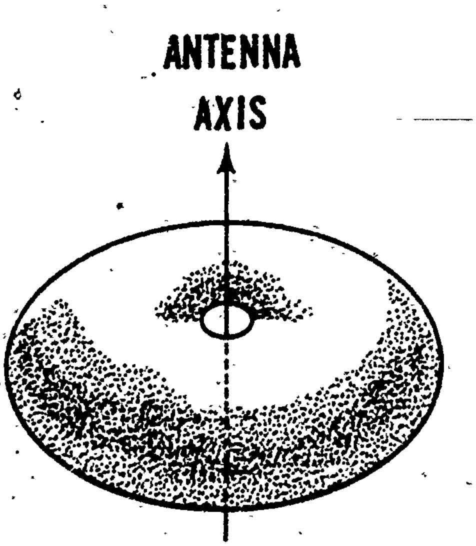
VARIOUS COMPONENTS OF A PROPAGATED ELECTROMAGNETIC WAVE

When a radio wave leaves a vertical antenna the field pattern of the wave resembles a huge doughnut lying on the ground with the antenna in the hole at the center, as seen in figure 7-2. Part of the wave moves outward in contact with the ground to form the GROUND WAVE, and the remainder of the wave moves upward and outward to form the SKYWAVE, as shown in figure 7-3. The ground and sky portions of the radio wave are responsible for two different methods of carrying the intelligence from transmitter to receiver. The ground wave is used both for short range communications at high frequencies with low power and for long range communication at low frequencies and with very high power. Daytime reception from most commercial stations is carried by the ground wave.

The sky wave is used for long range high frequency daylight communication. At night,



31.6
Figure 7-1.—Basic radio communication system.



179.474
Figure 7-2.—Vertical antenna field pattern.

the sky wave provides a means for long range contacts at somewhat lower frequencies.

GROUND WAVE

The physical mechanics of ground wave propagation are less complicated than those of sky wave propagation. Ground waves are propagated within the troposphere (the first 7 to 10 miles above the earth's surface). There are fewer variables involved, and these are not subject to such random behavior and extreme excursions as is the case for sky wave transmissions.

Refraction (bending) in the troposphere of electromagnetic energy (radio waves) toward the earth's surface accounts for the tendency of a ground wave to follow the contour of the earth's surface and thereby achieve transmission distances beyond the line of sight. In the troposphere, the amount of refraction normally decreases with height so that a ground wave is bent or tilted toward the earth in a manner similar to the refraction of radio waves in the ionosphere.

The defraction effect of an obstacle in the path of a radio wave is shown in figure 7-4. The resultant wave fronts are distorted, and the wave front is extended downward. Instead of being shielded, an antenna erected at point A would receive some energy from the transmitting antenna.

The ground wave is responsible for most of the daytime broadcast reception. As it passes over and through the ground, this wave induces a voltage in the earth, setting up eddy currents. The energy used to establish these currents is absorbed from the ground wave, thereby weakening it as it moves away from the transmitting antenna. Increasing the frequency rapidly increases the attenuation so that the ground wave transmission is limited to relatively low frequencies. Shore base transmitters are able to transmit long range ground wave transmissions by using frequencies between 18 and 300 kHz with extremely high power.

Since the electrical properties of the earth along which the surface wave travels are relatively constant, the signal strength from a given station at a given point is nearly constant. This holds essentially true in all localities except those having distinct rainy and dry seasons. There the difference in the amount of moisture causes the conductivity of the soil to change.

The conductivity of salt water is 5,000 times as great as that of dry soil. High power, low frequency transmitters are placed as close to the

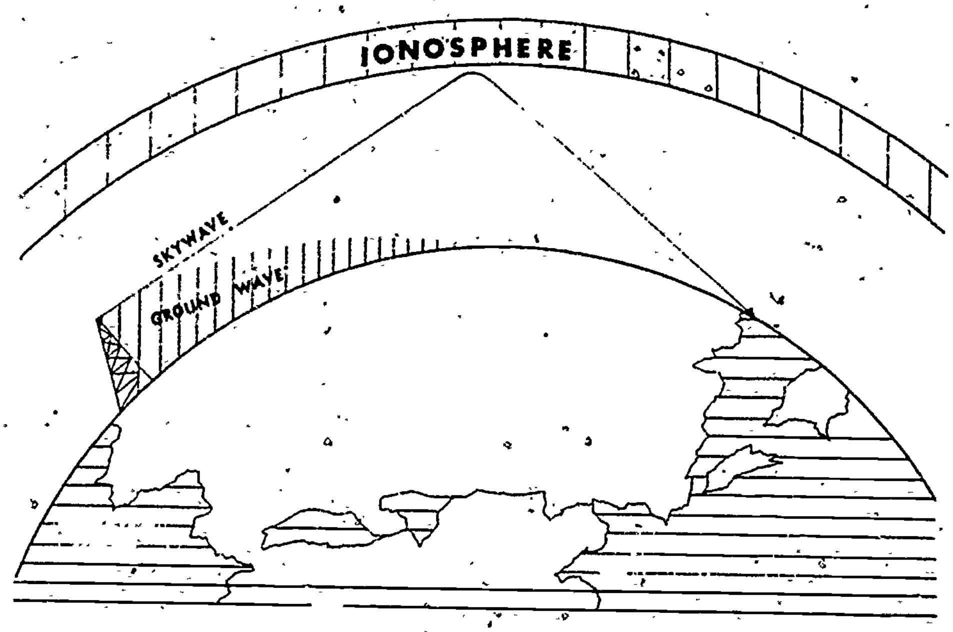
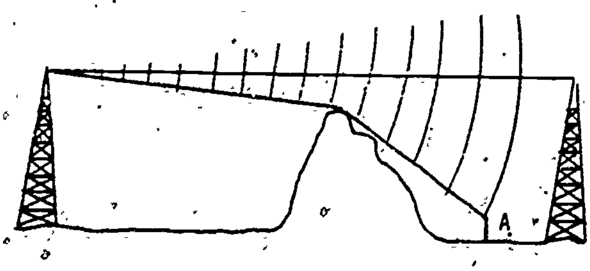


Figure 7-3.—Ground and sky waves. 179.495



179.499
Figure 7-4.—Diffraction of transmitted energy by sharp edge of a mountain.

edge of the ocean as practical because of the superiority of surface wave conduction by salt water.

SKY WAVE

That portion of the radio wave which moves upward and outward is not in contact with the ground and is called the SKY WAVE. It behaves similarly to the ground wave. Some of the energy of the sky wave is refracted (bent) by the ionosphere so that it comes back toward the earth. Some energy is lost in dissipation to particles of the atmospheric layers. A receiver located in the vicinity of the returning sky wave will receive strong signals even though several hundred miles beyond the range of the ground wave.

IONOSPHERE

The ionosphere is found in the very high atmosphere approximately 30 to 250 miles above the earth. It differs from other atmospheric parts in that it contains a much higher number of positive and negative ions. The negative ions are believed to be atoms whose energy levels have been raised to a high level by solar bombardment of ultra-violet and particle radiations. The rotation of the earth on its axis, the annual course of the earth around the sun, and the development of sun spots all affect the number of ions present in the ionosphere, and these in turn affect the quality and distance of electronic transmissions.

The ionosphere is constantly changing. Some of the ions are returning to their normal energy level, while other atoms are being raised to a higher energy level. The rate of variation between high and low level of energy depends upon the amount of air present and the strength of radiation from the sun.

STRUCTURE OF THE IONOSPHERE

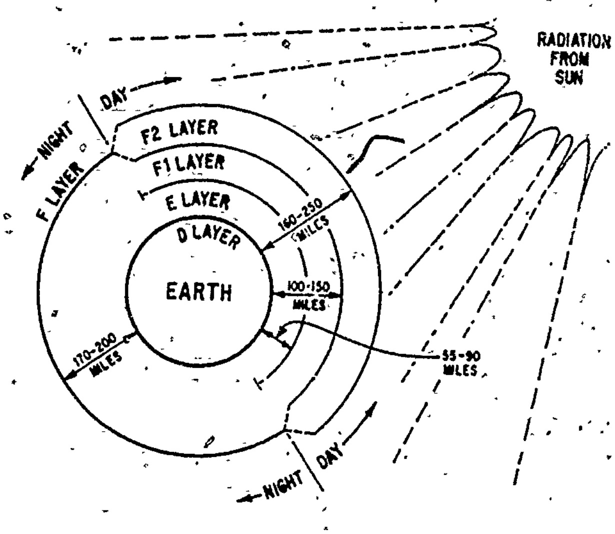
Densities of ionization in the ionosphere tend to peak at various heights above the earth as a result of differences in the physical properties of the atmosphere at different heights. The levels at which the electron density reaches a maximum are termed layers, and these are identified as the D, E, F1, and F2 layers in order of increasing height and ionization density. Actually, there is thought to be no sharp dividing line between layers, but for the purpose of discussion, such demarcation is indicated. The relative distribution of these layers above the earth is shown in figure 7-5. The number of layers, their heights, and their ionization (electron) density vary both geographically and with time.

D Layer

The D layer lies between heights of about 30 and 55 miles above the earth, and absorption in this layer is the principle cause of the daytime attenuation of high-frequency sky waves. The D layer exists only in the daylight hours and its ionization density correlates with the elevation angle of the sun. Compared to the other layers at higher altitudes the electron density is relatively low, but the free electrons are excited by the presence of an electromagnetic wave. Pronounced energy losses occur because of collisions between the electrons and the molecules of the atmosphere.

E Layer

The E layer, second in order of height, exists between 55 and 90 miles above the earth's surface with maximum density relatively constant at about 70 miles. The variations of this layer are regular and quite predictable. The intensity of ionization follows the sun's altitude closely, reaching a maximum about noon, and fading to such a weak level during the night as to be practically useless as an aid to HF radio communications. The density of electrons in the E layer is usually great enough to refract to earth radio waves at frequencies as high as 20 MHz. The height of this layer and its refractive properties make it important for daytime propagation at distances less than approximately 1200 miles. Longer distance transmission via the E layer is usually impractical because of the low layer height and correspondingly low vertical angle of departure of the transmitted wave. With this geometry, multiple reflections between the E layer and the earth's surface are required for long-distance transmission, and a wave following such a path suffers pronounced absorption during its travel through the D and E layers.



31.109

Figure 7-5.—Distribution of layers in the ionosphere.

An unpredictable phenomenon associated with the E layer is the Sporadic E, abbreviated Es. Irregular cloud-like areas of unusually high ionization often occur near the height of maximum ionization of the regular E layer. The physical processes that produce the quite unpredictable E ionization are not fully known, but the frequency of occurrence and the degree of ionization vary significantly with latitude. Sometimes the Es layer, or cloud, is opaque to radio waves and blankets the upper layers. At other times the Es may be so thin that, although its presence can be verified, radio waves penetrate it easily to be returned by the upper layers. These characteristics can be either helpful or harmful to radio communications. For example, blanketing Es may block propagation via a more favorable regular layer in a certain frequency range or cause additional attenuation at other frequencies. Partially reflecting Es can cause serious multipath interference especially detrimental to data transmission systems. On the other hand, Es may enable long-distance transmission at very high frequencies, or may permit short-distance transmission to locations that would ordinarily be in a skip zone.

F Region

For HF radio communications, the F region is the most important part of the ionosphere. Long term studies of the structure of the F region by remote probing techniques show conclusively the existence of two distinct layers, called the F1 and F2 layers. These two merge at night into a single F layer at a height of 170 to 200 miles. During the day, the F1 layer has a lower limit of approximately 100 miles, while the F2 layer has a lower limit of about 160 to 250 miles depending upon the season of the year and time of the day.

F1 LAYER.–The F1 layer has not been as well defined as the F2 layer in terms of its predictable characteristics. This layer occasionally is the refracting region for HF transmission, but usually oblique-incidence waves that penetrate the E layer also penetrate the F1 layer and are bent earthward by the F2 layer. The principal effect of the F1 layer is to introduce additional absorption of such waves.

F2 LAYER.–The F2 layer is by far the most important layer for HF radio communications, and unfortunately, it is also the most variable. It is the most highly ionized of all the layers and its height and ionization density vary daily, seasonally and over the 11 year sunspot cycle. The degree of ionization does not follow the altitude of the sun in any simple fashion, but it generally peaks in the afternoon and decreases gradually throughout the night. The absence of the F1 layer at night and reduction in absorption in the E layer cause nighttime signal intensities (and noise) to be generally higher than they are during daylight hours.

EFFECT OF IONOSPHERE ON THE SKY WAVE

The ionosphere has many characteristics. Some waves penetrate and pass entirely through it into space, never to return. Other waves penetrate but bend. Generally, the ionosphere acts as a conductor, and absorbs energy in varying amounts from the electronic wave. The ionosphere also acts as an electronic mirror and refracts (bends) the sky wave back to the earth, as illustrated in figure 7-6. Here the ionosphere does by refraction what water does to a beam of light.

The ability of the ionosphere to return an electronic wave to the earth depends upon the angle at which the sky wave strikes the ionosphere, the frequency of the transmissions, and ion density. When the wave from an antenna strikes the ionosphere at an angle the wave begins to bend. If the frequency and angle are correct and the ionosphere is sufficiently dense, the wave will eventually emerge from the ionosphere and return to the earth. If a receiver is located at either of the points B, figure 7-6, the transmission from point A will be received. The sky wave in figure 7-7 is assumed to be composed of rays that emanate from the antenna in three distinct groups that are identified according to the angle of elevation. The angle at which the group 1 rays strike the ionosphere is too nearly vertical for the rays to be returned to earth. The rays are bent out of

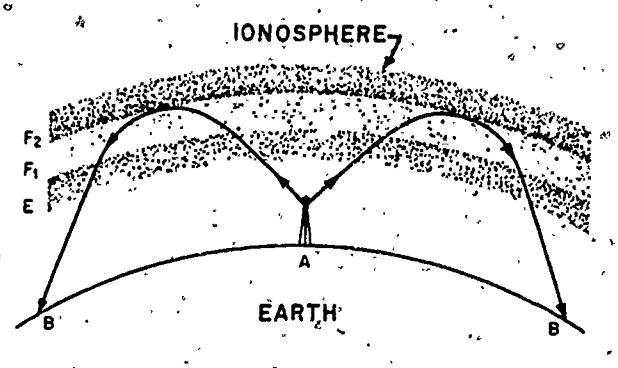
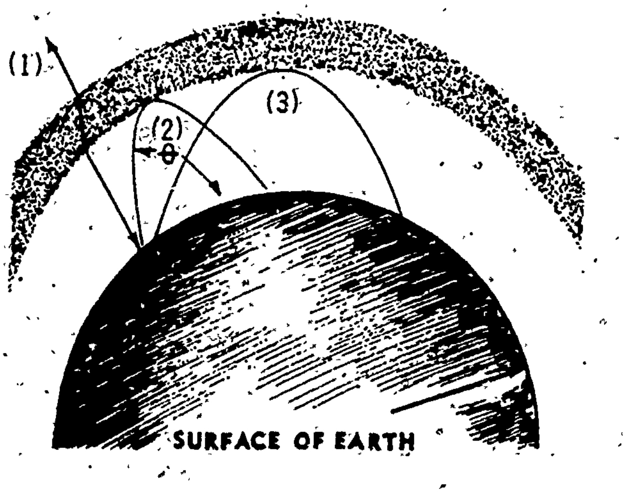


Figure 7-6.–Refraction of the sky waves by the ionosphere.



13.30
Figure 7-7.—Effect of the angle of departure on the area of reception.

line, but pass completely through the ionosphere and are lost. A currently popular theory on propagation is explained as follows.

The angle made by the group 2 rays is called the CRITICAL ANGLE for that frequency. Any ray that leaves the antenna at an angle greater than this angle (θ) will penetrate the ionosphere.

Group 3 rays strike the ionosphere at the smallest angle that will be refracted and still return to the earth. At any smaller angle the rays will be refracted but will not return to the earth.

As the frequency increases, the initial angle decreases. Low frequency fields can be projected straight upward and will be returned to the earth. The highest frequency that can be sent directly upward and still be refracted back to the earth is called the CRITICAL FREQUENCY. At sufficiently high frequencies, regardless of the angle at which the rays strike the ionosphere, they will not be returned to the earth. The critical frequency is not constant but varies from one locality to another, with the time of day, season of the year, and with the sunspot cycle.

Maximum Usable Frequency

As the incident angle is lowered from the vertical, there is a corresponding increase in the frequency which will be returned to earth. The factors which determine the actual frequency to be used for a communication circuit are the height of the ionized layer used for refraction and the distance between the two ends of the circuit. The maximum frequency which will be refracted for a given distance of transmission is called the maximum usable frequency (MUF). The MUF is always higher than the critical frequency.

Frequency of Optimum Traffic

Experience has shown that the MUF may increase or decrease significantly, especially during daytime because of changes occurring in the ionosphere. Therefore, the frequency of optimum traffic (FOT) is used so that variations in the ionosphere will have less effect on the communication circuit.

SKY WAVE PROPAGATION

Sky wave transmission are those refracted by the ionosphere. Ionosphere refracted sky waves are generally the only usable waves for long range communications. Figure 7-8 illustrates some of the many possible paths that radio waves of various frequencies may take between a transmitter and a receiver by refraction in the ionosphere. Some of the waves of too high a frequency (30 MHz and higher) for refraction by the ionized layer pass on through and are lost in space. Other components of the wave, which are assumed to be of the correct frequency (below 30 MHz) for refraction from the ionospheric layers, are returned to the earth; these waves provide communications. Note also that the skip distance is the distance from the transmitter to the nearest point at which the refracted waves return to earth. The skip zone and its relation to the ground wave are shown in figure 7-8.

Note the distinction between the terms SKIP DISTANCE and SKIP ZONE. For each frequency at which refraction from an ionospheric layer takes place, there is a skip distance that depends on the degree of ionization present. The skip zone, on the other hand, depends on how far the ground wave extends from the transmitter and where the sky wave first returns to earth by refraction from an ionized layer. The skip zone is the zone between

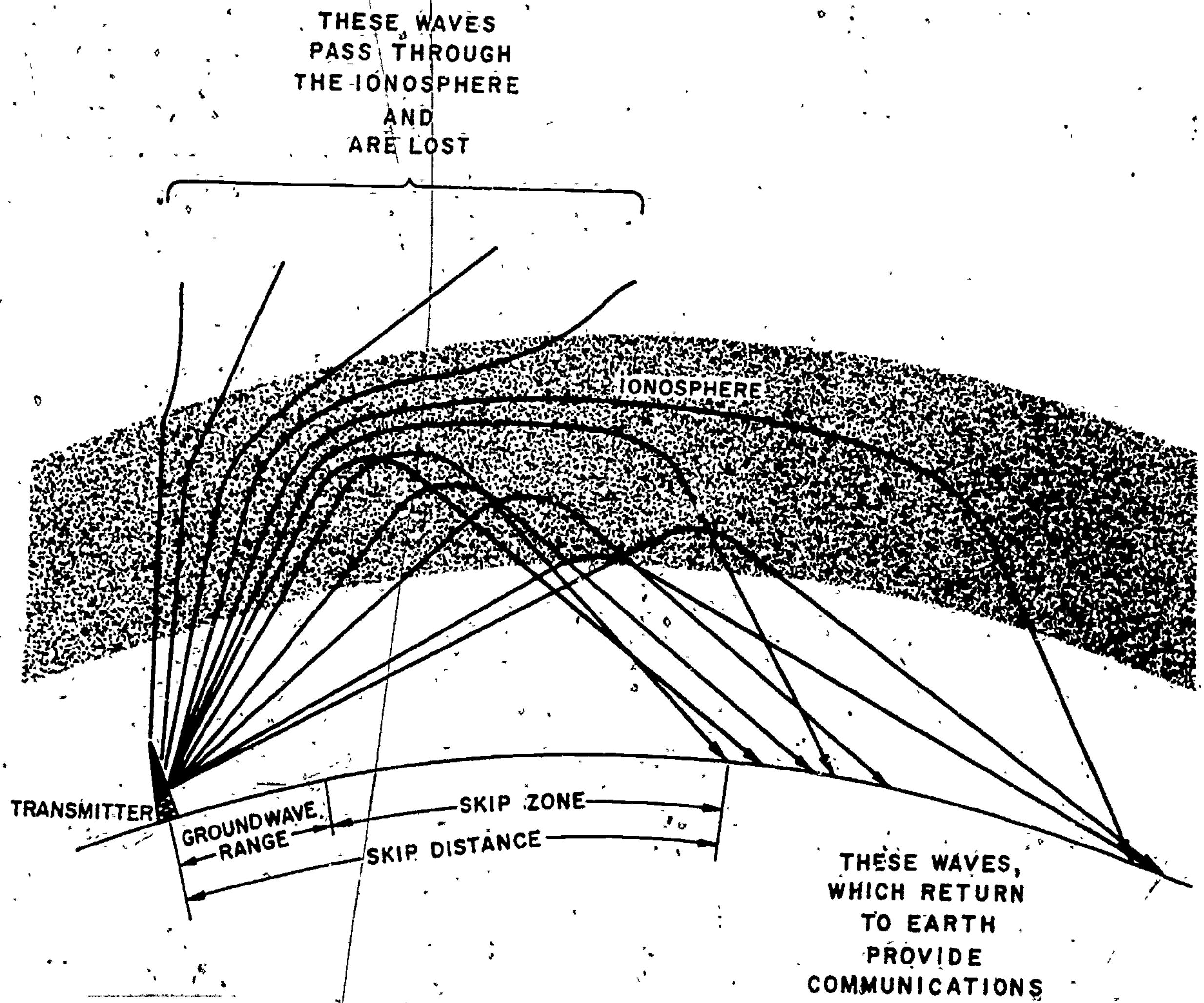


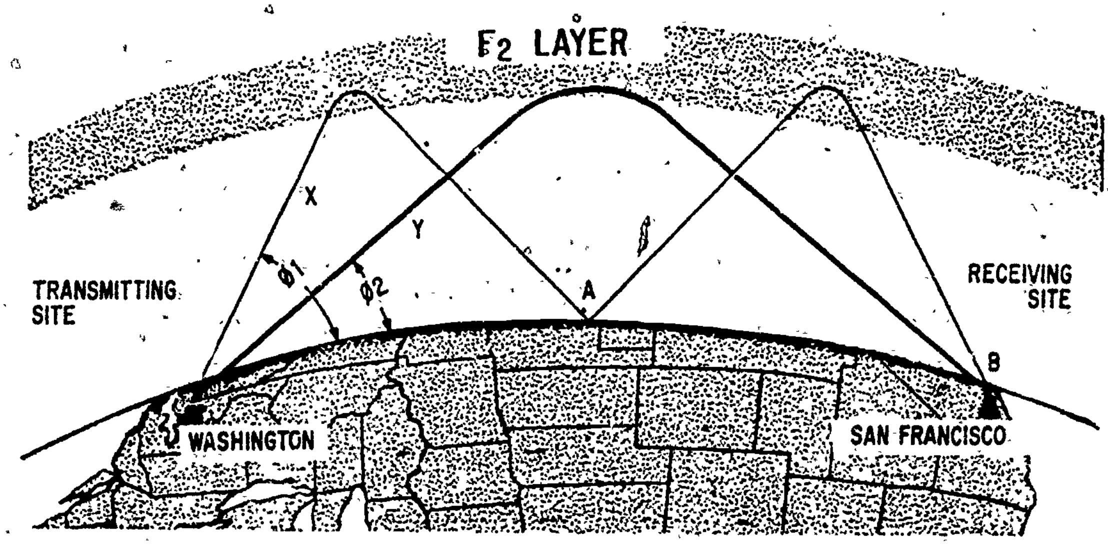
Figure 7-8.—Various sky-wave transmission paths. 31.16

the end of the ground wave transmission and the point on the earth where the sky wave first returns from the ionosphere.

As noted previously in the discussion of the ionosphere, the higher the frequency of a wave, the less it is refracted by a given degree of ionization.

MULTIPLE-HOP TRANSMISSION

The sky wave path of a signal propagated at two different vertical angles is illustrated in figure 7-9. When the vertical angle is Ø1, the signal is returned to the earth at point A, reflected back to the ionosphere and reappears at point B. If the same signal is transmitted at lower vertical radiation angle Ø2, it can reach



179.497

Figure 7-9.—Path of a sky wave signal propagated at two different vertical angles.

point B in a single hop. The signal transmitted at angle Ø1 will suffer more ionospheric and ground absorption losses than that signal transmitted at angle Ø2. In general, single hop transmissions result in greater field intensities at a distant point than multiple hop transmissions. By inspection of figure 7-9 it is evident that longer distances can be covered by multiple hop transmissions as the vertical radiation angle is decreased. Frequencies in the 9 to 80 MHz range are generally utilized for long distance transmissions, and in order to minimize the number of reflections of the signal in arriving at a distant point, lower vertical radiation angles are used. However, there is a limit to the improvement obtained by low angle radiation, because absorption and other factors make operation on vertical radiation angles below 3 degrees impractical.

FADING

When a received signal varies in intensity over a relatively short period of time, the effect is known as fading, which is one of the most troublesome problems encountered in electronic reception.

There are several conditions which can produce fading. One type of fading is prevalent in areas where sky waves are relied upon for transmission. Figure 7-10 shows two sky waves traveling paths of different lengths, thereby varying about the same point out of phase and thus producing a weakening of the signal. For instance, if a portion of the transmitted wave front arrived at a distant point via the E layer and another via the F layer, a complete cancellation of signal voltages would occur if the waves arrived 180 degrees out of phase and with equal amplitude. Usually, one signal is weaker than the other; therefore, a usable signal is obtained.

One method of overcoming fading is to place two antennas a wavelength apart, feed two separate receivers, and combine the audio outputs. This is known as diversity reception.

DUCTING

Unusual ranges of VHF and UHF contacts are caused by abnormal atmospheric conditions a few miles above the earth. Normally, the warmest air is found near the surface of the water. The air gradually becomes cooler as the altitude increases. Sometimes, unusual situations

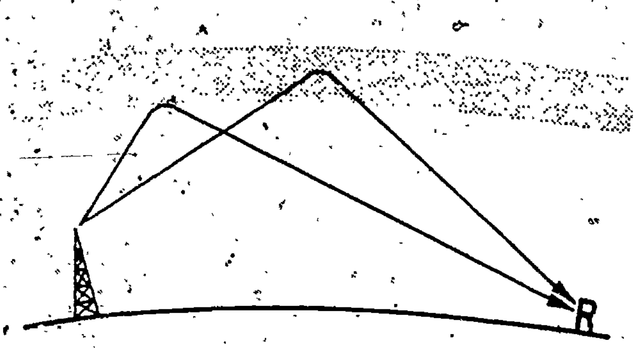


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Figure 7-10.—Fading caused by arrival of two sky-waves at the same point (R) out of phase.

develop where warm layers of air are found above cooler layers. The condition is known as TEMPERATURE INVERSION.

When a temperature inversion exists, the amount of refraction (index of refraction) is different for the particles trapped within the boundaries from those outside them. These differences form channels or ducts that will conduct the radio waves many miles beyond the assumed normal range.

Sometimes these ducts are in contact with the water and may extend a few hundred feet into the air. At other times the duct will start at an elevation of between 500 and 1,000 feet and extend an additional 500 to 1,000 feet in the air.

If an antenna extends into the duct or if the wave enters a duct after leaving an antenna, the transmission may be conducted for a long distance. An example of this type of transmission of radio waves in ducts formed by temperature inversions is shown in figure 7-11.

With certain exceptions, ducts are formed over water where the following conditions are observed aboard ship:

1. A wind is blowing from the land.
2. There is a stratum of quiet air.
3. High pressure, clear skies and little wind.
4. Cool breeze over warm open ocean.
5. Smoke, haze, or dust fails to rise.
6. Received signal is fading rapidly.

TROPOSPHERIC PROPAGATION

The foregoing sections of this chapter have provided a discussion of that portion of radiated energy which is acted upon by the ionosphere and returned to earth and also that portion of radiated energy which is propagated along the earth's surface. In this section, consideration is given to that part of the total radiated energy which undergoes reflections and refractions in the troposphere.

Refraction of radio waves in the troposphere is a function of various meteorological variables. Because of the uneven heating of the earth's surface, the air in the troposphere is in constant motion. This motion causes small turbulences, or eddies, to be formed. These turbulences are quite similar to the whirlpools in a rapidly moving stream of water. The turbulence is most intense near the earth's surface and gradually diminishes with altitude.

For frequencies up to about 30 MHz, radio wavelengths are large compared to the size of the turbulences; therefore, the turbulences have little effect on the transmitted signal. However, as the frequency is increased, these local turbulences become increasingly important because they are responsible for tropospheric scatter transmission.

FORWARD PROPAGATION BY TROPOSPHERIC SCATTER

This scattering phenomenon in the troposphere is based on the theory that

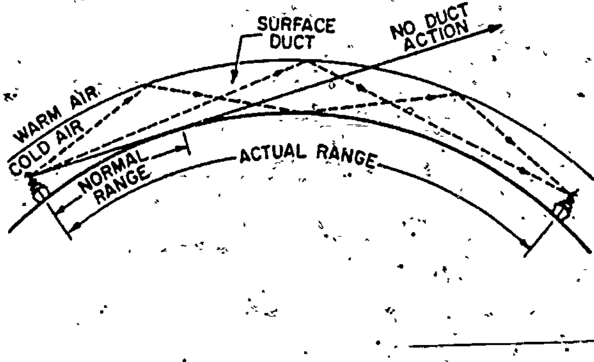

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Figure 7-11.—Duct effect in high frequency transmission.

turbulences prevailing in the troposphere cause scattering of the signal beyond the horizon, and take place primarily when operation is in the UHF range. The scatter effect is the same as if each turbulence received the signal and reradiated it. When properly engineered, Forward Propagation by Tropospheric Scatter (FPTS) is reliable up to distances of 600 miles.

The word "scatter" implies that the spreading of energy is equal in all directions; however, the direction of energy distribution in tropospheric scatter propagation differs only slightly from the direction of the path of the main wavefront. The scattering occurs chiefly in the forward direction; therefore, the term "forward scatter" is sometimes used when talking about tropospheric scatter.

The magnitude of the received signal depends on the number of turbulences causing scatter in the desired direction and the direction and gain of the receiving antenna beam. This quantity or magnitude is called the scatter volume. The scatter volume and scatter angle are shown in figure 7-12. As the scatter angle is increased, the amount of received scattered energy decreases very rapidly.

The amount of received energy decreases as the height of the scatter volume is increased. There are two reasons for this: (1) scatter angle increases as height is increased, (2) the amount of turbulence decreases with height. As the circuit distance is increased, the height of the scatter volume must also be increased. Therefore, the received signal level decreases as the circuit distance is increased.

Since tropospheric scatter depends on turbulences in the atmosphere, changes in atmospheric conditions will affect the received signal level. Both daily and seasonal variations are noted. These changes are called long-term fading. In addition to long-term fading, the tropospheric scatter signal often is also characterized by very rapid fading which is caused by multipath propagation. The signals received at any one time are the sum of all the signals received from each of the turbulences in the volume. Since the turbulent condition is constantly changing, the path lengths and individual signal levels are also changing, resulting in a rapidly changing signal. Although the signal level is constantly changing, the average signal level is persistent, and no complete fade-out occurs.

Another characteristic of a tropospheric scatter signal is its relatively low power level. The scatter volume can be pictured as a relay station, located above the horizon, receiving the transmitted energy and reradiating it to some

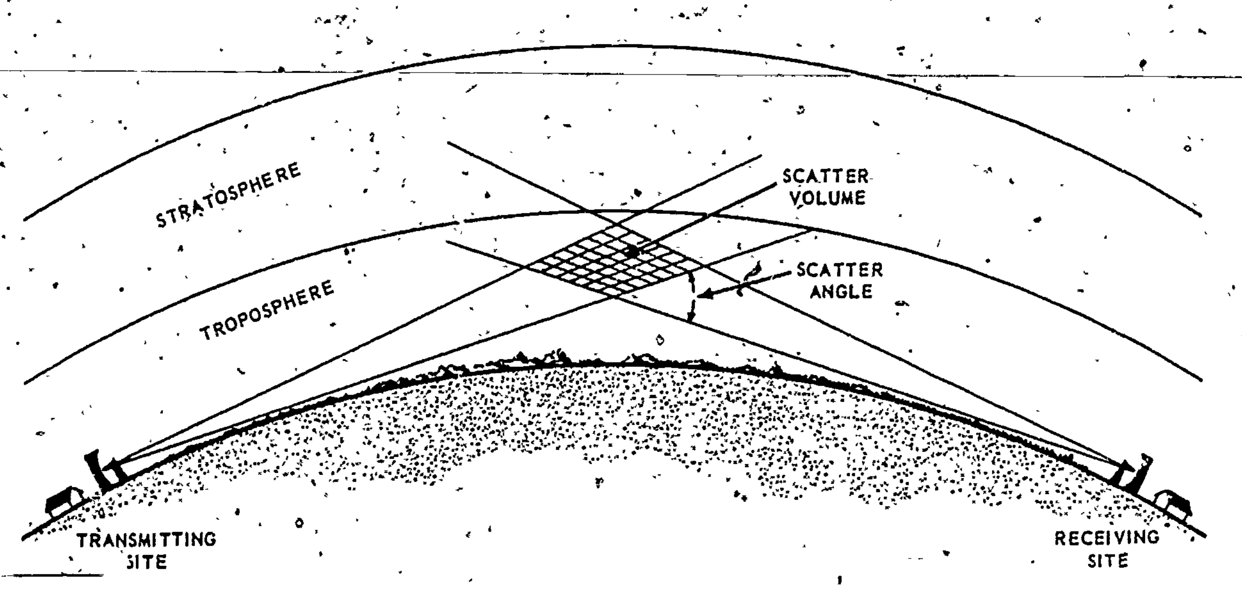

Figure 7-12.—Scatter propagation.

point beyond the line-of-sight distance. Since most of the transmitted energy is not reradiated to the receiver, the efficiency is very low, and the signal level at the final receiver point is low. To compensate for the low efficiency in the scatter volume, the incident power must be high. This is accomplished by using high-power transmitters and high-gain antennas which concentrate the transmitted power into a beam, thus increasing the intensity of energy on each turbulence in the volume. The receiver must also be very sensitive to detect the low level signals.

FREQUENCY SELECTION

Radio wave propagation conditions have their greatest effect on MF/HF circuits between ships and stations separated by great distances. Frequency selection in the MF/HF range is determined by propagation conditions, frequency authorizations and frequency availabilities. The sky waves of higher frequencies can be used during the daytime, while lower frequencies must be used at night. The key to frequency selection is the condition of the ionosphere midway between the two stations. NTP 6, SUPP-1 or other frequency prediction information is used to determine the recommended frequency band. The selected frequency is monitored to be sure it is not already in service.

In all other frequency ranges, circuits usually operate under semi-stable propagation conditions, and frequency selection is based on frequency authorization and frequency availability.

FREQUENCY PREDICTIONS

The Institute for Telecommunication Sciences, previously known as the Central Radio Propagation Laboratory of the National Bureau of Standards, receives and analyzes ionospheric data from many stations throughout the world. These ionospheric data are utilized by the Armed Forces as well as by many other users to produce Monthly Median Frequency Predictions.

OBLIQUE IONOSPHERIC SOUNDER RECEIVER AN/UPR-2

The Ionospheric Sounder Receiver is an equipment that will aid the fleet communicator in frequency selection. As previously stated, the key to frequency selection is the condition of the ionosphere midway between the two stations that are communicating. Frequency selection with the aid of the Ionospheric Sounder Receiver is accomplished in the following manner. A transmitter stationed ashore sends a series of pulse sequences at precise times specified by its published transmission schedule. The sounder receiver is programmed to automatically tune to each of 80 frequencies in the range from 2 to 32 MHz. The tuning changes must occur at exactly the right times and allowances must be made for the time taken for the signal to travel from the transmitter to the receiver. Frequencies that propagate are displayed on a cathode-ray oscillograph in the form of an Ionogram. The Ionogram also shows multipath propagation which produces excessive distortion and the effects of solar flares which cause increased absorption of the lower range of frequencies that propagate.

The Technical Manual contains tables that list the operating procedures of the AN/UPR-2 in a logical sequence.

FREQUENCY PLANS

Frequency plans contain information and guidance for intra-service, joint, and combined use, and for operating in specific areas. JANAP 195 contains information and guidance for U.S. Navy and Marine Corps use; supplements to ACP 176 contain information for units operating with NATO and SEATO pact nations.

ANTENNAS

An antenna is a conductor or a system of conductors for radiating (transmitting) or intercepting (receiving) radio waves. In its elementary form, an antenna may be simply a length of elevated wire like the common receiving antenna for an ordinary broadcast receiver. If an antenna is fed a radio-frequency current from a transmitter, it will radiate electromagnetic waves into space. If an antenna is placed in the path of an electromagnetic wave traveling through space, a radio frequency current will be induced in the antenna. The induced current is used as the input to a receiver. However, before discussing specific types of antennas, it will be helpful to discuss several terms which are used to describe the characteristics of antennas.

ELECTROMAGNETIC WAVE MOTION

The movement of waves in a pond and the movement of electromagnetic waves have characteristics in common.

Suppose you are standing at the edge of a small pond of water. The surface of the pond is smooth and unbroken except for a few dead leaves floating near your feet. If you toss a stone into the center of the pond, ripples spread out from the place where the stone struck the water. In a few moments, the disturbance reaches the leaves floating near you, and they begin to bob up and down. The energy imparted by the stone has made itself felt across the surface of the pond, as shown in figure 7-13.

When the stone is tossed into the pond, it sets up a disturbance at the place where it strikes the water. With the disturbance as the center, waves are produced which move outward in expanding circles. As each circle moves out toward the edge of the pond, a new one forms at the center. Eventually, the waves cover the surface of the pond, and the leaves are bobbing up and down as each wave passes. Notice that the leaves are not carried along with the waves and washed up on the shore, but have only an up and down motion. This is because the water on which the leaves float is not moved sideways by the waves. The only effect of the wave is to raise or lower each particle in its path. The part of the wave that raises a particle is called the crest; the part that lowers a particle is called the trough.

Suppose that a source of RF energy, such as a radio transmitter, is connected to an antenna. The antenna sets up fields in the surrounding space, and the resultant waves are propagated in all directions in the form of expanding concentric circles, as shown in figure 7-14. When these waves encounter some device, such as a receiving antenna, on which they can act, some of their energy is given up to that device. The essential fact in this picture is that energy is transmitted by means of wave motion- in this

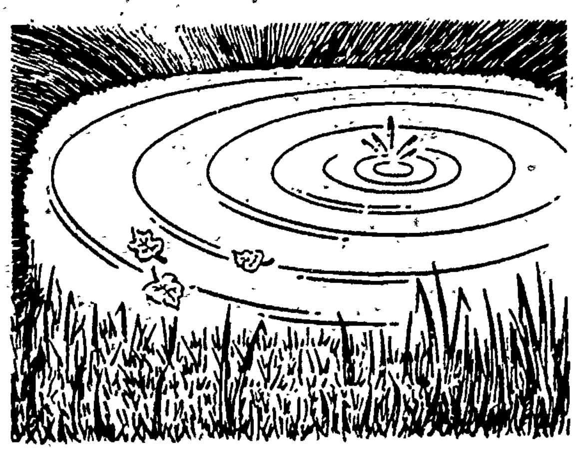

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Figure 7-13.—Wave motion in pond.

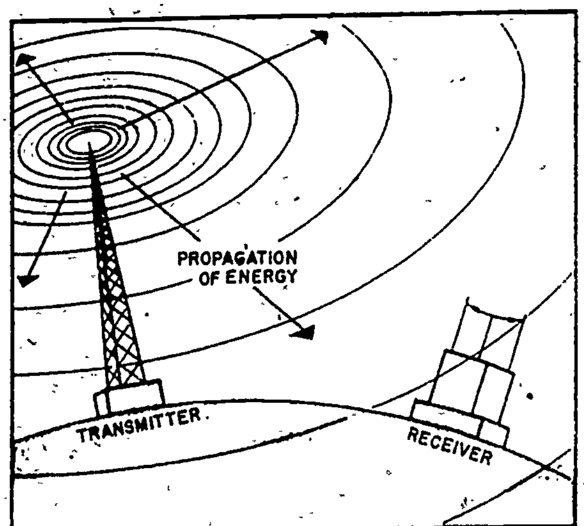

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Figure 7-14.—Electromagnetic wave motion in space.

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case by electromagnetic waves. Some of the energy produced by the transmitter is transferred through space to the receiver in somewhat the same way as some of the energy of the stone tossed in the pond was transferred through the water.

The velocity of these electromagnetic waves moving through space is found in the same manner as the velocity of the water waves. It is the distance divided by the time required to cover that distance. Instead of taking any distance, suppose you consider the distance from the crest of one wave to the crest of the next. This is the length of one wave, or one wavelength. The same distance can also be measured from the trough of one wave to the trough of an adjacent wave. The electromagnetic wave in space has definite wavelength which can be measured in the manner just described. It is usually measured in meters, and its symbol is the Greek letter lambda (λ).

Since the velocity of an electromagnetic wave in free space is considered to be 300 million meters per second, the formula for computing wavelength is expressed as:

$$\text{Wavelength in meters} = \frac{300{,}000{,}000}{\text{Frequency (in hertz)}}$$

For example, to compute the length of a full wave antenna for use on 10,000 kHz proceed as follows:

$$\frac{300{,}000{,}000}{10{,}000{,}000} = 30 \text{ meters, or, since } 1 \text{ meter} = 3.28 \text{ feet}$$

$$30 \times 3.28 = 98.4 \text{ feet}$$

If half-wave or quarter-wave antenna values are desired, simply divide the result by 2 or 4.

POLARIZATION

A radio wave consists of traveling electric and magnetic fields. The magnetic field (H) produces an electric field (E) and the two fields (called the electromagnetic field) radiate into space. The polarization of a wave is determined by the direction of the electric lines of force (E field). If the E field is vertical, the polarization is vertical. Since the E field is parallel to the wire or arms of a simple antenna, an antenna that is vertical with respect to the earth radiates a vertically polarized wave, while a horizontal antenna radiates a horizontally polarized wave. Figure 7-15A represents the vertical electric field component of a vertical antenna. Figure 7-15B shows the horizontal electric field component of a horizontal antenna. Therefore, we refer to the antennas as being vertically or horizontally polarized antennas.

For low frequencies the polarization is disturbed and the radiation field has the same polarization at the distant receiving station that it had at the transmitting antenna. When high-frequency transmission is used, the polarization usually varies, sometimes quite rapidly. Therefore, the polarization of the wave

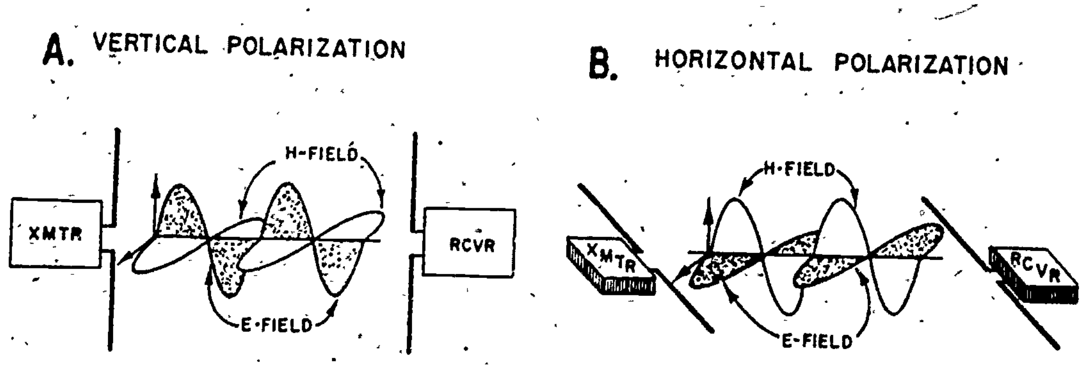

Figure 7-15.—Vertical and horizontal polarization.

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at the receiving station may or may not be the same as the polarization of the wave at the transmitting station.

When the antennas are close to the ground, vertically polarized waves yield a stronger signal close to the earth than do horizontally polarized waves. When the antennas are at least one wavelength above the ground, the two types of polarization give approximately the same field intensities near the earth. When the antennas are several wavelengths above the ground, horizontally polarized waves yield a stronger signal closer to the earth.

Directivity

All antennas are directional to some extent (except for a hypothetical unipole). This means that an antenna used for transmitting will radiate most of its energy in certain directions; an antenna used for receiving will best receive signals from certain directions. The directional characteristics of an antenna are determined to a great extent by its design and the position in which it is installed. Thus certain directional qualities are associated with each type of antenna. The radiation pattern, which is a good indication of the directivity of an antenna or antenna array, is plotted on a chart. Mathematical derivation of antenna patterns for many of the more common types of antennas are given in standard antenna texts, and will not be discussed in this manual.

The following three terms are used to describe general directional qualities of an antenna:

OMNIDIRECTIONAL. Receives or radiates equally well in all directions except off the ends.

BIDIRECTIONAL. Receives or radiates efficiently in two directions; for example, North and South or East and West.

UNIDIRECTIONAL. Receives or radiates efficiently in only one direction.

TRANSMISSION LINE

You make use of a transmission device each time you drive your car. The transmission transfers the power of the engine to the rear wheels; it is the connecting link. In radio we must have a connecting link between the transmitter and antenna, or between the receivers and antenna. This link is called a transmission line. The transmission line transfers energy from the transmitter to the antenna or energy from the antenna to the receiver. If the antenna could be built directly on the transmitter and the receiver, then there would be no need for the transmission line. However, even in a compact installation, such as a ship or aircraft, it is not usually convenient to locate the transmitter or receiver near the antenna. Perhaps you have gained the impression that transmission lines are used only for conducting radio frequency energy from one point to another. This is not true. The lines that supply electrical energy to your house are transmission lines just as much as are the wires connecting one circuit to another.

A transmission line can therefore be defined as a device for transmitting or guiding electrical energy from one point to another. A poor transmission line decreases the amount of energy available at the transmitting antenna for radiation or at the receiver for reception. Conversely, a perfect transmission line delivers the entire transmitter output to the antenna or the entire received signal to the receiver. In such an ideal system, the antenna alone radiates or receives energy.

RF transmission lines behave differently in different frequency ranges. An RF transmission line designed to operate at the relatively low frequencies used in the standard broadcast range is not likely to be usable in point-to-point aircraft communication system. An RF transmission line can be expected to transfer energy efficiently from one point to another only at the frequency for which it is designed. When this line is used at higher frequencies, it will have greater losses. In practice this means that different kinds of transmission lines must be available for use in different frequency ranges.

BASIC TYPES OF ANTENNAS

An invention often borrows the name of its inventor. This is true about two basic antennas, the Hertz and Marconi.

Half-Wave

A basic form of antenna with a length of one-half wavelength or a multiple thereof is known as a dipole or Hertz antenna. (See fig. 7-16.) This type of antenna will not function efficiently unless its length is one-half wave length (or a multiple thereof) of the frequency to be radiated or received. Therefore, this antenna is not suitable when a wide range of frequencies is to be used. A distinguishing feature of a dipole antenna is that it need not be connected to the ground as are other antennas which will be described later. At low frequencies, half-wave antennas are rather long; therefore they are used primarily at shore installations where there is sufficient room. At very high and ultrahigh frequencies, the shorter wavelength permits construction using metal rods or tubing. Depending upon the wave polarization desired, the dipole may be mounted either horizontally or vertically. Transmission lines may be connected in the center or at the ends of the dipole. Because the dipole is an ungrounded antenna, it may be installed far above the ground or other absorbing structures.

Quarter-Wave

A grounded antenna which is one-fourth wavelength, or any odd multiple thereof, of the frequency to be radiated or received is known as a Marconi antenna. (See fig. 7-17.) Notice that the transmission lines are connected between the bottom of the antenna and the ground. Although the antenna itself is only a quarter wavelength, the earth acts as another quarterwave antenna—the image antenna shown in figure 7-17. Half-wave operation is obtained by aid of this image. This type of antenna can be used on planes and ships where the plane's fuselage or the ship's hull provides the image antenna. It is often practical to use a quarter-wave antenna where space is a problem.

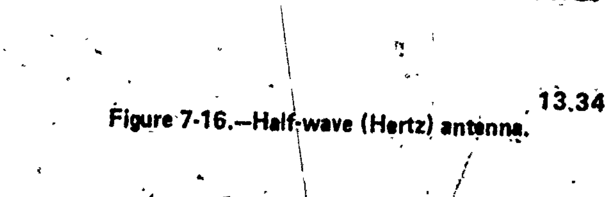

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Figure 7-16.—Half-wave (Hertz) antenna.

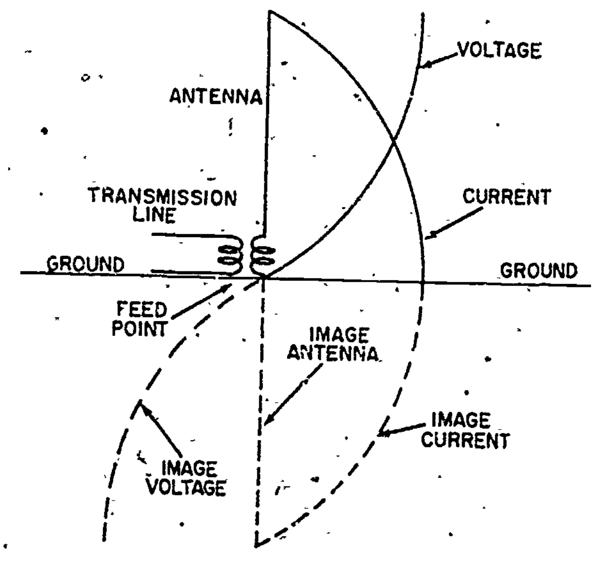

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Figure 7-17.—Marconi antenna and waveforms of current and voltage.

There are many variations of the quarter and the half-wave antenna as well as many different types designed for special use throughout the range of the radio frequency spectrum. They are often used as components of more complex antennas. Combinations of elements, electrically connected and physically spaced in the proper manner, can be used to obtain many desirable features. Such combinations of elements are called ARRAYS.

COMMON CONFIGURATIONS

It is difficult to classify a particular type of antenna as strictly a shore station type or a shipboard type unless, of course, its physical dimensions are the fundamental consideration. For this reason, several antennas described in the remainder of this chapter are used both ashore and afloat, even though they may be indicated as either typical shore station or typical shipboard types. The types described are merely a sampling of the many and varied antennas which will be encountered.

Horizontal Rhombic Antennas

In its basic configuration, a rhombic is composed of four long horizontal conductors or legs, arranged in the shape of a rhombus. The rhombics used at Naval Security Group receiver sites are generally the terminated, unidirectional type as shown in figure 7-18. Horizontal rhombic antennas are the most commonly used antennas for point-to-point HF naval communications. The main disadvantage of this type of antenna is the requirement for a large area.

Multi-Wire Rhombic

A rhombic antenna will improve in performance if more than a single wire is used to form each leg. By using three wires (see figure 7-19) to form each leg and connecting all of them at both ends to a common point, but spacing them vertically 5 to 7 feet apart at the side poles, an improved antenna known as a "curtain rhombic" is formed.

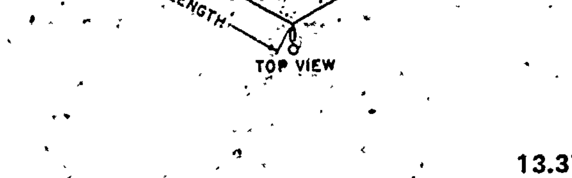

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Figure 7-18.—Typical rhombic antenna.

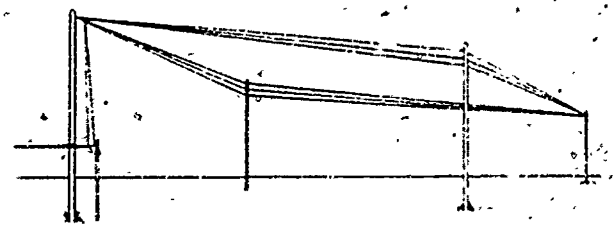

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Figure 7-19.—Three wire rhombic antenna.

Sleeve Antenna

The sleeve antenna is used primarily as a receiving antenna in Navy Communications. It is a broadbanded, vertically polarized omnidirectional antenna. Consequently, its primary applications are in broadcast, ship/shore/ship, and ground/air/ground service rather than point-to-point communications.

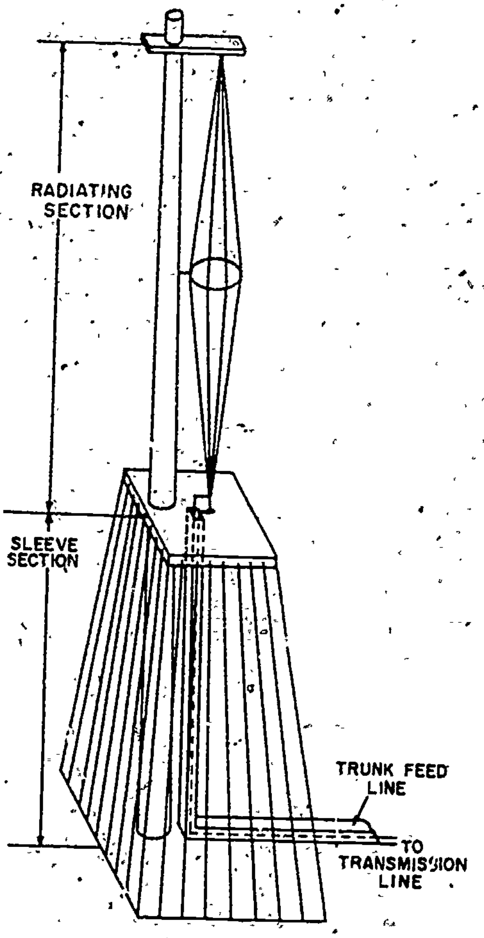
Originally, the sleeve antenna was developed to fill the need for a versatile antenna at shore stations, but it has been modified for shipboard use also. Figure 7-20 is a shore station version of a sleeve antenna. The shipboard sleeve antenna is shown in figure 7-21.

Conical Monopole Antenna

Conical monopoles are used extensively in HF Navy Communications. They were developed to fulfill a need for efficient broadband, vertically polarized, omnidirectional antennas that are compact in size. Their comparatively short height is a definite asset to be considered in conjunction with their excellent power handling capabilities and broad bandwidth. Conical monopoles are readily adaptable to ship/shore/ship, broadcast, and ground/air/ground service. A conical monopole antenna is shown in figure 7-22. Like the sleeve antenna, it is used both ashore and aboard ship.

Wire Antennas

For some applications ashore, especially in VLF and LF transmissions, it is practical to use



13.40
Figure 7-20.—Sleeve antenna (shore station).

an antenna that is simply a long wire with one end connected to the equipment. A long-wire antenna will usually be stretched between poles in such a manner that the wire is essentially parallel to the surface of the earth. (See fig. 7-23.) Long single-wire antennas are constructed several wavelengths long; in some cases in the VLF band, the antenna may extend several miles. If a long-wire antenna is five or more wavelengths, the more directional it will be along its axis.

Wire antennas (fig. 7-24) are installed aboard 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.

Much larger wire is used for shipboard antennas than for land installations. The larger wire is less likely to break under the strain of shipboard vibrations. Additionally, it can be stretched tighter to avoid sagging in hot weather. The wire is twisted and stranded for additional strength. Usually it is made of phosphor-bronze, a material that is nonmagnetic and resists corrosion. Wire of receiving antennas ordinarily is covered with a plastic insulation, but wire of transmitting antennas is uninsulated.

Receiving wire antennas normally 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 transmitting antennas so that a minimum of energy is picked up from local transmitters. The transmission line (lead-in) for each receiving antenna terminates in antenna transfer panels in radio spaces.

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

The metal rings, antenna knife switches, antenna hardwire, 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 in that it shows at a glance whether an antenna is used for radiating or receiving.

Inverted Cone Antenna

Inverted cone antennas similar to the one illustrated in figure 7-25 are vertically polarized,

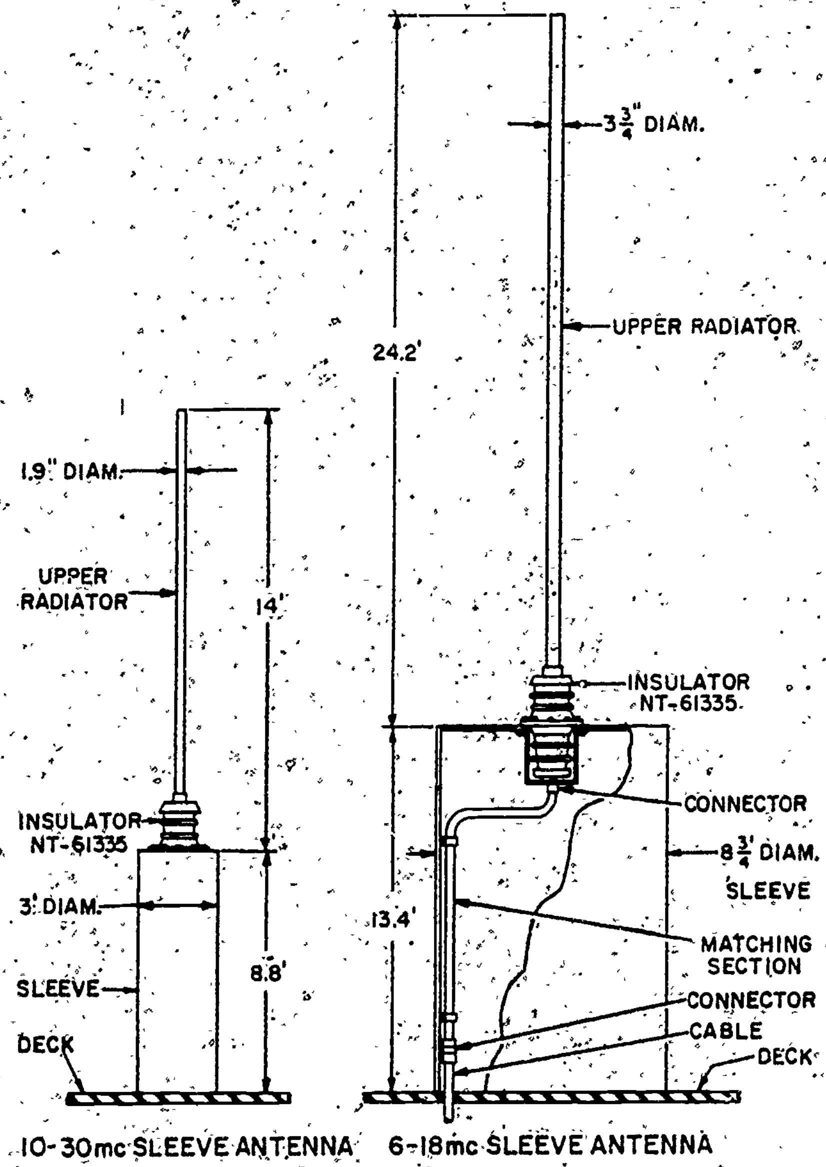


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Figure 7-21.—Sleeve antennas for shipboard use.

omnidirectional, very broadbanded radiators. This antenna is widely used in Navy HF communications in ship/shore/ship, broadcast, and ground/air/ground applications. The designed frequency range is for approximately 3 to 30 MHz.

The radial ground plane that forms the ground system for inverted cones is typical of the requirement for vertical ground mounted antennas. The radial wires are one-quarter wavelength long at the lowest design frequency, and are spaced 3 degrees apart.

HF inverted cones are electrically similar to conical monopole antennas. Also, the inverted cones generally are more expensive than other

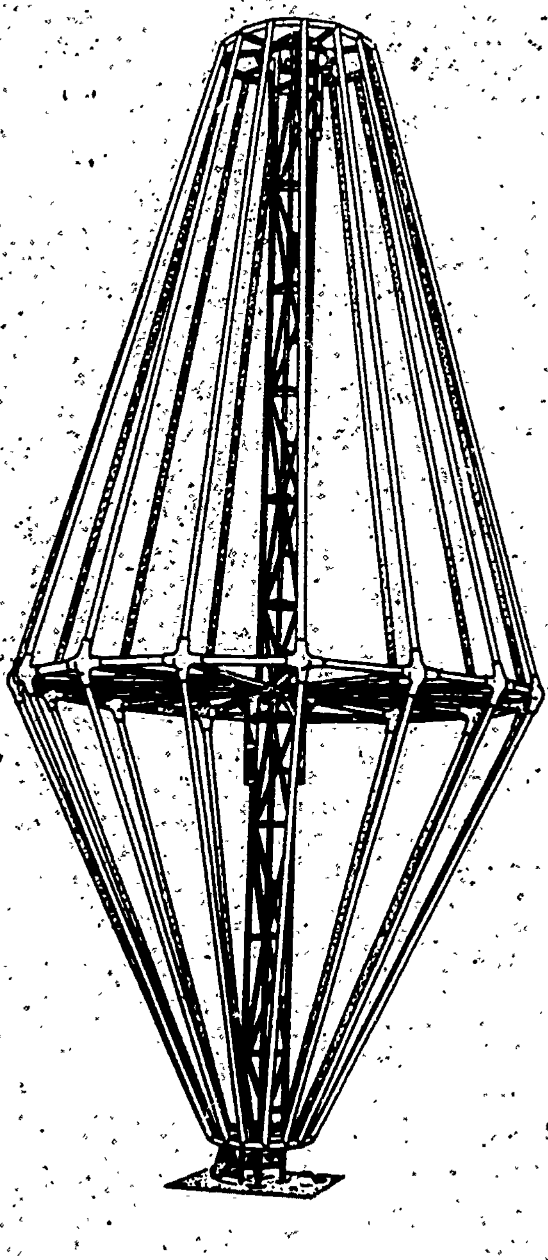

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Figure 7-22.—Conical monopole antenna.

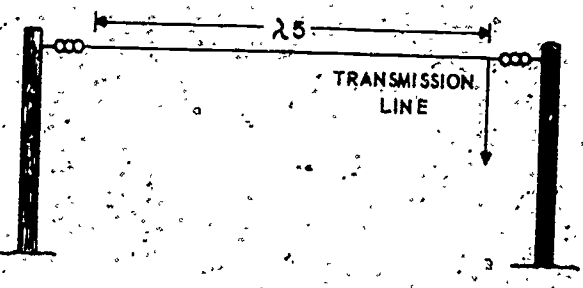

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Figure 7-23.—Long wire antenna.

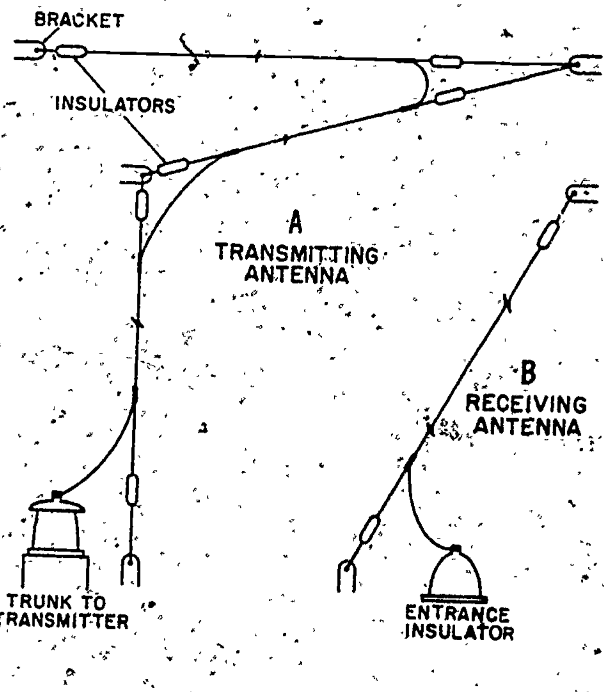

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Figure 7-24.—Shipboard wire antennas.

commonly used HF omnidirectional vertical antennas.

Whip Antenna

Whip-type antennas have replaced many wire antennas aboard ship because they are essentially self-supporting, may be deck-mounted, or mounted on brackets on the stacks or superstructure (figure 7-26). The physical characteristics of tiltable whips for use along the edges of aircraft carrier flight decks and retractable whips for use aboard submarines are two more advantages of the whip antenna for shipboard use. Whip antennas used in HF communications are made of tubular metal or fiberglass covered metal. They are usually 35 feet in length; however, some models are

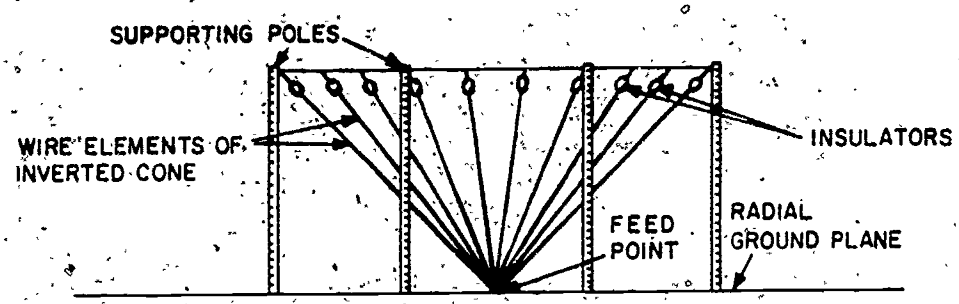

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Figure 7-25.—Inverted cone antenna.

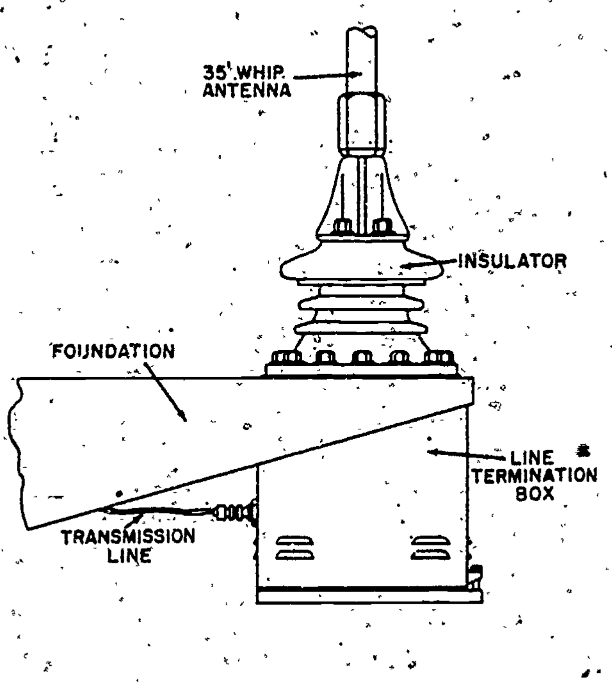

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Figure 7-26.—Whip antenna.

adjustable from a length of 2 feet to a maximum length of 35 feet. Their wide application in Navy HF communications is due primarily to their low cost and simplicity of installation. Even though it is generally assumed that HF whips are designed for efficient operation throughout the 2 to 30 MHz range, actual radiation efficiency is largely dependent upon their operation with associated tuning devices (normally used with transmitters) and a ground plane. Without an antenna tuning system, whips will generally have a narrow bandwidth and will also be limited in power radiating capability.

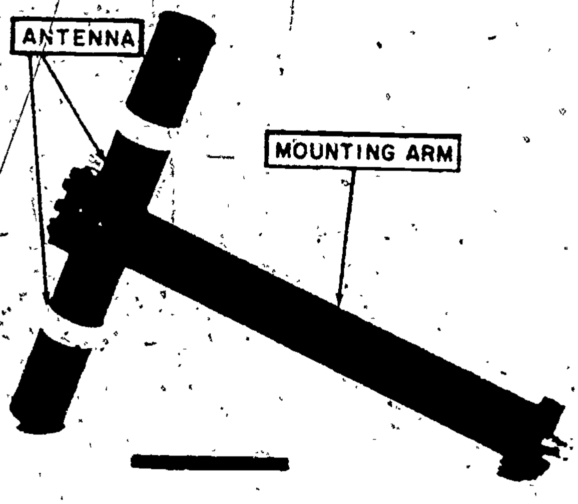
Whip antennas are vertically polarized omnidirectional monopoles which are electrically characteristic of the general class of vertical radiators. They are used in short-range ship/shore/ship communications, in transportable communications systems, and in laboratory and shop installations.

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. The reason for the high installation is that vertical conductors, such as masts, rigging, and cables in the vicinity, cause unwanted directivity in the radiation pattern.

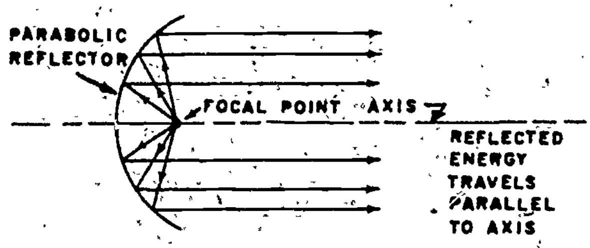
For best results in the VHF and UHF ranges, both transmitting and receiving antennas must have the same polarization. Vertically polarized antennas are used for all ship-to-ship, ship-to-shore, and air-ground VHF UHF communications. Usually, either a vertical half-wave dipole or a vertical quarter-wave antenna with ground plane is used.

An ultrahigh frequency antenna of the half-wave (dipole) type is the AT-150/SRC (figure 7-27). The horizontal (longer) portion of the antenna does not radiate, but acts as a mounting arm for the antenna and as an enclosure for the antenna feed line. This type of antenna is normally mounted horizontally.



1.48

Figure 7-27.—UHF antenna AT-150/SRC.



1.49

Figure 7-28.—Principle of parabolic reflection.

PARABOLIC ANTENNA.—Communication systems such as microwave line-of-sight radio and tropospheric scatter use parabolic antennas. These systems operate at frequencies that have radiation properties approaching those of light waves and therefore can be reflected in much the same manner that a searchlight reflector controls a light beam.

It thus becomes practicable at microwave frequencies to use high-gain antennas that resemble reflectors used in searchlights. These antennas concentrate energy into a narrow beam in the same manner as light energy. With the beam directed in the desired direction, it can be seen that a much larger signal arrives at the receiving antenna than would happen with a nondirectional antenna. Figure 7-28 depicts a parabolic antenna that is used for transmission and reception of microwave electromagnetic energy.

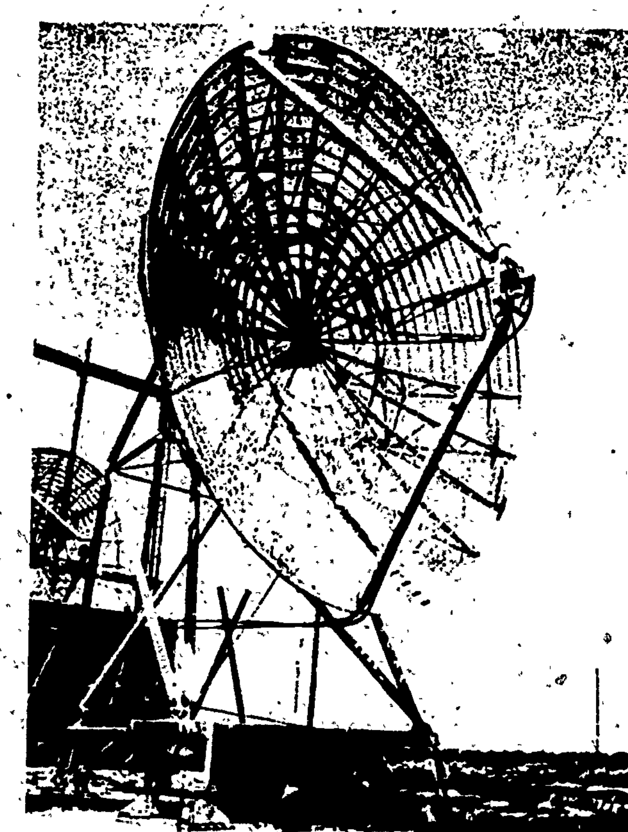


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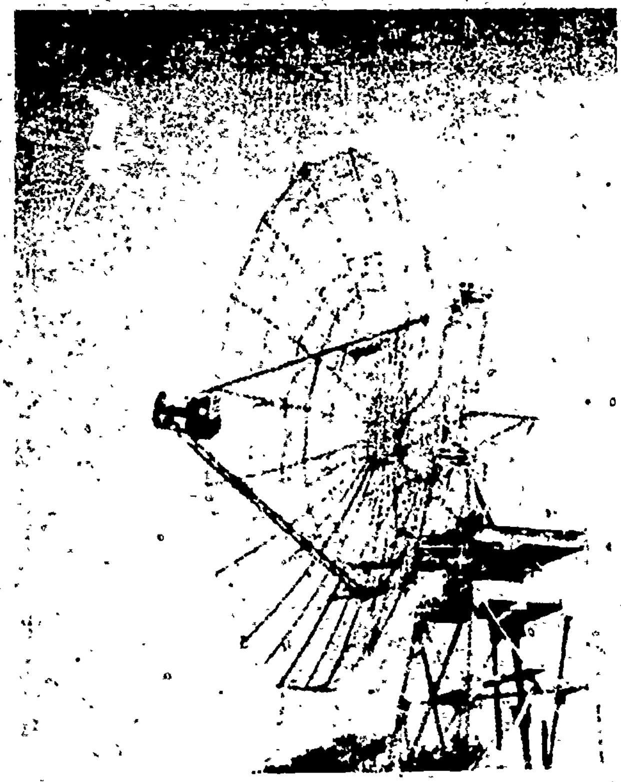
Figure 7-29.—Mobile tropospheric 30 foot scatter antenna.

Figures 7-29 and 7-30 show two types of tropospheric scatter antennas. Because of the wave propagation in the troposphere, the signal strength fluctuates considerably; consequently, much of the signal is lost. A steady signal can be maintained by using diversity reception. Energy from each of a number of fluctuating signals may be combined. All tropo scatter systems use diversity reception. To obtain signals over different paths that fade and vary independently, some or all of the following methods may be used. Signals obtained over two or more independent paths by these methods are



76.59
Figure 7-30.—Tropospheric scatter antenna.

combined in the receiver in such a way as to utilize the best signal at all times.

a. Space diversity: Receiving antennas separated by 50 wavelengths or more at the signal frequency (usually 10 to 200 feet is sufficient).

b. Frequency diversity: Transmission on different frequencies fades independently, even when transmitted and received through the same antenna.

c. Angle diversity: Two feedhorns produce two beams from the same reflector at slightly different angles. This method results in two paths based on illuminating different scatter volumes in the troposphere.

Figure 7-31 shows a possible arrangement of a tropospheric scatter site. Antennas on the left are called billboard antennas; those on the right are dish antennas. Antennas vary in size from 60 feet in diameter to 120 feet in diameter or more.

Log-Periodic Antenna

A requirement has existed in the HF and VHF bands, as well as other frequency bands, for an antenna which will operate over an extremely wide frequency range. Figure 7-32 shows a typical LPA designed for extremely broad-band, VHF communications. These antennas are of a general class whose structure is such that the directivity pattern will vary periodically with the logarithm of the frequency. If the variations over one period are small, and continue to be small for all periods, the result will be an extremely broad-band antenna.

The LPA can be mounted on steel towers or utility poles that incorporate rotating mechanisms and is particularly useful where antenna area is limited. A rotating LPA is known as an RLPA, and possesses essentially the same characteristics as the fixed LPA, but has a different physical form. (See fig. 7-33.) RLPA's commonly are used in ship/shore/ship and in point-to-point communications. The ability to rotate the array 360 degrees is a distinct advantage when the relative merits of the fixed and rotatable versions of the LPA are compared.

Wullenweber Antenna Array

The Wullenweber array is an effective vertically polarized antenna array for Navy HF receiving systems. Although its initial development was for high frequency direction finder applications, the Wullenweber has been accepted for service as a point-to-point communications antenna. Most Navy receiver sites using the Wullenweber antenna for

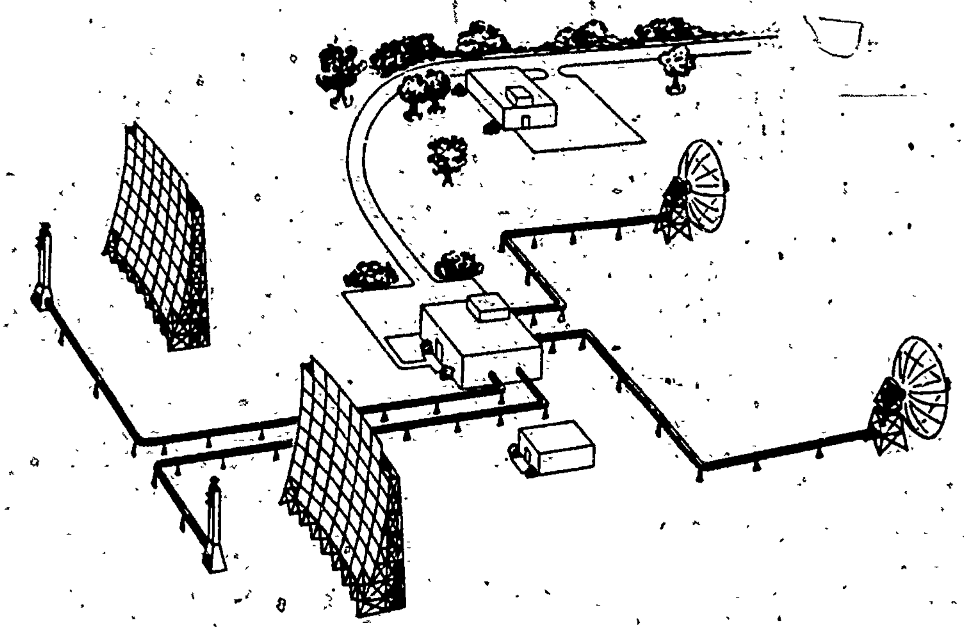


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Figure 7-31.—Possible arrangement of a tropospheric scatter communication site.

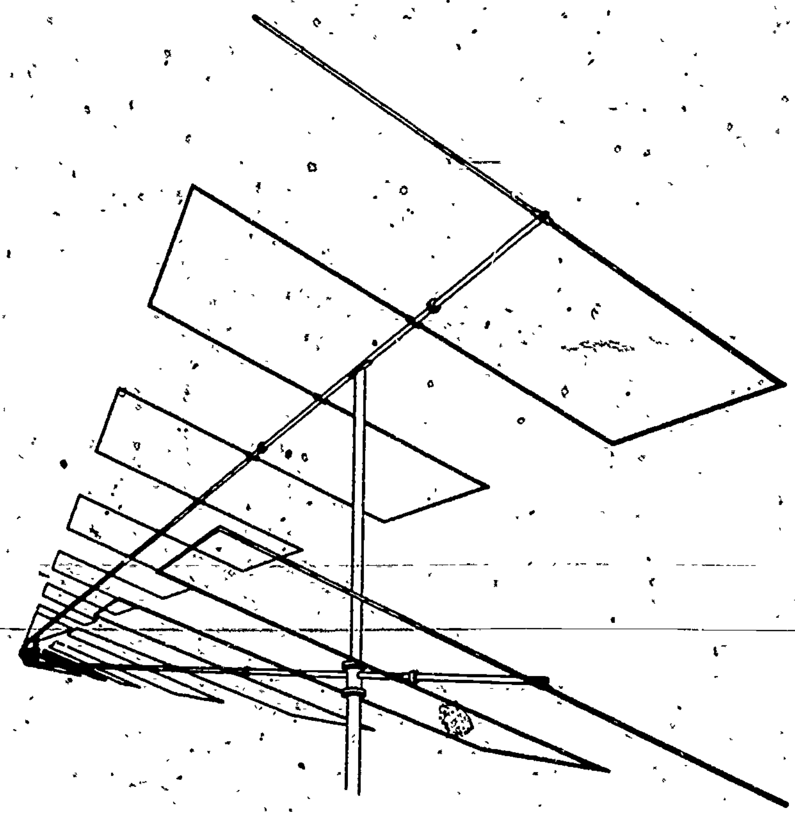

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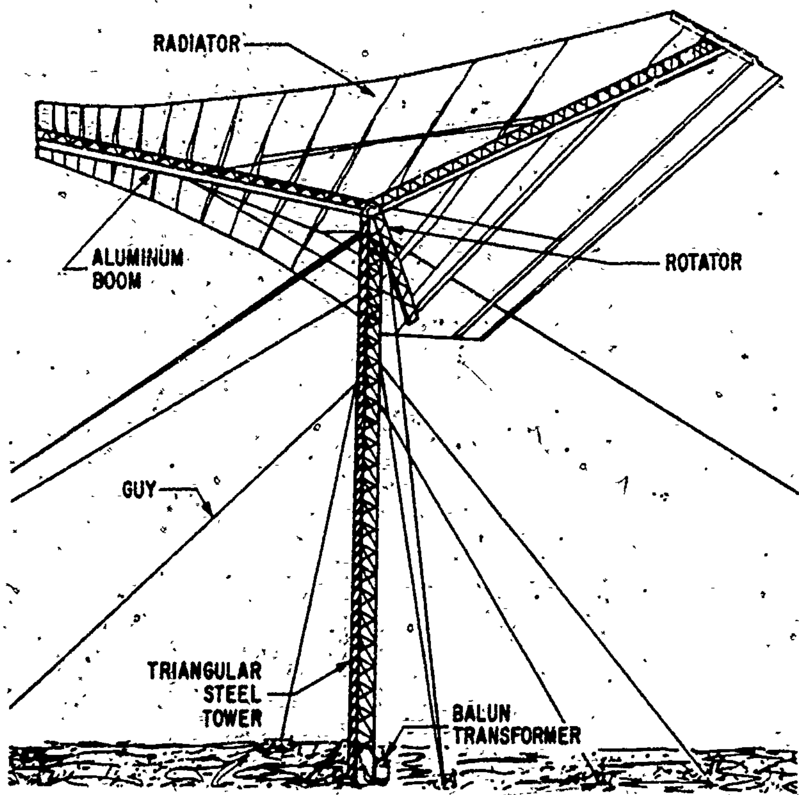
Figure 7-32.—Log periodic antenna.



31.114

Figure 7-33.—Rotatable log periodic antenna.

point-to-point communications do so on a shared basis with other mission requirements.

A typical Wullenweber array, as shown in figure 7-34, consists of two reflecting screens and two sets of antenna elements arranged in four concentric circles over a ground plane system of radials and mats. The low-band reflector screen forms the innermost circle; and, proceeding outward, there is the circle of 40 low band antenna elements, then the high-band reflector screen, and then the circle of 120 high-band antenna elements.

The Wullenweber array is designed to receive HF signals ranging from 2 to 10 MHz on the low-band, and from 10 to 30 MHz on the high band antenna.

The low and high-band reflector screens are composed of vertical wires attached at the upper end to pole-supported horizontal beams, and connected to the ground plane at the lower end. This vertical screen arrangement contributes to the directional characteristics for Wullenweber array.

Selectively Directional Monopole Antenna

The latest model of this antenna has been placed in service for Navy HF transmitting applications as the AN/FRA-109. It is a high power radiator capable of operating either omnidirectionally or directionally, as selected.

The AN/FRA-109 antenna system consists of two separate monopole antennas plus auxiliary equipment as shown in figure 7-35.

One monopole (the low-band) covers the 4 to 11 MHz range, while the other monopole (the high-band) covers the 11 to 30 MHz range. The two antennas are identical in construction except for differences in physical size dictated

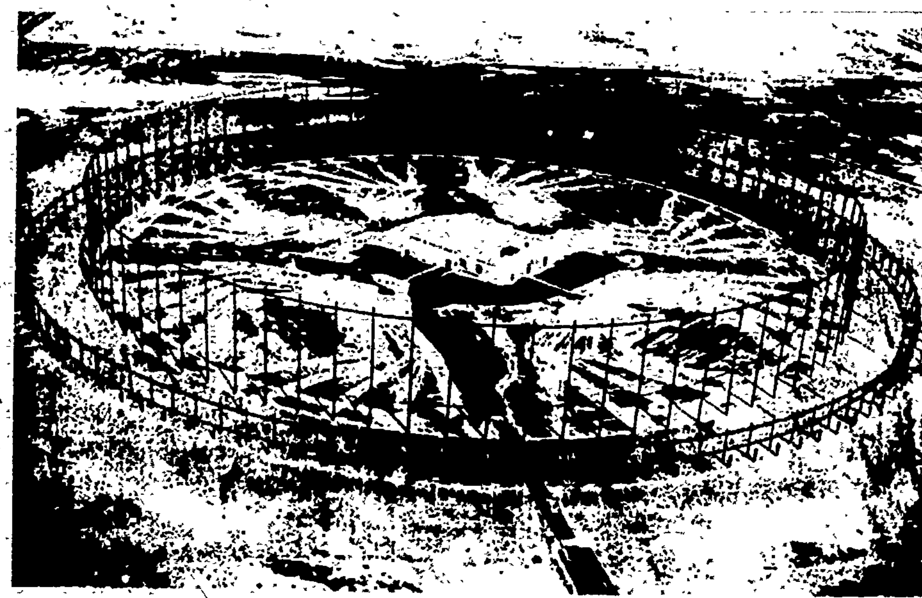


Figure 7-34.—Circularly disposed antenna array (CDAA). 25.117

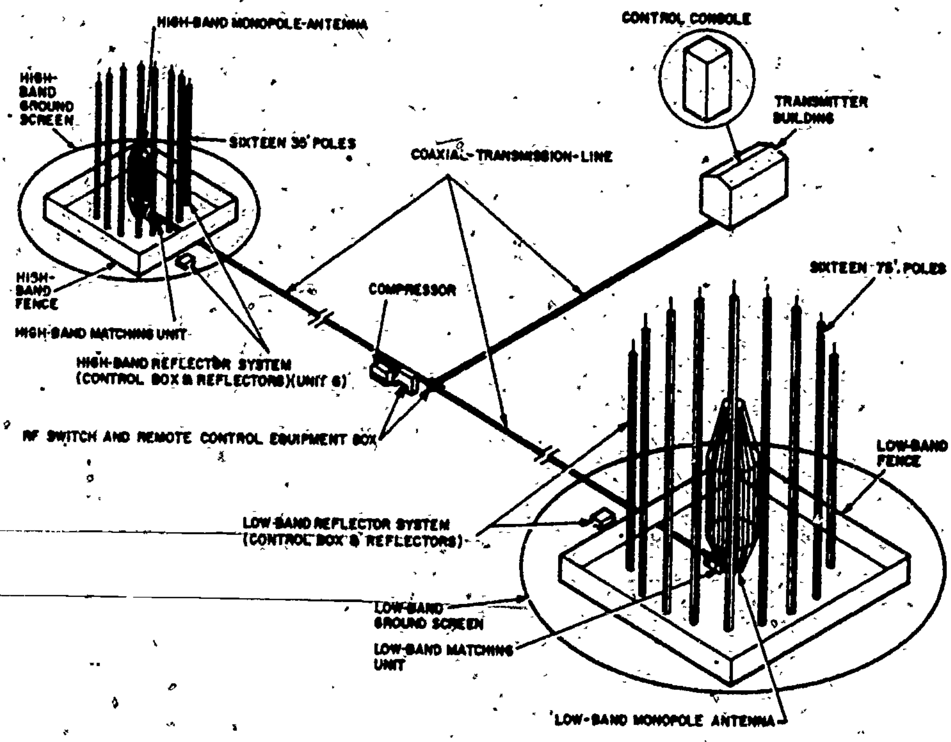
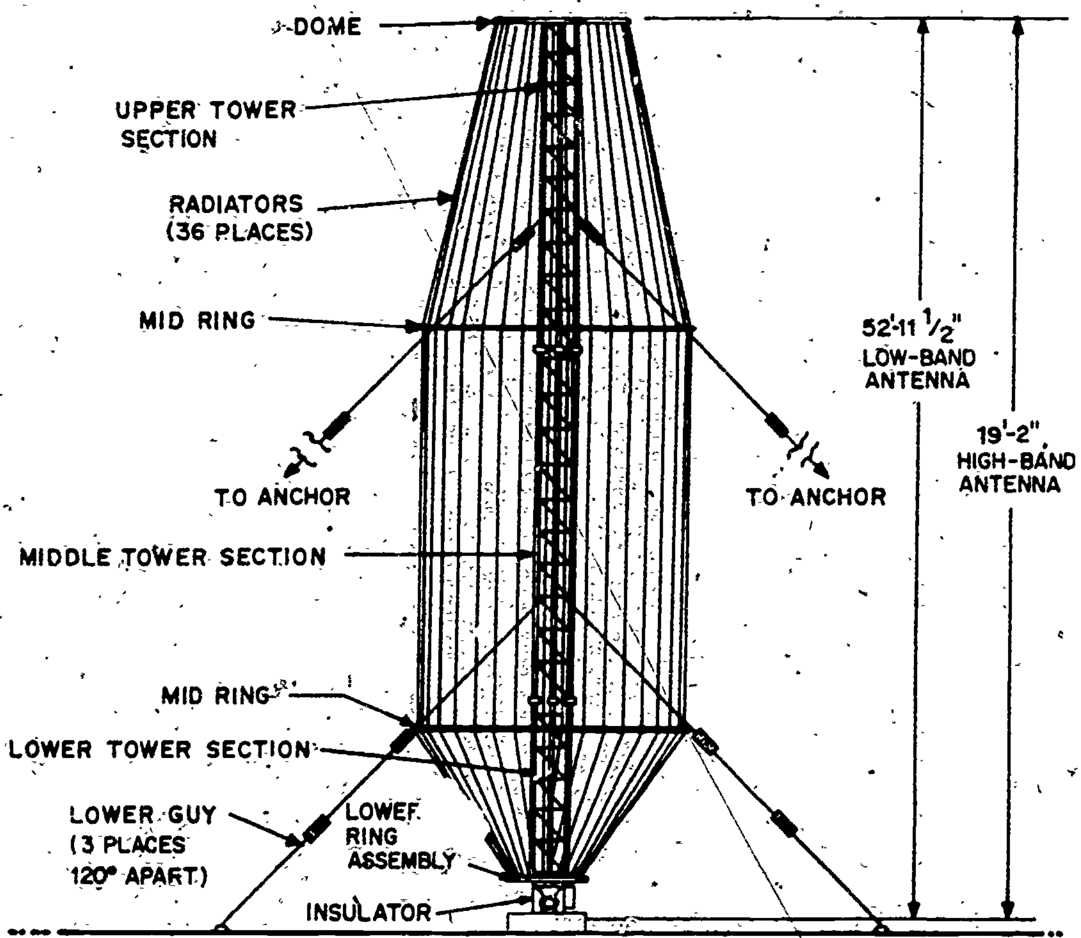


Figure 7-35.—Antenna set, AN/FRA-109. 31.115



31.116

Figure 7-36.—Low and high band monopole antenna.

by frequency. The monopole is illustrated in figure 7-36.

Emergency Antenna

Loss or damage to an antenna from heavy seas, violent winds, or enemy action may cause serious disruption of communications. Sections of a whip antenna may be carried away, insulators may be damaged, or a wire antenna may snap loose from its moorings or break. If loss or damage should happen when all available equipment is needed, you may have to rig an emergency antenna (or at least assist) to restore communications on a temporary basis until the regular antenna can be repaired.

The simplest emergency antenna consists of a length of wire rope to which a high-voltage insulator is attached to one end and a heavy alligator clip or lug is soldered to the other. The end with the insulator is hoisted to the nearest structure and secured. The end with the alligator clip (or lug) is attached to the equipment transmission line. To radiate effectively, the antenna must be sufficiently clear of all grounded objects.

CHAPTER 8

COMMUNICATION TRANSMITTERS AND RECEIVERS

Transmitters and receivers must each perform two basic functions. The transmitter must generate an electric current of sufficient power and at the desired frequency, and have some means of varying (or modulating) the basic frequency so that it can carry an intelligible signal. The receiver must select the desired frequency to receive and reject any undesired frequencies. Selecting the intelligible portion of the desired signal and converting the intelligence into audible sound waves or some type of visual presentation (page print, facsimile copy, etc.) so that it can be understood. In addition, receivers must have provisions for amplification to increase the volume of the received signal in order to overcome the attenuation that it necessarily suffers in its journey through space.

Generally, transmitters are located at remote sites and operated by personnel of the RM (radioman) rating. In description of representative transmitters, only fundamental features are discussed in this manual.

TRANSMITTER TYPES

Basic communication transmitters include the continuous wave (CW), amplitude modulated (AM), frequency modulated (FM), and single sideband (SSB) types. A brief description of each type follows.

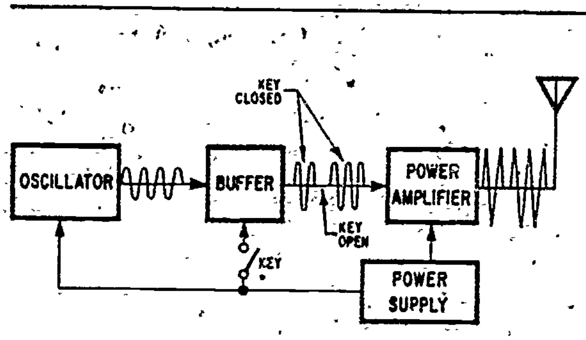
CONTINUOUS WAVE (CW) TRANSMITTER

The continuous wave is used principally for radiotelegraphy—that is, for the transmission of short or long pulses of RF energy to form the dots and dashes of the Morse Code characters. This type of transmission is sometimes referred to as interrupted continuous wave. CW transmission was the first type of radio communication used, and it is still used extensively for long range communications. Some of the advantages of CW transmission are a narrow bandwidth and a high degree of intelligibility even under severe noise conditions.

The four essential components of a CW transmitter are: (1) a generator of RF oscillations; (2) a means of amplifying these oscillations; (3) a method of turning the RF output on and off (keying) in accordance with the intelligence to be transmitted; and (4) an antenna to radiate the keyed output of the transmitter.

A block diagram of a CW transmitter together with the power supply is shown in figure 8-1. The oscillator generates the RF carrier of a predetermined frequency and maintains it within required limits. The oscillator may be the self-excited type, which originates a signal in electron tubes or transistors and associated circuits. Or it may be of the crystal type, which uses, in conjunction with an electron tube or transistor, a quartz crystal cut to vibrate at a certain frequency when electrically energized. In either type, voltage and current delivered by the oscillator are weak. Thus, the output of both types of oscillators must be amplified many times to be radiated any distance.

The buffer stage or first intermediate power amplifier stage is a voltage amplifier that increases the amplitude of the oscillator signal to a level that will drive the power amplifier. Power delivered by the buffer varies with the type of transmitter, but it may be hundreds or thousands of volts.



179.383
Figure 8-1.—CW transmitter block diagram.

The buffer serves two other purposes, one of which is to isolate the oscillator from the amplifier stages. Without the buffer, changes in the amplifier due to keying or variations in source voltage would vary the load on the oscillator and cause it to change frequency. It may also be a frequency multiplier, as we will see later.

The final stage of a transmitter is the power amplifier. Power is the product of current times voltage, and in the power amplifier a large amount of RF current is made available for radiation by the antenna.

The key is used to turn the buffer on and off. When the key is closed, the RF carrier passes through the buffer stage, and when the key is open, the RF carrier is prevented from getting through.

The power amplifier of a high-power transmitter may require far more driving power than can be supplied by an oscillator and its buffer stage. One or more low-power intermediate amplifiers may be required between the buffer and the final amplifier that feeds the antenna. The main difference between many low and high-power transmitters is in the number of intermediate power-amplifying stages that are used.

In the block diagram of figure 8-2 the input and output powers are given for each stage of a typical medium-frequency transmitter. It is shown that the power output of a transmitter can be increased by adding amplifier stages capable of delivering the power required.

AMPLITUDE MODULATED (AM) TRANSMITTER

In amplitude modulation, the instantaneous amplitude of the RF output signal is varied in proportion to the modulating signal. The modulating signal may consist of many frequencies of various amplitudes and phases, such as the signals comprising speech.

The block diagram of a simple AM radiotelephone transmitter is shown in figure 8-3. The oscillator, buffer, and power amplifier serve the same purpose as in the CW transmitter. The microphone converts the audio (sound) input into corresponding electrical energy. The modulator amplifies the audio signal to the amplitude necessary to fully modulate the carrier. The output of the modulator is applied to the power amplifier. The RF carrier and the modulating signal are combined in the power amplifier to produce the amplitude modulated RF carrier output for transmission. In the absence of a modulating signal, a continuous RF carrier is radiated by the antenna.

SINGLE SIDEBAND (SSB) TRANSMITTER

A single sideband (SSB) transmitter translates audio frequency intelligence to desired radio frequencies. Unlike the amplitude modulated (AM) transmitter, usually only one of the sidebands, either the upper or the lower sideband, is transmitted while the remaining sideband and the carrier are suppressed.

Figure 8-4 is the block diagram of an SSB transmitter. The audio amplifier increases the amplitude of the signal to a level adequate to operate the SSB generator. Usually the audio amplifier is just a voltage amplifier.

The SSB generator combines the audio input and the carrier input from the frequency generator to produce the two sidebands, and then suppresses the carrier. The two sidebands are then fed to a filter which selects the desired sideband and suppresses the other one.

The SSB generator in most cases operates at a very low frequency compared with the normal transmitted frequency. It is necessary, therefore, to convert (or translate) the sideband output from the filter to the desired frequency. This is

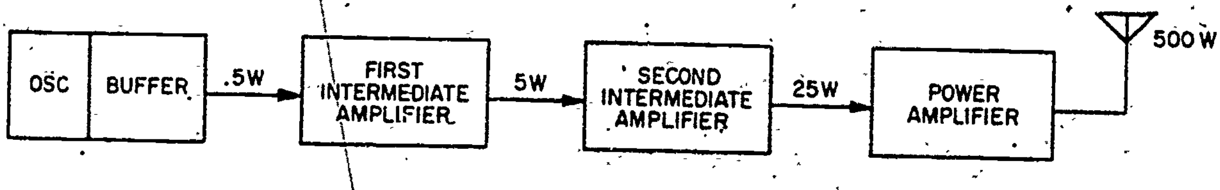


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Figure 8-2.—Intermediate amplifiers increase transmitter power.

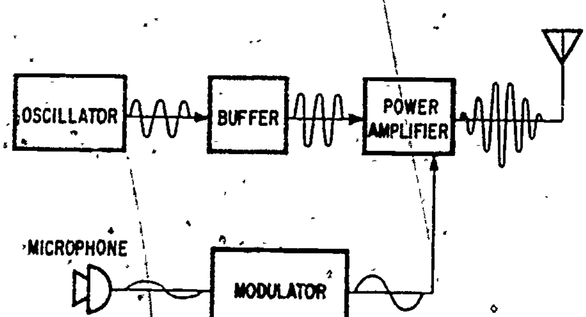

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Figure 8-3.—AM radiotelephone transmitter block diagram.

the purpose of the mixer stage. To obtain a higher carrier frequency for the mixer stage, a second output is obtained from the frequency generator and fed to a frequency multiplier. The output from the mixer is fed to a linear power amplifier to build up the level of the signal for transmission.

FREQUENCY MODULATED (FM) TRANSMITTER

In frequency modulation (FM) the modulating signal combines with the carrier in such a way as to cause the frequency of the resultant wave to vary in accordance with the instantaneous amplitude of the modulating signal.

Figure 8-5 is the block diagram of a narrow band frequency modulation transmitter. The modulating signal is applied to a reactance tube causing the reactance to vary. The reactance tube is connected across the tank circuit of the oscillator. With no modulation, the oscillator generates a steady center frequency. With modulation applied, the reactance tube causes the frequency of the oscillator to vary around the center frequency in accordance with the modulating signal. The output of the oscillator is then fed to a frequency multiplier to increase the frequency and then to a power amplifier to increase the amplitude to the desired level for transmission.

HARMONICS AND FREQUENCY MULTIPLICATION

The term harmonics sometimes is loosely used to designate unwanted radiations caused by imperfections in the transmitting equipment, but this interpretation is not entirely accurate. True harmonics are always exact multiples of the basic or fundamental frequency generated by an oscillator, and are created in vacuum tubes and their associated circuits. Even harmonics are 2, 4, 6, 8 (and so on) times the fundamental; odd harmonics are 3, 5, 7, 9 (etc.) times the fundamental. If an oscillator has a fundamental frequency of 2500 kHz, harmonically related frequencies are—

5,000 . . . . 2nd harmonic

7,500 . . . . 3rd harmonic

10,000 . . . . 4th harmonic

12,500 . . . . 5th harmonic

It should be noted that the basic frequency and the 1st harmonic are one and the same.

The series ascends indefinitely until the intensity is too weak to be detected. In general, the energy in frequencies above the third harmonic is too weak to be significant.

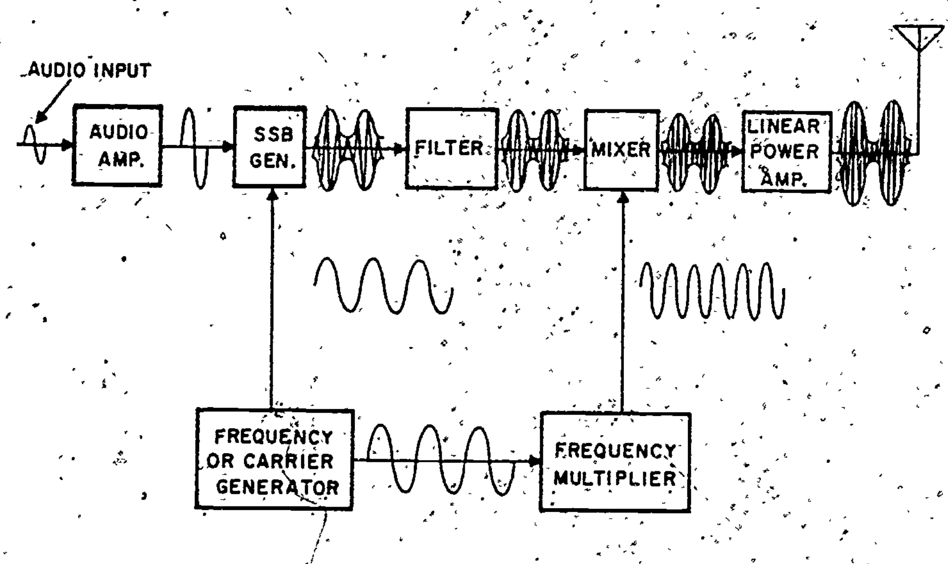

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Figure 8-4.—SSB transmitter block diagram.

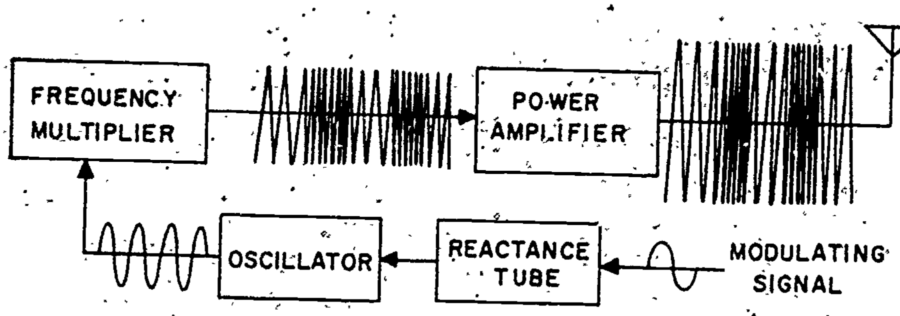

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Figure 8-5.—Narrow band FM transmitter.

It is difficult to design and build a stable crystal oscillator, because the crystal must be ground so thin that it might crack while vibrating. These transmitters therefore have oscillators operating at comparatively low frequencies, sometimes as low as one-hundredth of the output frequency. Oscillator frequency is raised to the required output frequency by passing it through one or more frequency multipliers. Frequency multipliers are special power amplifiers that multiply the input frequency. Stages that multiply the frequency by 2 are called doublers; those that multiply by 3 are triplers; and those multiplying by 4 are quadruplers.

The main difference between many low-frequency and high-frequency transmitters is in the number of frequency-multiplying stages used. Figure 8-6 shows the block diagram of a typical Navy UHF/VHF transmitter. The oscillator in this transmitter is tunable from 18.75 MHz to 33.33 MHz. The multiple stages increase the frequency by a factor of 12 by multiplying successively by 2, 2, and 3.

In high-power, high-frequency transmitters, one or more intermediate amplifiers may be

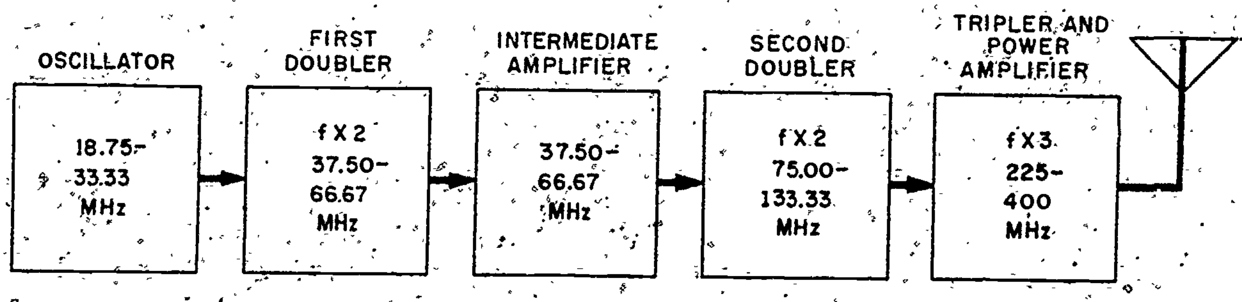

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Figure 8-6.—Frequency-multiplying stages of typical VHF/UHF transmitter.

used between the last frequency multiplier and the final power amplifier.

REPRESENTATIVE TRANSMITTERS

Modern medium-frequency and high-frequency shipboard transmitters must be capable of transmitting over a wide range of frequencies. In addition to CW and radiotelephone modes of operation, they must be capable of handling RATT and FAX transmissions. They must be of rugged construction for long service life. Transmitters that meet these requirements, therefore, are quite complex and because of the limited space available for their installation in naval vessels, they are of compact construction.

One method of obtaining equipment compactness is to combine a transmitter and a receiver into a single unit called transceiver. A transceiver uses part of the same electronic circuitry for both transmitting and receiving, hence cannot transmit and receive simultaneously. A transmitter-receiver, however, is a separate transmitter and receiver mounted in the same rack or cabinet. The same antenna may be utilized for the transmitter-receiver arrangement, (but the capability for independent operation of the equipment still exists). Both terms are used in the descriptions of equipment that follow.

In physical size, shore based transmitters are usually several times larger than shipboard transmitters. However, the power output of shore based transmitters is many times greater than shipboard transmitters. This high power output is necessary to provide reliable long-haul broadcast and point-to-point communications.

AN/FRT-39/40

The radio transmitter set AN/FRT-39 (figure 8-7) is a general purpose radio communications transmitter capable of providing 10,000 watts output throughout a frequency range of 2 to 28 MHz. The principle function of the equipment is to provide long range communications from shore-to-ship or point-to-point, by the single-sideband type of operation. The equipment may also be used for the following types of transmission:

(1) CW (keyed carrier)
(2) Frequency-Shift Carrier
(3) Single-Sideband Suppressed Carrier
(4) Double-Sideband Suppressed Carrier
(5) Independent Sideband (separate intelligence)
(6) Single- or Double-Sideband (with carrier)

With the addition of two cabinets, power amplifier and power supply, the AN/FRT-39 becomes an AN/FRT-40 (Figure 8-8). The power amplifier stage and antenna tuning controls of the AN/FRT-39 are slightly modified and become the intermediate power amplifier stage of the AN/FRT-40. The final power amplifier section of the AN/FRT-40 consists of a power amplifier capable of 40,000 watts together with ample power supply, relay and control, protective circuits and meters.

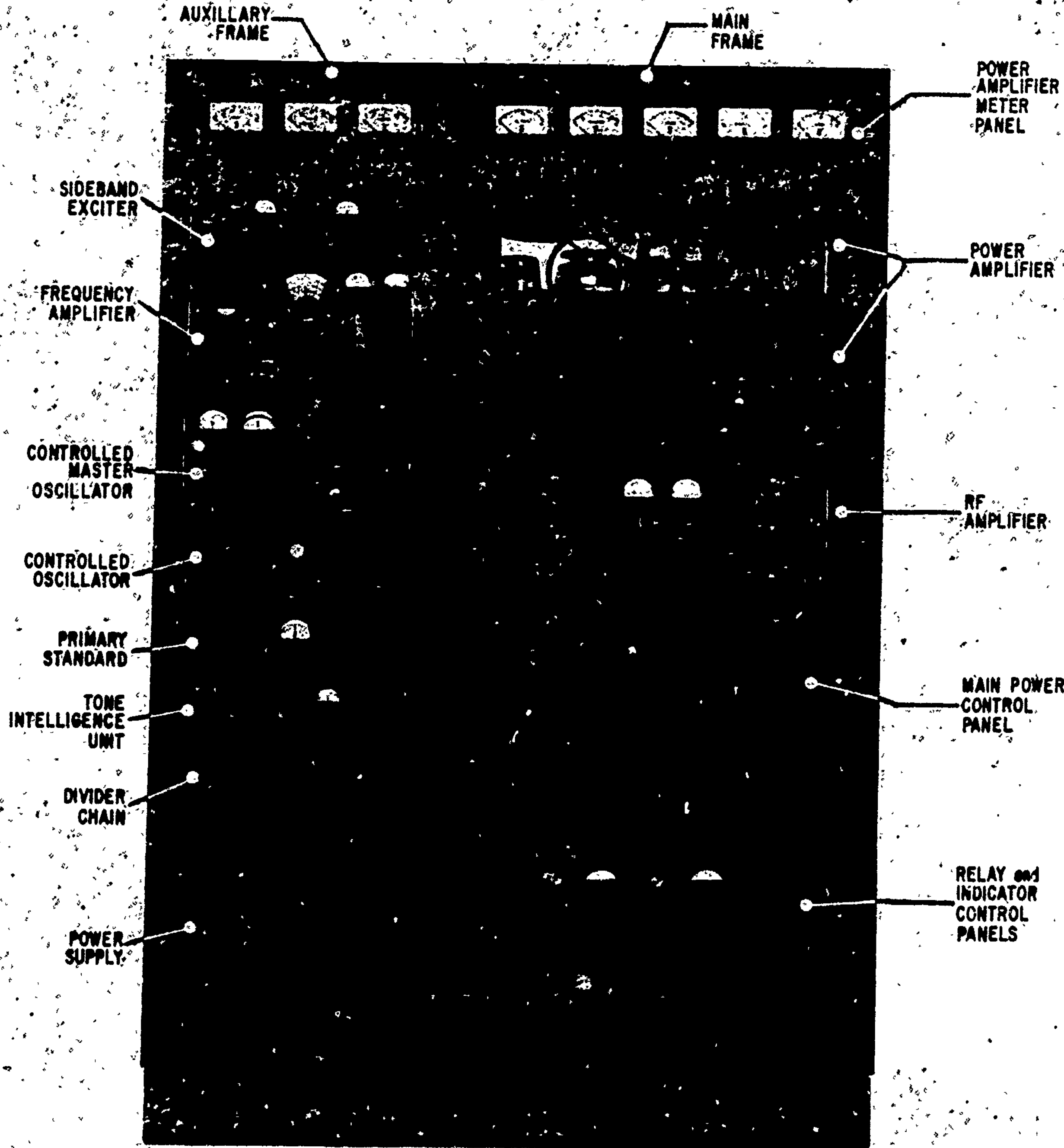

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Figure 8-7.—Radio transmitter set AN/FRT-39.

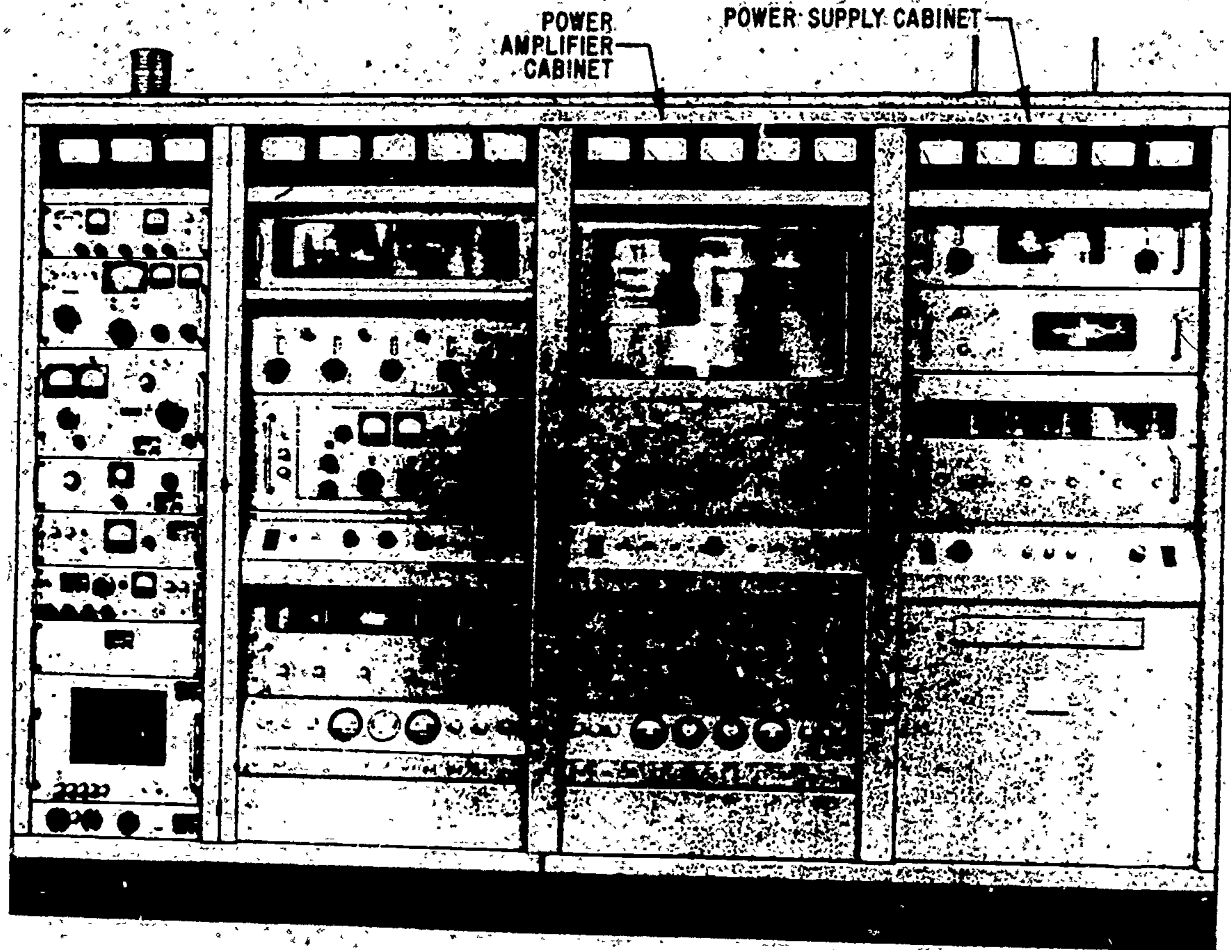

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Figure 8-8.—Radio transmitting set (synthesized), AN/FRT-40.

The AN/FRT-39 is constructed in two basic sections, the main frame and the auxiliary frame. The main frame is located to the right of the auxiliary frame and houses the power amplifier, the intermediate power amplifier, the main power supply, and high voltage section, the power amplifier loading and tuning controls, the relay and indicator control panels, and the meter panel. The auxiliary frame houses all of the sideband exciter equipment, exciter power supply equipment, and other control equipment for the various modes of operation.

AN/URC-32

One of the Navy's most versatile communication equipments is the AN/URC-32 (figure 8-9). It is a transceiver operating in the 2- to 30-MHz high-frequency range, with a transmitter peak envelope power of 500 watts.

The AN/URC-32 is designed chiefly for single-sideband transmission and for reception on either the upper or lower sidebands, or on both sidebands simultaneously with separate audio and IF channels for each sideband. In addition to single sideband operation, provisions

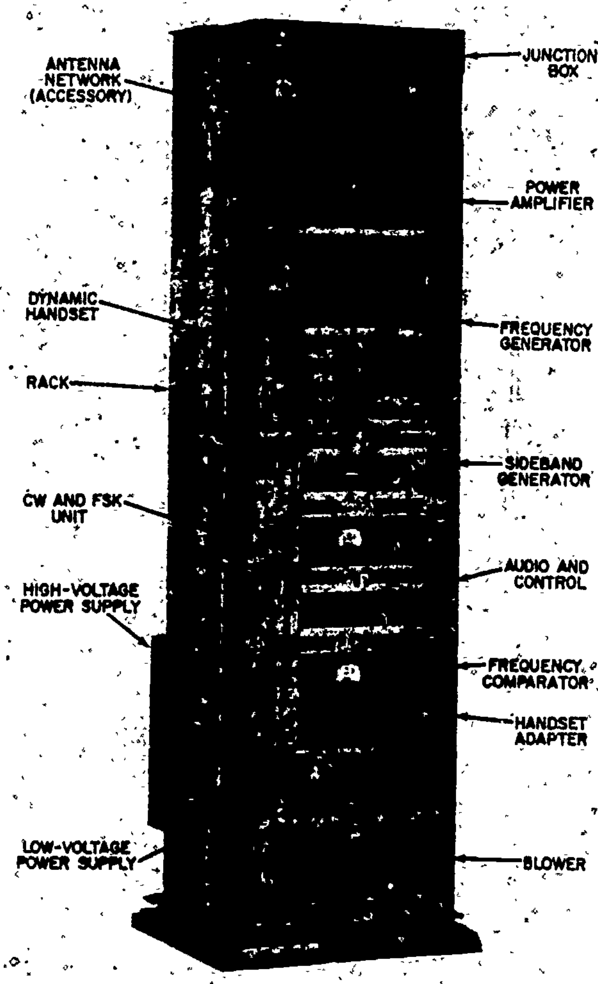

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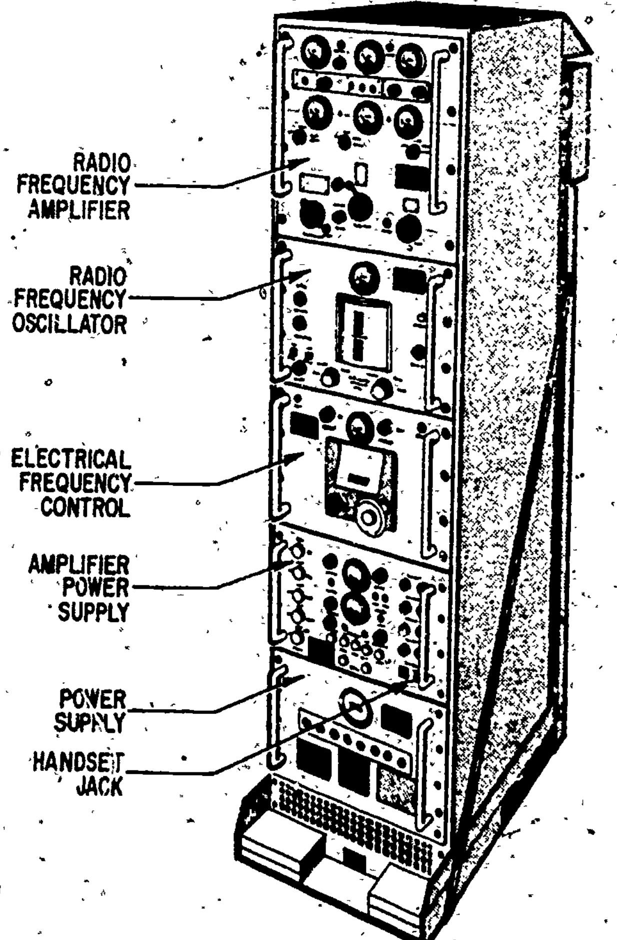
Figure 8-9.—Radio transceiver AN/URC-32B.



32.278(31B)
Figure 8-10.—Radio transmitter AN/WRT-2.

are included for AM (carrier reinserted), CW or FSK operation.

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.

AN/WRT-2

The AN/WRT-2 (fig. 8-10) is a modern HF transmitter used in surface ships and submarines. It provides complete frequency coverage in 1-kHz steps over the frequency range of 2 to 30 MHz. The RF oscillator produces fundamental frequencies from 2 to 8 MHz. Frequency multiplication produces frequencies from 8 to 30 MHz.

The AN/WRT-2 transmitter has an output power of 500 watts on CW, frequency shift RATT and FAX, and conventional AM radiotelephone. It has a power output of 1000 watts when transmitting single sideband or independent sideband.

Coupling to an antenna is through a radio frequency tuner mounted as close to the antenna as possible. The radio frequency tuner is constructed so that it may be installed on the weather decks of surface ships.

A front panel handset jack is furnished for local phone operation of the equipment. A built-in dummy load permits off-the-air tuning under conditions of radio silence.

AN/WRC-1

The AN/WRC-1 (fig. 8-11) is a single sideband radio transmitter-receiver. It is capable of transmitting on any one of 56,000 frequencies, spaced in 0.5-kHz increments, in the frequency range of 2 to 29.9995 MHz. This set has a maximum power output of 100 watts. Vernier (continuous) tuning enables reception on any frequency in the 2-to-30-MHz range.

The AN/WRC-1 is capable of transmitting and receiving SSB, CW, compatible AM, FSK, and ISB signals in either a simplex or duplex operation.

The AN/WRC-1 radio set consists of four separate units. These units are the R-1051/URR radio receiver, radio transmitter T-827/URT, RF amplifier AM-3007/URT, and an interconnection box used to connect the other three units together. Both the receiver and transmitter contain their own power supplies and can be operated as individual units.

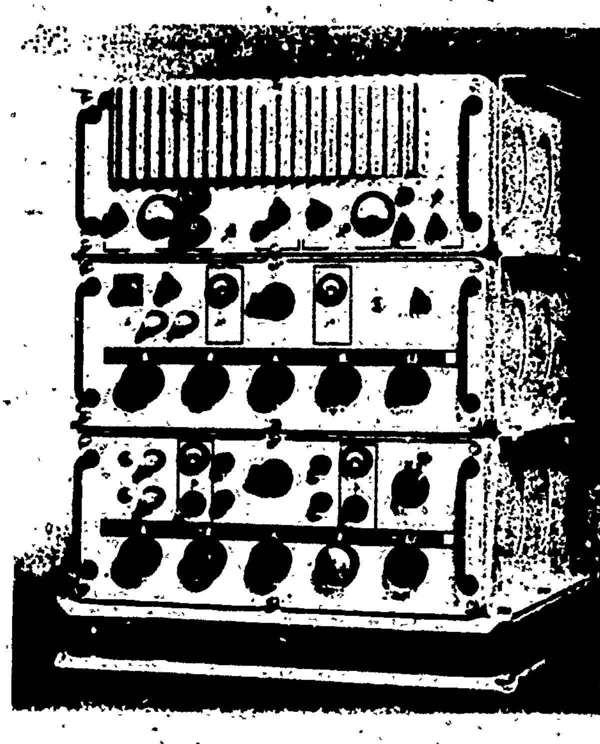


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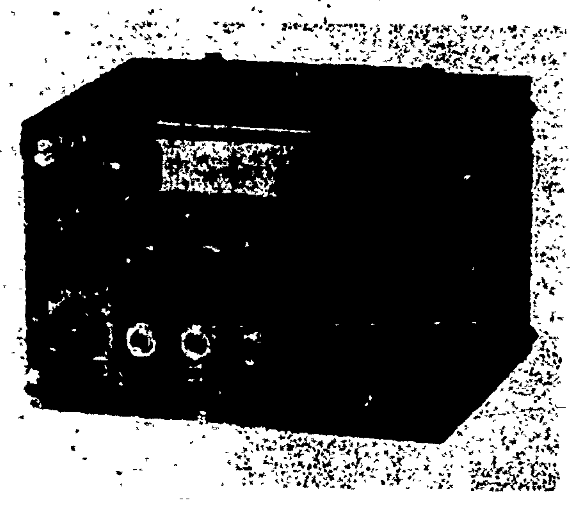
Figure 8-11.—Radio set AN/WRC-1.

REMOTE CONTROL UNIT

To operate a transmitter from a remote location requires a remote-control unit. A typical remote-control unit, commonly called RPU (radiophone unit), is type C-1138A/UR shown in figure 8-12. This unit contains a start-stop switch for turning the transmitter on or off, jacks for connecting a handset or chest set microphone, headphones, or telegraph key, a volume control for the headphones, and indicator lamps for transmitter-on and carrier-on indications.

DUMMY ANTENNAS

Under radio silence conditions, placing a carrier on the air during transmitter tuning would give an enemy the opportunity to take direction-finding bearings and determine the location of the ship. Even during normal periods of operation, transmitters are to be tuned by methods that do not require radiation from the



7.40.2A

Figure 8-12.—Radiophone unit (RPU).

antenna. The reason for this precaution is to minimize interference to other stations using the circuit.

One way to tune a transmitter without causing unwanted radiation is through use of previously determined and recorded calibration settings for the tuning controls. Another method is to use a dummy antenna. Dummy antennas (called dummy loads) have resistors that dissipate the RF energy in the form of heat and prevent radiation by the transmitter during the tuning operation. One model, typical of most dummy loads, is the DA-91/U (fig. 8-13), which can be used with transmitters up to 500 watts. It is enclosed in a metal case that has fins to increase its air-cooled surface area. The dummy load, instead of the antenna, is connected to the output of the transmitter, and the normal transmitter tuning procedure is followed. Use of the dummy load with transmitters such as AN/SRT-15 requires manual disconnection of the transmission line at the transmitter, and connection of the dummy load. Upon completion of transmitter tuning, the dummy load is disconnected and the antenna transmission line is connected again to the transmitter.

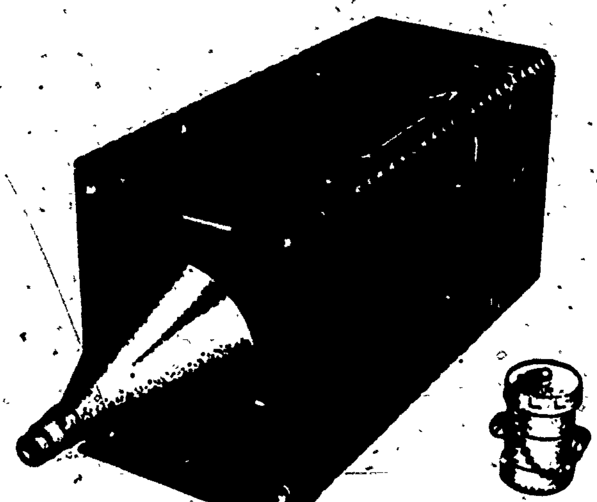


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Figure 8-13.—Dummy antenna DA-91/U.

Some Navy transmitters, such as the URC-32, have built-in dummy antennas. This arrangement permits connection of either the dummy antenna or the actual antenna by simply throwing a switch.

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.

FUNCTIONS OF RECEIVERS

Radio receivers must perform the following six functions (figure 8-14):

1. Signal interception.
2. Signal selection.
3. Radiofrequency amplification.
4. Detection.
5. Audiofrequency amplification.
6. Sound reproduction.

These six functions are sufficient for AM reception, but for CW reception an additional circuit (shown by dotted lines, figure 8-14), called a beat-frequency oscillator, is required.

Signal Interception

The receiving antenna intercepts a small portion of the passing radio waves. The signal voltage extracted by receiving antennas is only a few microvolts, sufficient for subsequent amplification as long as the noise energy intercepted by the antenna is substantially less than this.

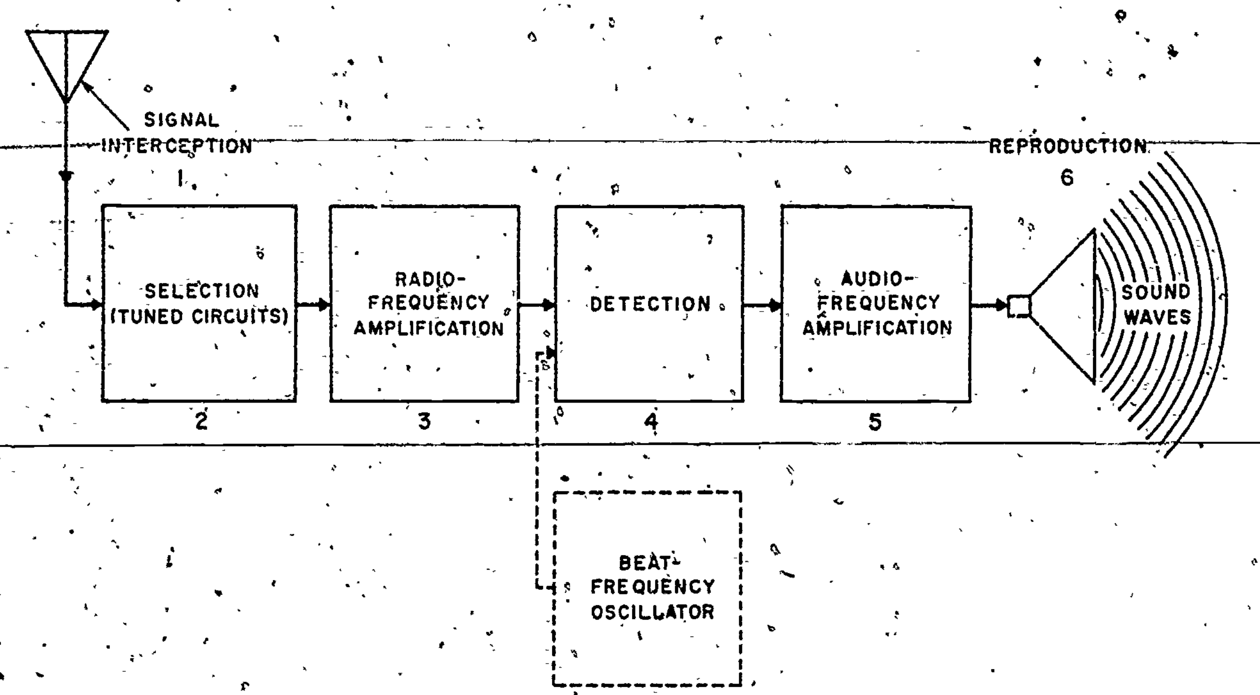

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Figure 8-14.—Essentials of radio reception.

Signal Selection

Some means must be provided to select the desired signal from all RF carriers intercepted by the antenna. This selection is made by tuned circuits that pass only their resonant frequency (frequency to which the receiver is tuned) and reject other frequencies. Thus the receiver is able to differentiate between the desired signal frequency and all other frequencies.

Radiofrequency Amplification

The weak signals intercepted by the antenna usually must be amplified considerably before the intelligence contained in them can be recovered. One or more RF amplifiers serve to increase the signal to the required level. A tuned circuit in each RF amplifier makes sure that only the desired signal is amplified.

Detection (Demodulation)

If the signal is amplitude modulated, the original intelligence must be recovered from it by separating the modulation signal from the RF carrier. The circuit that separates the audiofrequency signal variations from the RF carrier is called the detector or demodulator. Most detectors do not operate well at very low signal levels, and this is one of the reasons why RF amplification is required ahead of the detector.

In CW (radiotelegraphy) reception, a beat-frequency oscillator (bfo) is used in the receiver circuit. The bfo provides an RF signal that beats or heterodynes against the frequency injected into the detector. The resultant frequency is a low-level audiofrequency.

Audiofrequency Amplification

The signal frequency in the output of the detector generally is too weak to operate a headset or loudspeaker. One or more stages of AF amplification are therefore required to strengthen the audio output of the detector to a level sufficient to operate the headset or loudspeaker.

Sound Reproduction

The amplified AF signal is applied to the headset or loudspeaker that translates the electrical AF variations into corresponding sound waves. For AM, the sound output of the speaker is a close replica of the original audio sounds at the transmitter. For CW, the sound is a tone the frequency of which depends upon the frequency of the beat-frequency oscillator. This tone is heard whenever the key is depressed at the transmitter, and, consequently, it reproduces the interruptions of the RF carrier in accordance with the Morse code.

SENSITIVITY

The sensitivity of a receiver is a measure of how well it can amplify weak signals. Communication receivers are highly sensitive and can operate on far weaker signals than a home radio.

In an area of strong local interference, a receiver needs a strong signal to give good reception. If the local interference has a field strength of 100 microvolts per meter, a signal strength of from 500 to 1000 microvolts per meter is required to drown the noise. The same receiver, free of local interference, may give good reception on a signal strength of 10 microvolts per meter. It is hard to state the exact minimum field strength needed to operate a receiver satisfactorily, but many sets under ideal conditions can function on a signal strength of from 1 to 3 microvolts per meter. To bring such a signal to an audible level requires an amplification of many millions of times.

SELECTIVITY

Selectivity is the ability of a receiver to respond to one particular signal and to reject all others. A very selective receiver is said to tune sharply.

Some types of receivers are more selective than others. A radiotelephone communication receiver tunes more sharply than a commercial broadcast receiver, and a CW communication receiver is even more selective. You can compare the three tuning curves in figure 8-15.

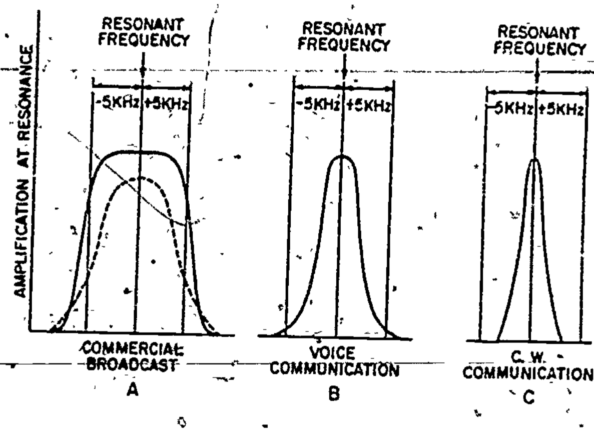

Figure 8-15.—Tuning curves of three types of radio receivers.

You will remember the analysis of amplitude modulation treated earlier in this chapter. It showed how the intelligence transmitted was contained in the sideband frequencies.

Carrier waves from commercial broadcast stations contain sideband frequencies that extend 5 kHz on either side of the carrier frequency. If a station is transmitting on 1140 kHz, the complete carrier wave contains frequencies from 1135 to 1145. If a receiver tunes too sharply, some of the sideband frequencies are lost, with a corresponding sacrifice of fidelity. The commercial broadcast receiver tuning curve shown in figure 8-15 is OPTIMUM—"at its best." The top is broad and flat and the sides are steep. Actually, most AM broadcast receivers have tuning curves resembling the broken line, and many frequency components of voice and music contained in the signal are not reproduced by the set.

Although sharp tuning in a home radio would make for poor listening, it is desirable for military sets for the sake of frequency economy and reduction of interference. Radiotelephone messages can be sent on frequencies that extend only 2 kHz on either side of the carrier frequency. The voice may sound unnatural, like a voice on the telephone, but it can be understood.

The CW sets tune so sharply that, unless an operator is careful, he can turn his dial through the signal without even hearing it.

BASIC SUPERHETERODYNE RECEIVER

The basic stages for AM superheterodyne reception are shown in figure 8-16 in the order in which a signal passes through the receiver. The illustration also shows the changes in wave-shape of the signal as it passes through the receiver. The operation of the superheterodyne receiver for the reception of AM signals is as follows:

1. Modulated RF signals from many transmitters are intercepted by the antenna. They are fed to the first stage of the receiver, which is a variable-tuned RF amplifier.
2. The desired RF signal is selected by the tuning circuit of the RF amplifier. This signal is amplified, and all other signals are rejected to some degree.
3. The amplified RF signal is coupled to the mixer stage, where it is combined with the output of the local oscillator. In this process of heterodyning (mixing), two new frequencies are produced. One is equal to the sum of the incoming signal and the local oscillator; the other equals the difference between the incoming signal and the local oscillator frequencies. Most receivers are designed with selective circuits to reject the sum frequency; the difference frequency is used as the intermediate frequency (IF). Thus, the RF amp and local oscillator are tuned simultaneously (gang-tuned), so that the difference frequency from mixer is always the same. It contains the same modulation as the original RF signal.
4. The IF signal is amplified in the fixed-tuned IF amplifier stages and is coupled to the detector.
5. The detector stage removes the audio modulation contained in the IF signal and filters out the IF carrier, which no longer is needed.
6. The resulting audio signal is amplified to the level required by the loudspeaker.
7. The electrical audio variations are converted into the corresponding sound waves by the loudspeaker (or headphones).

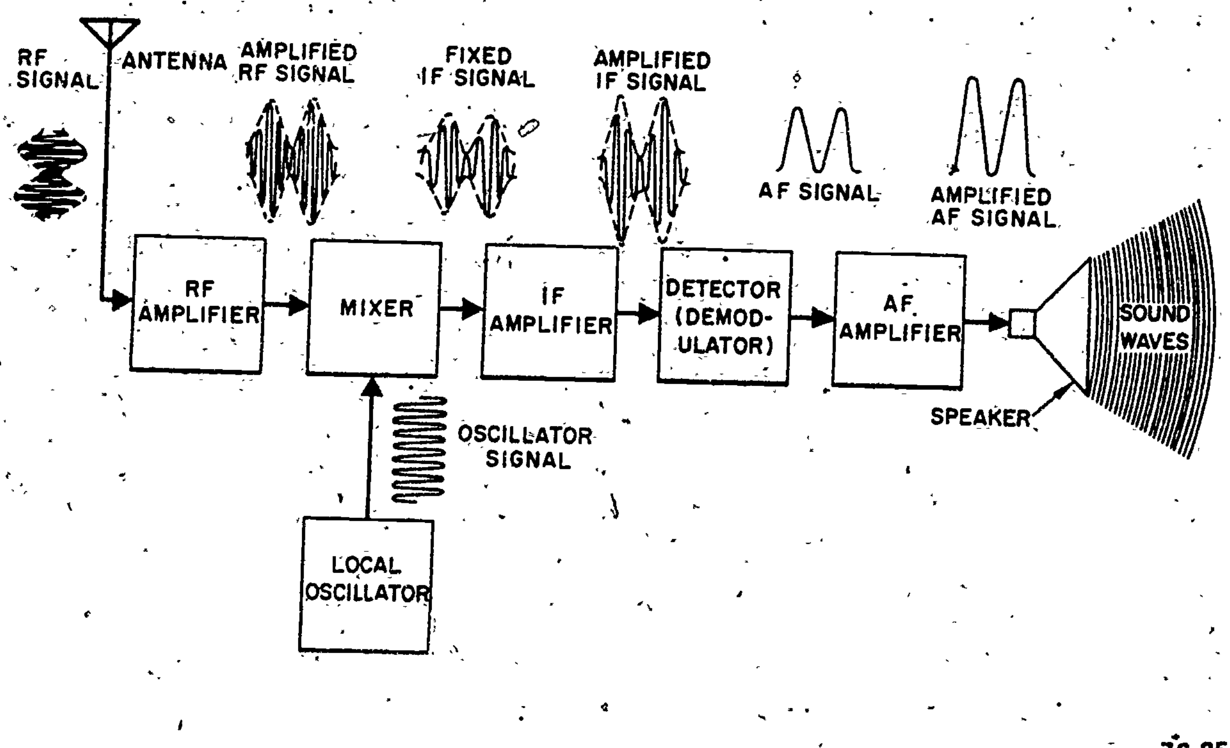

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Figure 8-16.—Superheterodyne receiver, showing signal wave-shape.

REPRESENTATIVE RECEIVERS

Most radio receivers operating in the VLF, LF, MF, and HF bands of the frequency spectrum are of the continuous tuning type. They can be attuned 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 R-390A/URR

The radio receiver R-390A/URR (Fig. 8-17) is a superheterodyne type and provides reception of CW (continuous wave), MCW (modulated-continuous-wave), FSK (frequency-shift keyed), and SSB (single sideband) signals. NOTE: SSB reception requires use of SSB converter (CV 591), discussed later. A double sideband signal, either AM or PM (phase-modulated), occupying up to a total of 12 kHz of spectrum for voice transmission may also be received.

The receiver furnishes an AF (audio frequency) output to a local loudspeaker and/or headset. There is also a balanced line audio output for connection to a remote speaker. An IF (intermediate frequency) output is also provided so that received radio teletypewriter signals may be fed to other equipment for conversion into signals usable by teletypewriter printers.

Two or three receivers can be connected as a space-diversity receiving system for reception of voice signals (fig. 8-18). This system provides substantially uniform audio output to a loudspeaker or headset, minimizing the effect of fading signals. Rhombic antennas spaced at least 600 feet apart are connected to the receivers.

Figure 8-19 shows two receivers connected in a space diversity teletypewriter system. Rhombic antennas feed the incoming frequency shift signals to the receivers. The output of the receivers is applied to a converter which provides diversity combining and produces d.c. (direct current) signals for the operation of teletypewriter equipment.

A receiver and a single sideband converter may be connected as shown in figure 8-20. This system permits the reception of SSB signals occupying 12 kHz of RF spectrum space divided into two 6 kHz sidebands, one 6 kHz sideband on each side of a reduced carrier. This system is used primarily for the reception of multichannel radio-teletypewriter transmissions.

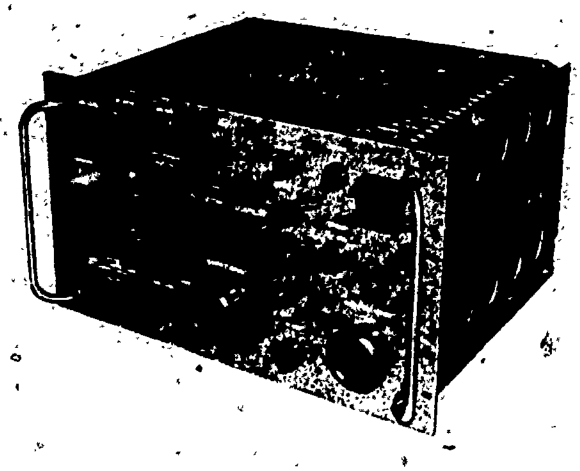

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Figure 8-17.—Radio receiver R-390A/URR.

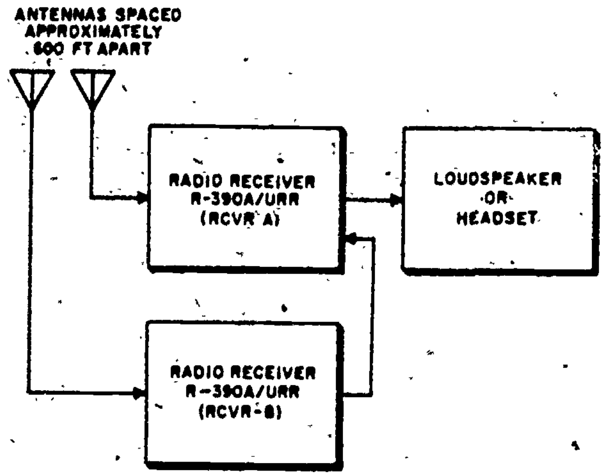

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Figure 8-18.—Space-diversity receiving system.

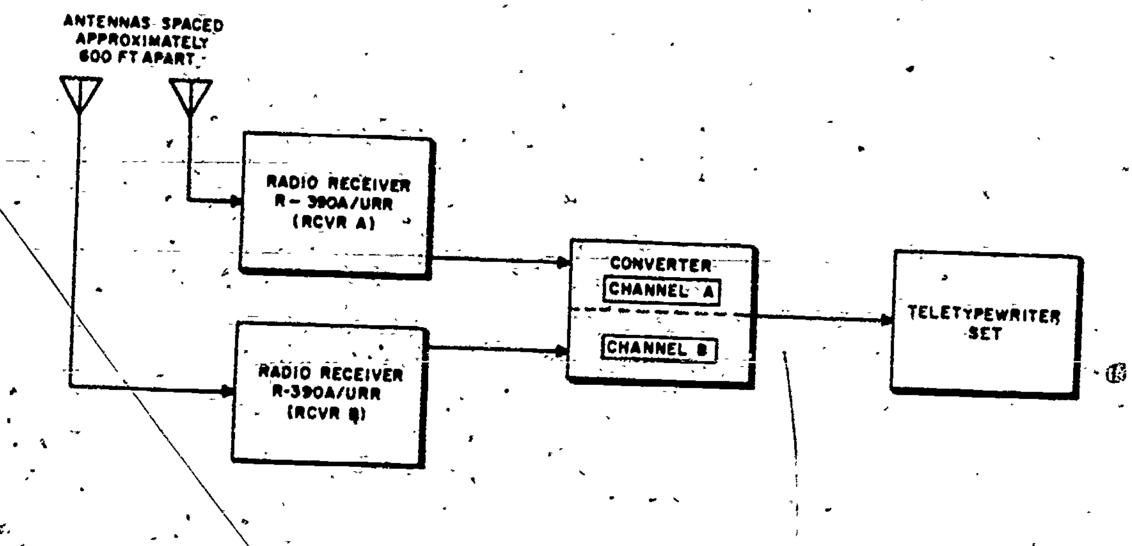

Figure 8-19.—Space-diversity radio teletypewriter receiving system. 31.118

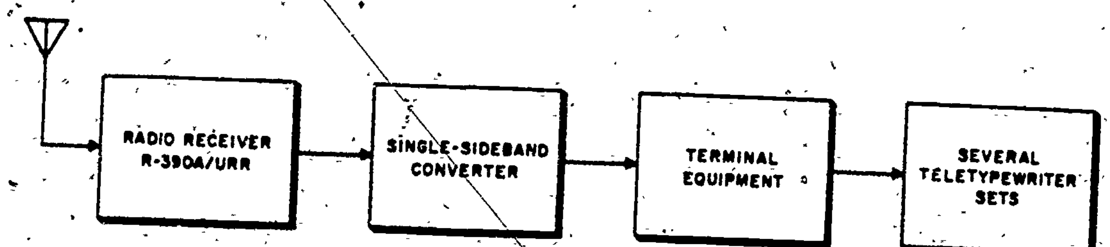

Figure 8-20.—Single-sideband radio teletypewriter receiving system. 31.119

RECEIVER TUNING

Although much of the Navy's communication equipment is set up or tuned automatically, an operator still must do a lot to obtain proper operation from the equipment. The operating procedures of the R-390A/URR, being a representative receiver, are covered in Appendix I. The controls on other receivers may vary somewhat in their placement, appearance, and perhaps their nomenclature, but the basic operating functions will be similar to those on the R-390A/URR.

RADIO RECEIVER R-1051/URR

The R-1051/URR (fig. 8-21) is one of the newest 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, such as radio set AN/WRC-1 described previously (see figure 8-11).

Basically a crystal-controlled equipment, the R-1051/URR employs a digital tuning scheme for automatic tuning to any one of 56,000 operating frequencies. A display window directly above each control provides a readout of the digits to which the controls are set. The displayed frequency can be changed in 1 kHz increments. An additional fine tuning control provides continuous tuning throughout the receiver's frequency range.

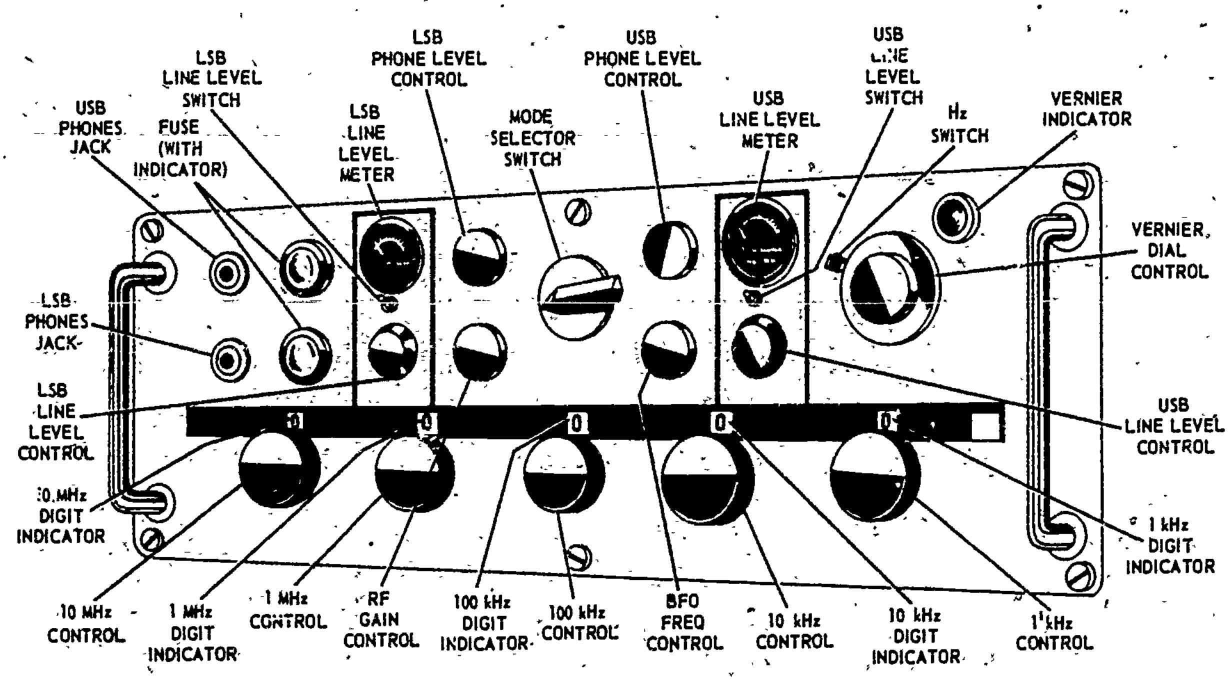

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Figure 8-21.—Radio receiver R-1051/URR, operating controls and indicators.

This receiver is designated as standard equipment for use aboard all ships. Although presently available in limited numbers only, it is being procured for distribution throughout the fleet.

RADIO RECEIVER R-1401A/G

The R-1401A/G VLF receiver (Figure 8-22) is tunable over the frequency range of 1 kHz to 600 kHz in one band. It may be used for the reception of AM, CW, MCW, SSB or FSK signals. A direct-reading digital readout is used to indicate the frequency to which the receiver is tuned. The frequency is normally displayed with an accuracy of 100 hertz per second. A front-panel switch permits expanding the readout by a factor of 10, so that the frequency may be read to an accuracy of 10 hertz per second. A fine-tuning control is provided so that the receiver can be easily tuned to this accuracy. Four IF bandwidths are provided: 150 hertz per second, 1 kHz, 3 kHz, and 6 kHz. Selection of the desired bandwidth is by means of a front-panel switch. The intermediate frequency is 2 MHz.

RADIO RECEIVER R-1414/URR

The R-1414/URR radio receiver (fig. 8-23) is a solid-state, general purpose HF receiver intended primarily for operation in fixed stations or in transportable vans when at a fixed station. It is capable of detecting AM, CW, SSB, ISB, FM, and FSK signals within the 1.5 to 32 MHz frequency range.

Although the future status of the R-1414/URR receiver is in doubt at present, a description is included in this text for your information. Initial distribution of a limited number of these receivers has been made for field evaluation. It is anticipated that the R-1414/URR will ultimately replace the R-390A/URR at all NAVSECGRU sites.

In comparison with the R-390A/URR, the modernization can be readily seen. The R-1414/URR is solid-state, mechanically tuned,

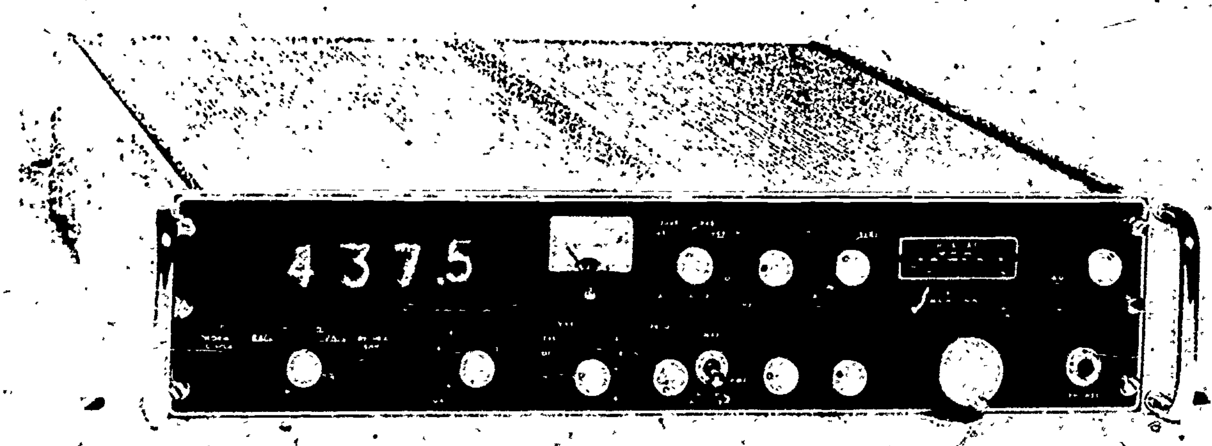

Figure 8-22.—R-1401A/G VLF receiver. 93.89

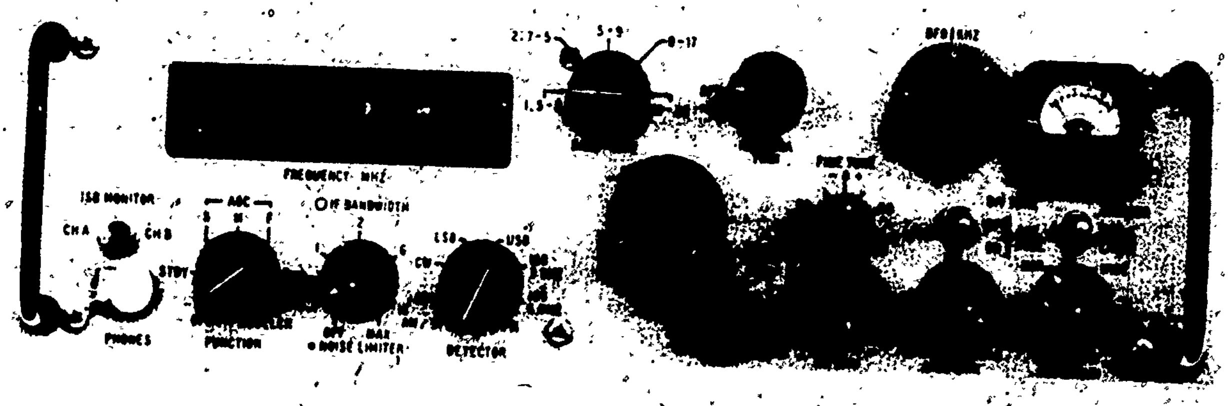

Figure 8-23.—Radio receiver R-1414/URR. 31.120

covers 1.5 to 32 MHz frequency range, uses double conversion, and has a digital electronic frequency counter display. Being solid-state, the R-1414/URR is smaller in size than the R-390A/URR, and operates cooler. It also has independent sideband monitoring capabilities that are not available in the R-390A/URR. Another feature of the R-1414/URR is its frequency stability achieved by an internal digital AFC network. Both frequency stability and readout accuracy are within ± 50 Hz throughout the frequency range of the receiver.

RADIO RECEIVER AN/SRR-19A

The AN/SRR-19A is a low frequency multi-channel shipboard radio receiver for the 30-300 kHz frequency range (fig. 8-24). This

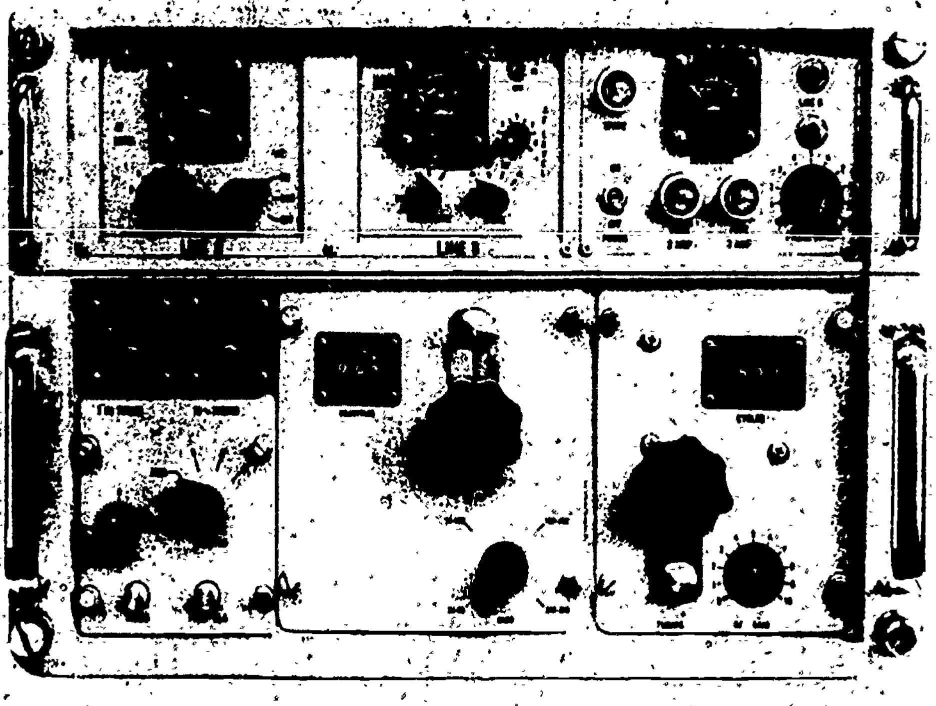

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Figure 8-24.—Radio receiver AN/SRR-19A.

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.

CV-591A/URR SSB CONVERTER

The CV-591A/URR single sideband converter (fig. 8-25) is used to convert standard communication receivers such as the R-390/URR for SSB use. Overall selectivity of most receiving systems is greatly sharpened, rejecting unwanted adjacent signals or interference with no detrimental effect to the desired signal. The tuning of single sideband signals is greatly simplified because final tuning is done at the converter, not the receiver. A mechanical and electrical bandspread tunes over the IF bandpass. This effective vernier easily tunes SSB or exalted carrier AM signals within cycles of correct tone. Either sideband is selectable, either with the bandpass tuning feature or by inverting the oscillator separation. Continuous wave and MCW signals are easily tunable with bandspread feature. For extreme stability, the first oscillator is switched to crystal control for both upper and lower sideband positions.

The local or remote tuned VFO feature of the converter permits operation with any receiver having an IF nominally centered at 455 kHz. When the oscillator is switched to crystal control and the proper cyrstals inserted, however, most any receiver IF may be accommodated.

All operational controls are located on the front panel. These controls are similar in

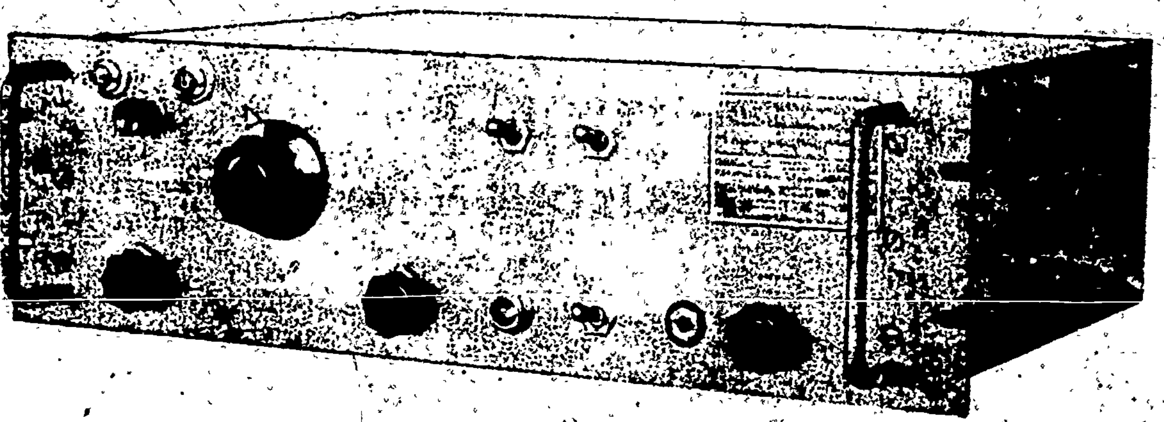

Figure 8-25.—SSB converter CV-591A/URR. 109.30

unction and effect to those found on any receiver. The BANDSPREAD control tunes the converter over a limited frequency range. A MANUAL/XTAL switch sets the first oscillator to either variable or fixed crystal operation. The BFO, Automatic Volume Control (AVC), and AUDIO GAIN controls perform similar functions as on a receiver. Terminals at the rear nel provide simple connections for remote atrol of the main features of the converter without modifications or the use of additional lines or tones. By this means it is possible to tune the converter remotely or locally across the receiver IF passband, select sidebands with a remote indication of which sideband is in use, and still retain all of the remote control features of the remote control system. The converter may be used with remote control system AN/FRA-19(V) or AN/FRA-501, without modification to the system.

CHAPTER 9

FACILITIES CONTROL OPERATIONS

Facilities Control Operations (FCO) is an integral section of each NAVSECGRU communications center. This section performs the functions of circuit and equipment control. The FCO is one of the most important operations within the NAVSECGRU communication center, since message traffic flow is dependent upon the quality of circuits and equipment provided.

The function of a facilities controller at large stations is usually performed by trained circuit and technical personnel. This function at small stations may, of necessity be performed by communication supervisory, operator, or maintenance personnel. The fundamental responsibilities of the facilities controller, however, remain unchanged.

The Naval Electronic System Command prepares and issues system plans for the processing and distribution facilities to be engineered for each type of shore station system.

To consolidate communications circuits into a network, the principles of system engineering must apply; namely, the system has a common purpose, compatible equipment, and standard procedures and practices. These standard procedures and practices assist facilities controllers in working with adjoining stations and coordinating with the commercial or DCS circuit supplier facilities. A few of the major coordination problems confronting a FCO controller are circuit interruption, frequency changes, restoration of circuits, equipment performance tests and similar technical functions. Standardization of equipment, procedures and practices also permits the transfer of personnel throughout the system with a minimum amount of training.

COMMUNICATION SYSTEM DESCRIPTION

Every ship or station is provided with communication system based on its mission. Communications systems can vary from the simple to the complex. For instance, a radiotelegraph receiver system consists of an antenna, receiver, and headphones or speakers. A multichannel broadcast—receiver system may consist of antennas, receiver, terminal equipment, several pieces of crypto equipment, an assortment of page printers, reperforators, and patching facilities.

The sole purpose of any communication system, however, is the efficient transmission and reception of information. The intelligence signal is the means by which this is accomplished. Figure 9-1 shows a simplified signal flow block diagram typical of either a shore or afloat secure teletype communication system. A description of the common equipment that makes up each stage (shown in Figure 9-1) how they are used and their interrelationship within a communications system are the subject of this chapter. When a basic understanding of the effect each stage has on the signal is acquired, the need for monitoring and precise control procedures becomes evident.

The audio signal containing the teletype signal must pass through several stages prior to being printed by the teletype printer. The audio signal output of a receiver must first pass through a receiver switchboard where it is switched to the desired conversion equipment. The conversion equipment will either demultiplex a number of independent telegraph channels which are simultaneously conveyed

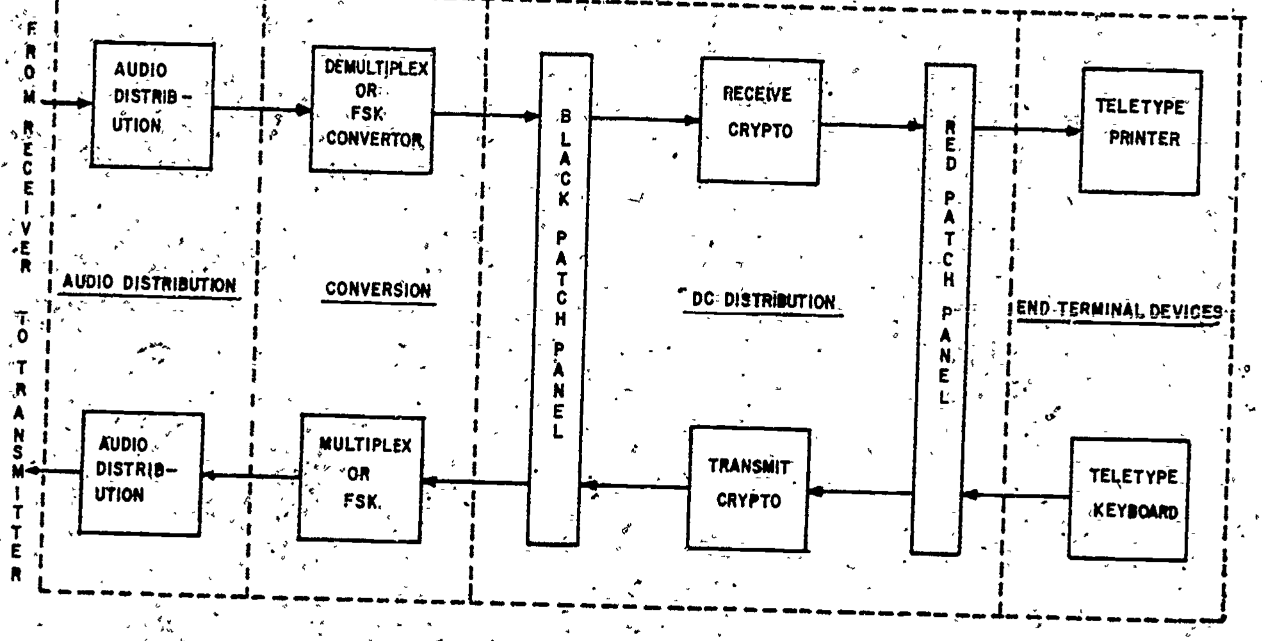

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Figure 9-1.—Signal flow for secure teletype communication system.

over one audio signal, or in the case of single channel frequency shift keying (FSK) reception it will be converted directly to a d.c. teletype signal.

Inter-connection between a NAVSECGRU FCO and the commercial or DCS circuit supplier facilities commences normally in the DC distribution. In other words, at this point the signal first enters the spaces where the SI communicator will be monitoring the signal. Obviously, coordination between FCO and circuit suppliers is of paramount importance, since the first two stages of the signal flow pass through other elements of a ship or station before reaching the SI FCO spaces.

The TTY signal is fed to the "Black" (unclassified/encrypted signals) patch panel which is wired or patched to COMSEC equipment for decryption to a plain text teletype signal. Following decryption, the plain text teletype signal is delivered via the "RED" (classified/decrypted signals) patch panel where it is wired or patched to the receiving teletype equipment for print out.

On the transmit side, the signal flow is quite similar to the receive side, only in reverse order. The originated teletype signal generated by the TTY keyboard or TD passes through the "RED" patch panel, to the COMSEC equipment for encryption. Following encryption the teletype signal is fed to the "BLACK" patch panel where it is patched directly to the transmitters frequency shift keyer or the multiplex equipment where it is converted into an audio signal. The audio signal now conditioned into a form suitable for transmission is routed to the transmitter via the transmitter transfer switchboard.

AUDIO DISTRIBUTION

Transferring the audio output of a receiver to the conversion stage, and conversely from the conversion to the transmitter, requires intricate switching capability. These operations are performed by control panels which utilize switches instead of plugs and patch cords. Such control panels are commonly referred to as switch boards.

Radio remote-control transfer plug panels have become too cumbersome to be used in shipboard radio installations of modern Navy ships. Therefore, control panels utilizing switches instead of plugs and patchboards are being installed in new construction and in conversion jobs. Two unit-constructed panels (one for receivers and one for transmitters) now provide all of the facilities that were available in three types of plug panels (the receiver transfer panel, the transmitter transfer panel, and the radiophone transfer panel), and in addition afford greater flexibility in the remote-control system. These units are Receiver Transfer Switchboard, Type BS-82/SRR, and Transmitter Transfer Switchboard, Type BS-863/SRT.

RECEIVER TRANSFER SWITCHBOARD

Receiver Transfer Switchboard, type SB-82/SRR, is shown in figure 9-2. The receiver switchboard has five vertical rows of ten double-pole, single-throw (ON-OFF) switches that are continuously rotatable in either direction. One side of each switch within a vertical row is wired parallel with the same sides of the other nine switches within that 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.

The audio output from five radio receivers, connected to the five vertical rows of switches, may be fed to any or all of the remote stations by closing the proper switch or switches. The knob of each switch is marked with a heavy white line to provide visual indication of the communication setup. In general, there are more remote stations than radio receivers, hence the switchboards normally are mounted in a vertical position (as in figure 9-2). This arrangement permits the outputs from five receivers to be fed to the five vertical rows and up to ten remote stations to be fed from the ten horizontal rows of switches.

Switchboards are always installed with the knobs in the OFF position when the white line is vertical. To further standardize all installations, receivers are always connected to the vertical rows of switches, and remote stations are always 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.

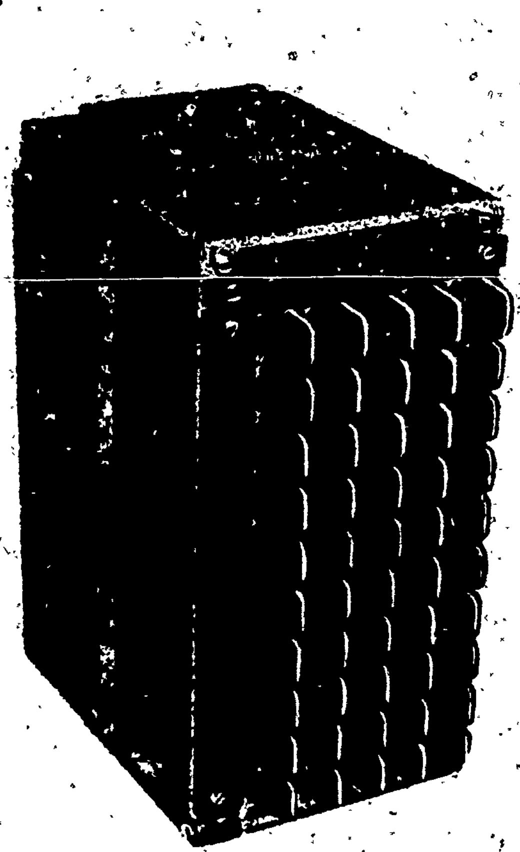

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Figure 9-2.—External view of the receiver switchboard type SB-82/SRR.

TRANSMITTER TRANSFER SWITCHBOARD

Transmitter transfer switchboard, type SB-863/SRT, has replaced type SB-83/SRT. The SB-863/SRT (figure 9-3) has ten 20-position rotary selector switches in two vertical columns. Each rotary switch corresponds to a remote control station, and each switch position (1 through 18) corresponds to a controlled transmitter. Thus, switching control is provided for up to 10 remote control stations or 19

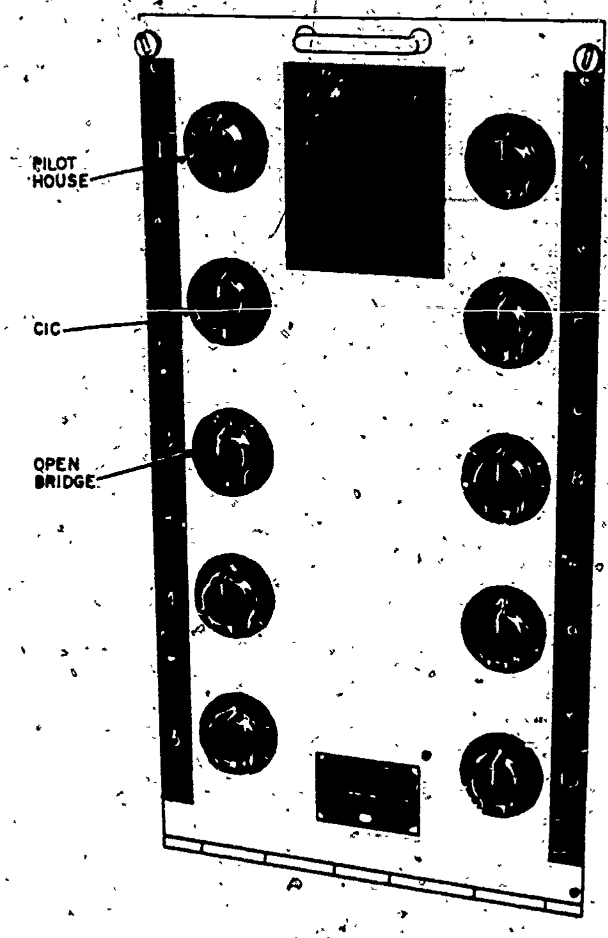

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Figure 9-3.—Transmitter transfer switchboard SB-863/SRT.

transmitters. When more than 10 remote stations or 19 transmitters are to be connected, additional transfer switchboards may be installed. Position 20 of each rotary switch is provided for connections to an additional transfer switchboard to control extra transmitters. The switches consist of 12 wafers that connect the start-stop indicator, keying, 12 volt d.c. microphone carrier control, and carrier indicator circuits for the various transmitters. Any of the remote stations may be connected to control any of the transmitters in the system.

CONVERSION

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 normally a separate piece of equipment.

The Navy uses several methods of transmitting teletype signals. FSK (Radio Frequency shift keying) and audio frequency shift keying in multiplexing are covered in the succeeding paragraphs.

FREQUENCY-SHIFT SYSTEM

The frequency-shift system is illustrated in figure 9-4. The transmitting end of this system (figure 9-4 A) is a teleprinter, a frequency-shift keyer unit, which is built into the transmitter, and a transmitter.

When the teleprinter is operated, the direct current teleprinter mark and space signals are changed by the keyer unit into frequency-shift intervals. An "on" or a "current" interval is called a MARK or MARKING impulse. An "off or no-current" interval is called a SPACE or SPACING impulse. The frequency shift intervals are transmitted as carrier frequency-shift (CFS) signals. The carrier shift is very small compared with the frequency of the carrier; it may be on the order of 850 cycles.

On the receiving side of this system (figure 9-4 B) are a receiver, a frequency-shift converter, and a teleprinter. When the carrier frequency-shift signal enters the receiver, it is detected and changed into a corresponding frequency-shifted audio signal. The audio output of the receiver is fed to the converter, which changes the frequency-shifted audio signal into the direct-current mark and space teletype signals.

COMPARATOR-CONVERTER GROUP AN/URA-17C

The Comparator-Converter Group AN/URA-17C is used to convert the FSK audio output of standard radio receivers into d.c. pulses for the operation of teletype printers. The AN/URA-17C consists of two identical frequency shift converters CV-483C/URA-17

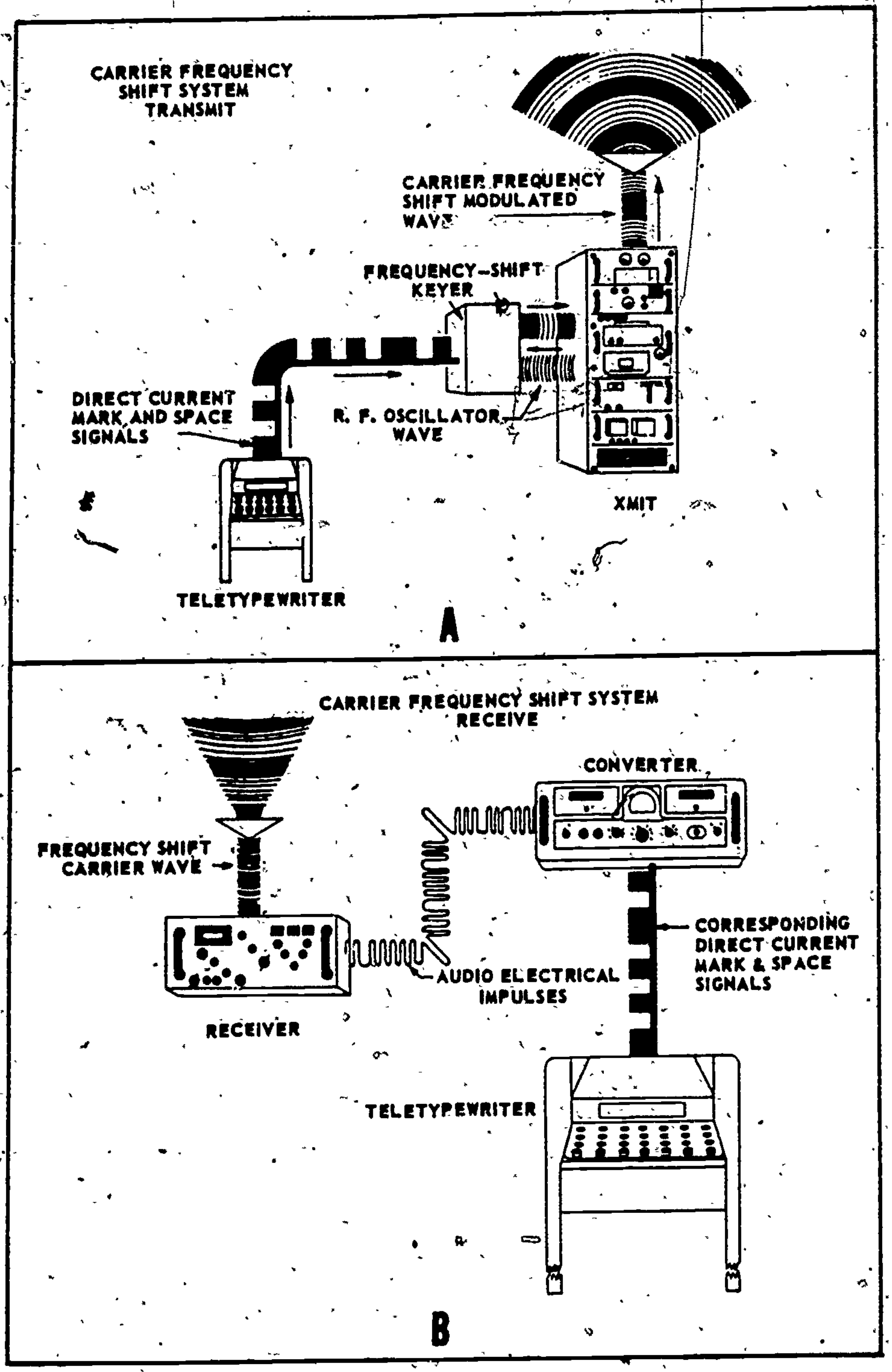

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Figure 9-4.—Frequency shift system.

shown in figure 9-5, a closeup of one converter illustrating controls in figure 9-6. Each converter has its own comparator circuitry. Hence, a separate comparator unit is not required as the case with the older model AN/URA-8B. The AN/URA-17C is a completely transistorized equipment with printed circuit boards making its physical size less than half the size of the AN/URA-8B. There is still a number of AN/URA-8B converters in use; however, present procurement of frequency shift converters is confined to the AN/URA-17C. Although

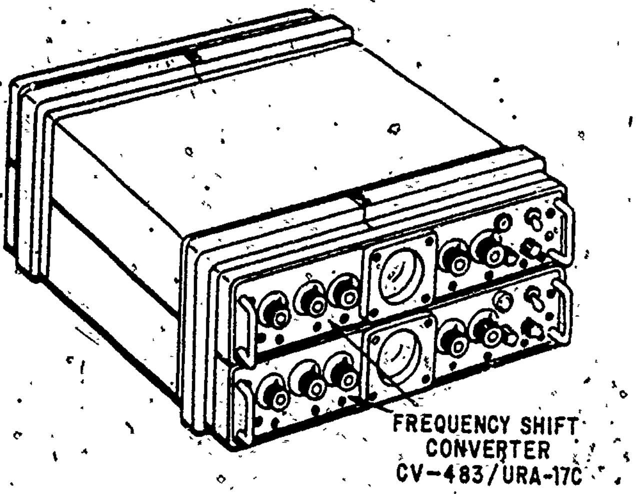

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Figure 9-5.—Comparator-converter group AN/URA-17(C).

discussion hereafter will be solely on the AN/URA-17C, both converters are designed to perform the same functions.

The comparator-converter can be operated with two radio receivers in either space diversity or frequency diversity receiving systems. When conditions do not require diversity operation, each converter can be used separately with a single receiver for reception of FSK signals. In this latter usage, the two converters can be operated in two independent communication circuits.

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 d.c. pulses. The d.c. (or mark-space) pulses from each converter are fed to the comparator. In the comparator, an automatic circuit compares the pulses and selects the stronger mark and the stronger space pulse for each character. The output of the comparator is patched to the teletypewriter.

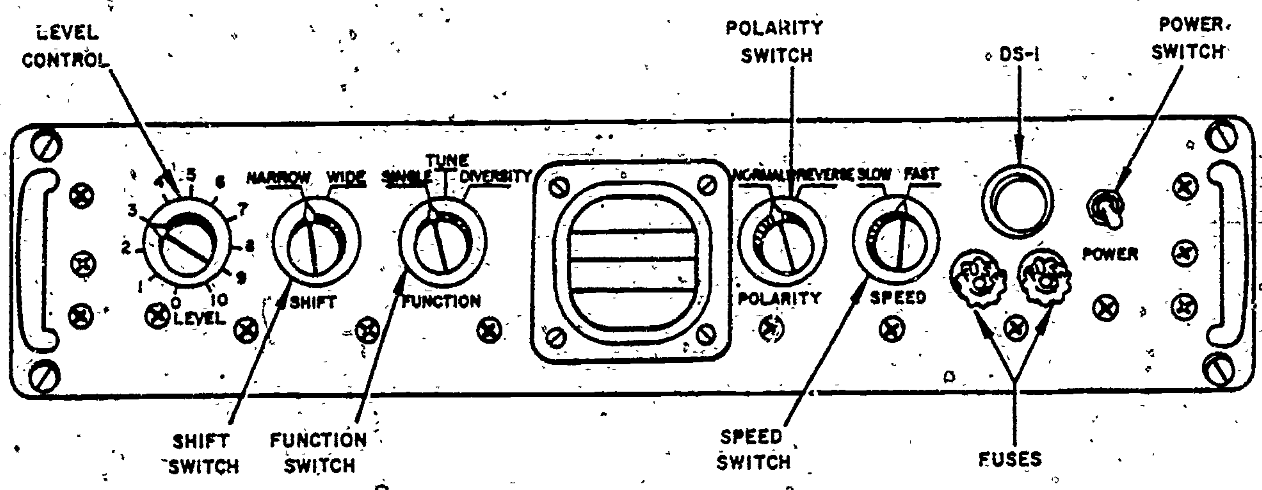
A description of all controls normally used during operation and the sequence of operation for the two modes (single receiver and diversity receiver operation) are contained in Appendix II of this manual.

ESSENTIALS OF MULTIPLEXING

Multiplexing is the term applied to the process of converting information received from a telephone, telegraph, or teletype circuit in original intelligence form into a common time or spectrum-shared signal with information received from other wire telephone, telegraph or teletype circuits.

The purpose of multiplexing is to increase the number of intelligence channels, hence volume of information, capable of being sent simultaneously over a given wireline or radio medium. This, naturally, reduces equipment and line requirements, and permits a greater number of users to operate in a given radio spectrum.

Either of two methods of multiplexing may be used. These are "TIME-DIVISION" and "FREQUENCY-DIVISION" multiplexing of which frequency division multiplexing is the most widely used method by the Navy.



50.77

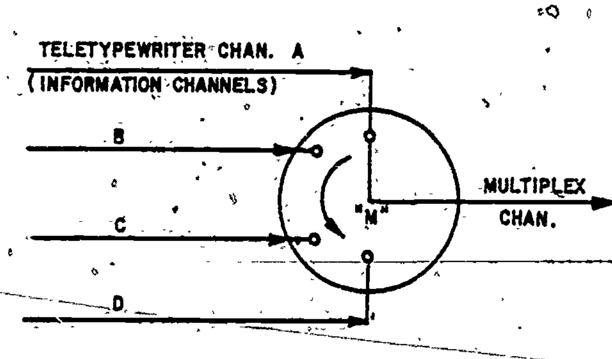
Figure 9-6.—AN/URA-17 frequency shift converter, front panel controls.

TIME DIVISION MULTIPLEXING AND DEMULTIPLEXING

Time division multiplexing is a method of combining two or more information sources into a single transmission by using time sharing or sampling techniques. All channels are transmitted on the same operating frequency, but alternately so that each one is transmitted only part of the time. Demultiplexing a time division multiplexed signal is the process of sensing and separating the channels from their position in the multiplexed signals.

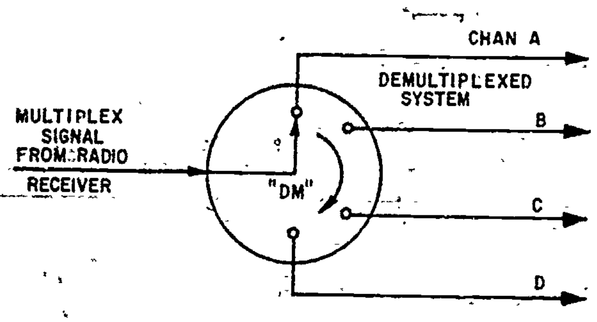
Time division multiplexing is used primarily on long haul HF circuits by commercial users, is illustrated in figure 9-7. Two to four separate teletype inputs are sampled in sequence by a distributor arm rotating at a predetermined rate. In one revolution of the distributor arm a character on channel A is picked up and transmitted, then the character on channel B, then channel C, then channel D. Thus, the time required for each revolution of the distributor arm is divided between the four separate TTY channels being multiplexed (combined).

Demultiplexing takes place at the receiving end of a circuit. Figure 9-8 illustrates the basic principles of reception and demultiplexing the multiplex signal. As the name implies, it reverses the multiplexing process. The multiplexed signal is fed into a demultiplexing distributor that is rotating at the same speed as the multiplex distributor, and in synchronization with it. At the instant that a channel A character is received, the demultiplex distributor is establishing electrical contact with the channel A receive equipment and routes the character to its intended receiver. It then makes contact with channels B, C, and D in sequence and routes a character to each before starting another revolution.



31.122

Figure 9-7.—Basic time division multiplex (transmit).



31.123
Figure 9-8.—Basic time division multiplex (receive).

FREQUENCY DIVISION MULTIPLEXING AND DEMULTIPLEXING

Frequency division multiplexing is a method of multiplexing in which the total frequency spectrum available is divided into channels, each of which occupies a particular frequency range all of the time.

Demultiplexing a frequency division multiplexed signal channel is the process of separation (filtering) of the individual channels from the common group of channels into which they have been multiplexed.

Frequency division multiplexing within a telegraph terminal involves translation from d.c. carrier to audio frequency carrier of the intelligence of two or more (normally sixteen) teletypewriter or other digital data channels connected to the send side of the terminal. The audio frequency carriers of the individual channels are then combined into a common voiceband channel called the multiplexed or composite channel. These audio frequency carriers are referred to normally as subcarriers, because they later modulate a radio frequency carrier. Each channel subcarrier is separated in frequency from adjacent subcarriers to an extent permitting the transmission of modulation information without the effects of interchannel interference or bandwidth restriction—the separation on military channels is a minimum of 170 Hz. Each channel subcarrier is assigned a specific center frequency, and is always adjusted to operate at a specific operating level.

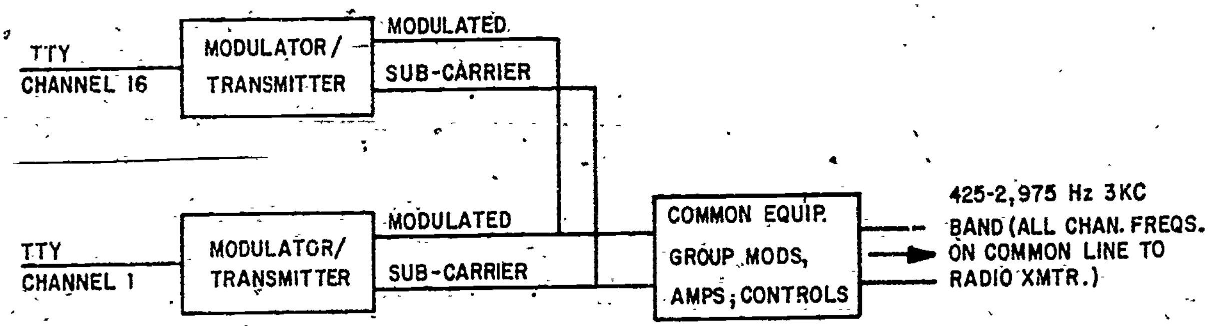
Figure 9-9 illustrates the basic principles of frequency division multiplexing. This principle is used on practically all Navy primary communication circuits from point-to-point. As illustrated, the telegraph system has a capacity of sixteen channels of telegraph (teletypewriter or other digital type) information. All channels are brought into a central point, called a Primary Technical Control Facility. All channels destined for a particular geographical area are connected to the telegraph terminal assigned to the appropriate communication circuit for that area.

Each teletypewriter circuit is connected to a "Modulator-Transmitter" which is connected by its output circuit to the output circuits of all other "Modulator Transmitters." This forms a "Bus," or common connecting line to the "Common Components" of the equipment, where the combined audio channel signals are amplified, modulated by group or sub-group modulators, and controlled by attenuators, meters, patch panels, and monitoring circuits.

The Modulator-Transmitter consists of a source of audio of specific frequency for each channel, and a special circuit by which the direct current teletypewriter signals modify the frequency determining characteristics of the channel oscillator in such a manner as to repeat in audio form what is received from the keying loop in direct current form.

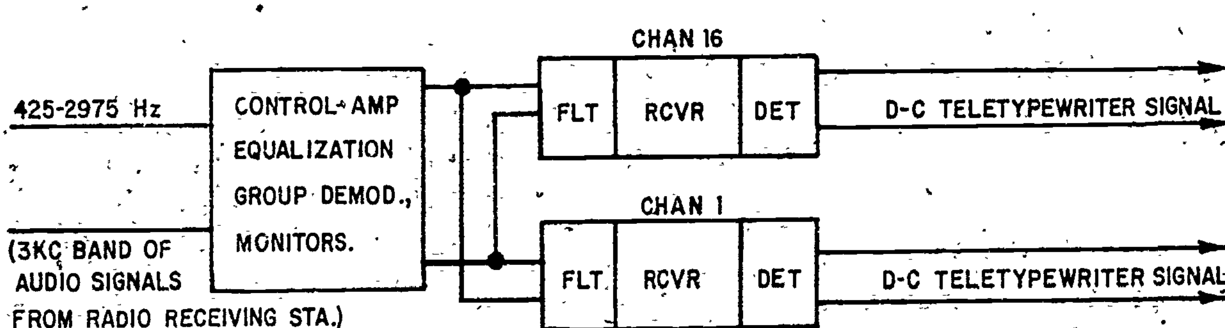
All channel oscillators are fed to the common "Bus," then amplified, further modulated for spectrum translation where necessary, and routed through attenuator pads, monitoring jack fields, patch panels and line matching transformers for proper transmission of the aggregate tone signals to the radio transmitter via land line or radio control link circuits.

The principles of demultiplexing within a telegraph terminal utilizing the principles of frequency division multiplexing are illustrated by Figure 9-10. The common band of audio signals are received from the radio receiving station. They first are applied via patch boards and monitoring panels to the system common amplifiers, equalizers, group demodulators and control attenuators. Then to the output "Bus"



31.124

Figure 9-9.—Basic frequency division multiplexing (transmit).



31.125

Figure 9-10.—Basic frequency division demultiplexing (receive).

of the common equipment to the inputs of all individual channel receiving and detecting circuitry, thence to the individual end terminal devices in the original direct current signal form.

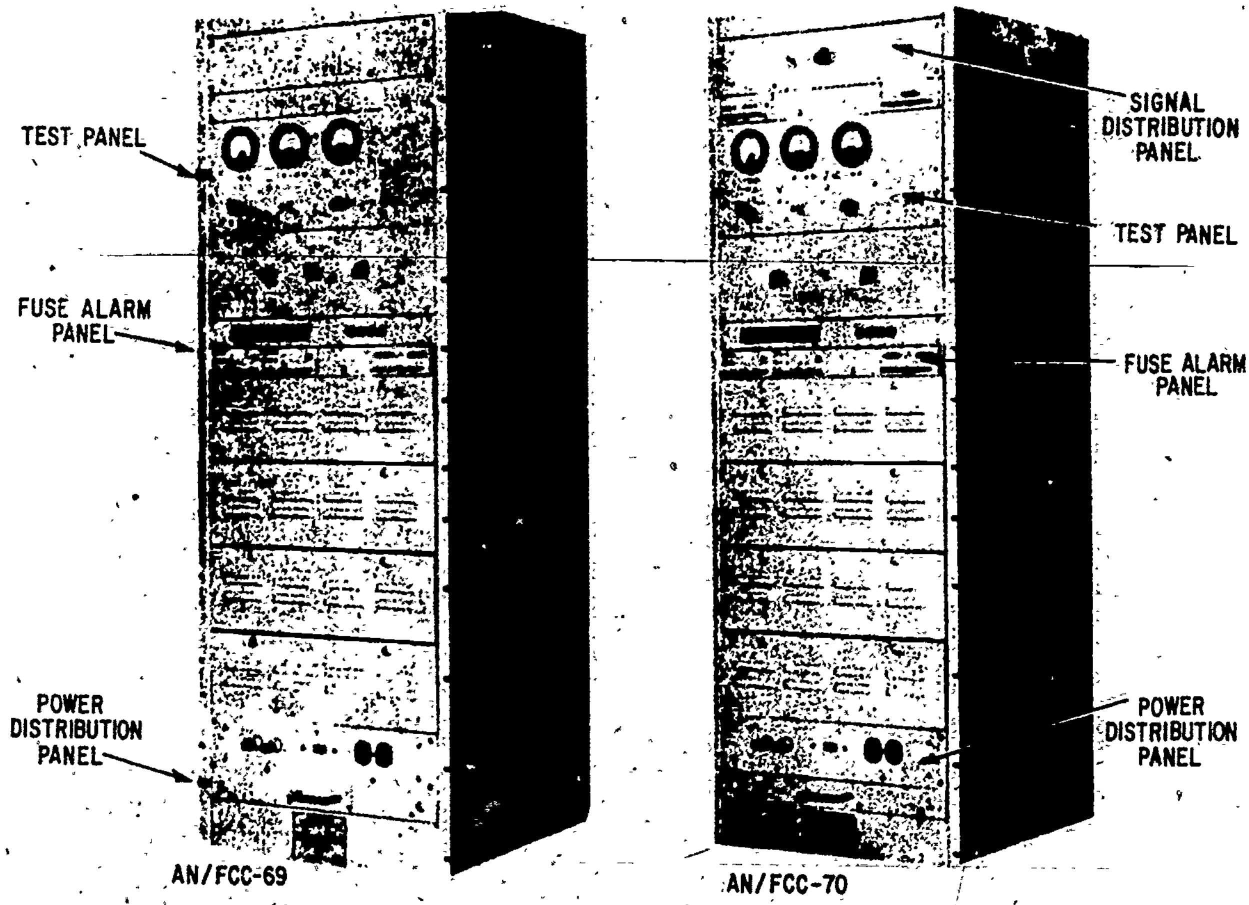
FREQUENCY DIVISION MULTIPLEX TERMINALS AN/FCC-69/70

The AN/FCC-69/70 is a two-unit multiplexing system consisting of one AN/FCC-69 and one AN/FCC-70 (figure 9-11) Telegraph Terminal. The AN/FCC-69 is a receive-only unit which demultiplexes a composite signal sent by a AN/FCC-70 send-only multiplexing unit.

The AN/FCC-69/70 system has a channel capacity of 16 channels with 170 Hz separation between channels and a maximum signaling rate of 90 bauds. Loop options include 60 ma neutral, 20 ma polar or 6-volts polar keying. The center frequency for channel one is 425 Hz and channel 16 is 2975 Hz with a 170 Hz progression for the channels between 1 and 16.

D.C. DISTRIBUTION

Maximum operational flexibility is achieved by the installation of circuit patchboards and distribution frames. The communications station employs distribution frames for concentrating individual circuits into cables: these frames serve as the point of equipment interconnection and as the interface point between the outside world and the distribution within the building. Interconnections between the cables are



31.126

Figure 9-11.–Frequency division multiplex terminals AN/FCC-69/70.

accomplished by "cross-connect" wires that are run between the individual wire termination of the cables at the frames. The patchboards serve as the access point for operators to monitor the signal carried by individual cable wire pairs and permit operators to reroute circuits and to substitute equipment serving a circuit. Types of equipment, distribution frames and patchboards are discussed below.

DISTRIBUTION FRAMES

Distribution frames are used to terminate cabling from equipments, patchboards, and battery sources. A distribution frame is also used to serve as a central point for the exit and entrance of all communication circuits concerned with the mission of the communications center. Four types of distribution frames may be used within a communications station and are identified by their employment.

Main Distribution Frame (MDF)

The MDF is the division point between a communication component and the outside. The MDF is configured of horizontal and vertical terminal blocks. The horizontal blocks terminate circuit cables entering the building. Vertical blocks are used to terminate cables that support circuit distribution within the building.

Intermediate Distribution Frame (IDF)

The IDF terminates internal distribution cables, equipments and patchboards that process black (unclassified) information. The IDF should be physically separated from the CIDF by a minimum of two inches; however, it is desirable to locate these units further apart or on opposite sides of the room.

Classified Intermediate Distribution Frame (CIDF)

The CIDF terminates cables, equipments, and patchboards that process RED (classified) information. Current security regulations prohibit the termination of circuits carrying classified information to the same distribution frame as those carrying unclassified information.

Combined Distribution Frame (CDF)

A CDF may be used at small stations, serving the purpose of both the IDF and MDF. When a CDF is used, the blocks that terminate cables and systems that interface with the outside world are to be positioned horizontally. Blocks used to terminate cables supporting internal distribution are to be positioned vertically.

PATCHING FACILITIES

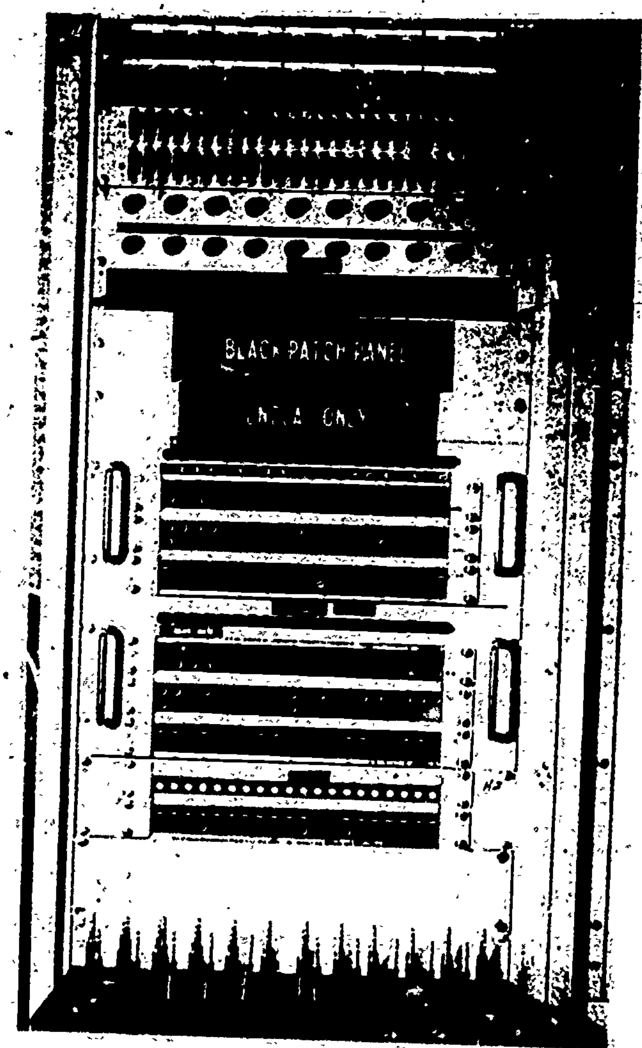
The smallest of switchboards or patch panels add flexibility in the capability of the station's equipment. The degree of utilization of such flexibility is primarily dependent on the ingenuity and resourcefulness of the operator or facilities controller. This means that spare and/or normal equipment and lines can be interchanged and interconnected without resorting to physical rewiring. The patch panel jacks are actually wired in series to the distribution frame wiring so that under normal circumstances each circuit and its associated equipment is "normalled-through", thus, for normal operation the use of patch cords is not necessary.

In order to attain complete flexibility, the patch panel and associated patch cords permit access to all lines and equipment and provide a means for testing inoperative equipment and/or lines. In most instances, test equipment is wired into a patch panel to facilitate testing.

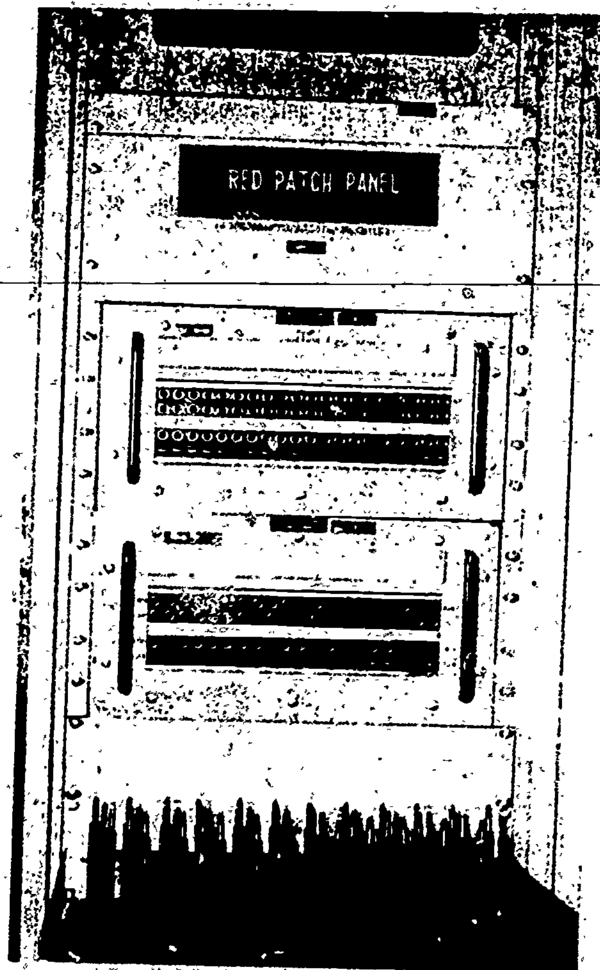
DC PATCH PANEL BAYS

For control purposes, all d.c. circuits appear on one or more d.c. patch panels, and all audio circuits appear on one or more audio panels. The patch panel with the incoming receive lines and the outgoing send lines is designated as the UNCLASSIFIED or BLACK patch panel (Figure 9-12). The patch panel with the crypto transmitter input circuits and the crypto receiver output circuits is designated as the CLASSIFIED or RED patch panel (Figure 9-13). The patch panels are wired so that technically any send device may be patched to any receive device, and any receive device may be patched to any send device. No two sending devices or receiving devices can be patched together without causing a visual alarm, as well as an audible alarm. Interrelated circuits are normally grouped as close together as possible (operationally and geographically). Send and receive portions of the same circuit are normally located side by side. The odd numbers are send details and the even numbers are the receive details.

Each circuit (send and receive) on the standard d.c. patch panel requires two types of labels, one on the BLACK patch panels and a corresponding label on the RED patch panels. A standardized labeling system giving as clear a picture as possible of the various equipments that are wired into each circuit is prescribed in the effective edition of COI 104 and is used throughout the NAVSECGRU. The basic difference between the RED and BLACK patch panel labels is that the RED label will identify terminal equipment and the BLACK label will identify trunk lines and circuit numbers. The important thing is for the facilities controller to be able to readily identify what is connected to the circuits.



31.66
Figure 9-12.—Unclassified patch panel (BLACK).



31.67
Figure 9-13.—Classified patch panel (RED).

BLACK PATCH PANEL

The black patch panel provides patching capability and control for all unclassified d.c. trunk lines and crypto equipment. In addition, the BLACK patch panel has ancillary equipment installed in it for various purposes (e.g., meter, alarms, fuses, and line current controls).

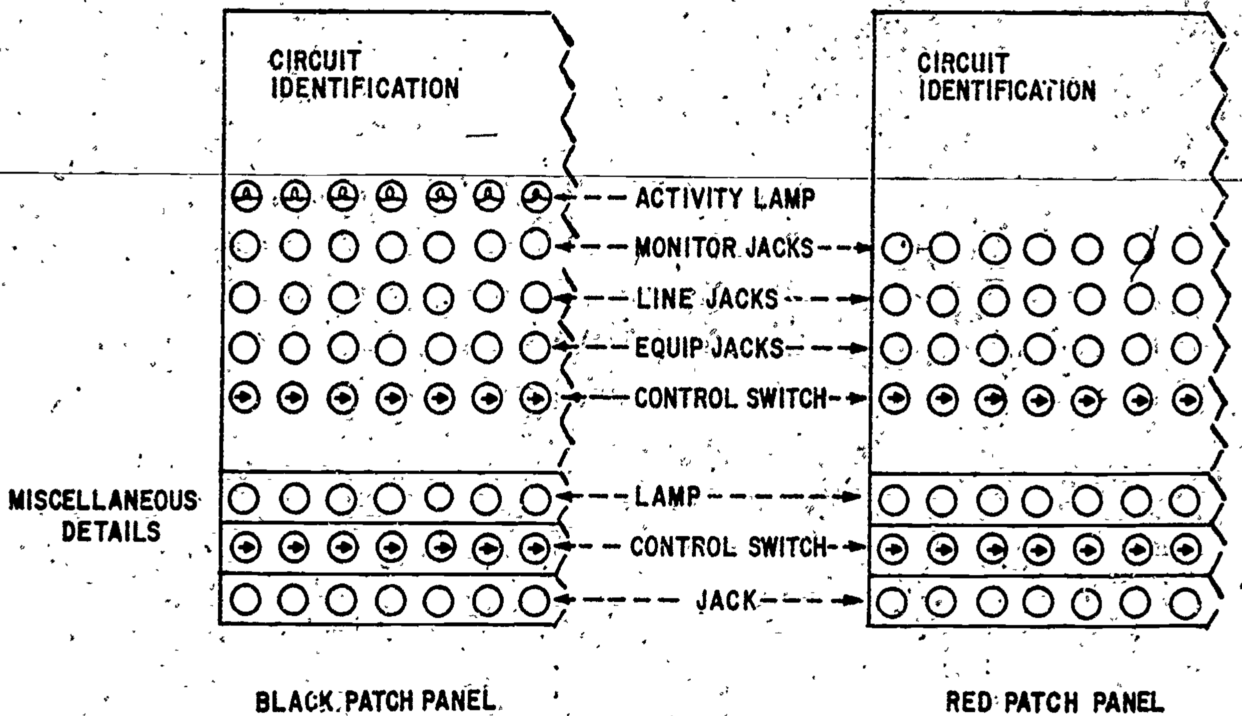
Circuits are assigned to specific details on the patch panel. Each detail consists of five appearances, activity lamp, monitor jacks, line jacks, equipment jack and control switch (see figure 9-14).

Located at the top of each detail is the activity lamp. This lamp is designed to blink when the circuit is being keyed. The lamp is activated (on) during a mark transmission and deactivated (off) during a space transmission.

Monitor jacks permit lines to be analyzed or monitored without interfering with the signal being passed on the circuit.

The line jack offers direct access to the outside line, send or receive. A patch cord inserted in this jack will electrically remove the line from the rest of the detail.

The third jack in the detail located just below the line jack offers direct access to the



31.127

Figure 9-14.—Standard details on a black and red patch panel.

equipment normally assigned to the circuit. When a patch cord is inserted in this jack the equipment normally assigned is electrically removed from the detail.

The control switch in each jack detail is used to control or to "cut off" the signal flow between the equipment jack and the line on the line jack or allow the signal to flow through the detail as normally wired. The switch is marked with an arrow in order to recognize its position. When the switch is in the vertical position the signal will flow through the detail. If the control switch is rotated to the horizontal position the signal flow is cut off.

MISCELLANEOUS DETAILS

Provisions have been made for miscellaneous details across the bottom of patch panels (figure 9-14) to serve various purposes. The miscellaneous details consist of a lamp, control switch and jack. They are not numbered in any numerical order due to their varied use. A breakdown of the miscellaneous details and their varied uses can be found in the current edition of CO1-104.

PATCH CORDS

Each patch panel bay has a cord shelf extending out from the panel. The shelf holds the retractable patch cords and also provides a writing space.

A three wire patching system (tip, ring, and sleeve circuitry) is employed in the cords and jacks as follows:

a. Tip Circuits. The tip of the patch cords and jacks carries the intelligence signals.

b. Ring Circuits. The ring of the patch cords and jack carries the timing or "step" information. Step circuitry on low speed links is utilized only on the input to the COMSEC or error control equipment. On high speed links, ring circuitry also carries step to the receive buffer or receive end equipment.

c. Sleeve Circuits. The sleeve of the patch cords and jacks carries the supervisory or alarm circuits. These alarm circuits indicate visually and audibly when a mispatch has been made (i.e., send equipment patched to a receive line, or an incorrectly seated patch cord).

Patch cords are usually color coded (white, red, black, and green) and have five different uses.

a. SEND. The send cords are white in color, equipped with a single plug, the other end being permanently wired to keyboards in the FCO spaces.

b. RECEIVE. The receive cords are red and also single plug with the other end being hard wired to monitors in the FCO spaces.

c. FOXTEST. The foxtest cords are black in color and equipped with a single plug, the other end being captive to electronic test keyers and designed the same as a Send Cord.

d. METER AND SCOPE. The meter and scope cords are also black and located on the right and left of each patch panel separated from the other rows of cords. The meter and scope cords are designed the same as receive cords, with a single plug. A push-to-read button is also associated with the meter cord to protect the meter from inadvertent shorts.

e. PATCH CORD. The patch cords are green and located in the two back rows farthest away from the controller facing the patch panel. These are double ended captive patch cords allowing the operation of the facility to patch both ends, neither being permanently wired to any facility. The patch cords are wired TIP to TIP and RING to RING, giving straight through reproduction of any signal on these two circuits.

By manipulation of the patch cords, the facilities controller can test out and/or interchange normal or spare lines and equipment as necessary. In the event of equipment failure, or when changes occur in operational requirements, the controller can virtually patch to or around any position on the jackfield.

AUDIO PATCH PANEL

The audio patch panel (figure 9-15) operates in a completely (unclassified) BLACK environment and is used primarily for high speed data circuits. Circuits appearing at this board are also routed through the commercial and DCS repeater stations, but the d.c. to audio conversion does not take place as the signals are already in audio form and ready for transmission.

The patch facility is divided into three sections: the uppermost section is a panel containing two decibel (db) meters; the second section contains the equipment, line, and jack patch modules; the third section contains all the test equipment jacks. There is no cord shelf associated with the audio patch facility.

Whereas the d.c. panel uses a ground return system, the audio panel uses two wires and therefore each detail contains two jacks each for monitor, line and equipment. Patch cords are necessarily two-pronged. The line jack on the audio board refers to the outgoing and incoming lines, and the equipment jacks are connected to the Modulator/Demodulator.

MODULATOR/DEMODULATOR (MODEM)

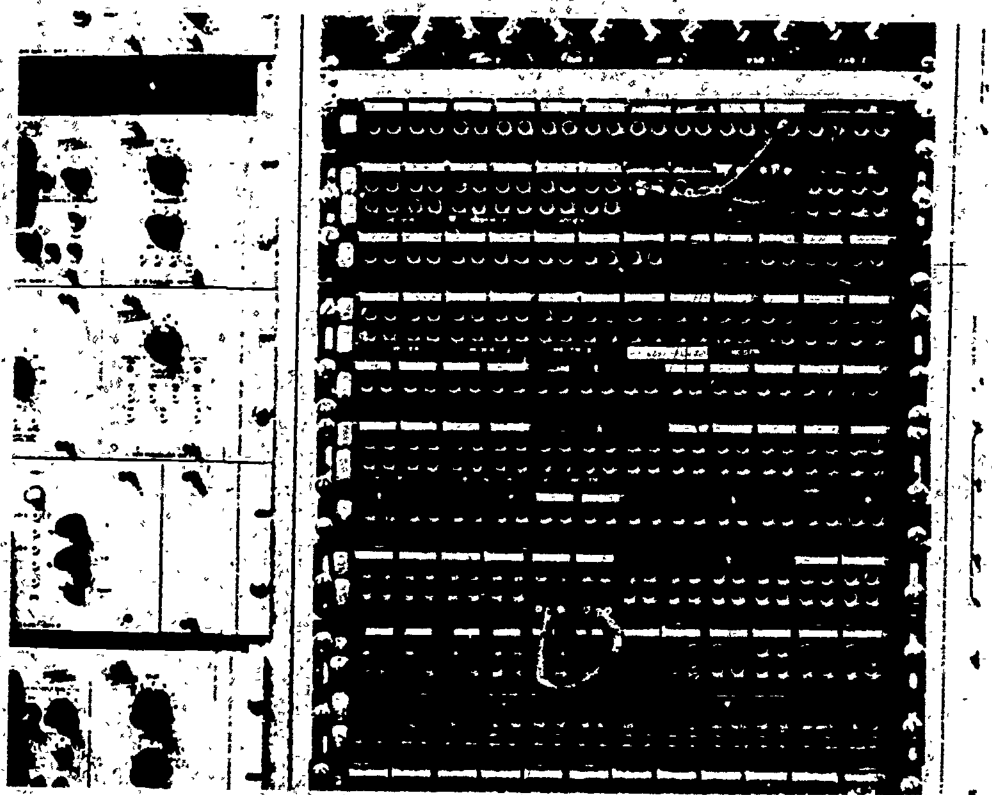
MODEM is necessary to convert an incoming signal to a form suitable for operation of receive terminal equipment and to convert the outgoing signal to a form suitable for transmission. There are various MODEMs used in the FCO spaces, most of which are discussed in the current edition of COI. 104.

Most MODEMs function automatically and require little or no adjustments by facilities control personnel after being initially set.

COMSEC EQUIPMENT

Though there are several different models of on-line crypto equipment in use throughout the Naval Security Group, they are all designed to perform the same function. This function is to encipher or decipher a teletype or digital data signal.

Basically, the crypto transmitter accepts a "plain text" teletype signal containing classified material, adds a "key" (randomly chosen marks



31.69

Figure 9-15.—Jackfield of audio board.

and spaces) generated within and transmits the sum as "cipher text," and enciphered teletype signal. The crypto receiver accepts the enciphered teletype signal and generates a key to match the one generated by the transmitter. The receiver subtracts the key from the cipher text input signal, which restores the plain text teletype signal, and passes it on to the RED patch panel for dissemination to the terminal equipment.

RED PATCH PANEL

The RED patch panel is, with one exception, electrically/mechanically of the same design as the BLACK patch panel. The absence of circuit activity lamps in the RED patch panel is the exception.

The "LINE" jacks are the termination point for the COMSEC equipment on the RED patch panel, and the "EQUIPMENT" jacks are the termination point for the teletype equipment. The jacks all function in the same manner as the BLACK patch panel.

As with the BLACK patch panel, the RED patch panel has ancilliary devices installed for monitoring and meter reading.

Another function of the RED patch panel is the "STEP" signal. This signal is a timed pulse emitted by the crypto transmitter used to synchronize the teletype keyboard/transmitter distributor (tape reader) with the crypto equipment.

The step pulse activates a clutching circuit, causing the keyboard or transmitter-distributor to "lock-up" (stop sending) momentarily. This action slows the teletype output to match the crypto transmitter's circuit timing.

END TERMINAL DEVICES

End Terminal Devices may be teletypewriter equipment and/or data terminals which consist of input and output equipment, modulation and demodulation devices, and manual or automatic supervisory controls. There is an ever increasing variety of END terminal equipment installed afloat and ashore, and for this reason a separate chapter (Chapter 10) is devoted to DSSCS low and high speed terminal configurations which include a variety of teletypewriter equipment.

A detailed examination of the 2 telegraph codes used in the NAVSECGRU communications will be the subject of this section.

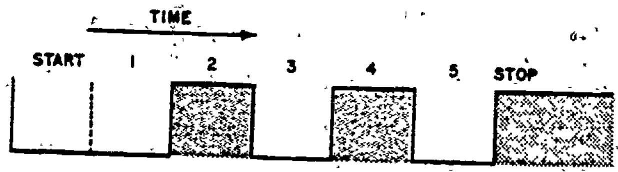
DIGITAL SIGNALS

All in-house teletypewriter and data bit signals are digital. A digital electrical signal is one that changes from one step to another in discrete steps. The signals that the SI facility controller is concerned with are digital signals that contain only two different steps or levels; these signals are termed digital binary signals. The use of digital binary signals requires equipments to react to only two conditions. The terms that are normally applied to these two conditions in the communication field are MARKS and SPACES. MARKS indicate the active condition and spaces indicate the passive condition. These binary digits (bits) are arranged in a sequential order to represent characters in a predetermined code.

Upon receipt of a deciphered teletype signal from the crypto equipment, the teletype equipment must convert it from an electrical code to mechanical actions which cause the information to be printed or punched. In order to understand this conversion process, an understanding of the teletype coding system is necessary.

INTERNATIONAL TELEGRAPH ALPHABET NO. 2 (ITA2) FIVE UNIT CODE

If a teletypewriter signal could be drawn on paper, it would resemble figure 9-16. In the common teletype configuration, a mark pulse is a condition where current flows in the circuit. A space pulse is a condition where no current flows in the circuit. Shaded areas show intervals during which the circuit is closed (mark), and the blank areas show intervals during which the circuit is open (space). Each character of the teletype code consists of a combination of five mark or space pulses. To transmit each character it takes a total of seven pulses. The first pulse is always a space and is called the start pulse. The next five pulses are those of the teletype code, and their arrangement is dependent upon which character is being transmitted. These five pulses all are called the intelligence pulses. The seventh pulse is always a mark and is called the stop pulse. Although a teletype machine may be operating at its maximum speed, there are always seven pulses generated for each character transmitted. The first and last (start/stop) pulses are there to maintain synchronization between sending and receiving units. The time duration of each pulse is determined by the speed of operation of the teletype machine.



1.197

Figure 9-16.—Mark and space signals in the teletype character R.

Examine figure 9-16 again. This is theoretically a perfect signal. The time between each unit remains the same during its transmission, and the shift from mark to space (and vice versa) is called a TRANSITION. A transition occurs at the beginning and end of each unit when it shifts from mark to space or space to mark, and there will be only 2, 4, or 6 transitions for each character.

When figuring time duration of a signal character no allowance for transition time is made, as the transition is instantaneous and is considered to have zero time duration. The time duration for each unit is measured in milliseconds. The uniform lengthening and shortening of each unit determines the MODULATION RATE (signaling speed).

There are many telegraph codes in military service; however, the ITA2 five-unit code has been the most commonly used code in modern printing telegraphy, and is universally employed for teletypewriter operation.

In the ITA2, the characters or symbols to be transmitted are represented by a series of five equal code elements, each of which occupies a specific position. The code element occupying any of the five positions may be either a mark or a space. With such an arrangement, a total of 32 combinations is possible. This includes the 26 characters of the alphabet, space bar, (movement of one space without printing), carriage return, line feed, blank, figures shift and letters shift. The 32 possible combinations available from the 5 unit code are insufficient to handle the alphabet and numbers, since 26 combinations are required for the letters of the English alphabet alone. This leaves only six combinations for numerals, symbols, or nonprinting functions. It was therefore necessary to adopt a plan to enable a larger number of characters to be included, and this was done as follows.

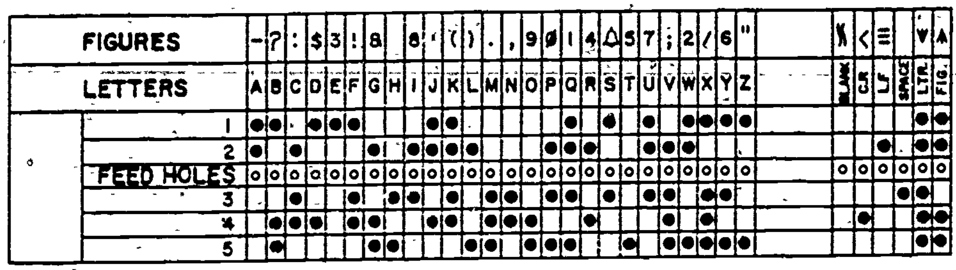
Two of the 32 combinations, (figure shift & letters shift) permit 30 of the available 32 combinations to have two meanings. When a letter shift is transmitted, it sets the receiving teletypewriter in a condition to recognize any signal combination subsequently received to be recorded in the letter case. All figures, punctuation marks, and other symbols are transmitted by using the figure shift and shifting to upper case. This enables transmission of a total of 52 printing characters and five functional characters. The one combination consisting of all spacing elements (blank) is possible but is not normally used except as part of some special signal, or when generated as a result of superpositioning of codes as in some security equipment. The ITA2 five unit code is shown in figure 9-17.

The ITA2 five unit code offers a high degree of efficiency in transmission, but with the penalty that any error introduced in a bit pattern during transmission changes the pattern into an incorrect but equally valid one. There is no way of correcting or detecting the error, except by reference to the message context. Fortunately, in the case of messages of a narrative nature, the inherent redundancy in written language is often sufficient to permit errors in transmission to be both detected and corrected by inspection of the decoded text.

On the other hand, the ITA2 five unit code is unacceptable in the modern world of figures (statistics, digital data, etc.) where the context of a character offers no clue to its accuracy, and when the transmission media (radio) involved is subject to high error rates. In these circumstances, and also where additional characters in alphabet are desired, a code with more signal elements per character, offering more permutation than the desired alphabet requires must be used.

AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE (ASCII).

The growing multiplicity of codes used in computer and other data processing systems led



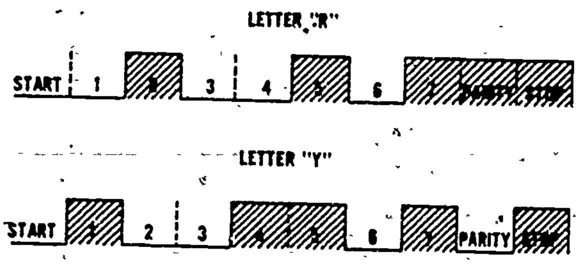
50.89:1.198

Figure 9-17.—ITA-2 five unit teletypewriter signal code.

to a study of the problem by the American Standards Association, with the object of devising a new coded character set that would be acceptable for the interchange of information among information processing systems, communication systems and associated equipment. The ASCII code has been adapted as the standard code for teleprinter equipment, the same as for digital data communication equipment.

The 7 unit ASCII code contains 10 bauds (or bits, a more commonly used term) per character, and is used wherever practicable. These are the start bit, seven intelligence bits, a parity bit, and a stop bit. The start, stop, and intelligence bits perform the same function as they do in the ITA2 code. The PARITY (even) bit is a check bit used to insure an even number of marking bits is in each character transmitted. The example of the letters "R" and "Y" shown in figure 9-18, utilizing the 7 unit ASCII code illustrates the parity bit usage. You will notice the letter "R" contains three marking intelligence bits and a marking parity bit (Shaded Area), whereas the "Y" contains four marking intelligence bits (Shaded Area) and a spacing parity bit. Thus both characters are insured even parity as required for military digital data processing equipment usage. The 7 unit ASCII code table presented in figure 9-19 provides 128 different bit patterns, all available for assignment to characters. The bits are numbered from b_7 (high order) to b_1 (low order).

Columns 2 through 7 in figure 9-19 contain the English alphabet (upper and lower case letters), the numerals 0-9 and a number of punctuation signs and mathematical symbols.



31.128

Figure 9-18.—Representation of characters "R" and "Y" using even parity 8-level ASCII (MILITARY) code.

Columns 0 & 1 contain those control functions that were considered most important to meet the requirements of data processing as well as communications. See Appendix III for a legend of characters listed in columns 0 & 1.

The seven intelligence bit character representation with b_7, the high order bit and b_1, the low order bit are shown below. Example: The bit representation for the character "K" positioned in column 4 row 11 is:

b_7	b_6	b_5	b_4	b_3	b_2	b_1
1	Ø	Ø	1	Ø	1	1

DIRECT CURRENT TELETYPEWRITER CIRCUITS

It has been pointed out that the two conditions, mark and space, may be represented by any convenient means. Within the DCS, the two most common are neutral operation, in which current flow represents the mark and no current flow represents the space, and polar operation, in which current impulses of one polarity represent mark and impulses of the opposite polarity of equal magnitude represent the space.

NEUTRAL OPERATION

Neutral circuits are common within the DCS and make use of the presence or absence of current flow to convey information. These circuits may operate with either a positive mark or with a negative mark; they may also use 60 milliamperes (mA as the line current value; or they may use 20 mA. A neutral teletypewriter circuit is composed of a transmitting device, a battery source to supply current, a variable resistor to control the amount of current, a receiving device, and a line for the transmission medium.

POLAR OPERATION

The most common direct current telegraph mode in NAVSECGRU is Polar operation. Polar operation differs from neutral, as information is always present in the system, and is either in a

B7 →					0	0	0	0	1	1	1	1
B6 →					0	0	1	1	0	0	1	1
B5 →					0	1	0	1	0	1	0	1
B4	B3	B2	B1	ROW \ COLUMN	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	\	P	@	[illegible]
0	0	0	1	1	SOH	DC1	!	1	A	Q	[illegible]	[illegible]
0	0	1	0	2	STX	DC2	"	2	B	R	[illegible]	[illegible]
0	0	1	1	3	ETX	DC3	#	3	C	S	[illegible]	[illegible]
0	1	0	0	4	EOT	DC4	$	4	D	T	[illegible]	[illegible]
0	1	0	1	5	ENQ	NAK	%	5	E	U	[illegible]	[illegible]
0	1	1	0	6	ACK	SYN	&	6	F	V	[illegible]	[illegible]
0	1	1	1	7	BEL	ETB	/	7	G	W	[illegible]	[illegible]
1	0	0	0	8	BS	CAN	(	8	H	X	[illegible]	[illegible]
1	0	0	1	9	HT	EM	)	9	I	Y	[illegible]	[illegible]
1	0	1	0	10	LF	SS	*	:	J	Z	[illegible]	[illegible]
1	0	1	1	11	VT	ESC	+	;	K	[	[illegible]	[illegible]
1	1	0	0	12	FF	FS	,	<	L	~	[illegible]	[illegible]
1	1	0	1	13	CR	GS	–	=	M	]	[illegible]	[illegible]
1	1	1	0	14	SO	RS	.	>	N	^	[illegible]	[illegible]
1	1	1	1	15	SI	US	/	?	O	_	[illegible]	DEL

INDICATES 8th BIT MARKING - EVEN PARITY

NOTE: THE UNSHADED AREAS INDICATE THE PRINTABLE CHARACTERS

31.129

Figure 9-19.—American standard code for information interchange (ASCII) for military use.

positive or negative condition. A polar teletypewriter circuit is composed of the same items as a neutral circuit plus an additional battery source. The reason for having an extra source of battery is that the standard polar circuit uses positive battery for mark and negative battery for space. The normal polar operation in NAVSECGRU is a 20 mA positive mark condition.

The most significant advantage to polar operation is that for all practical purposes it is almost impossible to distort a signal through low line currents, high reactance or random patching of signal circuits or equipment. Another advantage of polar signaling is that a complete loss of current (a reading of ZERO on the milliammeter) indicates line or equipment trouble whereas the same conditions with neutral signaling may only indicate that a steady space is being transmitted.

SIGNAL DISTORTION

As pointed out earlier in the chapter, the facilities controller's primary responsibility is to provide the highest quality circuit performance possible. To do this, he must learn to interpret circuit performance through distortion measurements of signals.

Any deviation of a signal parameter from that of the ideal signal is considered as distortion. In telegraphy, timing is a prime requisite, and excessive wrong timing is a form of distortion that could cause error in most binary systems.

An ideal teletypewriter circuit reproduces signals at the receiving end exactly as they are impressed at the sending end. Unfortunately this seldom happens under actual operating conditions, for signal units have a way of lengthening and shortening as they travel. This lengthening and shortening of marks and spaces occurring during transmission reduce the quality of the signal, and are called distortion.

Fundamentally, there are six types of distortion which adversely affect the fidelity of telegraph signals: these are bias, fortuitous, characteristic, cyclic, carrier and delay distortion.

BIAS DISTORTION

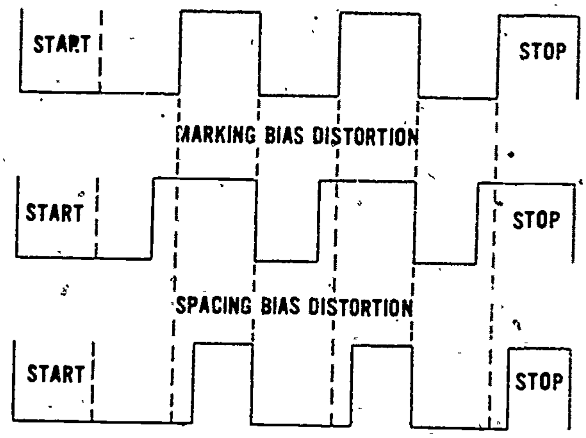
Bias distortion is the uniform lengthening or shortening of the mark or space elements, one at the expense of the other. This means that the total time for one mark and one space never changes: only the length of the mark or space element changes. If the mark is lengthened, the space is shortened by the same amount. Bias distortion may be caused by maladjusted teletype-line relays, detuned receivers, or a drift in frequency of either the transmitter or receiver. Figure 9-20 gives a graphic illustration of bias distortion.

FORTUITOUS DISTORTION

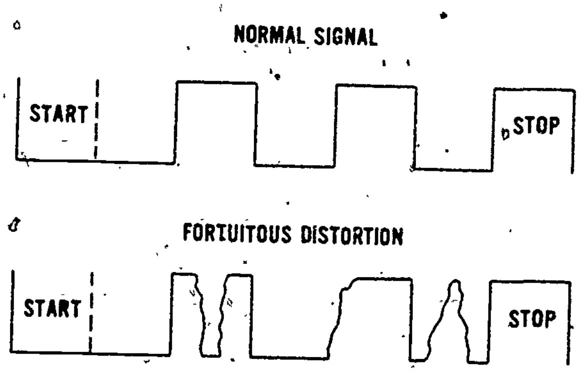
Fortuitous distortion is the random displacement, splitting, or breaking up of the mark or space elements. It is caused by cross-talk interference between circuits, atmospheric noise, power line induction, lightning storms, dirty keying contacts and such similar disturbances. Figure 9-21 gives a graphic illustration of fortuitous distortion.

CHARACTERISTIC DISTORTION

Characteristic distortion is a repetitive displacement or disruption peculiar to specific portions of the signal. It normally is caused by maladjusted or dirty contacts of the sending equipment. It differs from fortuitous distortion in that it is repetitive instead of random. An



31.130
Figure 9-20.—Normal and bias distorted signal.

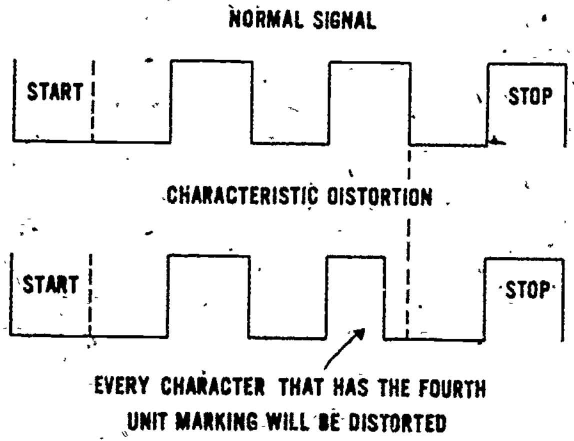


31.131
Figure 9-21.—Normal and fortuitous distorted signal.

example would be the repeated shortening of the fourth intelligence unit of a character, as shown in figure 9-22.

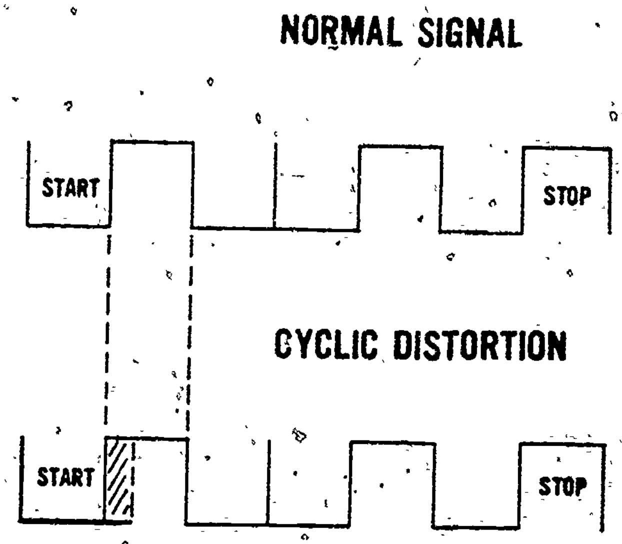
CYCLIC DISTORTION

Cyclic distortion is produced by a variety of causes. Although the type of distortion is periodic in nature, it originates from some defective or improperly adjusted device in the



31.132
Figure 9-22.—Normal and characteristic distorted signal.

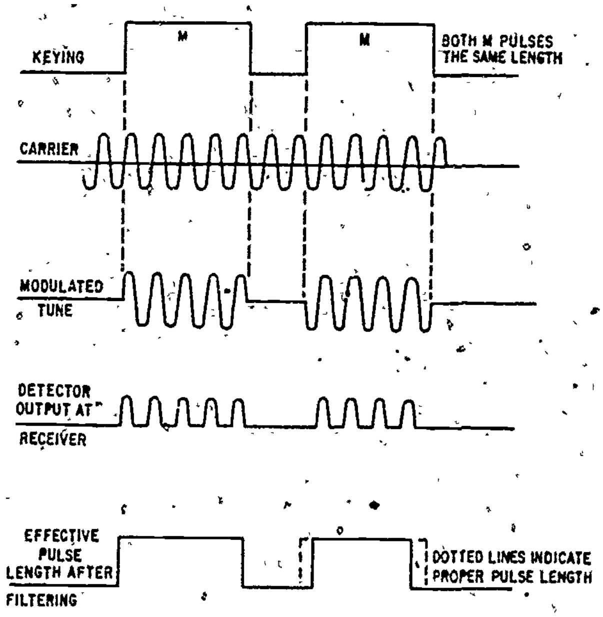
circuit. Some of the causes are poor filtering of a.c. components from power supplies, cross talk from adjacent channels, or radio frequencies beating against each other to produce other frequencies. Cyclic distortion is illustrated in figure 9-23.



31.133
Figure 9-23.—Normal and cyclic distorted signal.

CARRIER DISTORTION

Carrier distortion is the random displacement of signal element transition that is a characteristic of carrier equipment. It is directly related to the rate of the keying signal and frequency of the tone in the channel being keyed. As the ratio between the keying rate and the tone being keyed becomes smaller, the amount of distortion becomes greater. See figure 9-24.



31.134
Figure 9-24.—Theory of carrier distortion.

DELAY DISTORTION

Delay distortion is the arrival of some component of a signal at a later time than its other components. When comparators accept two signals and produce one demodulation output, the resultant signal may contain distortion due to the delay of some signal component compared to others.

One method of preventing signal distortion on synchronous circuits is achieved by using the

TSEC/HW-8, Transmission Delay Compensator (Figure 9-25). The HW-8 is a digital equipment that compensates for delays in propagation time over various communications media.

On a time synchronous communication system, the receiver synchronizes on the transmitter. If the length of a transmission line is changed, the receiver may lose time synchronization with the transmitter. To regain loss of synchronization, the HW-8 can artificially compensate for the increase or decrease of the inherent delay created by changing the length of the transmission line.

TROUBLESHOOTING TECHNIQUES

Troubleshooting techniques are based upon a systematic approach to a given problem. When trouble develops on a communication circuit, it is necessary for the facilities controller to apply his knowledge and equipment in the most logical manner possible to effect prompt restoral action.

RESPONSIBILITY FOR INTEGRITY OF SYSTEM

Facility control operations is responsible for troubleshooting all circuits. And as the facilities controller, your responsibility starts at the receive side of the circuits at your station and ends at the distant station's send side. In other words, troubleshooting is initiated on the receive side of a circuit and checked back to the source. If trouble develops on a circuit you must evaluate all available factors, weigh them against past experience with similar troubles, and take corrective action. Your responsibility for providing information to the distant station as to the progress being made towards restoration of the circuit is of the utmost importance. Without this guidance from the receiving terminal, the sending station cannot take effective action of its own.

Once the circuit is restored, the receiving station is further required to provide the sending station with the reason for outage and other pertinent information as required.

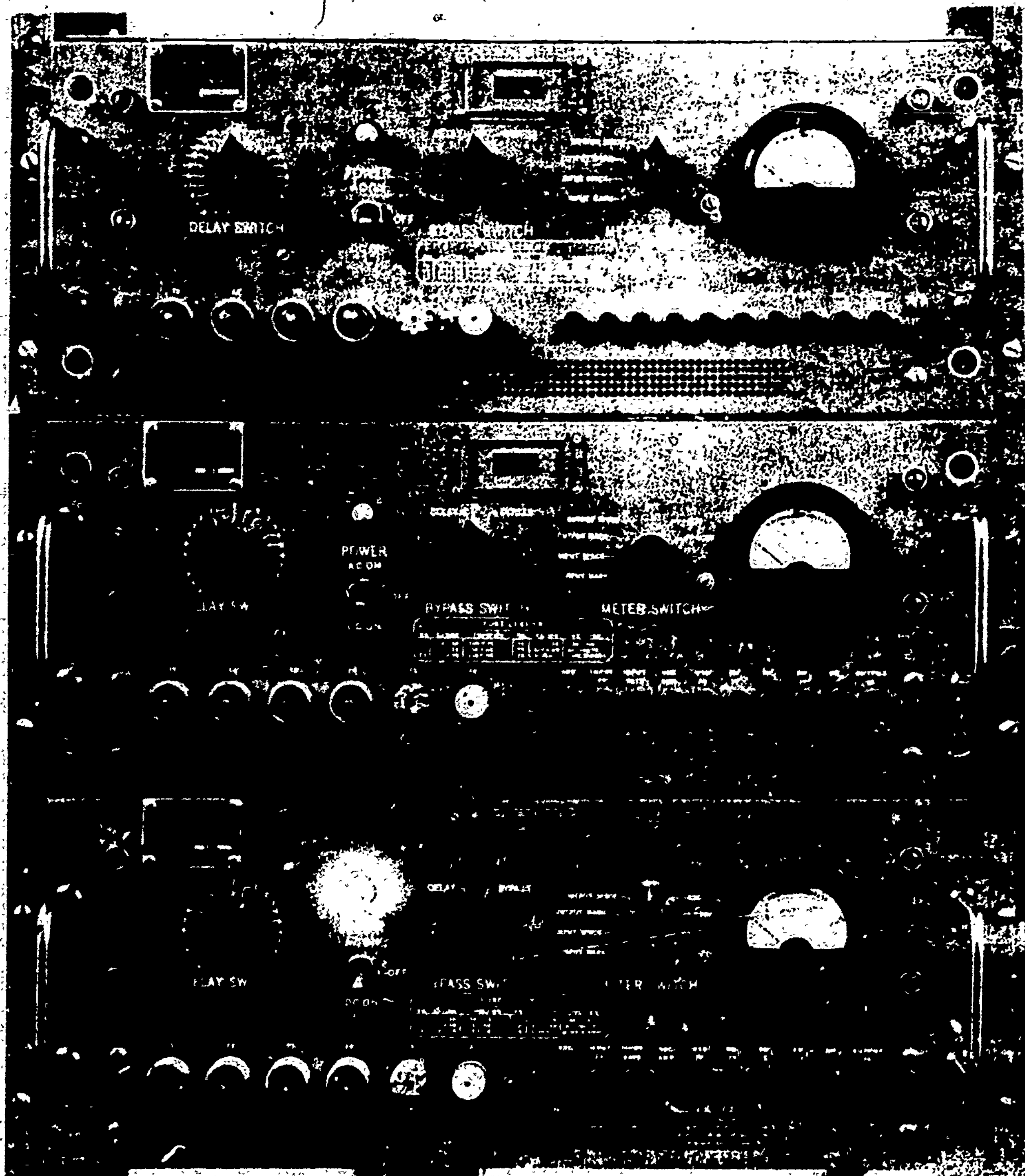
ISOLATION OF TROUBLES

It would be impossible to describe every type of trouble or interruption that may occur in cable, radio or wire circuits, or to describe what course of action should be taken when testing a circuit. Generally speaking, however, circuit difficulties fall into two broad categories, (1) equipment trouble and (2) line or signal trouble, depending on the communications media used. One of the most important steps in troubleshooting is to determine in which of those two categories the trouble lies; further steps will determine the exact cause of the trouble. Each trouble that is reported must be first verified and then evaluated. This is usually done by plugging a printer position into the monitor jack of the circuit reported. The two most common troubles are printers garbling and printers (receive positions) running open. Once the trouble is verified, its cause should be evaluated.

When equipment fails, the faulty equipment must be located and repaired or replaced. Replacement of equipment may be limited by patching facilities. For example, teletypewriter equipment is usually hard-wired (permanently wired) to the patch panels. If either equipment fails, it must be physically removed and replaced with similar equipment or a patch made to substitute a different teletypewriter/crypto combination. It is necessary, therefore, that facility controllers know their patching capabilities.

Evaluation of signal integrity is perhaps the most important step of the process. In fact, this one step may be all that is required to isolate the trouble. Evaluation of signal integrity should take place at the point the signal either enters or leaves the patch panel. Equipment or relays should never be assumed to be defective without first checking the distortion of the input signal to see if the amount of distortion is different from the output distortion.

The equipment at the distant station must also be eliminated as a possible source of trouble. This can be done by either a mental deduction, based on an evaluation of the signal integrity, or, by requesting a test from the distant station.



31.70

Figure 9-25.--TSEC/HW-8.

All circuit tests should be conducted in cipher. In fact, the transmitting station should never switch to plain language unless directed by the receive station. It is likely that the equipment would remain synchronized during short periods of outage, saving the time otherwise required to reestablish cipher contact.

After verifying that the incoming signal is substandard, make a report to the circuit supplier. This report will include the circuit identification and the nature of the trouble, including your efforts to restore the circuit.

One thing to remember, don't wait until the circuit has completely deteriorated before notifying the supplier. If promptly notified, the circuit supplier can usually save a considerable amount of lost circuit time. Note: The circuit supplier must be notified even when you test in cipher. If the circuit is "IN," but you have to stay in test and are unable to pass traffic, the supplier must be notified accordingly.

When a substandard circuit has been restored for you by the circuit supplier, conduct a final evaluation to be sure that the circuit will meet all in-station requirements before attempting to resume cipher contact.

UTILIZATION OF TEST EQUIPMENT

Communications personnel, whether engaged in facilities control, maintenance, or traffic handling, must have a means of quickly determining the quality of the communication circuits and equipment used. In determining transmission quality, traffic personnel rely on hard copy monitoring which is generally sufficient to recognize corruptions to formatted message headings and texts. Facilities control and maintenance must employ a more exacting method of measuring transmission quality and equipment performance without depending on message texts.

In the past there has been a tendency toward more rigid control equality of transmission in the operating system. The trend toward higher transmission speeds and the introduction of new modes of operation in the system have not only emphasized the need for better quality control, but have caused most of the equipment formerly used for analysis of signals to be obsolete or at least inadequate.

The test set described in the following paragraphs is the most current equipment in use. There are other test sets in use for signal analysis at various communication stations, but the principles provided in this manual are basically the same.

DIGITAL DATA DISTORTION TEST SET AN/USM 329(V) 1&2

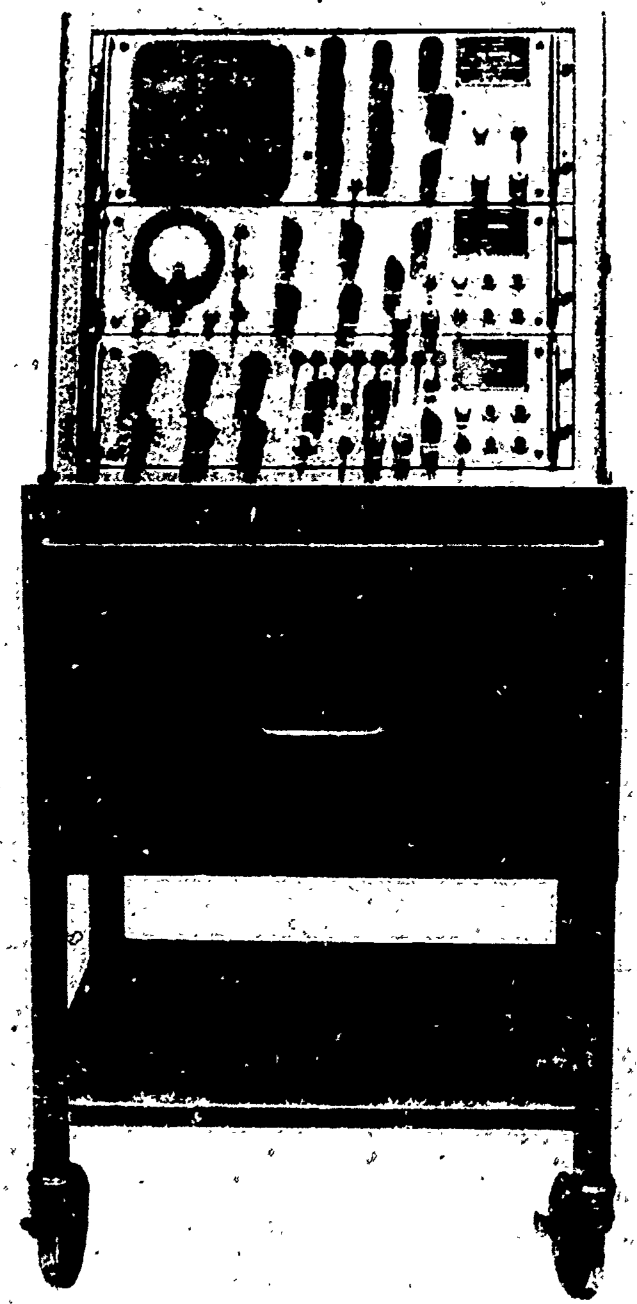
The Digital Data Distortion Test Set AN/USM 329(V) consists of a digital data signal generator and a digital data analyzing system composed of an analyzer and an oscilloscope. These units are mounted in either of two configurations, in a 19 inch cabinet mounted on a dolly and nomenclatured AN/USM 329(V) 1 (figure 9-26) or all three units rack mounted for fixed station use and nomenclature (AN/USM 329(V) 2. Each of the three units is self-contained and independently operable, although the analyzer and oscilloscope are normally operated together. For reference purposes and an indepth discussion on the controls and indicators, APPENDIX IV includes operating data for each of the functional units described below. Hereinafter, the Digital Data Distortion Test Set AN/USM 329(V) will be referred to as the test set.

Digital Data Signal Generator SG-885(P)/USM

The signal generator unit (figure 9-27) of the test set provides simulated teletype signals used to test digital data and teletype equipments. The generator provides a variety of simulated test signals with controlled amounts of distortion.

Digital Data Signal Analyzer TS-2936(P)/USM

The analyzer unit (figure 9-28) of the test set is used to determine the number and type of distortion of digital data and teletype signals. The analyzer is equipped with line matching circuits to minimize loading, and provides a meter read out capability of the percentage distortion of the received signal.



31.135

Figure 9-26.—Digital data distortion test set AN/USM 329V (1).

Oscilloscope OS-212/USM

The oscilloscope unit (figure 9-29) of the test set is used primarily to display the received digital data waveform for analysis by the operator. The input signal for the oscilloscope is supplied by the analyzer, along with selectable triggers and an intensity modulation signal.

OPERATIONAL PRACTICES

Procedures for circuit operation within NAVSECGRU FCO will conform to the procedures set forth in the current DCA, DSSCS Operating Instructions (DOI-101) and COMSEC operating instructions. Unclassified Fixed Station Call Signs should be used by FCO in place of routing indicators. Order wire transmissions and communications to distant stations should consist of precise times, prosigns, operating signal (Q & Z) and generally accepted communications phraseology. Clear text language will be used only when absolutely necessary to convey the particular information to be expressed. Order wire transmissions are to be suffixed with the operator's personal sign.

Greenwich Mean Time (GMT-ZULU TIME) is used throughout NAVSECGRU FCO and the DCS; however, local time is used when coordinating with commercial companies.

MASTER FACILITIES CONTROL LOG

A record of events is maintained in the MASTER Facilities Control Log as shown in figure 9-30. It should be utilized for the reporting of any unusual circuit interruption or circumstance. This includes instances such as personnel errors, short term forecast, scheduled COMSEC changeover or any information concerning the circuit operation which requires detailed explanation.

CIRCUIT PERFORMANCE LOG

The Circuit Performance Log (figure 9-31) provides for the detailed logging of outages on the individual circuit. One log or one set of logs, depending upon the number of circuits at the station, will be maintained for each radio log. The log provides for detailed accounting of circuit outages which might occur throughout an entire radio day. While each reporting hour is divided into 15 minute segments, outages of less

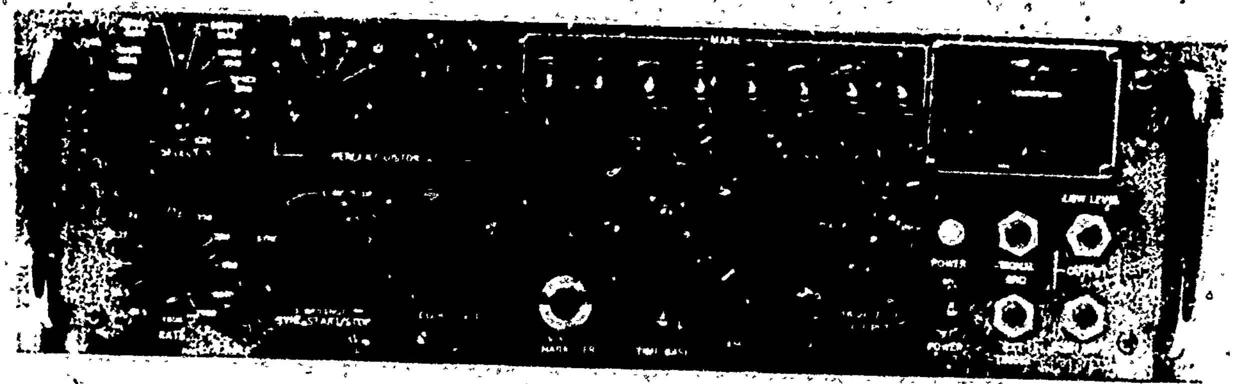


Figure 9-27.–SG-885(P)/USM digital data signal generator. 31.136

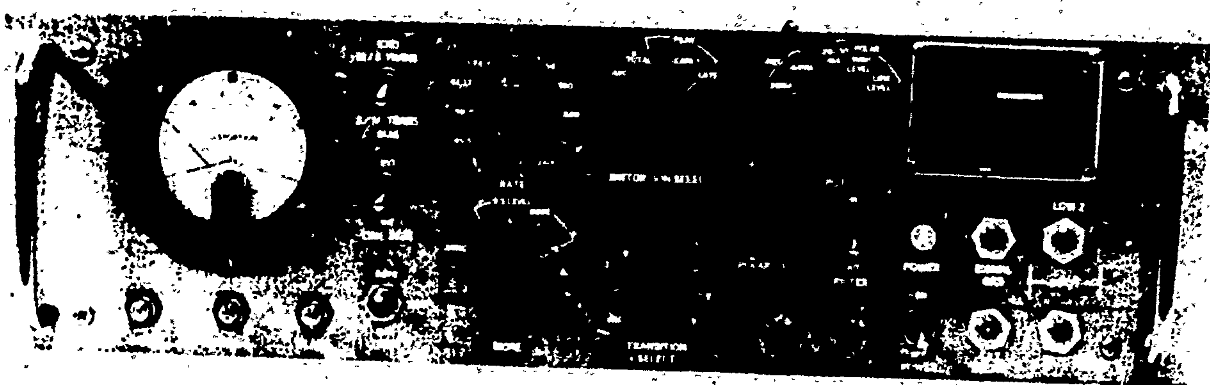


Figure 9-28.–TS-2936(P)/USM digital data signal analyzer. 31.137

than 15 minutes can be recorded by using symbols prescribed in COI 104.

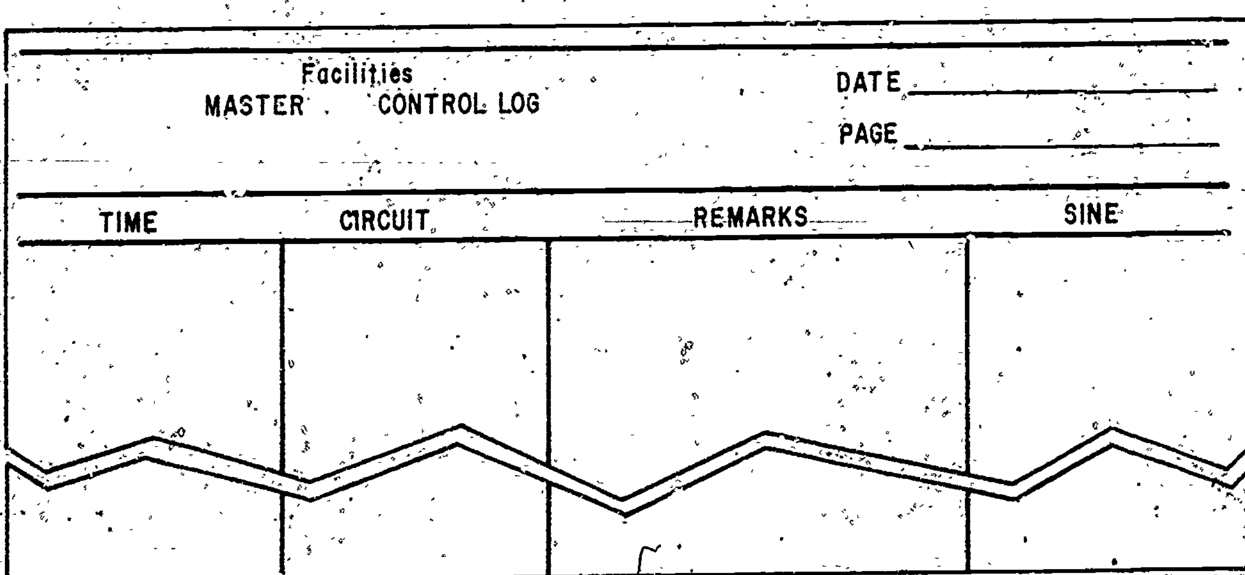
In addition to recording circuit outages on the Circuit Performance Log. the facilities controller is responsible for submitting reports of excessive outage to appropriate agencies. Basically, the outage report identifies the circuit experiencing the difficulty. the reason for outage (when known) and the expected time of restoration (when known). Both the timeliness of submission and the accuracy of the information and format are essential to the effectiveness of the reports. Prior to transmission, reports of circuit outage are usually double-checked for accuracy by supervisory personnel.

CIRCUIT STATUS

Posted within the facility control spaces is a status board, which reflects up-to-the minute circuit information. As a minimum, the status board shall list all full and part-time circuits activated. scheduled COMSEC changeover times, any equipment or line patches in effect, status of spare equipment and information

31.138

Figure 9-29.—OS-212/USM OSCILLOSCOPE.



31.63

Figure 9-30.—Master facilities control log.

pertinent to extensive outage. The accuracy of information on the status board should be verified at least once per watch. However, the communications center SOP may require more frequent verification.

DISTANT STATION/CONTROL AGENCY COORDINATION

Effective operation of any communication system requires timely coordination with local.

CONFIDENTIAL (unclassified until filled)
CIRCUIT PERFORMANCE

COM. NO (1)	DY WK (2)	GMT	DAY (3-4)	MONTH (5-7)	YEAR (8)	PROPAGATION FORECASTS	(9-10)	(11-12)	(13-14)	(15-16)	(17-18)
5											

CIRCUIT (19-22)	CHNL (23)	SIDE (24)	0–1 (25-26)	1–2 (27-28)	2–3 (29-30)	3–4 (31-32)	4–5 (33-34)	5–6 (35-36)	6–7 (37-38)	7–8 (39-40)	8–9 (41-42)	9–10 (43-44)	10–11 (45-46)	11–12 (47-48)	12–13 (49-50)	13–14 (51-52)	14–15 (53-54)	15–16 (55-56)	16–17 (57-58)	17–18 (59-60)	18–19 (61-62)	19–20 (63-64)	20–21 (65-66)	21–22 (67-68)	22–23 (69-70)	23–24 (71-72)	TOTAL OUTAGE (MINS)
		SEND-1																									
		REC-3																									
		SEND-1																									
		REC-3																									
		SEND-1																									
		REC-3																									
		SEND-1																									
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		SEND-1																									
		REC-3																									
		SEND-1																									
		REC-3																									

31.64

Figure 9-31.—Circuit performance log.

intermediate, and distant stations' facility controllers. This coordination goes beyond the mere ability to talk from one terminal to another. The cooperation must be mutual—it must work both ways. It doesn't take very long to realize that it can be difficult to communicate with anyone, distant station or local supplier, without a little mutual cooperation.

Nothing can be gained either, by losing your temper and trying to blame all of the troubles on the other end of the circuit. You have to be sure that "your own house is clean" before blaming something or someone else for circuit difficulties. It must be remembered that the man on the other end of the circuit is trying just as hard to get the circuit back in operation. Contrary to a number of people's way of thinking, it is not degrading in any manner to admit or to discover that circuit troubles are in-house. Rather than losing face, respect and goodwill usually result from an honest exchange of information whenever it is found. The important thing is to maintain communications and to provide the highest quality of circuits for passing traffic. It is even possible that future outages can be reduced from hours to minutes when information relating to the cause and cure of previous outages is freely exchanged.

A final consideration is that of being prepared and well informed of the job at hand. A competent facilities controller possesses the expertise to rapidly correct all circuit and equipment deficiencies. in addition to extending the necessary cooperation whenever possible. Ultimately, it pays large dividends in maintaining reliable circuit performance.

CHAPTER 10

END TERMINAL EQUIPMENT

Many variations of end-terminal equipment are utilized throughout the NAVSECGRU communication installations. The trend at present tends to be toward faster operating, digital data processing equipment. DSSCS subscribers will utilize existing input/output equipment with special interface devices or the AUTODIN Digital Subscribers Terminal Equipment (DSTE).

In this chapter we cover two topics: teletypewriter equipment and description of the various modes and terminal configurations used by the DSSCS subscribers.

INTRODUCTION TO THE TELETYPEWRITER

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 print characters in page form, called hard copy.

The characters appear at both sending and receiving stations. In this way, one teletypewriter will actuate as many machines as may be connected together. An operator transmitting from New York to Boston will have his message repeated in Boston, letter by letter, virtually as soon as it is formed in New York. The same will apply at all receiving stations that tie into the network.

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, quietness, and high speed operation. 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 teletypewriter is its ability to operate at speeds of 65 and 106 words per minute. Conversion from one speed to another is accomplished by changing the driving gears that are located within the equipment. Most of the Navy's teletypewriters are presently operated at 100 words per minute.

AUTOMATIC SEND-RECEIVE (ASR) TELETYPEWRITER SET AN/UGC-49

One of the more commonly used teletypewriters is the model AN/UGC-49 teletypewriter, shown in figure 10-1. It is an electromechanical apparatus for sending and receiving both printed and tape perforated messages and receives messages electrically from the signal line and prints them on page size copy paper. In addition, it can receive messages and record them on tape in both perforated and printed form. With page-printed monitoring, the teletypewriter electrically transmits messages that are originated either by perforated tape or keyboard operation. It mechanically prepares perforated and printed tape for separate transmission with or without simultaneous electrical transmission and page-printed monitoring.

The keyboard, typing perforator, typing unit, 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

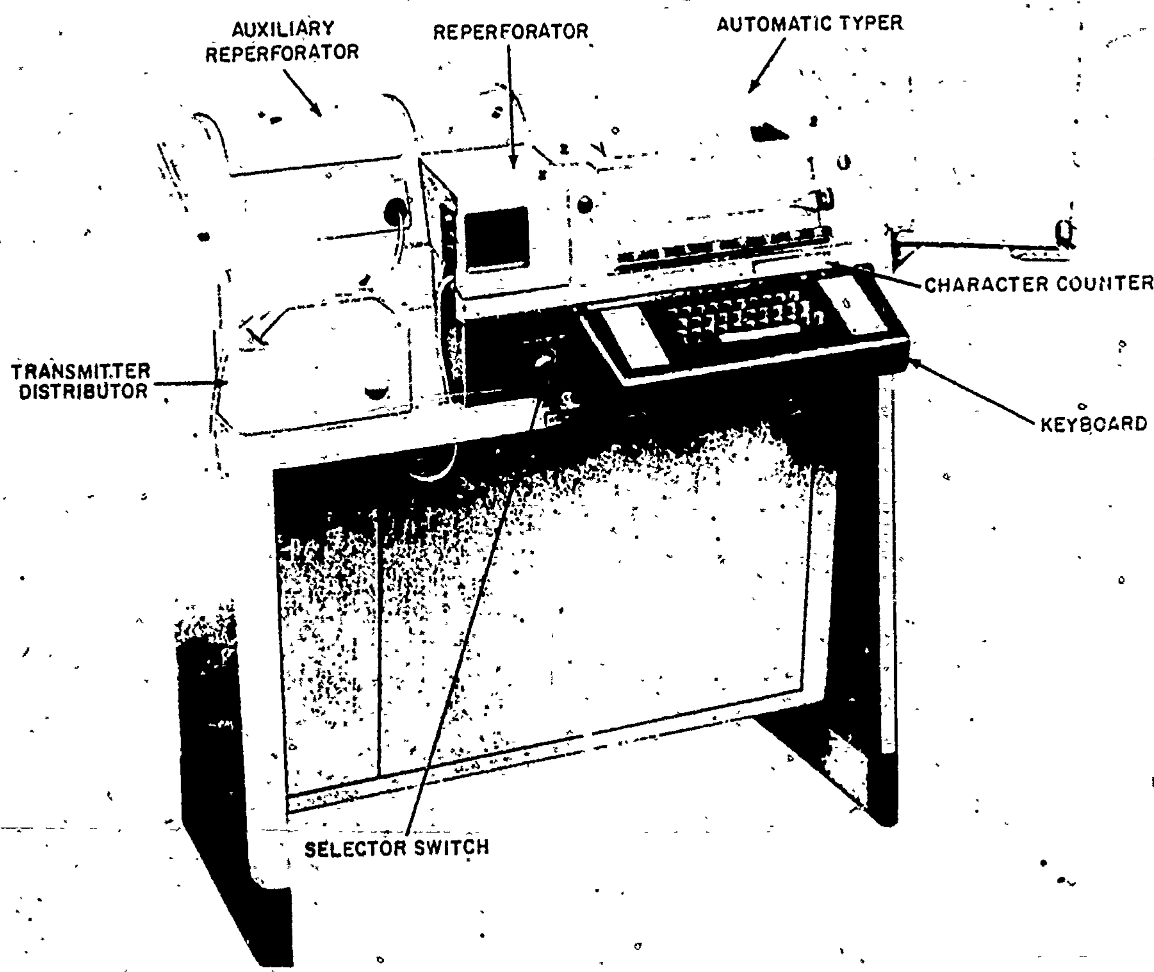

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Figure 10-1.—Model AN/UGC-49 teletypewriter.

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 shunting various components from the line. The typing reperforator is operated by a separate motor and power distribution system. It is connected to a separate external signal line.

DESCRIPTION OF MAJOR COMPONENTS

The major components of the AN/UGC-49 teletypewriter are described in greater detail in the following paragraphs and illustrations.

Keyboard Unit

The keyboard unit (fig. 10-2) provides a foundation for the a.c. motor, typing unit. and typing perforator This component incorporates the necessary electrical and mechanical elements for message transmission and for controlling the mechanical printing and perforating of the tape. It also supports the tape container, a character counter used in connection with the typing perforator, intermediate gears for operating the signal generator and typing unit. flexible connections for operating the typing perforator and transmitter distributor, and a three-position

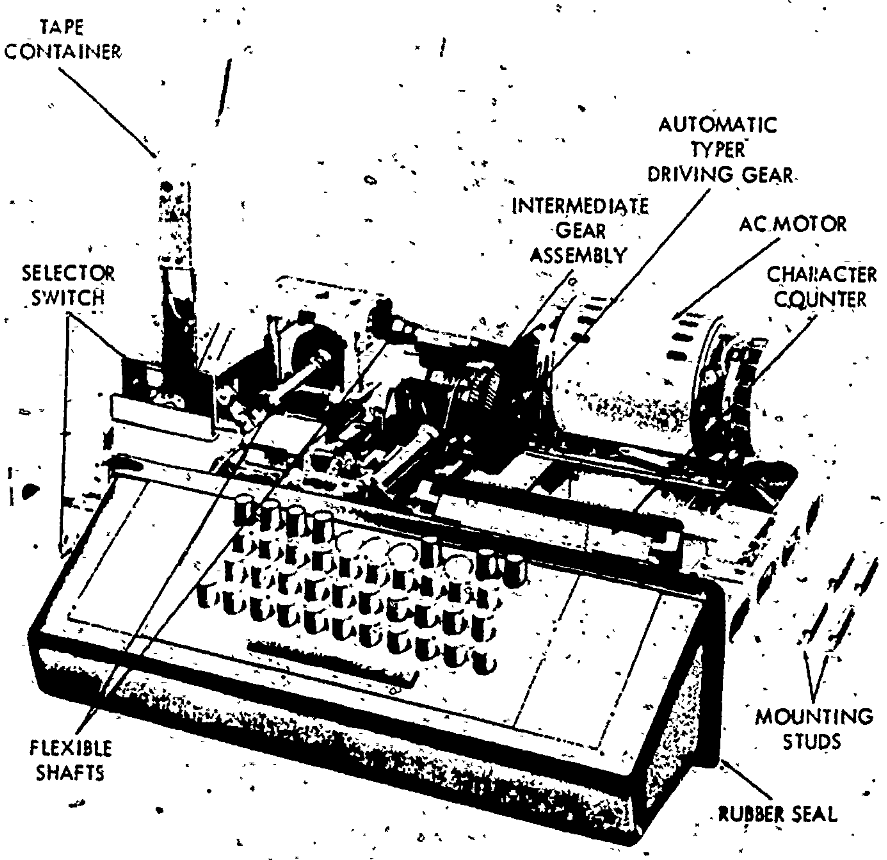


Figure 10-2.—Teletypewriter keyboard unit. 50.92

selector switch for choosing the mode of operation of the equipment.

The keyboard mounts in the cabinet on rails of a shock-mounted cradle. The front of the keyboard protrudes from the cabinet and is fitted with a rubber seal for a silencing effect. Mechanical power for activating the keyboard is derived from the a.c. motor through intermediate drive gears and the typing unit or the typing perforator, depending on the selected mode of the three-position switch.

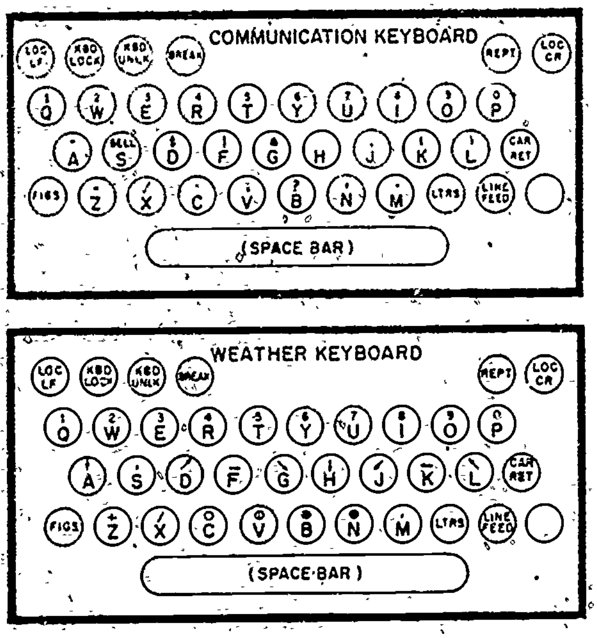
The Model 28 printer series is equipped with either of two types of keyboards: communication or weather. The communication keyboard contains letters and punctuation marks common to the standard typewriter. and the weather keyboard provides necessary symbols for transmission of weather data.

Similarities and differences in the two keyboards are illustrated in figure 10-3. Observe that the lowercase characters are the same, and that letters of the alphabet appear in the same positions. The difference lies in the uppercase of the bottom two rows. A trained operator can use either the communication or weather keyboard without loss of speed or efficiency.

Figure 10-4 is an illustration of the communication keyboard with emphasis placed on the function keys. The action performed by the function keys is described as follows:

a. SPACE BAR—The space bar, located at the front of the keyboard, is used to send spaces (as between words).

b. CAR RET (carriage return)—the carriage return key is used to return both the type box



31.23

Figure 10-3.—Two types of teletypewriter keyboards.

carriage and the printing carriage to the left to start a new line of typing.

c. LINE FEED—When depressed, this key causes the paper to feed upward one or two spaces depending upon the position of the single-double line feed lever located on the typing unit.

d. FIGS (figures)—The figures key is pressed to condition the machine for printing figures, punctuation marks or other uppercase characters.

e. LTRS (letters)—The letters key is used to condition the machine for printing the letters (lower case) characters.

f. BLANK (unlabeled key in bottom row)—Depressing the blank key twice (effective in either uppercase or lowercase) locks all keyboards in the circuit and renders them inoperative by setting up the receive condition. Restoration to the send condition is accomplished, under individual circumstances, through operation of the SEND key by the operator desiring to send from his keyboard. SEND and REC keys, when installed, will be located in spaces available in the center of the function key row.

g. REPT (repeat)—To repeat a character, depress the character key and the REPT key. The character will be repeated automatically at line speed as long as both keys are held down.

The three keys described next perform their functions only on the machine on which the key is operated (referred to as "local machine"), without affecting any other machine on the line.

h. LOC LF (local line feed)—To feed the paper up in the local machine, depress the LOC LF key, which feeds the paper up automatically and rapidly as long as it is held down. This key is for use in locally feeding up paper to tear off a message not fed up far enough by the transmitting station. It also is used when inserting a new supply of paper in the machine.

i. LOC CR (local carriage return)—To return the type box to the left margin on the local machine, depress the LOC CR key. This key is for use in omission of carriage return at the end of a transmission from another station.

j. BACK SPACE—A back space mechanism is available through the use of a modification kit, allowing the operator to back space while preparing a tape on the typing reperforator and letter-out any errors.

Typing Unit

The typing unit used in the AN/UGC-49 teletypewriter is pictured in figure 10-5. The typing unit incorporates the necessary electrical and mechanical elements to translate the signaling code combinations into mechanical actions that print the messages and perform functions incidental thereto.

Paper (single or multi-copy) feeds from a five-inch (maximum) diameter roll mounted at the rear of the typing unit. The paper feeds around a platen which rotates but which does not move horizontally.

Type pallets are arranged in a small type box (fig. 10-6), which is detached easily for cleaning or replacement. In operation, the type box moves across the paper and presents the proper type pallets to the printing hammer, which drives the pallets and inked ribbon against the

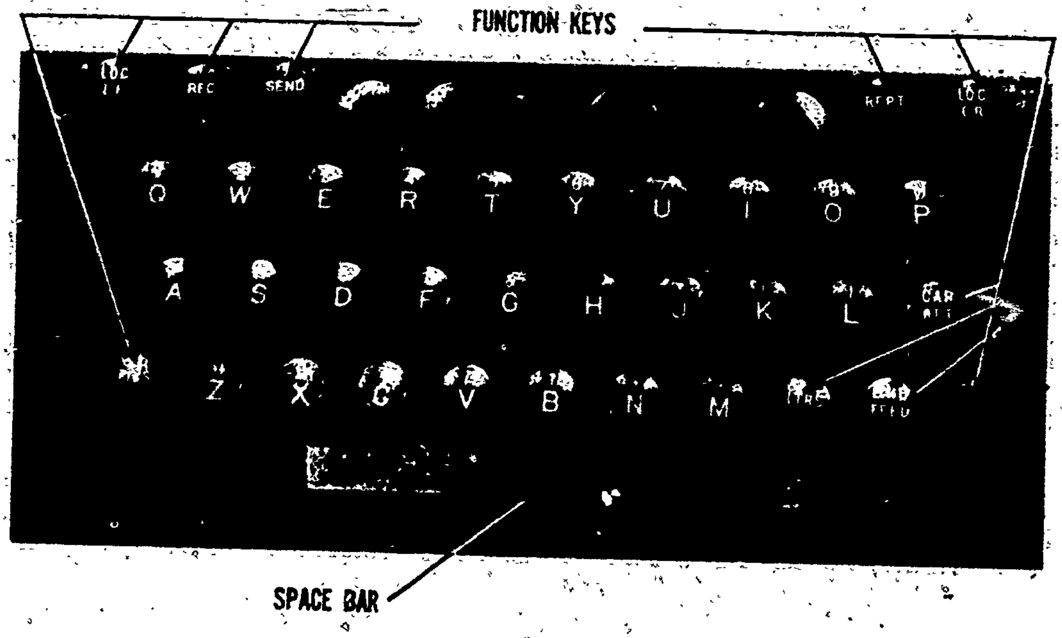


Figure 10-4.—AN/UGC-49 keyboard.   1.217.13B

paper to print the characters. Combined automatic carriage return and line feed features operate to return the carriage if overprinting occurs at the end of a line.

As each character is printed, the inked ribbon feeds from one spool to the other reversing automatically when the ribbon reverse lever is tripped by the small rivet at each end of the ribbon. The ribbon mechanism is shown in figure 10-7.

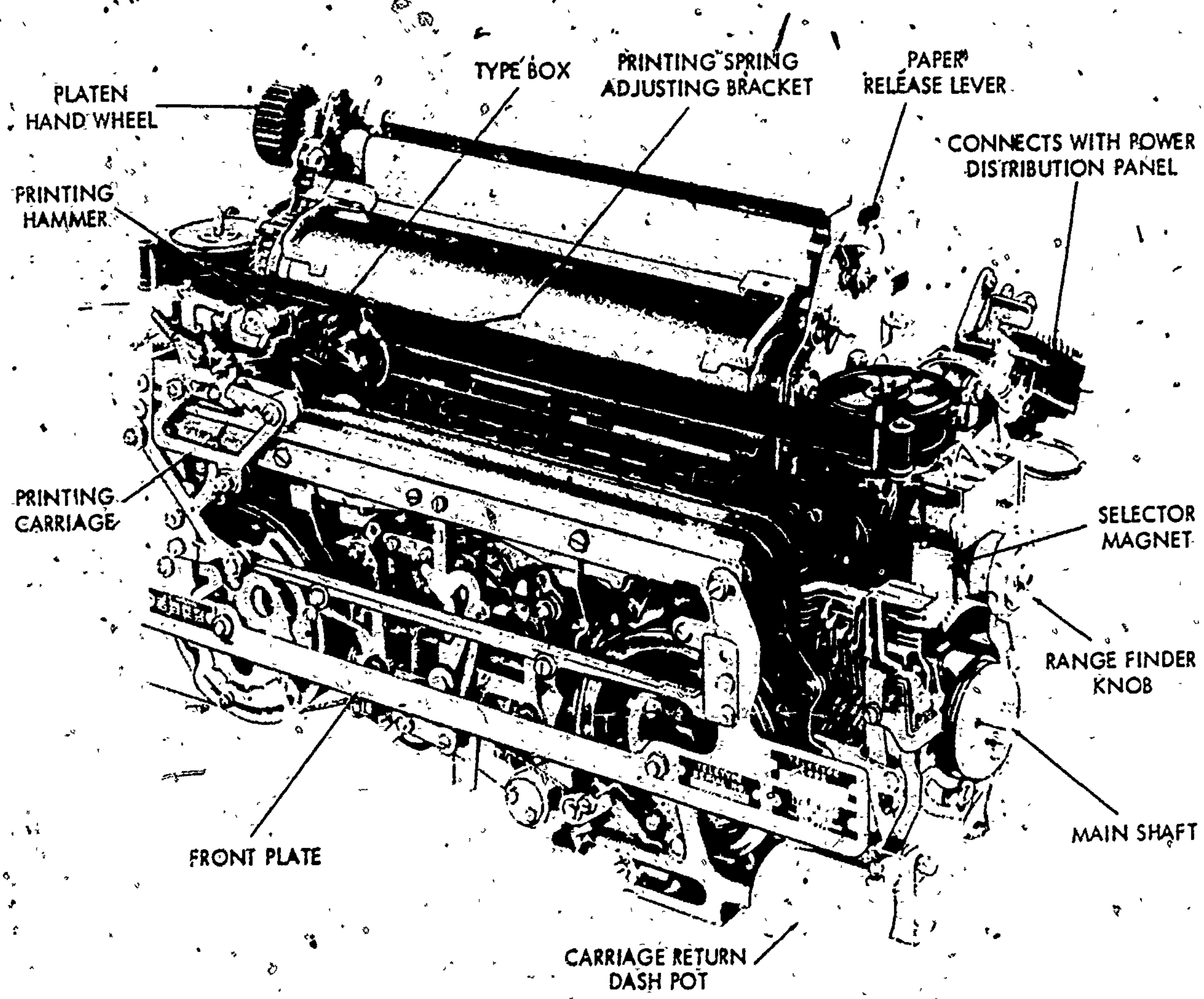
Printing is produced by the type box, which contains the characters and symbols shown on the key tops. Operation of keys and space bar moves the type box across the platen from left to right. On each key stroke the type box is moved into position for the printing hammer to strike the proper type pallet, printing the character on the paper. Operation of the CAR RET key returns the type box to the left margin, and operation of the LINE FEED key moves the paper up to the next line.

Typing Reperforator

Tape preparation, by operation of the keyboard, is accomplished by the typing reperforator (figure 10-8). This reperforator is controlled by mechanical linkages on the keyboard. The reperforator is a transmissible, five-level, chadless, perforated tape with printed characters corresponding to the perforated code.

The typing perforator, mounted on the left front corner of the keyboard, is powered through flexible connections and a jack shaft by the a.c. motor mounted on the keyboard. Its tape is supplied from a container mounted at the left rear corner of the keyboard.

With the keyboard selector switch in the K (keyboard) position, the typing perforator is inoperative. (See fig. 10-9.) In K-T (keyboardtape) position, the selector switch connects the selector magnet on the keyboard typing reperforator into the signal line circuit of



50.94

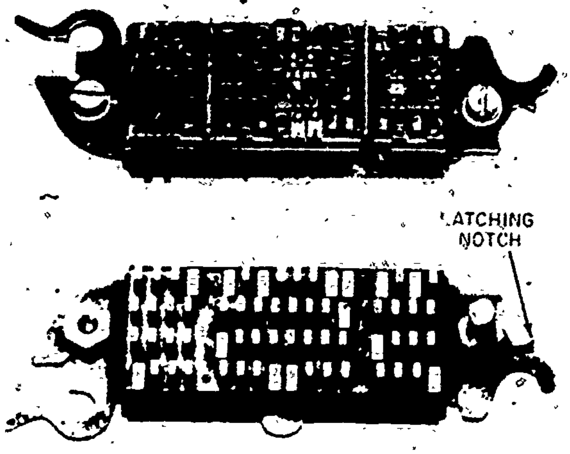
Figure 10-5.—Typing unit (front view).

the keyboard signal generator, at the cabinet terminal board, to permit preparation of perforated and typed tape simultaneously with signal line transmission. In T (tape) position, the selector switch mechanically engages linkages between the keyboard and the keyboard typing reperforator resulting in manual typing reperforator operation independent of the signal line.

Auxiliary Typing Reperforator

The auxiliary typing reperforator is similar in appearance, design and operation with identical sub-assemblies to the typing reperforator already described above. Because the reperforator is not controlled by keyboard but receives messages from an incoming signal line instead, it has a selector unit. The auxiliary typing reperforator is mounted on a special auxiliary base and is powered by an a.c. motor and a separate keyer located in the electrical service assembly.

The location of the reperforator in the cabinet is at the top left, above and behind the transmitter distributor.



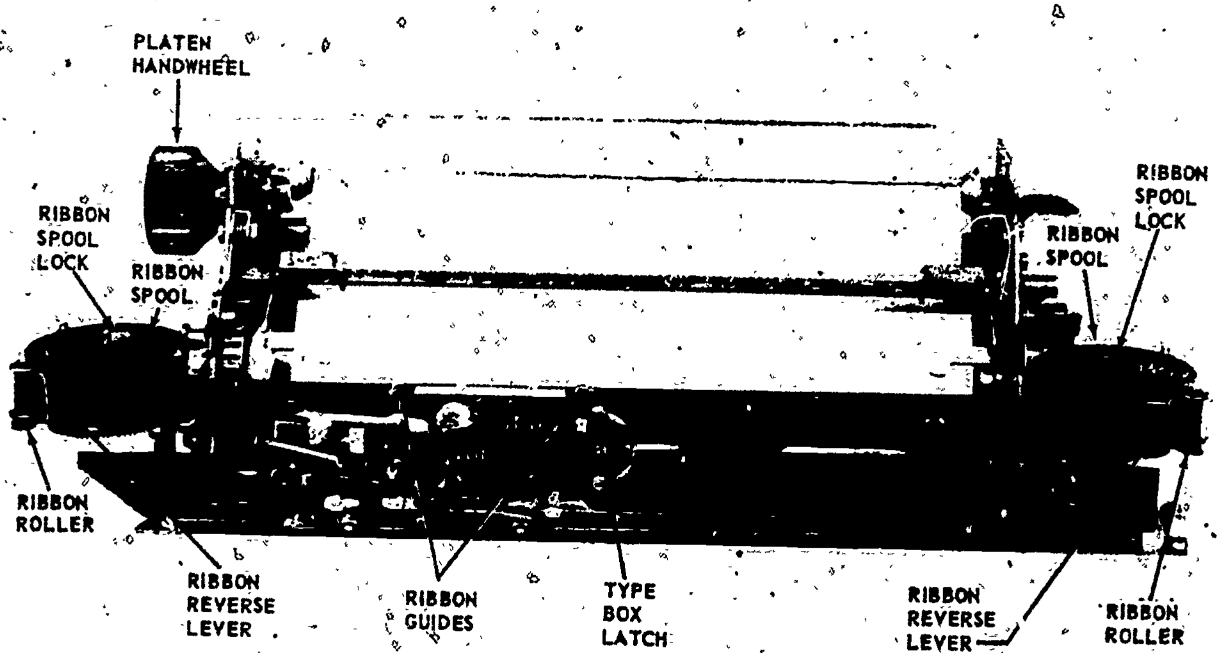
31.28
Figure 10-6.—Type box, front and back.

which provides a suitable length of "letters" at the end of each message (by operation of the Tape Feed-Out Switch on the dome of the cabinet), and a tape threading handwheel.

Both reperforators are provided with a chad chute which discharges the chad from the perforated tape by way of chad chute extensions into a common chad container located under the dome compartment of the cabinet. It is important that the container is emptied frequently to prevent chad from backing up and jamming the perforating mechanism.

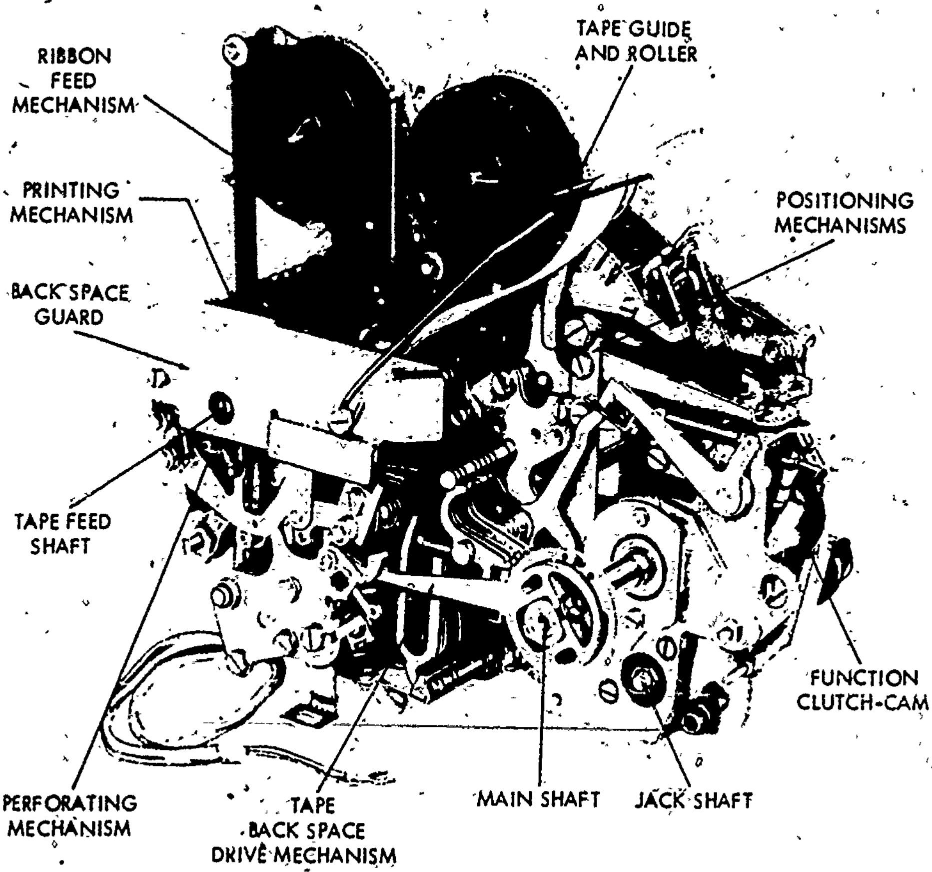
Transmitter Distributor

The transmitter distributor (fig. 10-10) is mounted on its own base in front of the cabinet on the left side. It is a mechanical tape reader used to convert messages on standard five-level chadless or fully perforated tapes to signaling code combinations for transmission on a telegraph channel.



1.222
Figure 10-7.—Ribbon inserted.

Additional features of the reperforator that are not common to the perforator are the signal bell and switch, low tape alarm and switch, the mechanical variable speed drive mechanism, a noninterfering letters tape feed-out mechanism



50.98

Figure 10-8.—Typing reperforator (front view).

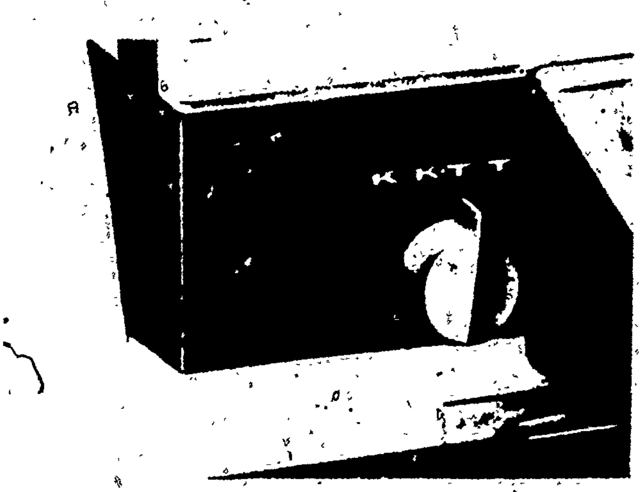
The unit includes a start-stop switch in which are incorporated tight-tape, shut-off, and free-wheeling tape feed features. A second switch shuts off the transmitter distributor automatically when tape runs out. Electrical requirements are supplied by way of the terminal blocks in the cabinet through a connector on the transmitter distributor base.

OPERATING THE AN/UGC-49

Power to the AN/UGC-49 is applied by a switch located on the front of the cabinet, slightly below and to the right of the keyboard. Turning the switch to its upper position, "ON." fully conditions the teletypewriter for on-line service in one of the three modes of operation determined by the selector switch at the left of the keyboard. If the auxiliary typing reperforator is not required, the auxiliary power switch can be turned to the "OFF" position.

Keyboard Mode of Operation

To transmit a message directly to the line as it is typed, rotate the selector switch to the K position. The usual procedure in transmitting is to depress the SEND key to unlock the local keyboard. Transmit five spaces, two carriage returns and a line feed (in that order) to align the sending machine, and start typing the message. The typing unit monitors the transmission, providing a printed copy of the message.



76.34

Figure 10-9.—Selector switch.

In the keyboard mode of operation, the typing perforator is mechanically isolated from the keyboard, and the character counter mechanism does not function. The transmitter distributor circuits also are inoperable.

Keyboard-Tape Mode of Operation

Keyboard operation in the keyboard-tape (K-T) mode is the same as when in the keyboard mode, except that typed, perforated tape is simultaneously prepared through electrical connection of the keyboard typing reperforator selector coils to the keyboard signal generator. The character counter is not operative in the (K-T) mode, but the operator can use the monitored page printed copy as a position indicator under those circumstances. The transmitter distributor can be operated.

Tape Mode of Operation

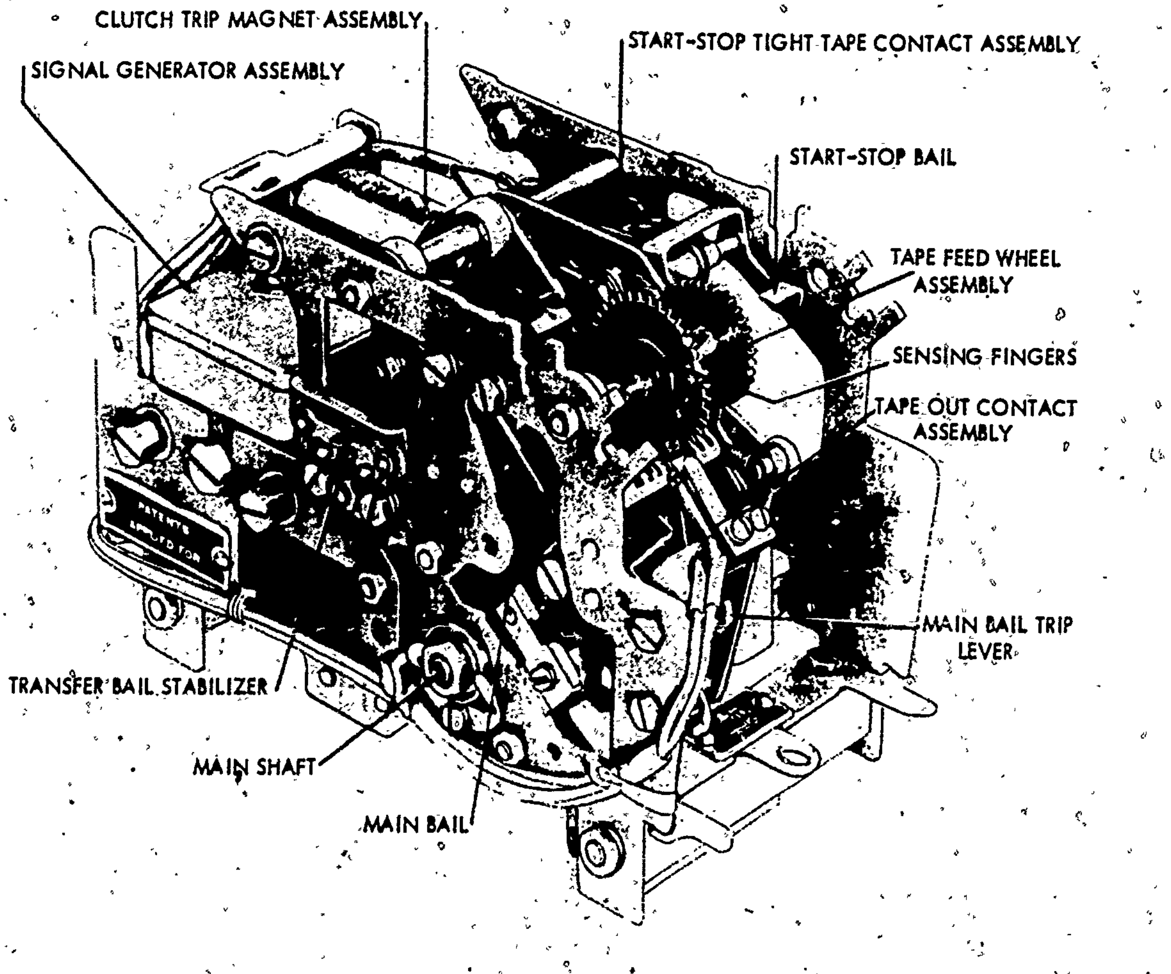
When the selector switch is in the T position, the keyboard and perforator are isolated from the other units. This mode of operation permits the operator to prepare tape for transmission while transmitting messages via the transmitter distributor, or receiving messages on the printer. The printed character occurs six units after the point at which the five-level code for the character is punched into the tape by the perforator. Since tape preparation is by direct mechanical linkage, typing may be at speeds up to 106 WPM; but a uniform rhythm is required to minimize operator induced error. No page copy is typed in this position, so the character counter automatically illuminates the end-of-line indicator lamp to avoid too many characters for the length of the line. As pointed out previously, the counter registers each spacing character. Non-printing functions, such as FIGS, LTRS, LF, and CAR RET, are not registered.

Using the Transmitter Distributor

The transmitter distributor (commonly called the TD) is operable only in the K-T and T modes of operation, and then only when the SEND key is depressed. In the following discussion of the TD, assume that the selector switch is in either the K-T or T position and that the SEND KEY IS DEPRESSED.

To place a tape in the TD, move the start-stop lever to the center (OFF) position. Release the tape lid by pressing the tape lid release button. Place the tape in the tape guide in such a manner that its feed holes engage the feed wheel with the portion of the tape having two perforations toward the rear of the TD. Insert printed tape so that the printed chad side is up. If nontyped chadless tape is used, position the tape so that the open side of the hinged chads is to the top. With fully perforated (chad) nontyped tape, you must be careful to feed the tape from the beginning. Reversing the tape results in a garbled transmission. While holding the tape firmly in place on the feed wheel, press down on the tape retaining lid until its latch is caught. Move the start-stop lever to the left (FREEWHEELING) position and manually adjust the tape so that the first character to be transmitted is located over the sensing pins. Figure 10-11 shows the path of the tape through the TD.

Another feature of the TD is the end-of-tape switch. The switch is controlled by a pin protruding through the tape guide plate. As



50.104

Figure 10-10.—Transmitter distributor (cover plate, top plate and tape guide plate removed).

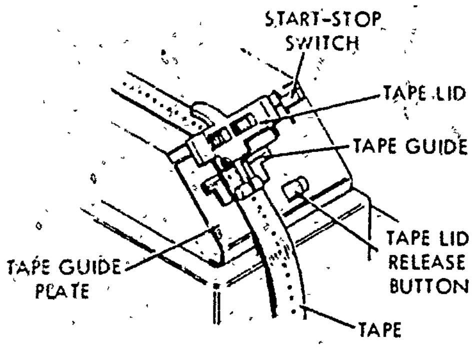
long as this is depressed by tape feeding through the guide, the TD is operable. When the end of the tape passes over the pin, the pin rises and the TD stops transmission automatically. If the tape is torn on the bottom edge, the tape out pin also raises and stops the transmission. For this reason tapes should be handled carefully.

ADDITIONAL MODEL 28 UNITS

The design and function of the individual units in the Model 28 line of teletypewriters remain basically the same but the AN nomenclature assigned the units when they are employed separately usually is changed.

KEYBOARD SEND-RECEIVE (KSR) TELETYPEWRITER SET

The KSR teletypewriter set will receive messages electrically from the telegraph channel and print them on page-size copy paper. It will electrically transmit on the channel messages which are originated by keyboard operation and monitor the message on page-size copy paper. The KSR may be contained in a cabinet for rack mounting as illustrated in figure 10-12 and is nomenclatured AN/UGC-51.



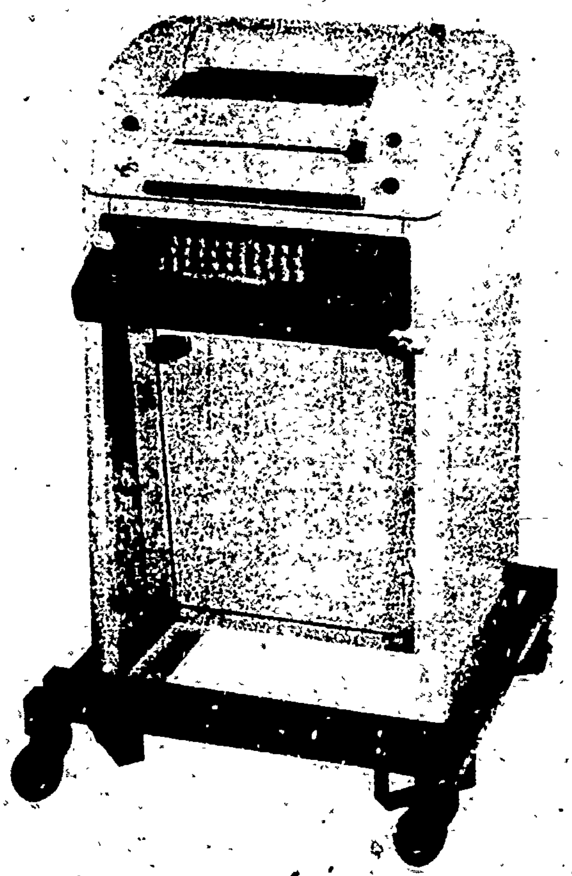
1.210
Figure 10-11.—Path of tape in transmitter distributor.

When the KSR is contained in a floor type console (figure 10-13), it is designated TT 471/UG. A dolly is supplied in which the KSR console can be placed for mobility where needed. Instead of a dolly, a sub-base may be added to the console which will increase the height of the cabinet for more convenient "stand-up operation."

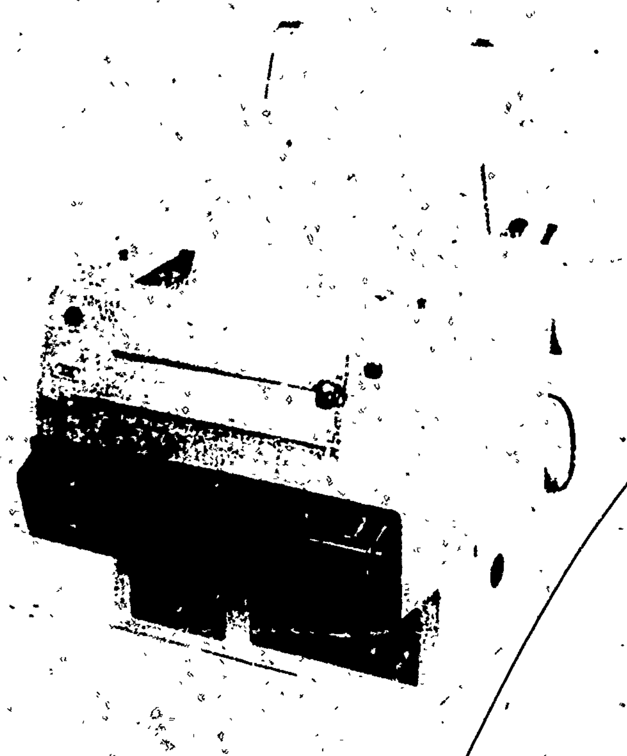
RECEIVE-ONLY (RO) TELETYPEWRITER SET AN/UGC-50

The AN/UGC-50 (figure 10-14) is housed in a cabinet for rack mounting. It is similar to the KSR teletypewriter set, except that parts required for transmitting messages are not

31.139
Figure 10-12.—Key board send-receive (KSR) teletypewriter set AN/UGC-51.



1.217.48
Figure 10-13.—Teletypewriter TT 471/UG.



31.140
Figure 10-14.—Receive only (RO) teletypewriter set AN/UGC-50.

provided. Typewritten page messages, therefore, can only be received. In contrast to the number of functions that can be performed by a sending and receiving teletypewriter, only two off line functions can be performed by the AN/UGC-50. These non-typing functions (Carriage Return and Line Feed) are provided so that they can be operated locally when required.

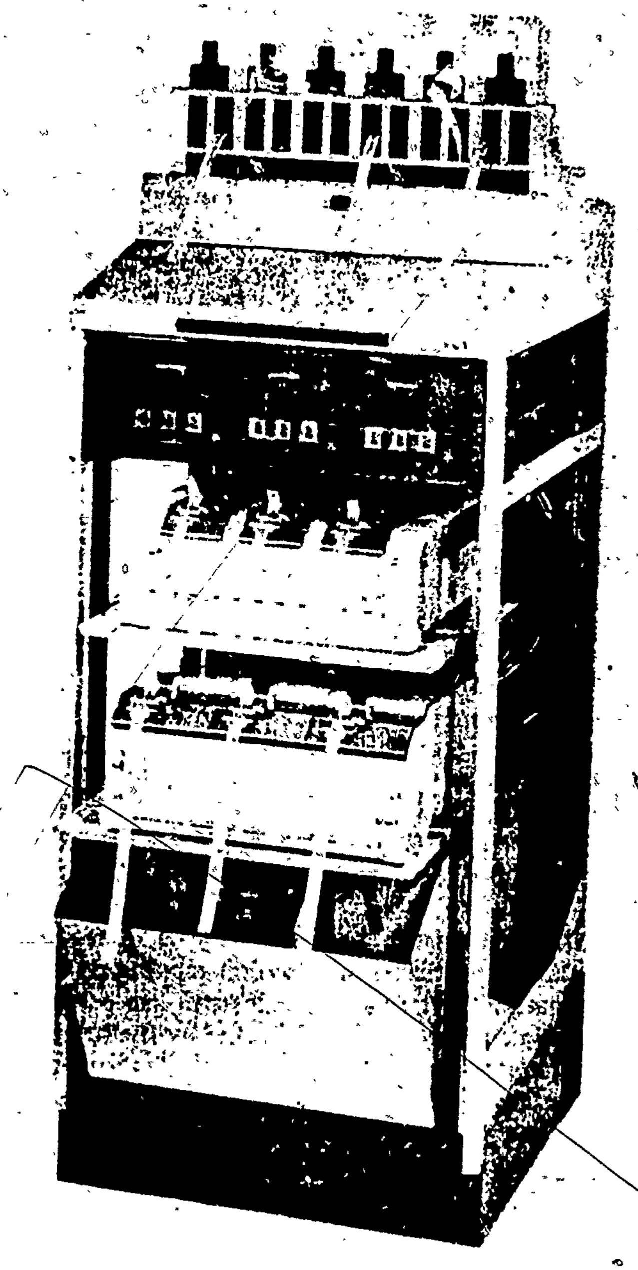
AN/FGC-59 TELETYPEWRITER EQUIPMENTS

The AN/FGC-59 Teletypewriter Set is an example of the type of equipment used in semiautomatic tape relay centers. The AN/FGC-59 consists of three groups: the TT308 Receiving Group, the TT309 Monitor Group, and the TT310 Transmitter Group.

In figure 10-15 are receiving banks or console packages, which house several typing reperforators for use on incoming lines in

1.369
Figure 10-15.—TT308 of AN/FGC-59; typing reperforator receiving group.

torn-tape relay centers. The operator logs each incoming message, tears it off at the end of the message, and determines the proper outgoing circuit from the routing indicators on the tape. He then hand-carries each tape to the appropriate sending bank of automatic transmitter distributors (figure 10-16) and inserts it in the appropriate circuit tape grid



1.367
Figure 10-16.—TT310 of AN/FGC-59; transmitter group.

(visible at tops of sending banks). The tape grid—sometimes called a washboard because of a certain similarity of appearance—is simply a place where tapes can remain during the period they are awaiting retransmission. They are stowed from top down in order of precedence. Other operators in attendance at the sending bank remove waiting tapes from the grid in order of precedence and insert them in the TDs. A numbering TD applies a sequential channel number to each message, thus keeping a record of traffic relayed over each channel.

If duplicate copies of relayed traffic are required for the files, monitoring equipment (figure 10-17) is used. This is a group of typing reperforators that produce duplicates of tapes undergoing transmission on the sending bank, and wind the monitor tapes on reels suitable for stowage. The monitoring equipment also duplicates the channel number for each message, providing a means of reference if the message should be needed in the future.

AUTODIN/DSSCS INTEGRATION

As explained in Chapter 5, AUTODIN is a operational on-going system. Before presenting the DSSCS terminal configurations and the various modes utilized by DSSCS subscribers, more discussion on how AUTODIN works will give you a clearer picture of the AUTODIN/DSSCS integration.

As a digital communications telegraphic store-and-forward network, AUTODIN consists essentially of switching centers interconnected by trunk lines with local lines radiating from each center to subscriber terminals in the area served by each center. Messages originating at any of the subscriber terminals are forwarded through one or more switching centers to their addressed subscriber destination. The message switching center's function is to accept messages from any of the subscribers, determine their classification and precedence, and relay the messages to the addressed subscribers. Figure 10-18 shows the switching center and its related terminals.

MODIFICATIONS

Pages 194- 292 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.

CHAPTER 16

MAINTENANCE AND SAFETY

As a communicator you are not expected to do the type of maintenance performed by an Electronics Technician. You must, however, be able to record inventory data, complete work logs and reports, and assist in obtaining part and stock numbers from applicable technical publications. Moreover, you are required to perform routine maintenance on teletypewriters and typewriters.

Basically there are two types of maintenance. (1) Preventive Maintenance includes regularly scheduled actions taken to reduce or eliminate failures and to prolong the useful life of equipment. (2) Corrective Maintenance includes the repair of failures which have occurred because of aging components, through accident or other causes.

Maintenance is further divided into levels. The department of defense, including the Navy specifies three separate levels of maintenance.

a. Organizational level.—Organizational level maintenance is performed by the using activity. In some cases (i.e., small craft) the organizational level maintenance is performed through outside assistance and yet retains the organizational level category.

b. Intermediate level.—Intermediate level maintenance is that maintenance which is performed by tenders and shore repair facilities. A user may also be designated to perform its own intermediate level maintenance. An example of this would be a tender using its own repair department to effect ship repairs.

c. Depot level.—Depot level maintenance is performed by Naval Ship Yards or civilian repair activities. The specific difference between Intermediate and Depot level maintenance is that at Depot level you are referring to facilities who have the capability to undertake major overhaul work beyond the ability of a tender or repair facility.

Although the line is not always clearly drawn between the three levels of maintenance, and there may be certain exceptions, it is intended that organizational level maintenance be performed by personnel assigned to the organization and other maintenance work be accomplished by employing the services of specialists.

Your hand in maintenance will be limited to operational use, manipulation, and operational maintenance of electronic equipment associated with the technical specialties of your rate. These portions of preventive maintenance will be of a nature as not to require equipment alignment after maintenance has been accomplished.

All other maintenance will be handled by the specialists having the adequate facilities to undertake the specific job.

PREVENTIVE MAINTENANCE

Preventive maintenance is defined as the care and servicing by personnel for the purpose of maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection, and correction of failures, either before they occur or before they develop into major defects. This form of maintenance consists principally of cleaning, lubricating, and periodic testing aimed at discovering conditions which, if not corrected, may lead to malfunctions.

To realize optimum results from the regular functional tests, a careful record of the performance data on each equipment must be kept. Comparison of data taken on a particular equipment at different times may reveal slow, progressive drafts that may be too small to show up significantly in any one test. While the week-to-week changes may be slight, they should be followed carefully so that necessary replacements or repairs may be effected before the margin of performance limits is reached. Any marked variations should be regarded as abnormal and should be investigated immediately.

Such an approach to preventive maintenance leads to maximum operational readiness of the equipment aboard your ship. Your contribution to the preventive maintenance program will be made through the 3-M System.

THE 3-M SYSTEM

The growing complexity of electronic equipment, increased tempo of fleet operations and the constant decline of available resources made it impossible for previous PM systems to control and accomplish required maintenance. The Maintenance, Material and Management (3-M) system was implemented in the Navy in an attempt to solve these problems and to provide a more adequate system of collecting information required to support equipment improvement projects. The 3-M system was designed to function as an integrated system which would improve the management of maintenance and provide for the collection and dissemination of maintenance related information. It is emphasized that 3-M is not a passive system and will not operate by itself. The key to success is active and aggressive supervision at all levels in order to achieve a high degree of combat operational readiness.

The 3-M system is composed of two subsystems, the PMS (Planned Maintenance Subsystem) and the MDCS (Maintenance Data Collection Sub-system); and will contribute significantly toward achieving improved readiness with reduced expenditure of resources.

The Planned Maintenance Sub-system (PMS) pertains to the planning, scheduling and management of resources (men, material and time) to perform those actions which contribute to the uninterrupted functioning of equipment within its design characteristics. It defines uniform maintenance standards and prescribes simplified procedures and management techniques for the accomplishment of maintenance. The Maintenance Requirement Card (MRC) schedules, describes and lists tools, materials and test equipment necessary to perform the minimum maintenance required on a specific piece of equipment. The Maintenance Data Collection Sub-system (MDCS) provides a means for recording the expenditures of resources (men, material and time) associated with certain categories of maintenance action. MDCS success is dependent on the accuracy, adequacy and timeliness of the information reported into the system by the operator. In addition, the system provides data concerning the initial discovery of a malfunction, how the equipment malfunctioned, how many man-hours were expended, which equipment was involved, what repair parts and material were used, what delays were incurred, the technical specialty or work center that performed the maintenance. MDCS reporting on OPNAV Form 4790/2K incorporates the use of coded data elements, for data standardization and facilitating automatic data processing. These codes and other amplifying information are contained in the 3-M Documentor's Handbook OPNAV 43P5.

CLEANING ELECTRONIC EQUIPMENT

All electronic equipment should be cleaned, not just for appearance, but to assure good performance. Before starting any kind of cleaning be sure to secure power to equipment and discharge all capacitors to ground. The safest and best method of cleaning inside transmitters and receivers is to use a vacuum cleaner with a nonmetallic hose. A small typewriter brush is handy for getting dust out of congested areas where the vacuum cleaner will not reach. A hand bellows can be used for blowing out dust particles, but is not as satisfactory as the vacuum cleaner because of the likelihood of blowing dust into inaccessible spaces where it is harder to remove.

During routine transmitter cleaning periods, the contacts of rotating inductors should be checked, as well as the surface of these parts. Poor operation of contacts is disclosed sometimes by erratic "jumping" of the plate current meters as the circuit is tuned through resonance. Both the contacts and the surface of the inductors must be clean and smooth. A tiny amount of petroleum grease may be applied if necessary to prevent scoring the copper surface.

Steel wool or emery in any form must not be used on electronic equipment. Sandpaper and files may be used only on competent guidance, or not at all.

MAINTAINING AIR FILTERS

The cleaning of air filters is exceedingly important for the proper operation of electronic equipment. For some reason (perhaps their importance is not fully recognized), filters often are neglected or disregarded until excessive heating causes a breakdown of the equipment.

Forced air cooling is used in most modern transmitters and receivers. This type of cooling system moves a large volume of air over the hot portions of the equipment. The air is filtered to keep dust and other foreign particles out of the equipment. If the filters are efficient, they remove most of this foreign material from the air that passes through them. Dust and dirt tend to clog the filter and prevent the air from moving through. The result is that the equipment becomes overheated and may be ruined.

An analysis of the failures of parts in electronic equipment indicates that the majority of failures can be traced to excessive heat caused by dirty air filters. Obviously, then the maintenance man can reduce his workload substantially by ensuring that air filters are serviced properly.

TELETYPEWRITER PREVENTIVE MAINTENANCE

Use of the equipment technical manual is required for proper preventive maintenance on teletypewriters. The scope of the information contained in the technical manual is indicated in ensuing topics.

Preventive maintenance is applied for the purpose of detecting and correcting troubles before they develop to the point of interference with satisfactory operation of the teletypewriter equipment. Proper lubrication—but not overlubrication—is an important preventive maintenance measure. When work on equipment is necessary, use care to avoid introducing trouble.

A thorough visual inspection of equipment during periodic checks may uncover conditions that could possibly cause trouble later. Appearance of oxidized (red) metal dust adjacent to any bearing surface indicates insufficient lubrication. Adjustable clearances of working parts should be observed also.

A visual examination should be accompanied by a manual test. Connections at terminal boards should be checked for tightness. Vibrations sometimes loosen these connections just enough to give intermittent troubles that are difficult to locate. Nuts and screws that lock adjustable features should be observed carefully for looseness, and should be tightened if necessary. While cleaning the units, care should be exercised to avoid damage or distortion to delicate springs that might weaken their tension. Electrical contact points should be kept free and clear of dirt, oil, corrosion, or pitting. Check that operating clearance is maintained when a contact is cleaned.

LUBRICATION

More than 60 pictures and diagrams in the equipment technical manual illustrate lubrication points of the teletypewriter. In addition to points to be lubricated, technical manual pictures show the type and quantity of lubrication to use. A new teletypewriter should be lubricated before it is placed in service for the first time. After a few weeks in service, relubricate to make certain that all points are lubricated adequately.

Lubrication Schedule

A teletypewriter must be lubricated more frequently as operating speed increases. Thus, a machine geared for operating speed of 100 wpm requires lubrication more often than one operating at 60 wpm. Here is the recommended lubrication schedule:

Operating speed (words per minute)	Lubricating interval (whichever occurs first)
60	3000 hours or 1 year
75	2400 hours or 9 months
100	1500 hours or 6 months

Regarding the lubrication interval, an important point to remember are the words "whichever occurs first." To illustrate a machine in continuous use at 100 wpm will accumulate 1500 operating hours in only 2 months. For machines used occasionally or intermittently, some kind of log is needed to keep track of total operating hours.

OPERATOR'S EMERGENCY MAINTENANCE

Even though some teletype operators may have received no maintenance training, they can be authorized to perform emergency maintenance to the extent of replacing fuses and lamps.

Fuses

Power circuits of the teletypewriter are protected by two cartridge-type fuses. The main fuse for the basic equipment is on the right end of the power distribution panel under the cabinet dome behind the keyboard. A separate fuse for power circuits of the typing reperforator is located on the terminal board bracket to the left of the printing unit on the typing reperforator base. Fuse location and symptoms of failure are summarized in the accompanying tables.

Lamp Replacement

Four bayonet-type lamps for the teletypewriter are located beneath the cabinet dome. Maintenance and copy illumination lamps are 6-volt lamps in a circuit supplied by a transformer at the rear of the cabinet. These lamps are installed on either side of the right front dome door and above the typing perforator (three lamps) and the margin indicator or end-of-line lamp (one lamp) at the extreme right of the dome. All lamps are accessible when the dome is raised. The accompanying lamp replacement data table gives the location and electrical characteristics of lamps.

Symptoms of Fuse Failure

Maintenance lamps	Keyboard motor	Reperforator motor	Blown fuse	Value (amps)	Comments
Out	Off	Operating	F800	6.25	In power distribution panel.
On	Operating	Off	F2300	4	On typing reperforator base.

WARNING: Never replace a fuse with one of higher rating except in emergency or battle condition when continued operation of equipment is more important than possible damage.

If a fuse burns out immediately after replacement, do not replace a second fuse until the cause is corrected.

Fuse Location

Reference designation symbol	Location	Protects	Amps	Volts
F800	In power distribution panel.	Main a-c supply	6.25	250
F2300	On typing reperforator base	Reperforator a-c supply.	4	250

Lamp Replacement Data

Reference designation symbol	Function	Location	Volts	Watts	Amps	Base
I4250	Maintenance and copy illumination	Left of right front cabinet dome door.	6-8	6	1.14	Bayonet, double contact
I4251	. . . . do	Right of right front cabinet dome door.	. do .	. do .	. do .	do.
I4252	. . . . do	Left front door of cabinet dome.	. do.	. do.	. do.	do.
I4350	. . . . do	Right front end of cabinet dome.	. do.	. do .	. do .	do.

TYPEWRITER PREVENTIVE MAINTENANCE

Your typewriter may be heavy and rugged looking, but it is really a delicate instrument. Treat it like one and give it daily care. A machine in first-class condition is easier and quicker to operate and turns out better-looking work.

Observe the following routine procedures:

a. Be sure your typewriter is properly placed on the desk, or secured to the well type of desk, so that it will not fall.

b. In lifting a typewriter, grip it by its case, NEVER by its carriage.

Keep your typewriter covered when not in use. Always cover it or close it into the desk at the end of the day.

c. Keep it clean by wiping the outside with a soft dry cloth and dusting the inside with a long-handled brush.

d. Clean the type daily with a stiff brush, and it seldom will be necessary to use chemicals.

e. Take care in erasing to move the carriage to one side so that erasure crumbs will not fall into the mechanism.

At regular intervals you should give the typewriter a more thorough cleaning. Frequency of these cleanings will depend on the amount of use the typewriter receives and the amount of dust in your office atmosphere. In general, it is recommended that the following procedures be carried out weekly:

f. Clean the carriage rails and marginal stop bar, using a cloth slightly moistened with oil. Move the carriage back and forth in the process.

g. Clean the platen or cylinder. Remove, if possible, and wipe with a cloth moistened with a very small amount of denatured alcohol or cleaning fluid. Do not wipe off; allow fluid to evaporate.

h. Clean type, using a short-bristled type brush. Tap lightly with the points of the bristles to loosen the dirt; then brush up lightly.

i. Brush type bar segments and dust the interior of the machine. Use a long-handled brush, brushing toward the front of the machine. By elevating a few type bars at a time, you can reach into the mechanism. DO NOT FORCE THE BARS. Use a soft cloth alternately with brush.

j. Wipe the sides and back of the machine. Always clean the typewriter before cutting a Mimeograph stencil. If the typewriter ribbon lever is set for stencils (usually a white dot on the machine), both the type and the ribbon will be cleaner than otherwise.

If operating instructions for your typewriter are available, they will help you identify parts and give you additional information about care.

If further oiling or repair work is needed, the machine should be turned over to a typewriter mechanic.

MAINTAINING HEADPHONES AND MICROPHONES

The best way to maintain headphones and microphones is to ensure that they are handled properly. Proper handling includes hanging up headphones by their straps, not by the cord; removing a plug from a jack by grasping the plug, not the cord; avoiding kinks or other strains in the cord; avoiding rough handling of microphones and headphones; and avoiding exposure to moisture. Carbon microphones may be dried out with heat lamps; periodic heating may prevent accumulation of moisture.

NOTE: Do not blow into a microphone. This practice is resorted to much too often when testing a microphone. This practice should be avoided to ensure longer life for the microphone.

Repair of headphone and microphones consists largely of replacing or repairing plugs, jacks, and cords. Always try to repair defective equipment first. If you are unable to repair defective equipment, tag it as defective and then use ready spares. When time permits, see that defective phones are repaired.

SAFETY AND ACCIDENT PREVENTION

When working with radio, or with any electronic equipment, one rule that must be stressed strongly is: SAFETY FIRST. Dangerous voltages energize much of the equipment with which you work. Power supply voltages range up to 40,000 volts, and radiofrequency voltages are even higher.

Special precautions are also necessary because electrical fields, which exist in the vicinity of antennas and antenna leads, may introduce fire and explosion hazards, especially where flammable vapors are present. Additional precautions are needed to warn personnel working aloft to prevent injuries from falls and stack gases.

Safety precautions outlined in this chapter are not intended to supersede information given in instruction books or in other applicable instructions for installation of electronic equipment. Additional safety information is contained in *NAVSHIPS 0967-000-0100 (Section 3) Electronics Installation and Maintenance Book (EIMB).*

Most accidents are preventable. However, through ignorance or misunderstanding, there is a common belief that they are the inevitable result of unchangeable circumstances or fate.

This belief is untrue because it fails to consider the basic law of "cause and effect" to which accidents are subject. In other words, accidents do not occur without a cause; most accidents are the direct result of some deviation from prescribed safe operating procedures.

A preventable accident may be traced to causes as basic as the heredity and early environment of the individual. These causes may be revealed in the form of personal characteristics which permit the individual to perform an unsafe act or permit a hazardous condition to exist: when an accident results, the "cause and effect" sequence is completed.

One purpose of safety rules is to remind the individual of the dangers inherent in his work. Training in the observance of safety precautions can be instrumental in avoiding preventable accidents and in maintaining a work environment which is conducive to accident-free operation. Operating procedures and work methods adopted with hazard prevention as a specific criteria do not expose personnel unnecessarily to injury or occupational health hazards. Accidents which are about to happen can be prevented if the "cause" is detected and appropriate remedial action is taken.

RESPONSIBILITY

Responsibility for the safety of personnel is vested in the commanding officer, so he necessarily delegates his authority to the executive officer, safety officer and other subordinates to ensure that all prescribed safety precautions are understood and strictly enforced. The commanding officer attempts to insure that the personnel under his jurisdiction are instructed and drilled in applicable safety precautions; he requires that adequate warning signs be posted in dangerous areas; and he establishes a force to see that such precautions are being observed. It is the responsibility of supervisory personnel to see that precautions are strictly adhered to in their own work areas, since they are responsible to the commanding officer. Furthermore, each individual concerned should strictly observe all safety precautions applicable to his work or duty. Thus, it is obvious that accident prevention is the business of every individual–not just a delegated few.

As an individual, you have a responsibility to yourself and to your shipmates to do your part in preventing accidents. You must always be alert to detect and report unsafe work practices and unsafe conditions so that they may be corrected before they cause accidents.

Each individual must:

a. Report any condition, equipment, or material which he considers to be unsafe.

b. Warn others whom he believes to be endangered by known hazards or by their failure to observe safety precautions.

c. Wear protective clothing or use protective equipment of the type approved for the safe performance of his work or duty.

d. Report to his supervisor any injury or evidence of impaired health occurring in the course of his work or duty.

e. Exercise reasonable caution as appropriate to the situation in the event of an emergency or other unforeseen hazardous condition.

Post-accident investigations have revealed that the majority of accidents result from unsafe practices or acts, most of which are known beforehand to be unsafe and in violation of safety practices, rules, regulations, or directives. Other human factors found to be the cause of accidents include fatigue, monotony, preoccupation at a critical moment (inattention), mental and/or physical problems, improper supervision, lack of motivation and such. Because of various factors, individuals do not always act (or react) as they were trained, instructed, or directed to act. Results of this condition, most probably, will be an accident because of "human error."

Human error includes all the actions or inactions of an individual having a bearing on an accident or on an unsafe practice that can lead to an accident. To reduce human error as a predominant cause of accidents, it is the responsibility of every individual to acquaint himself with the environmental hazards surrounding him. He should condition himself to be alert, both mentally and physically, so that he can protect himself and others by not foolishly or unnecessarily exposing himself to hazards.

Accidents do not happen without a cause; when each individual can be made aware of the hazards involved with his work, fewer accidents will result. Accident prevention must be a continuous effort in which each individual gains experience and knowledge through day-to-day association with co-workers who are aware of the hazards of their environment.

Remember! As an individual, you have a responsibility to yourself and to your shipmates. You must always be alert to detect and report hazardous work practices and conditions so that they can be corrected before they cause accidents. In all cases, when working on or near electrical or electronic equipment, learn to respect your equipment's potential for accidental damage and injury.

ELECTRIC SHOCK

Fundamentally, current rather than voltage is the criterion of shock intensity. The passage of even a very small current through a vital part of the human body will cause death. The voltage necessary to produce the fatal current is dependent upon the resistance of the body, contact conditions, the path through the body, etc. The probable effects of shock are shown in the accompanying table.

AC, 60 Hz (mA)	DC (mA)	Effects
0-1	0-4	Perception
1-4	4-15	Surprise
4-21	15-80	Reflex action
21-40	80-160	Muscular inhibition
40-100	160-300	Respiratory block
Over 100	Over 300	Usually fatal

It is imperative to recognize that the resistance of the human body cannot be relied upon to prevent a fatal shock from 115 volts or even lower voltages—fatalities from as low as 30 volts have been recorded. Tests have shown that body resistance under unfavorable conditions may be as low as 300 ohms and possibly as low as 100 ohms from temple to temple if the skin is broken. Volt for volt, DC potentials are normally not as dangerous as AC as evidenced from the fact that reasonably safe "let-go currents" for 60 hertz alternating current is 9.0 milliamperes for men and 6.0 milliamperes for women while the corresponding values for direct current are 62.0 milliamperes for men and 41.0 milliamperes for women.

SYMPTOMS OF ELECTRIC SHOCK

In the event of severe electric shock, the victim is usually very white or blue. His pulse is extremely weak or entirely absent, unconsciousness is complete, and burns are usually present. The victim's body may become rigid or stiff in a few minutes. This condition can be caused by muscular reaction to shock, and it shall not, necessarily, be considered as rigor mortis. Therefore, artificial respiration shall be administered immediately, regardless of body stiffness, as recovery from such a state has been reported. Consequently, the appearance of rigor mortis should not be accepted as a positive sign of death.

RESCUE OF VICTIMS

The rescue of electric shock victims is dependent upon prompt administration of first aid.

WARNING

DO NOT ATTEMPT TO ADMINISTER FIRST AID OR COME IN PHYSICAL CONTACT WITH AN ELECTRIC SHOCK VICTIM BEFORE THE POWER IS SHUT OFF. OR, IF THE POWER CANNOT BE SHUT OFF IMMEDIATELY, BEFORE THE VICTIM HAS BEEN REMOVED FROM THE LIVE CONDUCTOR.

When attempting to administer first aid to an electric shock victim, proceed as follows:

a. Shut off the power. If the power cannot be shut off, use a well insulated axe and cut the power cable, if such cable is involved.

b. If the power cannot be deactivated, per Step a, remove the victim immediately, observing the following precautions.

Protect yourself with dry insulating material.
Use a dry board, belt, dry clothing, or other available non-conductive material to free the victim (by pulling, pushing, or rolling) from the power-carrying object. DO NOT TOUCH the victim.

c. Immediately after removal of the victim from the power-carrying object, administer artificial respiration, as described later in this chapter.

GENERAL SAFETY PRECAUTIONS AND POLICIES

When working on electronic circuits, operational and maintenance personnel must bear in mind that accidents are always ready to strike those who are careless. Therefore, some essential precautions must be taken before starting any work on electronic circuits. For example, a technician must always remember that prior to working on an electronic circuit, he must deactivate all power sources to that particular circuit, or use the proper and authorized safety device and procedures when he thinks that it is not practical to secure power to the circuit. Such a basic, but vital, safety precaution, as well as other such vital safety precautions pertaining to the proper handling of electronic equipment circuits, are compiled in this subsection. These safety precautions, together with those contained in equipment technical manuals and Maintenance Requirements Cards, comprise a nucleus for the promulgation of detailed instructions for accident-free installation, maintenance, and operation of electronic equipment and facilities ashore and afloat.

INTENTIONAL SHOCKS ARE FORBIDDEN

Intentionally taking a shock at any voltage is always dangerous and is STRICTLY FORBIDDEN. Whenever it becomes necessary to check a circuit to see if it is alive, a test lamp, a voltmeter, or some other appropriate indicating device shall be used. The indicating device employed shall be suitable for obtaining the desired check without jeopardizing personnel, and if necessary, it should be used in conjunction with authorized safety devices. Never implicitly trust insulating material: treat all wiring as though it were bare of insulation. Insulating material has failed before and may fail again—be on the alert!

RUBBER FLOOR MATTING

To eliminate likely causes of accidents and to afford maximum protection to personnel from the hazards associated with electric shock, only the approved rubber floor matting for electric and electronic spaces shall be used. In many instances, after accidents had occurred, investigations showed that the operating locations and areas around electric and electronic equipment were covered with only general-purpose black rubber floor matting. This type of matting should not be used because its electrical characteristics do not provide adequate insulating properties to protect personnel from the possibility of electric shock; also, the material used in the manufacture of this matting is not fire-retardant.

The careful design and fabrication of the floor matting material minimizes the possibility of accidents. However, to ensure that the safety factors which were incorporated in the manufacture of the material are effective, and that the matting is completely safe for use, operation and maintenance personnel must make certain that all foreign substances that could possibly contaminate or impair the dielectric properties of the matting material are promptly removed from its surface areas. For this reason, scheduled periodic visual inspection and cleaning practice procedures should be established. During visual inspections, personnel should make certain that the dielectric properties of the matting have not been impaired or destroyed by oil impregnation, piercing by metal chips, cracking, or other causes. If it is apparent that a section or the entire length of matting is defective for any reason, it should be removed, and replaced immediately by new matting material.

NEVER WORK ALONE

Never work on electronic equipment by yourself; have another person (safety observer) qualified in first aid for electrical shock present at all times. The safety observer should also know which circuits and switches control the equipment, and should be given instructions to pull the switch immediately if anything unforeseen happens.

AUTHORIZED PERSONNEL ONLY

Because of the danger of fire, damage to material, and injury to personnel, all repair and maintenance work on electronic equipment shall be done only by duly authorized and qualified persons.

ENERGIZED ELECTRONIC EQUIPMENT

Personnel should not reach within or enter energized electronic equipment enclosures for the purpose of servicing or adjusting except when such servicing or adjusting is prescribed by official applicable technical manuals (instruction books) and then only with the immediate assistance of another person capable of rendering adequate aid in the event of an emergency. Personnel will be warned to exercise extreme caution when reaching into the enclosures of equipment having internal exposed high voltage points. The metal shielding shell of some capacitors, klystrons, cathode-ray tubes, and other components are at high potentials above ground.

In addition, be careful with loose metal parts, tools, and liquids. No person shall take loose metal parts, tools or liquids near or above a starter box or above open electric or electronic equipment. No person shall be permitted above open electric or electronics apparatus with loose metal objects attached to clothing. Stowage or insertion of tools or other foreign articles in or near switchgear, control appliances, panels, etc., is strictly forbidden.

Post-accident investigations usually have shown that accidents resulting from energized electronic equipment could have been prevented by adherence to established safety precautions and procedures. Among the established safety precautions are the following.

a. Carefully study the schematic and wiring diagrams of the entire circuit, noting which circuits must be de-energized in addition to the main power supply.

b. Obtain permission from your supervisor and the maintenance supervisor in charge if it becomes necessary to work on energized equipment.

c. If approval is given to work on equipment with the power applied, never work alone; always have an assistant who can provide or get help in an emergency.

d. When making measurements or tests, always keep one hand behind your back or in your pocket.

e. Do not reach into the equipment enclosure unless absolutely necessary. When this must be done, make sure that approved insulating material and procedures are used; stand on a rubber matting, wear rubber gloves, and the like.

REPAIR OF ENERGIZED CIRCUITS

Corrective maintenance, or any other type of repair work, shall not be performed on energized circuits except under emergency conditions which are considered essential by the commanding officer. In such an emergency, the corrective maintenance of energized circuits shall be accomplished under the supervision of an experienced electronic technician or officer, and every care shall be taken to observe the following safety precautions.

a. Provide ample light for illumination.

b. Remove loose clothing and metallic objects such as bracelets, rings, etc., from the worker.

c. Insulate the worker from ground with sheets of phenolic insulating material or a suitable rubber mat, depending upon conditions involved.

d. Cover metal tools with insulating rubber tape.

e. Use only one hand, if practical, in accomplishing the work.

f. Rubber gloves will be worn on both hands if at all possible. If not possible, a rubber glove shall be worn, at least, on the hand not used for handling tools.

g. Have men stationed by circuit breakers or switches so that the circuit or switchboard can be deenergized immediately in case of emergency.

h. A man qualified in first aid for electric shock shall be present during the entire period of repairs.

i. If equipment must be energized after removal from its normal rack or mounting, make certain that all parts, normally at ground potential, such as chassis-to-frame ground terminals, are securely grounded.

OPERATING CIRCUIT BREAKERS

Except for operating handles, all parts of circuit breakers are normally conductive. While opening or closing circuit breakers:

a. Use only one hand.

b. Keep your hands clear of parts other than operating handles.

c. Touch only one breaker handle at a time.

d. In case where positive and negative breakers have two handles, close one breaker at a time.

e. Close the breaker first and then close the switches.

f. Trip circuit breakers before opening switches.

g. Never disable a circuit breaker.

h. Keep your face turned away while closing circuit breakers. Wearing of safety goggles is recommended while opening or closing non-enclosed types of circuit breakers and switches.

i. Never stand over a circuit breaker while power is on.

OPERATING POWER SWITCHES

As a general rule, use only one hand for switching. Keep the other hand clear. Only one switch should be touched at one time by one person. Before closing a switch, make sure that:

a. The circuit is ready and all parts are free.

b. Men near moving parts are notified that the circuit is to be energized. This is particularly important in cases where rotating antennas are energized.

c. Proper fuses are installed for protection of the circuit.

d. Circuit breakers are closed.

When opening and closing switches, ease the lever or knob to a position where safe and quick action can be made, and then make the final motion positive and rapid. For switches carrying high current, the break should be positive and rapid.

For switches enclosed in watertight cases, such as snap switches and multiple rotary switches, it is important to make sure that the switch has been operated to the position actually intended. Reports have been received indicating that switch handles were not moved far enough when transferring circuits from one station to another. Consequently, the switch contacts were left in an "in-between" position and the circuit was actually open, leading to possible casualty. The cause was traced to excessively tightened gland rings on the switch shafts which prevented the action of the switch detent mechanisms from being readily felt by the operators.

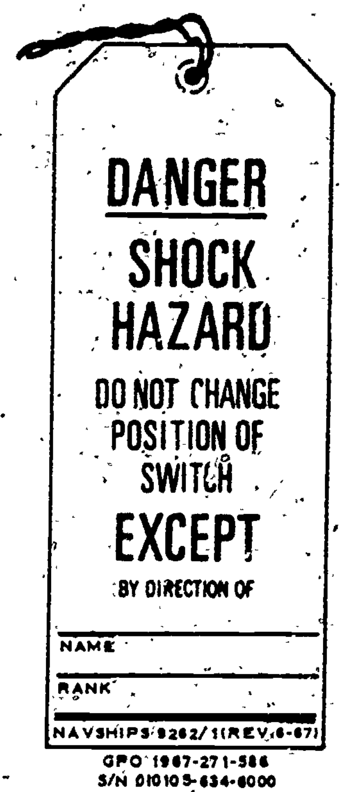
Maintenance personnel should check all water-tight rotary switches used as "safety" switches on rotating and transmitting devices to ensure that each is operated to its proper positions and that none are sticking in an "in-between" position.

TAGGING OF OPEN SWITCHES

Before performing corrective or routine maintenance on any electric or electronic equipment, the main supply switches or cutout switches in each circuit, from which power could possibly be fed, will be secured in the open or "safety" position and tagged when repairs of energized circuits are required. The tag shall read: "THIS CIRCUIT WAS ORDERED OPEN FOR REPAIRS AND SHALL NOT BE CLOSED EXCEPT BY DIRECT ORDER OF" (Name and rank of person making, or directly in charge of repairs), or "DANGER—SHOCK HAZARD—DO NOT CHANGE POSITION OF SWITCH EXCEPT BY DIRECTION OF" (name and rank of person making, or directly in charge, of repairs, or as specified by the operational/type commander). The latter of the two tags described above is shown in Figure 16-1.

When more than one repair party is engaged in the work, a tag for each party shall be placed on the supply switch. Each party shall remove only its own tag upon completion of the work.

Where switch-locking facilities are available, the switch should be locked in the open (SAFETY) position and the key retained by the person doing the work so that only he, or a person designated by him, can remove the lock and restore the circuit.



40.67(67B)C

Figure 16-1.—Warning tag for marking open position of switches.

USE OF STEELWOOL AND EMERY CLOTH

The use of steel wool or emery cloth for cleaning is harmful to the normal operation of electronic equipment. Also emery cloth or steel wool must never be used to clean contacts. Considering the harmful effects of using steel wool in electronic equipment the following statements show how steel wool is a menace:

a. Ventilation currents distribute them where they do the most harm and magnetic materials, often being present, will collect ferrous particles.

b. The use of steel wool on electronic equipment is not permitted, since residual particles of steel may cause a short circuit.

The above statements are clear and to the point. When cleaning electronic parts or equipment, DO NOT USE STEEL WOOL OR EMERY CLOTH.

PORTABLE ELECTRICAL TOOLS AND EQUIPMENT

Improperly wired electrical tools, portable electrical and electronic equipment, test equipment, etc. are extremely hazardous; especially when they are powered by the ship's 115-volt, 60-hertz, single-phase power. The safety precautions involving the use of portable electrical tools and equipment and the policies regarding certain wiring procedures are contained in the paragraphs that follow. These safety procedures and policies will be practiced by all personnel.

WARNING

NEVER USE ANY METAL-CASED PORTABLE EQUIPMENT, APPLIANCE, OR POWER TOOL, OR

ANY CABLE OR EXTENSION CORD UNLESS YOU ARE ABSOLUTELY SURE THAT IT IS EQUIPPED WITH A PROPERLY CONNECTED SAFETY GROUND CONDUCTOR.

The hazards associated with the use of portable power tools are electrical shock, bruises, cuts, particles in the eye, falls, explosions, and such. Safe practice in the use of these tools will reduce or eliminate such accidents. Listed below are some of the general safety precautions that will be observed when your work requires the use of portable power tools.

a. Ensure that all metal-cased portable power tools are grounded.

b. Do not use spliced cables unless an emergency warrants the risk involved.

c. Inspect the cord and plug for proper connection. Do not use any power tool that has a frayed cord or broken or damaged plug.

d. Make sure that the on/off switch is in the off position before inserting or removing the plug from the receptacle.

e. Always connect the cord of a portable power tool into the extension cord before the extension cord is inserted into a live receptacle.

f. Always unplug the extension cord from the receptacle before the cord of the portable power tool is unplugged from the extension cord.

g. See that all cables are positioned so that they will not constitute a tripping hazard.

h. Wear eye protection when working where particles may strike the eyes.

i. After completing the task requiring the use of a portable power tool, disconnect the power cord as described in Steps d and f and stow the tool in its assigned location.

HAZARDOUS EQUIPMENT AND MATERIALS

This section provides information pertaining to hazards and hazardous items of equipment that may cause injury and, in severe cases, death. It is the purpose of this section to supply operator and maintenance personnel with information pertaining to these hazards and to provide sufficient safety practices which, when faithfully enforced, will aid in the elimination of accidents.

CLEANING SOLVENTS

The technician who smokes while using a volatile cleaning solvent is inviting disaster. Unfortunately, many such disasters have occurred. For this reason, the Navy does not permit the use of gasoline, benzine, ether, or like solvents for cleaning purposes, since they present potential fire or explosion hazards. Only non-volatile solvents shall be used to clean electrical or electronic apparatus.

In addition to the potential hazard of accidental fire or explosion, most cleaning solvents can damage the human respiratory system, in case of prolonged inhalation. The following list of "DO NOT's" will serve as an effective reminder to technical personnel who must use cleaning solvents.

a. DO NOT work alone in a poorly ventilated compartment.

b. DO NOT use carbon tetrachloride. This is a highly toxic compound.

c. DO NOT breathe directly over the vapor of any cleaning solvent for prolonged periods.

d. DO NOT spray cleaning solvents on electrical windings or insulation.

e. DO NOT apply solvents to warm or hot equipment since this increases the toxicity hazard.

The following steps are positive safety precautions which will be followed when cleaning operations are underway.

a. Use a blower or a canvas wind chute to blow air into a compartment in which a cleaning solvent is being used.

b. Open all usable port holes and place wind scoops in them.

c. Place a fire extinguisher close by, ready for use.

d. If feasible, use water compounds instead of other solvents.

e. Wear rubber gloves to prevent direct contact with solvents.

f. Use goggles when a solvent is being sprayed on permissible surfaces.

g. Hold the nozzle close to the object being sprayed.

Where water compounds are not feasible, inhibited methyl chloroform (1, 1, 1, Trichloroethane) shall be used instead of the dangerous carbon tetrachloride. Methyl chloroform has a threshold of 500 parts-per-million (ppm) in air, whereas carbon tetrachloride has a threshold of 25 ppm. (Threshold is the point above which the concentration in air becomes dangerous.) Methyl chloroform is an effective cleaner and as safe as can be expected when reasonable care, such as adequate ventilation and observance of fire precautions, is exercised. When using inhibited methyl chloroform, avoid direct inhalation of the vapor—it is not safe for use, even with a gas mask, because its vapor displaces oxygen in the air.

AEROSOL DISPENSERS

Deviation from prescribed procedures regarding the selection, application, storage, or disposal of aerosol dispensers containing industrial sprays can result in serious injury to personnel because of toxic effects, fire, explosion, and so on. Specific instructions concerning the precautions and procedures that must be observed to prevent physical injury cannot be given in this manual because of the multiplicity of available industrial sprays. However, all personnel concerned with the handling of aerosol dispensers containing volatile substances should clearly understand the hazards involved and the importance of exercising protective measures to prevent personal injury. Strict compliance with the instructions printed on the aerosol dispensers will prevent many of the accidents which result from misapplication, mishandling, or improper storage of industrial sprays.

The basic rules which must be observed to ensure safety in the use of aerosol dispensers are:

a. Carefully read and comply with the instructions printed on the container.

b. Do not use any dispenser that is capable of producing dangerous gases or other toxic effects in an enclosed area unless the area is adequately ventilated.

c. If a protective coating must be sprayed in an inadequately ventilated space, either an air respirator or self-contained breathing apparatus should be provided. However, fresh air supplied from outside the enclosure by use of exhaust fans or portable blowers is preferred. Such equipment will prevent inhalation of toxic vapors.

d. Do not spray protective coatings on warm or energized equipment, because to do so creates a fire hazard.

e. Avoid contact of your skin with the liquid contained in the dispenser. Contact with some of the liquids being used may result in burns, while milder exposures may cause only rashes.

f. Do not puncture the dispenser, because it is pressurized. Injury can result from this practice.

g. Do not discard used dispensers in wastebaskets that are to be emptied into an incinerator; an explosion of the dispenser may result.

h. Keep dispensers away from direct sunlight, heaters, and other sources of heat.

i. Do not store dispensers in an environment where the temperature is above the temperature limits printed on the dispenser case. Exposure to high temperature may cause the container to burst.

FUNGUS-PROOFED AND FIBERGLASS-INSULATED WIRES

Handling fungus-proofed, fiberglass-insulated wire requires certain precautions to prevent skin irritation. Insulation stripped from these types wires should be placed in containers to keep it off floors, benches, and clothing. Insulation "dust" (small particles of insulation shed during stripping or flexing of the wire) should be collected with a vacuum cleaner. Compressed air shall never be used to remove "dust" from benches, equipment, or floors.

After stripping or handling fungus-proofed wire, the hands and arms should be washed thoroughly with soap and water. If an itching sensation is experienced, a good hand cleaner should be used to remove the remaining particles of fiberglass. Scratching of the affected area shall be avoided. If skin irritation persists, medical advice shall then be sought.

CATHODE-RAY TUBES

Cathode-ray tubes (CRTs) are, potentially, extremely hazardous items. The phospor coating on their internal faces is toxic and the large physical size of their glass envelopes can create violent implosions, if broken. Their glass envelopes are highly evacuated and, consequently, their large surface areas are subjected to considerable force by atmospheric pressure. For example, the total force exerted on the overall surface of a 10-inch CRT is nearly 2,000 pounds, of which 1,000 pounds is exerted on the face alone. When a CRT breaks, the high external pressure causes the tube to implode (burst inwards) and, as a result, the inner metal parts, glass fragments, and toxic phospors are violently expelled.

Extreme care shall also be taken whenever disposal of CRTs is necessary. All defective tubes will be stored in such a way that injury to personnel will be avoided. When a CRT is removed from a unit, it should not be allowed to remain exposed to damage or shock on work benches etc., but should be immediately placed in the container provided for that purpose or in the container that held the replacement tube, until disposal.

WARNING

THE PHOSPOR COATING ON THE INTERNAL FACE OF THE CRT IS EXTREMELY TOXIC. WHEN DISPOSING OF A BROKEN TUBE, BE CAREFUL NOT TO COME INTO CONTACT WITH THIS COMPOUND. IF CONTACT IS MADE, CONSULT A MEDICAL OFFICER IMMEDIATELY.

Before a CRT is discarded, it should be made harmless by breaking the vacuum glass seal. To accomplish this, proceed as follows:

a. Place the tube that is to be discarded in an empty carton, with its face down.

b. Make sure that goggles are worn.

c. Carefully break off the locating pin from its base. (See Fig. 16-2.)

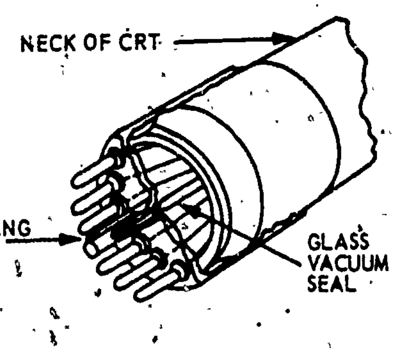
d. With a small screwdriver or probe, break off the tip of the glass vacuum seal.

ELECTROMAGNETIC RADIATION

Electromagnetic radiation (also referred to as RF radiation) can be neither seen nor easily sensed. Therefore, its presence must be measured by use of special sensitive instruments, or by theoretical calculations, so that the safety of personnel involved in various activities within the electromagnetic environment will be assured. A discussion of the various methods used to sense the presence of electromagnetic energy is beyond the scope of this manual. However, the importance of remaining alert to the danger of overexposure to electromagnetic radiation as well as to the dangers of other radiation hazards is emphasized.

BIOLOGICAL EFFECTS OF MICROWAVE ELECTROMAGNETIC ENERGY

The energy impinging on an object in an electromagnetic field may be reflected or absorbed. Only the absorbed energy constitutes a biological hazard. The amount of penetration of energy into the body and its absorption



20.320(40)
Figure 16-2.—Cathode-ray tube base structure.

depends upon the physical dimensions of the body, the electrical properties of the tissues, and the wavelength of the electromagnetic energy.

For any significant effect to occur, the physical size of the object must be equivalent to at least one tenth the wavelength of the radiated energy. Neglecting other physical measurements of the human body, a man's height determines at what wavelength the electromagnetic energy will be most hazardous to him. As the wavelength decreases, the man's height represents an increasingly greater number of electrical wavelengths. Inversely, as the wavelength increases, the man, therefore, becomes a less significant object in the radiation field. Consequently, the likelihood of the occurrence of biological effects on human body increases as the wavelength decreases (or frequency increases). Additionally, as the wavelength becomes progressively shorter, the dimensions of parts and appendages of the human body become increasingly more significant in terms of the number of equivalent electrical wavelengths. Briefly, the effects from microwave electromagnetic radiation on the human body increase in proportion to frequency of the radiated energy. The higher the frequency, the greater the absorption by the human body and, consequently, the greater the danger from exposure to electromagnetic radiation.

When electromagnetic energy is absorbed by tissues of the body, heat is produced in the tissues. If the organism cannot dissipate this heat-energy as fast as it is produced, the internal temperature of the body will rise, resulting in damage to the tissue and, if the rise is sufficiently high, in destruction of the organism. The body's ability to dissipate heat successfully depends upon many related factors, such as environmental air circulation rate, humidity, air temperature, body metabolic rate, clothing, power density of the radiation field, amount of energy absorbed, and duration of exposure.

Certain organs of the body are considered to be more susceptible than others to the effects of RF radiation. Organs, such as the lungs, the eyes, the testicles, the gall bladder, and portions of the gastrointestinal tract, are not cooled by an abundant flow of blood through the vascular system. Therefore, these organs are more likely to be damaged by heat resulting from excessive exposure to radiation. Information presently available and experience indicate that, of the organs just mentioned, the eyes and testicles are the most vulnerable to microwave radiation. Therefore, the possibility of becoming partially blind or temporarily sterile is most likely.

HAZARDS OF ELECTROMAGNETIC RADIATION TO ORDNANCE (HERO)

The uses of electrically initiated explosive devices are increasing greatly, i.e., for initiating booster rocket igniters and warhead detonators, for stage separation in multistage rockets, for reliable, high-speed operation of switches and valves, and for many other purposes. Some weapons contain more than 75 electroexplosive devices (EED). Continuous development efforts are directed toward reducing weight and space, lowering power requirements, assuring positive response, and increasing reliability and safety. However, these are not always complementary goals.

At the same time, the power of communications and radar transmitting equipment is being constantly increased and the frequency spectrum broadened. The radio frequency spectrum utilized by the Navy now extends from 10 kilohertz to about 20,000 megahertz.

Transmitter power outputs may approach 10 kilowatts at communication frequencies, and peak power outputs extend to approximately 5 megawatts at radar frequencies.

These trends produce incompatible situations. Transmitters and their antennas have only one purpose—to radiate electromagnetic energy, whereas the initiating elements of ordnance items need only to be supplied with the proper amount of electrical energy for an explosion to take place. Several shipboard incidents involving ordnance items have been attributed to initiation of their EEDs by electromagnetic radiation from the ship's transmitting equipment. Each incident occurred during shipboard operations while the ordnance item was handled normally. Therefore, with many explosive ordnance items, constraints are required for safety and to ensure reliable performance.

To meet the growing need for new shipboard procedures to reduce the hazard to ordnance equipment from RF radiation, the Naval Sea Systems Command (NAVSEASYSCOM) has sponsored tests which, coordinated with studies by other agencies, have enabled the formation of new guidelines and restrictions for handling electrically initiated ordnance equipment. The basic problem in determining an ordnance system's susceptibility to RF radiation lies in the evaluation of the antenna-like couplings that exist between illuminating fields and the various EEDs employed in the system. RF energy may enter a weapon as a wave radiated through a hole or crack in the weapon skin. RF energy may also be conducted into the weapon by the firing leads or other wires that penetrate the weapon enclosure. The precise probabilities of EED actuation are relatively unpredictable, being dependent upon variables of frequency, field strength, geometric orientation, environment, and metallic or personnel contacts with ordnance and aircraft. Actuation of an EED is often undetectable without disassembly of weapons. The most susceptible periods are during assembly, disassembly loading, unloading, or testing in electromagnetic fields. The most likely effects of premature actuation are dudding, reduction of reliability, or propellant ignition. In the very worst environments there is a low, but finite probability of warhead detonation.

WARNING SIGNS AND POSTERS

Warning signs and suitable guards will be provided for preventing personnel from accidentally coming in contact with dangerous voltages, for warning personnel of possible presence of explosive vapors and RF radiation, for warning personnel working aloft of poisonous effects of stack gases, and for warning of other dangers which may cause injuries to personnel. Equipment installations should not be considered complete until appropriate warning signs have been conspicuously posted.

HIGH VOLTAGE WARNING SIGNS

What is the ultimate goal for the posting of signs which portray the danger of shock hazards? Is it for the safety of personnel and not solely for passing material and administrative inspections? Surely, but inspection requirements must also be met. It's policy! However, this policy exists for a very good reason—<u>to ensure personnel safety!</u>

A frequent discrepancy noted on material and administrative inspections is the use of improper, or the complete absence of, "Danger High Voltage" signs in spaces or on equipment where dangerous electrical shock hazards exist. To satisfy material and administrative inspections, and at the same time to ensure personnel safety, the following minimum requirements apply.

a. One "Danger High Voltage" sign shall be mounted within each entrance of each electronic space and any other space containing permanently—installed and/or portable electric or electronic equipment which afford a shock hazard of 70 volts or above. A space containing two entrances required two signs, etc. The mounting of each sign must be in a conspicuous location so it will be in view of all personnel upon their entering such spaces. Excluded from this requirement are living, eating, storage, supply, and other habituate-type spaces which have only lighting, convenience, and ventilation circuits.

b. Switchboards, radio antennas and tuners, and like equipments having <u>exposed</u> terminals at potentials of 70 volts and above, must, in addition to being caged or otherwise protected from accidental contact by personnel, have a "Danger High Voltage" sign displayed on each side of the cage and on each door or entrance of the cage. "Dead-Front" type switchboards not enclosed in a cage or not having a protective barrier do not require display of "Danger High Voltage" signs.

The "Danger High Voltage" sign shown in figure 16-3, is 7 inches by 10 inches in size and made of 18 gauge sheet steel—the largest of available "Danger High Voltage" signs.

RADIO FREQUENCY RADIATION HAZARD WARNING SIGNS

There are six radio frequency radiation hazard warning signs as shown in Figure 16-4.

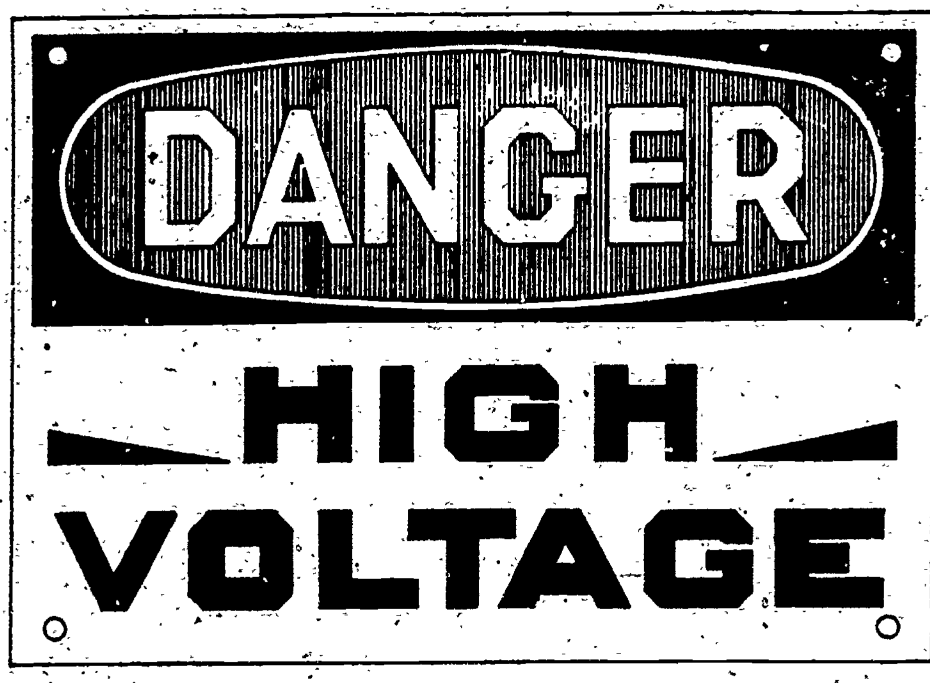


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Figure 16-3.—High voltage warning sign.

Instructions as to where these signs are to be posted are included in the illustration of each sign.

RESUSCITATION AND ARTIFICIAL RESPIRATION

At suitable intervals, the competent authority shall require that all personnel, who engage in the operation and maintenance of electronic equipment, demonstrate their practical knowledge in the application of resuscitation and artificial respiration procedures. He, also, shall arrange for any additional training, if he deems that it is necessary, so that all personnel will attain proficiency in resuscitation techniques.

RESUSCITATION FOR ELECTRIC SHOCK

Artificial resuscitation, after an electric shock, includes artificial respiration to re-establish breathing, and external heart massage ~~to re-establish~~ heart beat and blood circulation. To aid a victim of electric shock, after removal from contact with the electricity, immediately apply mouth-to-mouth artificial respiration. Also, if there is no pulse, immediately apply heart massage. Do not waste precious seconds carrying the victim from a cramped, wet, or isolated location to a roomier, dryer, frequented location. If so desired, you may breathe into the victim's mouth through a cloth or a handkerchief placed over his face. If assistance is available, interchange the task of respiration and heart massage.

Cardiac Arrest (Loss of Heart Beat)

If a subject is a victim of electric shock, and has no heart beat, he most probably has suffered a cardiac arrest. This condition can be verified by a complete absence of pulse at the wrist or at the neck. Additionally, the pupils of his eyes will be very dilated, respiration will be weak or

LOCATION: ON RADAR ANTENNA PEDESTALS.

REQUISITION: NAVSHIPS 0967-305-1010

SIZE: 6½"X 6½"

LOCATION: IN A SUITABLE LOCATION IN VIEW OF DECK FORCE PERSONNEL.

REQUISITION: NAVSHIPS 0967-315-2010.

SIZE: 6½"X 6½"

LOCATION: AT FUEL HANDLING AREAS WHICH ARE SUBJECTED TO RF RADIATION.

REQUISITION: NAVSHIPS 0967-315-1010.

SIZE: 6½"X 6½"

LOCATION: IN RADIO TRANSMITTER ROOMS IN SUITABLE LOCATION FOR FULL VIEW BY OPERATION PERSONNEL.

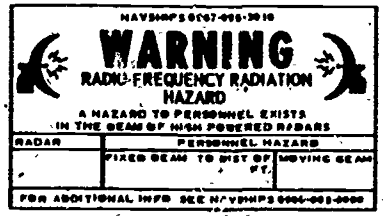
REQUISITION: NAVSHIPS 0967-098-1010.

SIZE: 6½"X 6½"

LOCATION: AT EYE LEVEL AT THE FOOT OF ALL LADDERS OR OTHER ACCESSES TO ALL TOWERS, MASTS AND SUPERSTRUCTURES WHICH ARE SUBJECTED TO HAZARDOUS LEVELS OF RADIATION.

REQUISITION: NAVSHIPS 0967-153-8010.

SIZE: 6½"X 6½"



LOCATION: ON OR ADJACENT TO, RADAR SET CONTROL.

REQUISITION: NAVSHIPS 0967-096-3010

SIZE: 3"X 6"

NOTE: REFER TO RF RADIATION HAZARDS MANUAL, NAVSHIPS 0900-005-0000 FOR INSTRUCTIONS TO INTERPERT OR INSERT DATA ON THIS SIGN.

40.67(76E)

Figure 16-4.—Radio frequency radiation hazard warning signs.

stopped, and he may have the appearance of a dead person. Under these conditions, severe brain damage will occur within four minutes, unless the circulation is reestablished by application of cardiac massage.

Closed Chest Cardiac Massage

This method has been widely adopted because it is practical and it can be learned easily by anyone who is properly instructed. The object of the closed chest cardiac massage is to squeeze the heart through the chest wall, thereby, emptying it to create a peripheral pulse. This must be done approximately 60 times per minute.

Resuscitation Procedure

a. Place the victim on his back; a firm surface, such as the deck, is preferred. Expose the subject's chest.

b. Kneel beside the victim; feel for the lower end of the victim's sternum (breastbone). Place one hand across breastbone so that heel of the hand covers the lower part, and place the second hand on top of the first so that the fingers point toward the neck, as in Figure 16-5.

c. With the arms nearly straight, rock forward so that a controlled amount of your body's weight is transmitted through your arms and hands to the breastbone of the victim. The amount of pressure to be applied depends on the victims age. However, it should be applied as smoothly as possible. The chest wall of an adult victim should be depressed 2 to 3 inches with each pressure application.

d. Repeat application of pressure approximately 60 times per minute.

e. An assistant should be ventilating the victim's lungs preferably with pure oxygen under intermittent positive pressure. If oxygen is not available, he shall administer mouth-to-mouth resuscitation. However, closed chest massage will cause some ventilation of the lungs. Therefore, if you are alone you must concentrate on the massage until help can arrive.

f. Direct other assistants, when available, to keep checking the patient's pulse. Use the least pressure that will secure an effective pulse beat. The pupils will become smaller when the cardiac massage is effective.

g. Pause occasionally to determine if a spontaneous heart beat has returned.

h. Precautions. Make every effort to keep the hands positioned as described in Step 2, in order to prevent injuries to the liver, ribs or

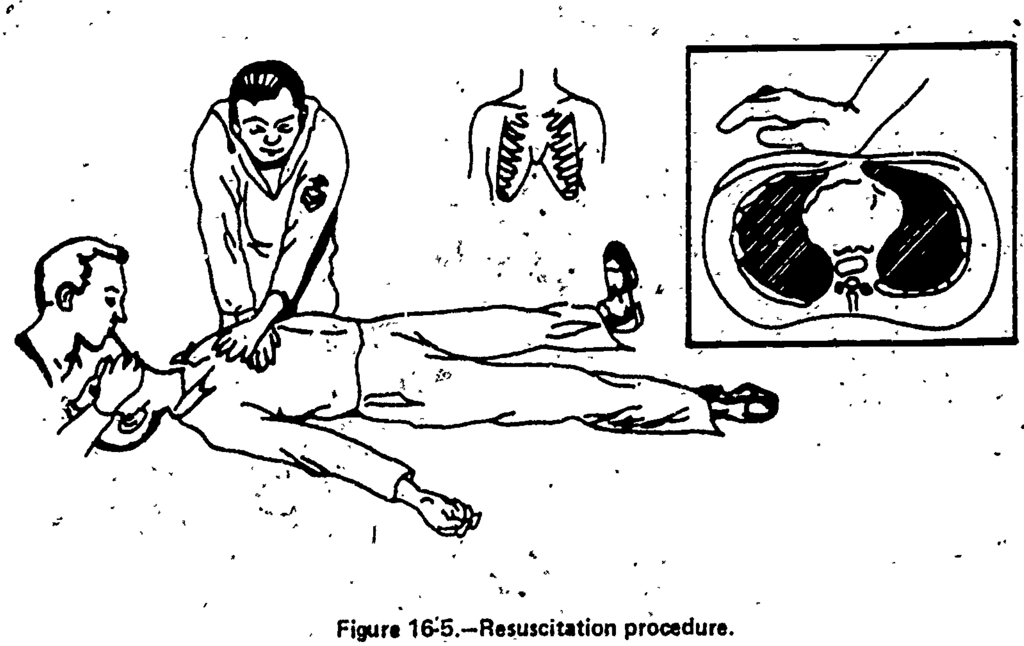


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Figure 16-5.—Resuscitation procedure.

other vital organs. Since the heart cannot recover unless supplied with oxygenated blood it is essential that cardiac massage be administered simultaneously with mouth-to-mouth respiration. Whenever there is only one rescue worker available, the cardiac massage must be interrupted every 30 seconds or so, for administration of rapid mouth-to-mouth respiration for three or four times.

ARTIFICIAL RESPIRATION

The mouth-to-mouth (or mouth-to-nose) technique of artificial respiration is the most effective method of the resuscitation techniques for emergency ventilation of an individual of any age who has stopped breathing. whenever special breathing equipment or help from another person are not available.

People who are trained in basic first aid only, usually do not, have the experience, special training, or the required special equipment to distinguish whether lack of breathing is a result of disease or accident. Therefore, some form of artificial respiration should be administered at the earliest possible moment.

Any means that will obtain and maintain an open air passageway from the lungs to the mouth and provide for an alternate increase and decrease in the size of the chest, internally or externally, will move air in and out of a non-breathing person. Mouth-to-mouth respiration is an excellent emergency technique which serves this purpose well. In addition to the advantage of providing pressure to inflate the victim's lungs immediately, this technique provides the rescuer with accurate information on the volume, pressure, and timing of efforts needed.

When a person is unconscious and not breathing, the base of the tongue tends to press against, and block, the upper air passageway. The procedures described below should provide for an open air passageway when a lone rescuer must perform aritificial respiration.

Mouth-to-Mouth Method for Adults

Refer to Illustrations A through G of Figure 16-6. First, if there is foreign matter visible in the mouth, remove it quickly with your fingers or a cloth wrapped around your fingers.

a. Tilt the head back so the chin is pointing upward, (Illustration A). Pull or push the jaw into a jutting-out position (Illustrations B and C). These maneuvers should relieve obstruction of the air-way by moving the base of the tongue away from the back of the throat.

b. Open your mouth wide and place it tightly over the victim's mouth. At the same time, pinch the victim's nostrils shut (Illustration D) or close the nostrils with your cheek (Illustration E). As an alternative method, close the victim's mouth and place your mouth over the nose (Illustration F). Then blow into the victim's mouth or nose. Air may be blown through the victim's teeth, even though they may be clenched. The first blowing efforts should determine whether or not obstruction exists.

c. Remove your mouth, turn your head to side, and listen for the return rush of air that indicates air exchange. Repeat the blowing effort. For an adult, blow vigorously at the rate of 12 breaths per minute.

d. If you are not getting air exchange, recheck the head and jaw position, If you still do not get air exchange, quickly turn the victim on his side and administer several sharp blows between the shoulder blades in the hope of dislodging the obstructing matter (Illustration G). Again sweep your fingers throughout the victim's mouth to remove foreign matter.

NOTE

Those who do not wish to come into direct contact with victim may hold a cloth over the victim's mouth or nose and breathe through it. The cloth does not, significantly, affect the exchange of air.

Back-Pressure Arm-Lift Method

Refer to Illustrations A through E of Figure 16-7. For this method of artificial respiration, place the victim in a prone position (Illustration A). Bend his elbows and place his hands one upon the other. Turn his face to one side and

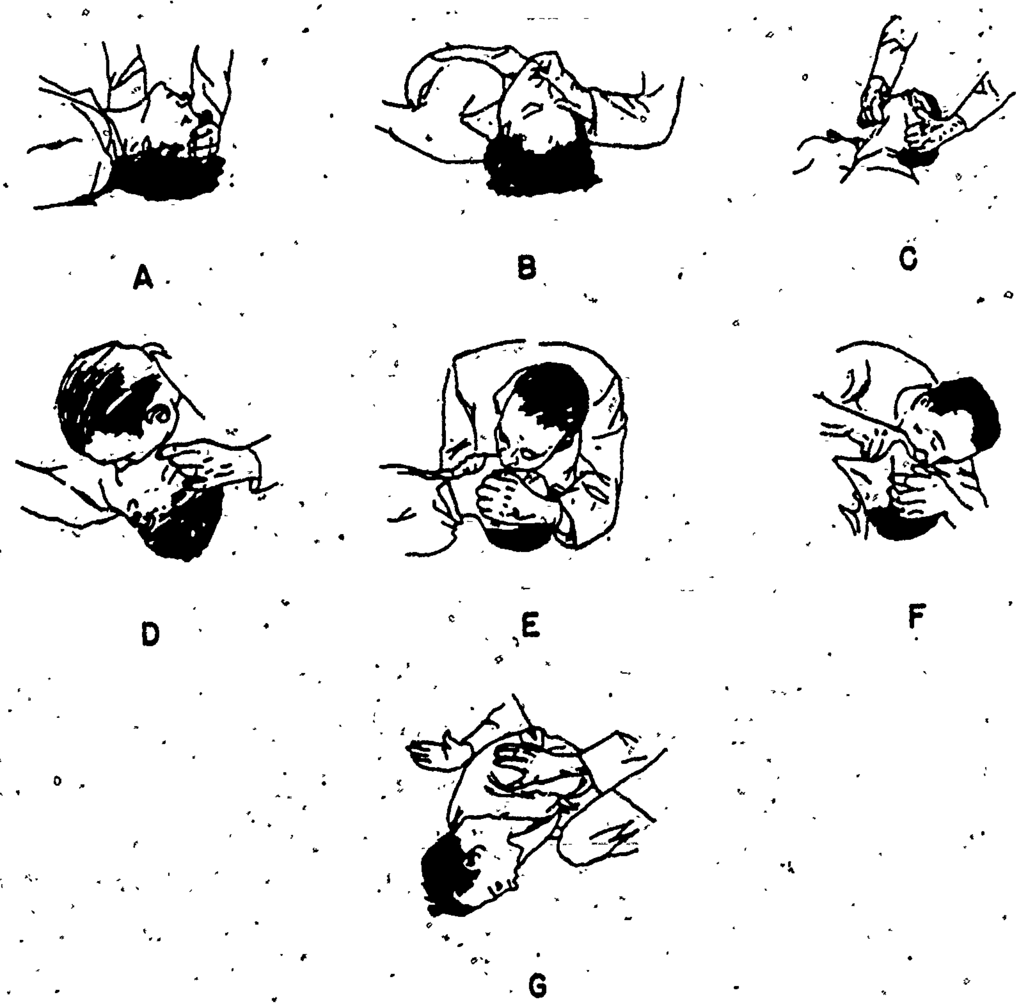

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Figure 16-6.—Mouth-to-mouth respiration method for adults.

place his cheek upon his hands. Quickly sweep your fingers into the victim's mouth to remove any froth or particles, while drawing the tongue forward. DO NOT waste time in loosening the victim's clothing or warming the victim; this can be done by an assistant while artificial respiration is in process.

Kneel on either the right or left knee by the head of the victim, facing him. Place your knee at the side of the victim's head, close to his forearm. Place your other foot near his elbow. If it is more comfortable, kneel on both knees, one on either side of the victim's head, being very careful not to obstruct his breathing. Place your hands upon the flat of the victim's back in such a way that the heels of your hand lie just below an imaginary line between his armpits. With the tips of your thumbs just touching, spread your fingers downward (Illustration B).

For the COMPRESSION PHASE (Illustration C), rock forward until your arms are approximately vertical, and allow the weight of the upper part of your body to exert a slow, steady, even, downward pressure. This forces air out of the victim's lungs. Your elbows should be

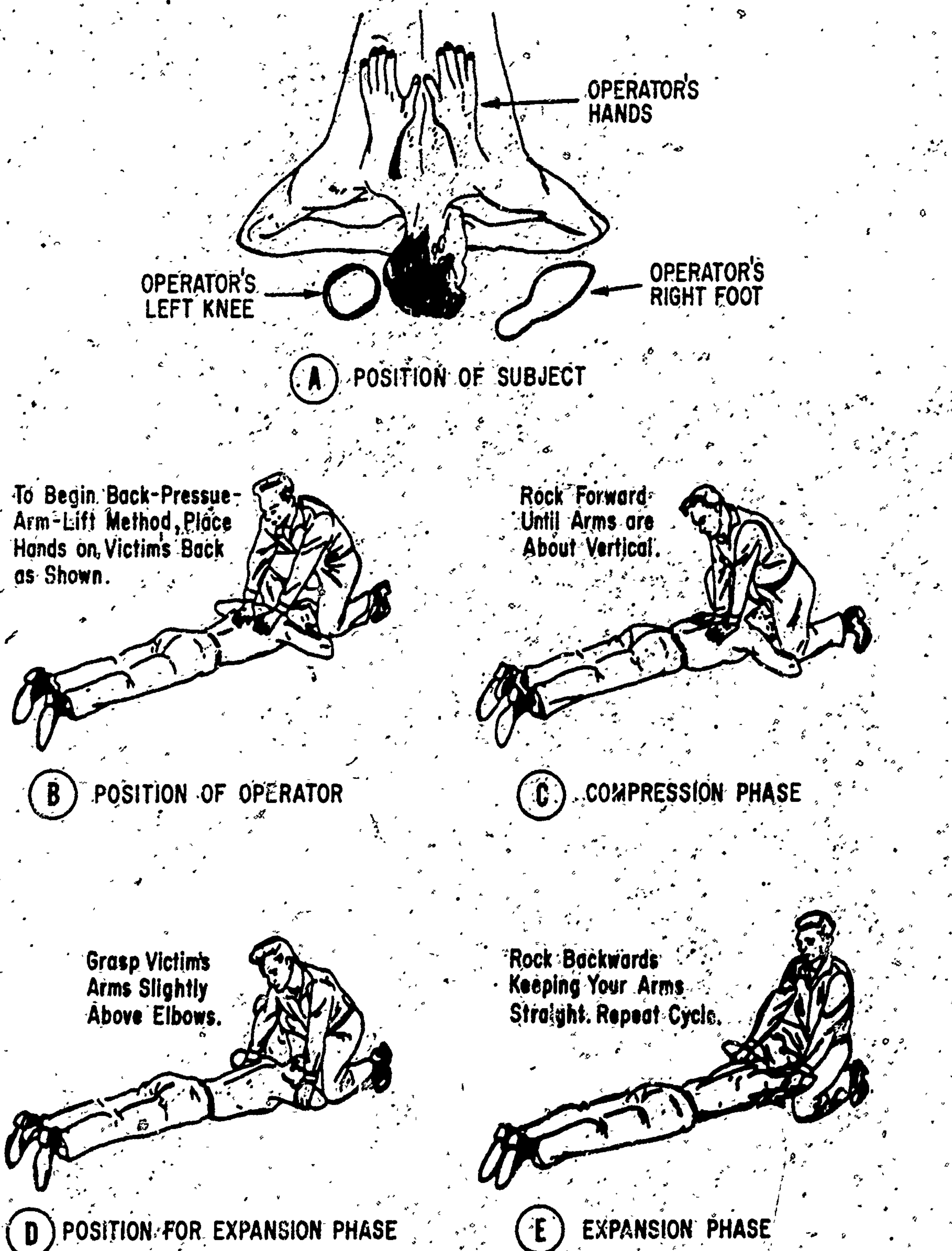

Figure 16-7.—Back-pressure arm-lift method.

kept straight and the pressure should be exerted almost directly downward on the back.

For the EXPANSION PHASE, (Illustrations D and E), release the pressure avoiding a final thrust, and commence to rock slowly backward. Place your hand upon the victim's arms, just above his elbows (Illustration D). Draw his arms upward and toward you (Illustration E), but apply just enough lift to feel resistance and tension at the victim's shoulders. Do not bend your elbows as you rock backward. Then, lower the victim's arms to the ground. This completes the full cycle. The arm lift expands the chest by pulling on the chest muscles, arching the back, and relieving the weight on the chest.

The cycle should be repeated approximately 12 times per minute at a steady, uniform rate. The compression phase should take approximately the same time as the expansion phase, with release periods of minimum duration. The whole process should be continued without interruption until the victim is revived. If possible, nothing should be allowed to interfere with proper and rythmic motions.

If a dry blanket is available, slide it under the victim without interrupting the respiration cycles. This may be accomplished easily with the aid of an assistant. Cover the victim loosely by wrapping the ends of the blanket around him. Between cycles, also loosen all tight clothing such as belts and collars.

Do not give up hope. Continue to apply artificial respiration until the victim begins to breathe regularly. Sometimes, as much as eight hours of continuous artificial respiration is necessary to restore regular breathing. Remember, only a doctor is qualified to pronounce death under circumstances requiring artificial respiration. A revived person may suddenly stop breathing and additional respiration may be required. For this reason, he must be carefully watched. Never leave a resuscitated person alone until you are certain that he is fully conscious and breathing normally.

ELECTRICAL FIRES

Any fire is a potential source of disaster. In electrical fires, the following procedures should be observed.

a. Deenergize circuit for the affected equipment. Every radio transmitter has an EMERGENCY OFF switch that removes all power from equipment. In addition to local power switches on equipment, the power supply to all transmitters and receivers, converters, and teletypes can also be secured at power distribution panels.
b. Spread the alarm. Ashore, call the fire department. Aboard ship, use the phone or intercom. If available, send another person to sound the alarm in accordance with ship's fire bill.
c. Secure ventilation. Turn off blowers; close doors.
d. Report fire to the OOD by telephone or messenger.
e. Attack fire with equipment available in immediate vicinity, such as portable 15-pound CO_2 (carbon dioxide) extinguishers.

When extinguishing an electrical fire, remember that quick action is required only to deenergize the circuit. When this action has been taken, STOP! LOOK! THINK! The use of CO_2 fire extinguishers directed at the base of the flame is always best for all electrical fires. Because carbon dioxide is a dry, noncorrosive, inert gas, it will not damage electrical equipment. And, because it is a nonconductor of electricity, it can be used safely in fighting fires that otherwise would present the additional hazard of electric shock.

PORTABLE FIRE EXTINGUISHERS

Some portable 15-pound carbon dioxide fire extinguishers have a squeeze-grip style release valve that is operated by a simple hand squeeze-grip. Others have a release valve operated by a handwheel at the top. Both valves have a locking pin to prevent unintentional discharge of the carbon dioxide. To operate, observe the following steps.

a. Carry fire extinguisher in an upright position, and approach fire as closely as heat permits. (Keep extinguisher erect while using it. Because of its construction, it should not be laid on its side.)

b. Remove locking pin from valve.

c. Grasp nozzle horn by its handle. (It is insulated to protect your hand from extreme cold of discharging carbon dioxide.)

d. Open valve by turning valve wheel to left (or, squeeze release lever), thus opening valve and releasing carbon dioxide. At the same time direct the flow toward the base of the fire. Move horn slowly from side to side, and follow flames upward as they recede.

e. Close valve as soon as conditions permit, and continue to open and close it as necessary. The firefighter may shut off handwheel-type valve for brief intervals without appreciable loss of carbon dioxide. But once valve seal is broken, carbon dioxide will leak away in 10 minutes or so. The squeeze-grip type likewise may be turned off while in use, but it will hold contents indefinitely without leakage. In continuous operation, the 15-pound cylinder of either type will expend its contents in about 40 seconds.

f. The discharge should not be stopped too soon. When flame is extinguished, coat entire surface engaged in fire with carbon dioxide snow in order to prevent reflash.

The firefighter must be warned that the very qualities that make carbon dioxide a desirable extinguishing agent also make it dangerous to life if the compartment should become filled with it. Certainly, when it replaces oxygen in the air to the extent that combustion cannot be sustained, breathing cannot be sustained either. Radio rooms do not have CO_2 systems for total flooding such as those installed in uninhabited spaces used for gasoline and paint stowage. Consequently, when using 15-pound portable fire extinguishers, the firefighter usually does not have to consider the possibility of harm to personnel. Because carbon dioxide is heavier than air, it does not rise, but remains in a pool close to the deck. The quantity of gas released from one—or several—of these extinguishers is insufficient to reduce below a dangerous minimum the total oxygen content of the air in a compartment.

Anyone using a carbon dioxide extinguisher should be warned that snow blisters the skin and causes painful burns if allowed to remain on the skin.

If all efforts with carbon dioxide fail to put out a fire, fresh water applied with a fog applicator may be used. Because of the fine diffusion of its particles, fog reduces but does not entirely remove danger of electric shock.

In cable fires in which the inner layers of insulation (or insulation covered by armor) support combustion, the only positive method of preventing the fire from running the length of the cable is to cut the cable after it is deenergized, and separate the two ends. This preventive action should be accomplished only with well-insulated tools, such as wooden-handled fire axes or insulated pliers.

BURNS

Burns and scalds are caused by exposure to intense heat, such as that generated by fire, bomb flash, sunlight, hot solids, hot gases, and hot liquids. Contact with electric current also causes burns, particularly if the skin is dry. (Dry skin offers about 20 times more resistance than moist skin to the passage of electric current. When the skin is dry, therefore, local heating effects (burns) are greater, even though total damage to the body is less than when the skin is wet.)

It should be noted that burns and scalds are essentially the same type of heat injury. When injury is caused by dry heat, it is called a burn; when caused by moist heat, it is called a scald. Treatment is the same in both cases.

Classification of burns: Burns are classified in several ways—by the extent of the burned surface, by the depth of the burn, and by the cause of the burn. Of these categories, the extent of body surface burned is the principal factor in determining seriousness of the burn, and also plays the greatest role in the casualty's chances for survival.

Shock can be expected in adults with burns of over 15 percent; in small children, with burns of over 10 percent of body surface area. In adults, burns to more than 20 percent of the body endanger life. Usually 30-percent burns are fatal if adequate medical treatment is not received.

The depth of injury to the tissues is spoken of in degrees. First-degree burns are the mildest, producing redness, increased warmth, tenderness, and mild pain. Second-degree burns redden and blister the skin and are characterized by severe pain. Third-degree burns destroy the skin and may destroy muscle tissue and bone in severe cases. Severe pain may be absent because nerve endings have been destroyed. The color may vary from white and lifeless (scalds) to black (charred).

Always remember that the size of a burned area may be far more significant than the depth of a burn. A first-degree or second-degree burn that covers a large area of the body usually is more serious than a small third-degree burn. A first-degree sunburn, for example, can cause death if a large area of the body is burned.

In general, the causes of burns are classified as thermal (heat) or chemical, or as resulting from sunburn, electric shock, or radiation. Whatever the cause of the burn, shock always results if the burns are extensive.

Treatment of Burns and Scalds

First aid for all burns consists of the following main items: (1) relieve pain, (2) prevent or treat shock, and (3) prevent infection.

In electric shock, the burn may have to be temporarily ignored while resuscitative measures are carried out. Otherwise the treatment is the same as for heat burns.

Local treatment for chemical burns varies, depending on the causative agent. Chemical burns are discussed more fully later in this chapter.

Ice water treatment: Clean water and ice are not always available, but when they are, ice water (as an emergency measure) provides immediate relief from pain and also seems to lessen the damaging effects of burns. For burns affecting less than 20 percent of the body, immerse the burned part in ice water or, where immersion is not practical, repeatedly apply ice-cold moist towels to the burned area. Treatment should be continued until no pain is felt when the burned area is withdrawn from the water. This treatment may last from 30 minutes to as long as 5 hours. When available, hexachlorophene should be added to the water to destroy bacteria. After the ice water treatment, the regular treatment for burns should follow (discussed later).

Relief of pain: Simple first-degree burns that do not cover a large body area may require no more than one or two aspirin tablets to relieve discomfort. Severe burns cause extreme pain, which contributes to the severity of shock. A person who has suffered extensive burns may be given not more than ¼ grain of morphine to relieve the pain. The injection site should be massaged for a few minutes to help circulate the morphine. (CAUTION: The casualty may have other injuries. Do not give morphine to any person who has a head injury, chest injury, or who is in deep shock, even if he is suffering from extensive burns.)

Treatment for shock: Any person who has been seriously burned must be treated for shock immediately. Serious shock always accompanies an extensive burn, and is, in fact, the most dangerous consequence of the injury. Start the treatment for shock before making any attempt to treat the burn itself.

Relieving the casualty's pain is, of course, an important part of the treatment for shock. After easing his suffering, place him in a position so that his head is lower than his feet. Make sure that he is warm enough; do not remove his clothing immediately. Remember that exposure to cold will cause shock to become worse, but do not overheat him.

In burn cases, an exception must be made to the rule of withholding liquids from a patient. A seriously burned person has an overwhelming need for liquids; and administering liquids in such cases is an indispensable part of treatment for shock caused by burns. Give small amounts of sweetened tea, fruit juice, or sugar water, if the casualty has no internal injuries, 's conscious, and is able to swallow.

Prevention of infection: Second- and third-degree burns are, in effect, open wounds and must be covered to reduce possibility of infection. Every effort must be made to use a sterile covering, but makeshift wrappings such as clean sheets and freshly laundered towels may be used.

Ointments and other medicines must never be put on the burn wound. Using these agents may make later treatment by a physician difficult or impossible.

Do not open any blisters. Do not cough or sneeze near the casualty. If possible, keep a piece of sterile gauze over your mouth and nose while you are working near the burn victim. Contamination by micro-organisms from the mouth and nose is a frequent cause of serious (and possibly fatal) burn infections.

Treatment: If the casualty is to receive medical attention soon, do nothing more than relieve his pain, treat for shock, and cover the burn with a sterile wrapping or clean sheet or towel. Do not attempt treatment of the burn wound itself.

If more than 3 hours may elapse before the services of a physician can be obtained, you should dress the burn. First remove the casualty's clothing from around and over the burned area, preferably by cutting it away. Be especially careful not to cause further injury. If clothing sticks to the burn wound, do not attempt to pull it loose. Merely cut around the part that sticks, and leave it in place. If any material such as wax, metal, dirt, grease, or tar adheres to the burn, do not try to remove it. Do not allow absorbent cotton, powder, adhesive tape, or other substances that might cling to the burn to come in contact with the burn. Never apply iodine or any other antiseptics on a burn.

When you have cleared away as much of the clothing as you can, dress the burn. Apply a single layer of sterile, fine-mesh petrolatum gauze over the burn wound, beginning at the outside of the burn wound and working toward the center in a circular manner. Next, place bulky fluffs of gauze over the burn, with a large padded dressing as the outer layer. Wrap gauze strips smoothly and gently around the dressing. The bandage should give light, even pressure and immobilize the injured part. Once the bandage is applied, it should be left alone. Leave it in place until the casualty receives medical care.

Burns of the eye: Burns of the eye require special attention. If they are true heat burns, caused by exposure to steam, bomb flash, welding arc, or any other source of intense heat, treat them as follows:

a. Put a few drops of clean mineral oil or olive oil into each eye.
b. Cover each eye with a small, thick compress, and fasten the compress in place with a bandage or an eyeshield.
c. Make sure that the casualty does not rub his eyes.
d. Get medical attention for the casualty as soon as possible.

APPENDIX I

RECEIVER R-390A/URR OPERATING PROCEDURES

Haphazard operation or improper settings of receiver controls can result in poor reception. It is important, therefore, to know the function of every control. The front panel of a Receiver R-390A/URR is shown in figure A1-1. Refer to figure A1-1 when studying the following descriptions of switches and controls.

a. Function switch: The function switch serves several purposes. It has a number of positions, each of which is discussed. Its OFF position (self-explanatory) simply turns off power to the receiver.

When the function switch is in STANDBY position, filament-supply voltages are energized, but plate supply voltages are not applied to the tubes. This condition readies the receiver for instant use without a long warmup time.

The abbreviation AGC stands for automatic gain control. Placing the function switch in the AGC position activates the circuitry, which automatically adjusts the RF and I-F amplifier gain to compensate for variations in the level of the incoming signal. In connection with the AGC function, notice that the AGC switch at the top of the panel has three positions marked SLOW, MEDIUM, and FAST. This AGC switch adjusts the rate at which the AGC circuitry responds to a change in the signal level. The correct position of the AGC switch depends on the type of signal received.

The abbreviation MGC stands for manual gain control. When the function switch is in the MGC position, the AGC circuitry is not activated, and the gain is controlled manually by means of the RF gain control.

When the function switch is in the calibrate (CAL) position, a stable crystal oscillator introduces a signal at the input circuitry of the receiver. This signal allows the operator to calibrate his receiver; that is, to ascertain that the reading of the tuning dial corresponds to the frequency received. The calibration circuitry of the R-390A permits the operator to calibrate the receiver at each 100-kHz point throughout the tuning range of the receiver. In connection with calibration, notice the ZERO ADJ knob near the frequency dial. When turned clockwise, this knob disengages the frequency indicator from the KILOCYCLE CHANGE tuning control. The calibration procedure consists essentially of the following steps:

1. Tune the receiver to a point where the frequency indicator dial shows an exact multiple of 100 kHz.
2. Turn the ZERO ADJ knob clockwise to disengage the tuning controls from the frequency indicator.
3. With the function switch in the CAL position, turn the KILOCYCLE CHANGE control to give the maximum response to the calibration signal.
4. Turn the ZERO ADJ knob counterclockwise to reengage the tuning control to the frequency indicator.

b. Tuning controls: Two front panel knobs provide the tuning control of the R-390A. They are the MEGACYCLE CHANGE knob and the KILOCYCLE CHANGE knob. The MEGACYCLE CHANGE knob selects any 1-mHz bandwidth of the tuning range. Turning this knob changes the reading of the first two digits of the frequency indicator. The KILOCYCLE CHANGE knob tunes the receiver to any desired frequency within the megahertz band selected by the MEGACYCLE CHANGE control. The last three

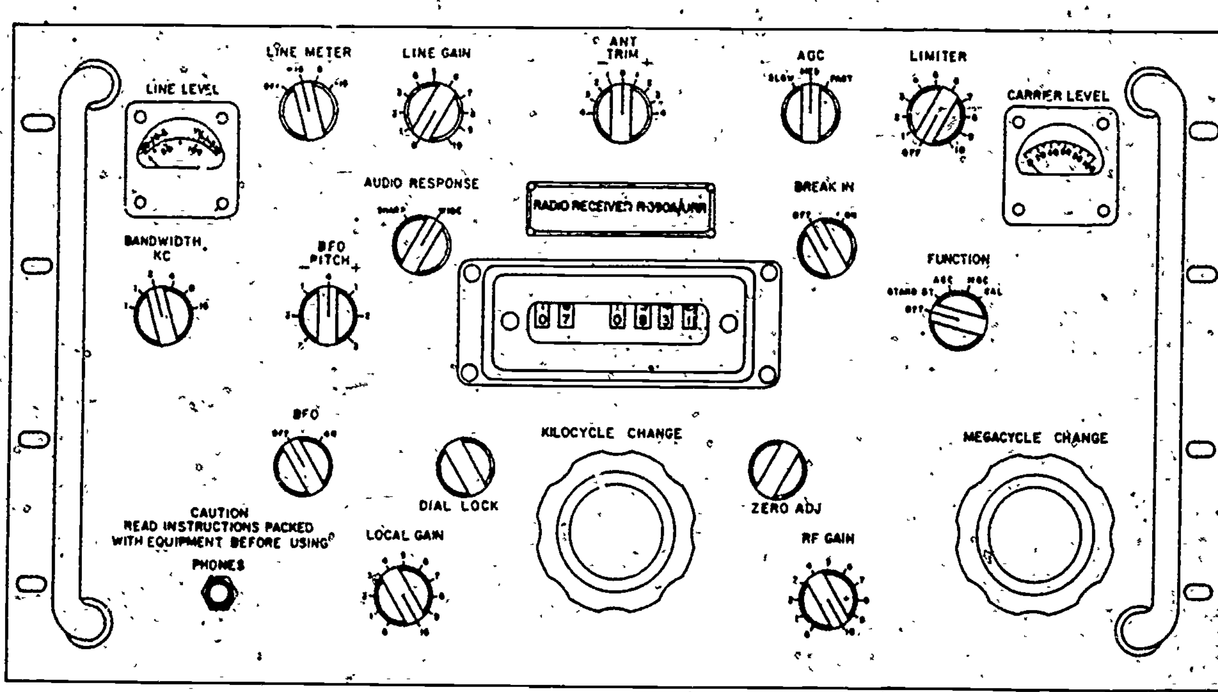

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Figure A1-1.—Front panel of R-390A/URR.

digits of the frequency indicator dial provide the kilohertz reading. The tuning controls actually adjust the tuning circuits in the RF stages and in the local oscillator in order to select the desired station frequency and to provide simultaneously the desired I-F signal to the I-F portion of the receiver. The DIAL LOCK knob is associated with the tuning controls. This knob locks the KILOCYCLE CHANGE control so that the frequency setting will not be changed accidentally.

c. Bandwidth control: Some transmissions use narrower bandwidths in the RF spectrum than others. Receivers are therefore provided with a control that allows the operator to adjust the pass band of the receiver so that only the desired bandwidth is received. On the R-390A receiver, this control is achieved by the BANDWIDTH KC switch. It adjusts the tuned circuits of the I-F portion of the receiver, thereby controlling receiver selectivity. Proper adjustment of this control helps to eliminate noise and interfering signals. If the bandwidth is set too narrow, part of the incoming signal will, of course, be lost.

d. Beat frequency oscillator: Some radio transmissions, such as Morse telegraphy and FSK teletype contain no audio frequency information when they are received. The R-390A is equipped with a Beat Frequency Oscillator (BFO) to produce an audible output if required. The BFO is activated by the BFO On-Off switch and the pitch of the audio output can be adjusted by the BFO Pitch Knob.

e. Gain control: The R-390A has three front panel gain controls. The RF GAIN control permits manual adjustment of the gain of the RF and I-F sections of the receiver. The LOCAL GAIN and LINE GAIN knobs control the gain of the a-f circuits. The LOCAL GAIN controls adjust the level of the output to the phone jack. The LINE GAIN controls the level of the audio output used to operate terminal equipment.

f. Antenna trimmer: The front panel control labeled ANT TRIM adjusts the input circuit in such a manner that optimum coupling from the antenna to the receiver can be achieved at each frequency.

g. Audio response: The AUDIO RESPONSE control, which adjusts the bandwidth of the audio circuits, has two settings: SHARP and WIDE. The setting of this control depends on the type of signal received.

h. Limiter: When the control labeled LIMITER is activated, the operator can control the amplitude of the audio output circuits to predetermined limits. The setting of the limiter control depends on the type of signals received. A low setting of the control, for example, would be desirable to prevent loud crashes of static in the output when monitoring voice signals. If the received signal is fsk-modulated, it may be desirable to remove all amplitude variations by using a high setting on the LIMITER control. For many types of reception, however, the LIMITER should not be activated.

i. Break-in: The ON-OFF switch labeled BREAK IN is used when a receiver and transmitter are operated together as a radio set. In the ON position, circuits are activated for removing the antenna from the receiver and for grounding the antenna and receiver audio circuits whenever the transmitter is energized.

j. Indicators: Three indicators are mounted on the front panel of the R-390A. The frequency indicator dial indicates the frequency to which the receiver is tuned. This dial is of the digital-counter type, which permits frequency to be read directly with little chance of misreading.

THE CARRIER LEVEL indicator—a meter measures the level of the RF signal appearing at the input of the receiver. The operator will find this meter valuable in tuning to the exact frequency that gives the strongest signal. It is also used to indicate proper adjustment of the antenna trimmer. The indicator labeled LINE LEVEL monitors the level of the line audio out used to drive the terminal equipment. This meter is placed across the output circuit by the LINE METER switch. The three available values of meter sensitivity (voltage required for full-scale deflection) are determined by the setting of the LINE METER switch. This meter is valuable in maintaining the proper output level when making tape recordings.

APPENDIX II

CONVERTER COMPARATOR GROUP AN/URA-17C OPERATING PROCEDURES

All controls normally used during operation are located on the front panels of the two identical convertors (figure A2-1). Table A2-1 lists all operator's controls by name and function. Other controls are to be adjusted only by a maintenance technician.

The operator has a choice of two modes of operation: (1) single-receiver operation or (2) diversity operation.

Ascertain if equipment is connected for single or diversity receiver operation. Allow the associated receivers and teletype printer(s) to warm up. Turn the converter POWER switches to the ON (up) position and allow a five minute warmup period.

Proper tuning of the receivers feeding the converters is important. Good communications are often the result of properly tuned receiver. Each converter has a small oscilloscope mounted in the front which supplies the operator with a visual presentation of the input signal into the converter. The scope patterns for correct and incorrect tuning are shown in figure A2-2. Following is a step by step summary of operating procedures for single receiver operation and diversity operation.

Single-Receiver Operation.—

1. Turn receiver and teletype printer power switches to On.

2. Set converter controls as follows:
   a. POWER switch to ON.
   b. FUNCTION switch to TUNE.

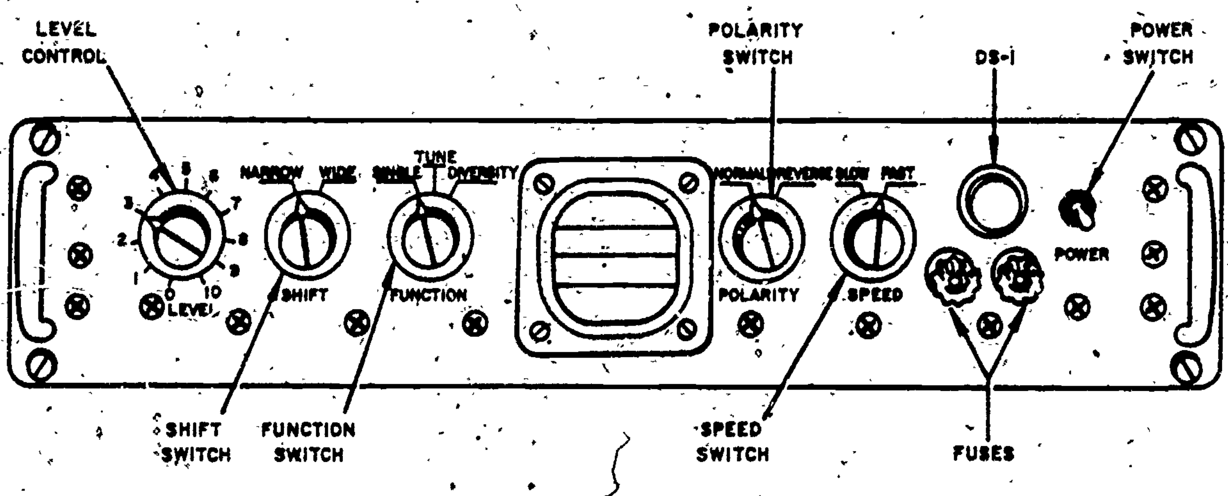

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Figure A2-1.—AN/URA-17 frequency-shift converter, front panel controls.

Table A2-1.—Frequency shift converter CV-483C/URA-17 operating controls

CONTROL	POSITION	FUNCTION
LEVEL	Variable, 0 to 10	Adjusts the signal level to the discriminator.
SHIFT	NARROW	Selects the narrow input filter and discriminator (10 to 200 cps shift width).
	WIDE	Selects the wide input filter and discriminator (200 to 1000 cps shift width).
FUNCTION	SINGLE	Used for single-receiver operation.
	TUNE	Used when tuning the receiver (removes the input signal from teletype printer).
	DIVERSITY	Used for diversity operation.
POLARITY	NORMAL	Used when keying pulses are of normal polarity.
	REVERSE	Used when keying pulses are of reversed polarity.
SPEED	FAST	Used for high speed keying signals.
	SLOW	Used for low speed keying signals.
POWER	On - Off	Turns line voltage on and off.

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c. POLARITY switch to NORMAL.

d. LEVEL control to 3.

e. SHIFT switch to WIDE (for wide-shift signals) or to NARROW (for narrow-shift signals).

3. Set receiver controls as follows:

a. Set receiver bfo to 1 kc for narrow-shift signals or to 2.0 kc for wide-shift signals.

b. Tune receiver to desired rf signal.

c. Set receiver bandwidth to approximately 3 kc for wide-shift signals or to approximately 800 cps for narrow-shift signals.

d. Tune receiver for strongest beat-note.

e. Tune receiver for symmetrical, vertically centered pattern on converter tuning indicator. (If two receiver tuning positions occur, use stronger.)

f. Adjust receiver audio output to 60 milliwatts.

4. Set converter SPEED switch to SLOW for single-channel teletype signals or to FAST for four-channel, time-division multiplex.

5. Adjust converter LEVEL control until pattern fills space between upper and lower horizontal lines on crt.

6. Set converter FUNCTION switch to SINGLE.

NOTE

If teletype printer is printing garbled copy, set converter POLARITY switch to REVERSE.

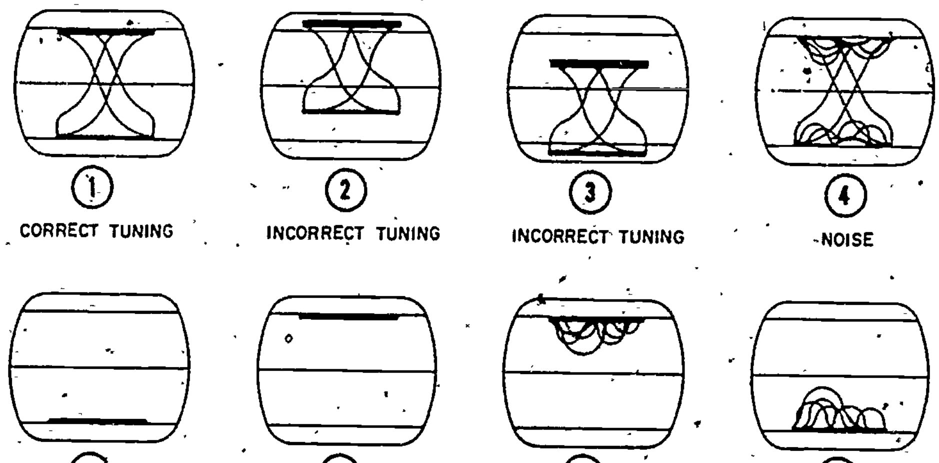

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Figure A2-2.—Monitor oscilloscope patterns for frequency-shift converters.

TO SECURE.

Turn converter POWER switch to Off.

Diversity Operation.—

1. Turn receiver and teletype printer power switches to On.

2. Set controls on one converter as follows:

a. POWER switch to On.

b. FUNCTION switch to TUNE.

c. POLARITY switch to NORMAL.

d. LEVEL control to 3.

e. SHIFT switch to WIDE for wide-shift signals or to NARROW for narrow-shift signals.

3. Adjust associated receiver controls as follows:

a. SET receiver bfo to 1 kc for narrow-shift signals or to 2.0 kc for wide-shift signals. If receiver has agc switch, turn on.

b. Tune receiver to desired rf signal.

c. Set receiver bandwidth to approximately 3 kc for wide-shift signals or to approximately 800 cps for narrow-shift signals.

d. Tune receiver for strongest beat-note.

e. Tune receiver for symmetrical, vertically centered pattern on converter tuning indicator. (If two receiver tuning positions occur, use stronger.)

f. Adjust receiver audio output to 60 milliwatts.

4. Set converter SPEED switch to SLOW for single-channel teletype signals or to FAST for four-channel, time-division multiplex.

5. Adjust converter LEVEL control until pattern fills space between upper and lower horizontal lines on crt.

6. Set converter FUNCTION switch to DIVERSITY.

NOTE

If teletype printer is printing garbled copy, set converter POLARITY switch to REVERSE.

7. Set FUNCTION switch to TUNE.

8. Repeat steps 2 through 6 for second converter.

9. If teletype printer is printing garbled copy, set converter POLARITY switch to REVERSE.

10. Set FUNCTION switch of first converter to DIVERSITY. To secure turn power switches of both converters to OFF.

APPENDIX III

AMERICAN STANDARD CODE FOR INFORMATION INTERCHANGE (ASCII)

Modern technology has led to the improvement of telecommunication capabilities in many areas, thus improving the quality and speed of communications. Throughout this manual we discussed the concept and objectives of some automated systems and data transmissions. To accomplish data transmissions a new code was needed because of the specific limitations to the teletypewriter 5-unit code.

The ASCII Code was developed for data transmission and provides for additional symbols and also parity checking (error detection) of transmitted data. (Refer to Chapter 9 of this manual for more details on the ASCII Code). Figure A3-1 illustrates the ASCII code and a legend of characters listed in columns 0 and 1. The discussion that follows applies to ASCII control as they apply to Model 40 Data Terminals.

MODEL 40 DATA TERMINALS

ON-LINE TERMINAL CONTROLS

Receipt of ASCII Controls

Receipt of the following ASCII controls cause the following actions to be performed:

ETX (End of Text)—Displays symbol E_X and switches terminal from receiving mode to local mode, unless option elected not to. Also feeds out 16 blank lines of paper from printer, if option elected. Receiver-only printer terminal feeds paper only.

EOT (End of Transmission)—Displays symbol E_T and switches terminal from receiving mode to local mode, unless option elected not to. Ignored by receive-only printer terminal.

BEL (Bell)—Displays symbol B_L and causes beep sound.

BS (Back Space)—Moves cursor left, one character.

HT (Horizontal Tab)—Displays symbol ▶ and moves cursor to first tab stop on right, if equipped with tab control feature. If there is no tab setting on right, cursor moves to start of next line. If there is protected data en route the cursor stops instead at first unprotected character following protected data, whether on that line or next line. If not equipped with tab control feature, the cursor moves one character to the right after displaying ▶.

NL (New Line)—Displays symbol ≡ and moves cursor to start of next line, and causes printer to print next character at start of next line. Also scrolls display up on line if cursor was on last line on screen.

VT (Vertical Tab)—Displays symbol V_T and causes printer to print next character at start of next line.

FF (Form Feed)—Displays symbol F_F and switches terminal from receiving mode to local mode, unless option elected not to. Causes printer to print next character at start of next line.

B7 B6 B5 →					0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
B4	B3	B2	B1	COLUMN → / ROW ↓	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	\	P	@	[illegible]
0	0	0	1	1	SOH	DC1	!	1	A	Q	[illegible]	[illegible]
0	0	1	0	2	STX	DC2	"	2	B	R	[illegible]	[illegible]
0	0	1	1	3	ETX	DC3	#	3	C	S	[illegible]	[illegible]
0	1	0	0	4	EOT	DC4	$	4	D	T	[illegible]	[illegible]
0	1	0	1	5	ENQ	NAK	%	5	E	U	[illegible]	[illegible]
0	1	1	0	6	ACK	SYN	&	6	F	V	[illegible]	[illegible]
0	1	1	1	7	BEL	ETB	/	7	G	W	[illegible]	[illegible]
1	0	0	0	8	BS	CAN	(	8	H	X	[illegible]	[illegible]
1	0	0	1	9	HT	EM	)	9	I	Y	[illegible]	[illegible]
1	0	1	0	10	LF	SS	•	:	J	Z	[illegible]	[illegible]
1	0	1	1	11	VT	ESC	+	;	K	[	[illegible]	[illegible]
1	1	0	0	12	FF	FS	,	<	L	~	[illegible]	[illegible]
1	1	0	1	13	CR	GS	–	=	M	]	[illegible]	[illegible]
1	1	1	0	14	SO	RS	.	>	N	^	[illegible]	[illegible]
1	1	1	1	15	SI	US	/	?	O	—	[illegible]	DEL

NOTE: THE UNSHADED AREAS INDICATE THE PRINTABLE CHARACTERS

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Figure A3-1.—American Standard Code for Information Interchange (ASCII).

LEGEND

NUL... NULL/IDLE. A character which may be inserted into or removed from a stream of data without affecting the information content of that stream. Some transmission systems may not be able to accept the use of this charactor.

SOH... START OF HEADING. A transmission control character used at the beginning of a sequence of characters which comprise a machine-sensible address or routing information. Such a sequence is referred to as the heading.

STX... START OF TEXT. A transmission control character which precedes a sequence of characters that is to be treated as an entity and entirely transmitted through to the ultimate destination. Such a sequence is referred to as text.

ETX... END OF TEXT. A transmission control character used to terminate a sequence of characters started with STX and transmitted as an entity.

EOT... END OF TRANSMISSION. A transmission control character used to indicate the end of transmission.

ENQ... ENQUIRY. A transmission control character reserved for use in data communication systems as a request for a response from a remote station. The response may include station identification and/or station status.

ACK... ACKNOWLEDGE. A transmission control character transmitted by a receiver as a positive response to a sender.

BEL... A character for use when there is a need to call for human attention; it may control alarm or attention devices.

BS... BACKSPACE. A layout character which controls the movement of the printing position one printing space backward on the same printing line.

HT... HORIZONTAL TABULATION. A layout character which controls the movement of the printing position to the next in a series of predetermined positions along the printing line.

LF... LINE FEED. A layout character which controls the movement of the printing position to the next line.

VT... VERTICAL TABULATION. A layout character which controls the movement of the printing position to the next of a series of predetermined printing lines.

FF... FORM FEED. A layout character which controls the movement of the printing position to the first predetermined printing line on the next form.

CR... CARRIAGE RETURN. A layout character which controls the movement of the printing position to the first printing position on the same printing line.

SO... SHIFT OUT. The shift-out character means that all the code combinations which follow shall be interpreted as outside of the character set of the standard code table until a shift-in character is reached.

SI... SHIFT-IN. The shift-in character means that all the code combinations which follow shall be interpreted according to the standard code table.

DLE... DATA LINK ESCAPE. A transmission control character which will change the meaning of the following code combination(s). It is used exclusively to provide supplementary control in data transmission networks.

DC1-DC4.. DEVICE CONTROLS.

NAK... NEGATIVE ACKNOWLEDGE. A transmission control character transmitted by a receiver as a negative response to the sender.

SYN... SYNCHRONOUS IDLE. A transmission control character used by a synchronous transmission system in the absence of any other character (condition to provide a signal from which synchronism may be achieved or retained).

ETB... END OF TRANSMISSION BLOCK. A transmission control character used to indicate the end of a block of data for transmission purposes.

CAN... CANCEL. A character used to indicate that the data with which it is associated is in error or is to be disregarded.

EM . . . END OF MEDIUM. A control character which may be used to identify the physical end of the medium, or the end of the used, or wanted, portion of information recorded on a medium. The position of this character does not necessarily correspond to the physical end of the medium.

SS . . . START OF SPECIAL SEQUENCE. A character which is used to indicate the start of a variable length sequence of characters which have special significance or which are to receive special handling. This SS may be used for transmission control purposes.

ESC . . . ESCAPE. A functional character which may be used for an extension of the standard character set of the code by changing the meaning of the next single following code combination. The precise meaning of this following character requires prior agreement between the sender and the recipient of the data. The "ESCAPE" character itself may therefore be regarded as a warning or non-locking shift character affecting the next single following character. The single character which follows "ESCAPE" may be interpreted as a graphic or control character not included in the standard set. Alternatively the meaning of this single character may be "go into code X and stay in it."

FS . . . FILE SEPARATOR. (See IS for definition)

GS . . . GROUP SEPARATOR. (See IS for definition)

RS . . . RECORD SEPARATOR. (See IS for definition)

US . . . UNIT SEPARATOR. (See IS for definition)

IS . . . INFORMATION SEPARATOR. There are four information separators (FS, GS, RS, US) which have a hierarchial relationship with each other. They are related, as follows:
UNIT SEPARATOR (US), RECORD SEPARATOR (RS), GROUP SEPARATOR (GS), and FILE SEPARATOR (FS). (FS) is the most powerful separator. A "UNIT" cannot include a "FILE", "GROUP", or "RECORD."

A "RECORD" may include (and if it includes, it includes completely) a variable number (none, one or more) of "UNITS."

A "RECORD" cannot include "FILE" or "GROUP."

A "GROUP" may include (and if it includes, it includes completely) a variable number (none, one or more) of "RECORDS" and/or "UNITS." A "GROUP" cannot include a "FILE."

A "FILE" may include (and if it includes, it includes completely) a variable number (none, one, or more) of "GROUPS", "RECORDS", and/or "UNITS."

SP . . . SPACE. A normally non-printing graphic character used to separate words. It is also a layout character which controls the movement of the printing position, one printing position in the forward direction.

CR (Carriage Return)–Display symbol ← and causes printer to print next character at start of line, unless option elected not to.

DLE EOT sequence (Data Link Escape, End of Transmission)–Displays symbols D_L and E_T and causes terminal to disconnect from line and switches it from receiving mode to local mode. Receive-only printer terminal disconnects only.

GS (Group Separator)–Displays symbol G_S and switches terminal from receiving mode to local mode, unless option elected not to. Ignored by receive-only printer terminal.

Receipt of ESC (Escape) Sequences

Receipt of the following ESC (Escape)—character sequences cause the following actions to be performed, if the terminal is so equipped and the option is elected to perform them. Terminals not equipped or not elected to perform the actions display the sequence symbols instead.

ESC 0 (zero) sequence—Sets a tab stop and displays the tab symbol . (a small dot at the lower left-hand corner of the character position) at the cursor location, on that line only.

ESC 1 sequence—Sets tab stops and displays tab symbols at the cursor location, on that line and on all lines below, to the end of display memory.

ESC 2 sequence—Clears tab stops from the cursor location to the end of the line, on that line and on all lines below, to the end of display memory.

ESC @ sequence—Moves cursor to first tab stop on right. If no tab setting on right, cursor moves to start of next line. If there is protected data en route, the cursor stops instead at first unprotected character following protected data, whether on that line or the next line.

ESC 7—Moves cursor up, one line.

ESC B—Moves cursor down one line.

ESC C—Moves cursor right, one character.

ESC G—Moves cursor to start of line.

ESC H—Advances display to first segment and moves cursor to start of first line.

ESC 3—Causes characters that follow to be highlighted.

ESC 4—Causes characters that follow to not be highlighted.

ESC W—Puts terminal in protected data mode, during which all received data will be displayed as protected data, and during which receipt of ESC J will cause protected as well as unprotected data to be cleared.

ESC X—Removes terminal from protected data mode.

ESC J—Clears all unprotected data from all lines below line cursor is on and to the right of the cursor on the line the cursor is on.

ESC R sequence—Advances display to first segment, moves cursor to start of first line and clears all data from display memory, whether protected or unprotected, and all tab stops.

Transmission of ASCII Controls

Transmission of the following ASCII controls from the terminal cause the following actions to be performed by the terminal:

ETX (End of Text)—Halts transmission and switches terminal from send mode to receive or local mode, depending on option elected, or does not switch mode at all if option elected not to.

EOT (End of Transmission)—Halts transmission and switches terminal from send mode to receive mode, unless option elected not to.

GS (Group Separator)—Halts transmission and switches terminal from send mode to receive or local mode, depending on option elected, or does not switch mode at all if option elected not to.

FF (Form Feed)—Halts transmission and switches terminal from send mode to receive or local mode, depending on option elected, or does not switch mode at all if option elected not to.

Transmission of ESC (Escape) Sequences

Transmission of the following ESC (Escape)—character sequences can be elected to accompany the transmission of data stored in display memory:

ESC 3—Precedes transmission of each block of highlighted characters.

ESC 4—Follows transmission of each block of highlighted characters.

ESC W—Precedes transmission of each block of protected characters.

ESC X—Follows transmission of each block of protected characters.

ESC 0 (zero)—Transmitted ahead of character at any location where there is a tab stop setting.

APPENDIX IV

DIGITAL DATA DISTORTION TEST SET AN/USM329(V) OPERATING PROCEDURES

SECTION I

SIGNAL GENERATOR OPERATING DATA

a. CONTROLS AND INDICATORS.–The controls and indicators of the signal generator are shown in figure A4-1 and listed in table A4-1.

b. POWER TURN-ON.–Power is applied to the generator by the POWER switch (18, figure A4-1). Check that POWER lamp (13) goes on when the switch is set to its ON position.

c. OPERATING PROCEDURES.–The operation of the signal generator is largely dependent on the type of signal desired. The signal, in turn, is determined by the settings of the generator front panel controls. The front panel controls, and their functional relationship to the output signal, are shown in figure A4-2. Note that for convenience, the diagram is divided into four parts as follows:

Selection of signal pattern
Selection of signal characteristics
Selection of distortion
Selection of output circuit

> **NOTE**
>
> The implied sequence and left-to-right flow shown in figure A4-2 is for illustrative purposes only. It does not represent signal flow. The controls may be set in any sequence desired by the operator.

(1) SELECTION OF SIGNAL PATTERN.–The OUTPUT switch (22, figure A4-1) selects the type of signal pattern. As shown in figure A4-2 selection of the steady mark (STDY MK) or steady space (STDY SP) signal routes these signals direct to the output circuit. Selection of CHARACTER involves the MARK/SPACE switches (6 through 11, figure A4-1), which must be set to the desired character; and the CODE LEVEL switch, which must be set to the desired unit level. The MESSAGE position selects the Fox Message signal pattern, which is available in the 5-unit code, The REVERSALS position selects the mark-to-space-to-mark reversal pattern.

(2) SELECTION OF SIGNAL CHARACTERISTICS.–Five switches are involved in setting the general characteristics of the output signal: the RATE switch (28), the TIME BASE switch (23), the SYNC-START/STOP (Stop Length) switch (27), and the CHARACTER RELEASE switch (25) with the associated SINGLE CHARACTER switch (24). The RATE switch sets the baud rate of the signal. The TIME BASE switch selects either the internal timing generator or an external timing signal connected to the EXT TIMING connector. The SYNC-START/STOP (Stop Length) switch selects either synchronous or start/stop operation with four options on the method of signal transmission:

(a) In the SINGLE CHAR position, a start/stop signal is released one character at a time each time the SINGLE CHARACTER switch is pressed.

(b) In the EXT STEP position, a start/stop signal is released one character at a time each time an external step input is applied to the External Step Input terminals located on the rear panel of the signal generator.

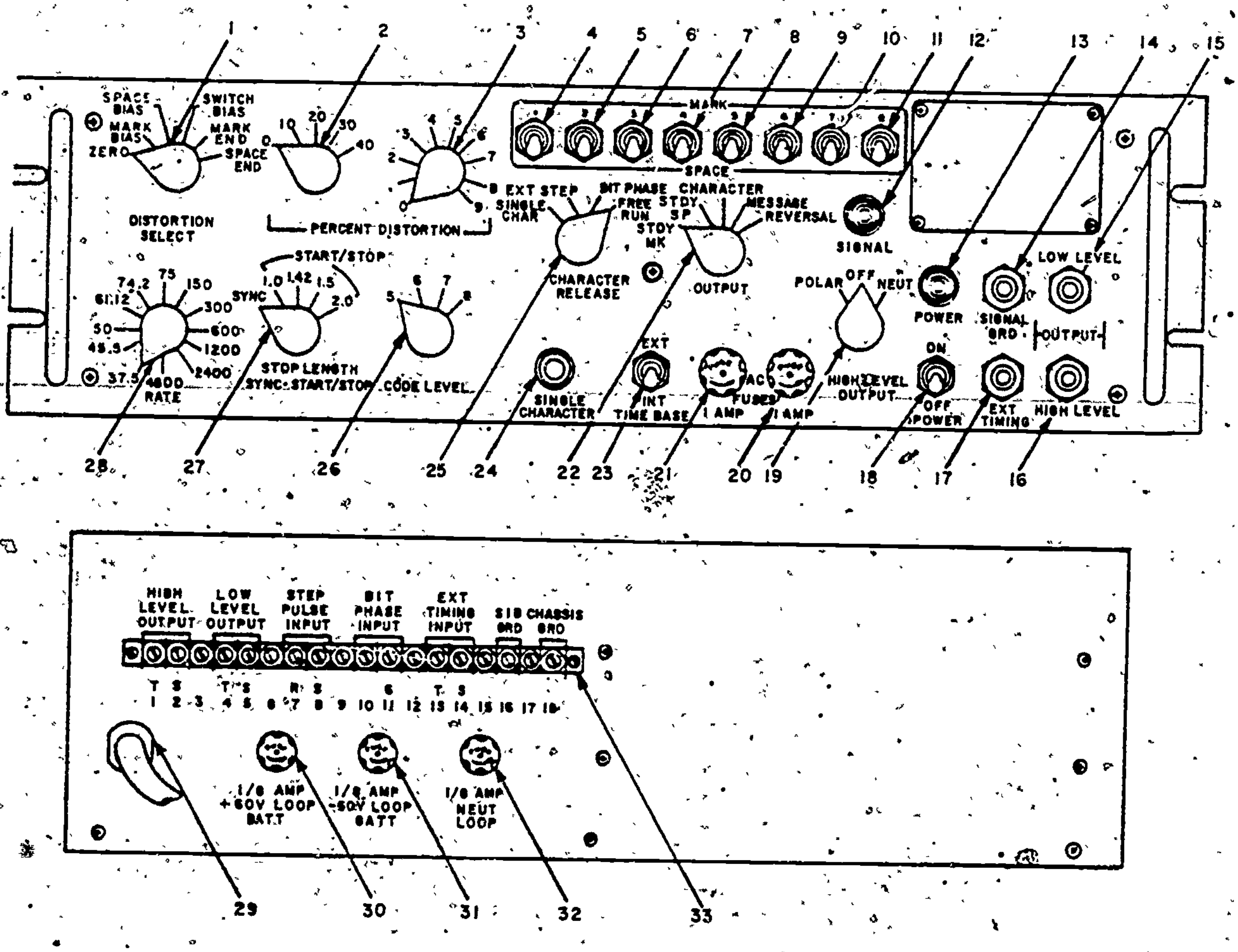

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Figure A4-1.—Signal generator controls and indicators.

(c) In the BIT PHASE position, a synchronous signal is phase-locked with an external bit-phase timing signal to ensure that the signal generator output is synchronized with the timing generator in the receiving unit.

(d) In the FREE RUN position, the signal (synchronous and start/stop) is released continuously without interruption.

(3) SELECTION OF DISTORTION.—The amount and type of distortion are selected on three switches. The DISTORTION SELECT switch (1) selects one of five types of distortion: mark-bias, space bias, switch bias, mark end, and space end. Refer to figure A4-3 for examples of these distortions. The amount of distortion is selected on the PERCENT DISTORTION switches (2 and 3) which set the amount in tens and units, respectively.

(4) SELECTION OF OUTPUT CIRCUIT.—The signal generator provides both high and low level outputs. The LOW LEVEL jack (15) provides a low-level polar output at ±6 volts established by an internal power supply. This jack and the corresponding terminals at the rear of the signal generator should be used for low-level polar output connections. For high-level polar and neutral signals, the HIGH LEVEL jack (16) should be used. With the HIGH LEVEL OUTPUT switch (19) in the POLAR position, the output signal available at the HIGH LEVEL jack is a ±60 volt polar signal (negative mark). The same signal is also available

Table A4-1.—Signal generator controls and indicators

FIGURE A4-1 INDEX NO.	CONTROL OR INDICATOR	FUNCTION
1	DISTORTION SELECT Switch	Selects type of distortion of output test signal
2	PERCENT DISTORTION Switch (TENS)	Selects percent distortion in output test signal in units of 0, 10, 20, 30, and 40
3	PERCENT DISTORTION Switch (UNITS)	Selects percent distortion in output test signal in units from 0 to 9
4	MARK/SPACE 1 Switch	One of a set of 8 switches. Sets first digit to mark (up) or space (down)
5	MARK/SPACE 2 Switch	Sets second digit to mark or space
6	MARK/SPACE 3 Switch	Sets third digit to mark or space
7	MARK/SPACE 4 Switch	Sets fourth digit to mark or space
8	MARK/SPACE 5 Switch	Sets fifth digit to mark or space
9	MARK/SPACE 6 Switch	Sets sixth digit to mark or space
10	MARK/SPACE 7 Switch	Sets seventh digit to mark or space
11	MARK/SPACE 8 Switch	Sets eighth digit to mark or space
12	SIGNAL Indicator Lamp	Illuminates to show presence and type of signal: glows steadily for steady mark, remains off for steady space and blinks for keying signal
13	POWER Indicator Lamp	Illuminates when ac power is applied to the signal generator
14	SIGNAL GRD Jack	Connector signal ground
15	OUTPUT - LOW LEVEL Jack	Connector for low level output signals
16	OUTPUT - HIGH LEVEL Jack	Connector for high level output signal
17	EXT TIMING Jack	Input connector for external timing signal
18	POWER Switch	Ac power switch for signal generator.

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Table A4-1.—Signal generator controls and indicators—continued

FIGURE A4-1 INDEX NO.	CONTROL OR INDICATOR	FUNCTION
19	HIGH LEVEL OUTPUT Switch	3-position selector switch that selects either polar or neutral signal circuits
20	AC FUSES - 1 AMP Fuse	1-ampere 250-volt fuse connected to one side of input power line
21	AC FUSES - 1 AMP Fuse	1-ampere 250-volt fuse connected to one side of input power line
22	OUTPUT Selector Switch	Selects type of output signal. In STDY MK, the output consists of a continuous mark signal. In STDY SP, the output consists of a continuous space signal. In CHARACTER, the output consists of the 5- to 8-unit character selected on the MARK/SPACE switches. In MESSAGE, the output consists of the Fox message. In REVERSALS 1:1, the output consists of alternate marks and spaces
23	TIME BASE Switch	Selects either the internal or external timing signal
24	SINGLE CHARACTER Pushbutton Switch	Operates in conjunction with CHARACTER RELEASE switch set to SINGLE CHAR position
25	CHARACTER RELEASE Switch	Selects character release operating mode. In SINGLE CHAR, the output is released as single characters each time the SINGLE CHARACTER switch is pressed. In EXT STEP, the output is released when a step signal is applied to the external step input connector. In BIT PHASE, the internal timing reference is synchronized with an external timing reference. In FREE RUN, the output signal is continuous
26	CODE LEVEL Switch	Selects 5-, 6-, 7-, or 8-unit code levels in conjunction with the MARK/SPACE toggle switches

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Table A4-1.—Signal generator controls and indicators—continued

FIGURE A4-1 INDEX NO.	CONTROL OR INDICATOR	FUNCTION
27	SYNC-START/STOP Switch (STOP LENGTH)	Selects synchronous or start/stop mode. Also selects stop length in start/stop mode
28	RATE Switch	Selects baud rate from 37.5 to 4800 of internal time base
29	Power line cord	Applies 115 volts 60 Hz power to the unit.
30	+60V LOOP BATT fuse	Fuses +60V loop battery line.
31	-60V LOOP BATT fuse	Fuses -60V loop battery line
32	NEUT LOOP fuse	Fuses neutral loop
33	Terminal Block TB1	Provides input and output terminations.

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at the corresponding high level terminals at the rear of the signal generator. With the HIGH LEVEL OUTPUT switch in the NEUTRAL position, the output signal drives an electronic switch (closed for mark) connected to the HIGH LEVEL jack. This jack and the corresponding terminals at the rear of the signal generator should be used for all neutral outputs and high level polar outputs.

(a) The SIGNAL lamp (12), shown in the output circuit, goes on whenever the output of the signal generator is at the mark level and goes off whenever the signal is at the space level. Hence, for a steady mark signal, the lamp glows steadily. For a steady space signal, the lamp remains off. And for keying signals the lamp blinks on and off.

OPERATING PRECAUTIONS

The following summary of operating precautions and general information is provided for use by the operator.

a. The external timing input signal must be 200 times the desired baud rate. The external timing input must be a square wave having an amplitude of ±6 volts.

b. The external step input signal must be a 12-volt positive-going pulse (-6 to +6 to -6 volts) at least 20 milliseconds wide.

c. The external bit-phase input signal must be a square wave having an amplitude of ±6 volts.

WARNING

Observe the following precaution when connecting the signal generator to the signal loop to prevent voltage from appearing on the test cable tip and presenting a shock hazard.

Polar outputs: Connect test cable to signal loop before connecting test cable to signal generator (generator provides loop voltage).

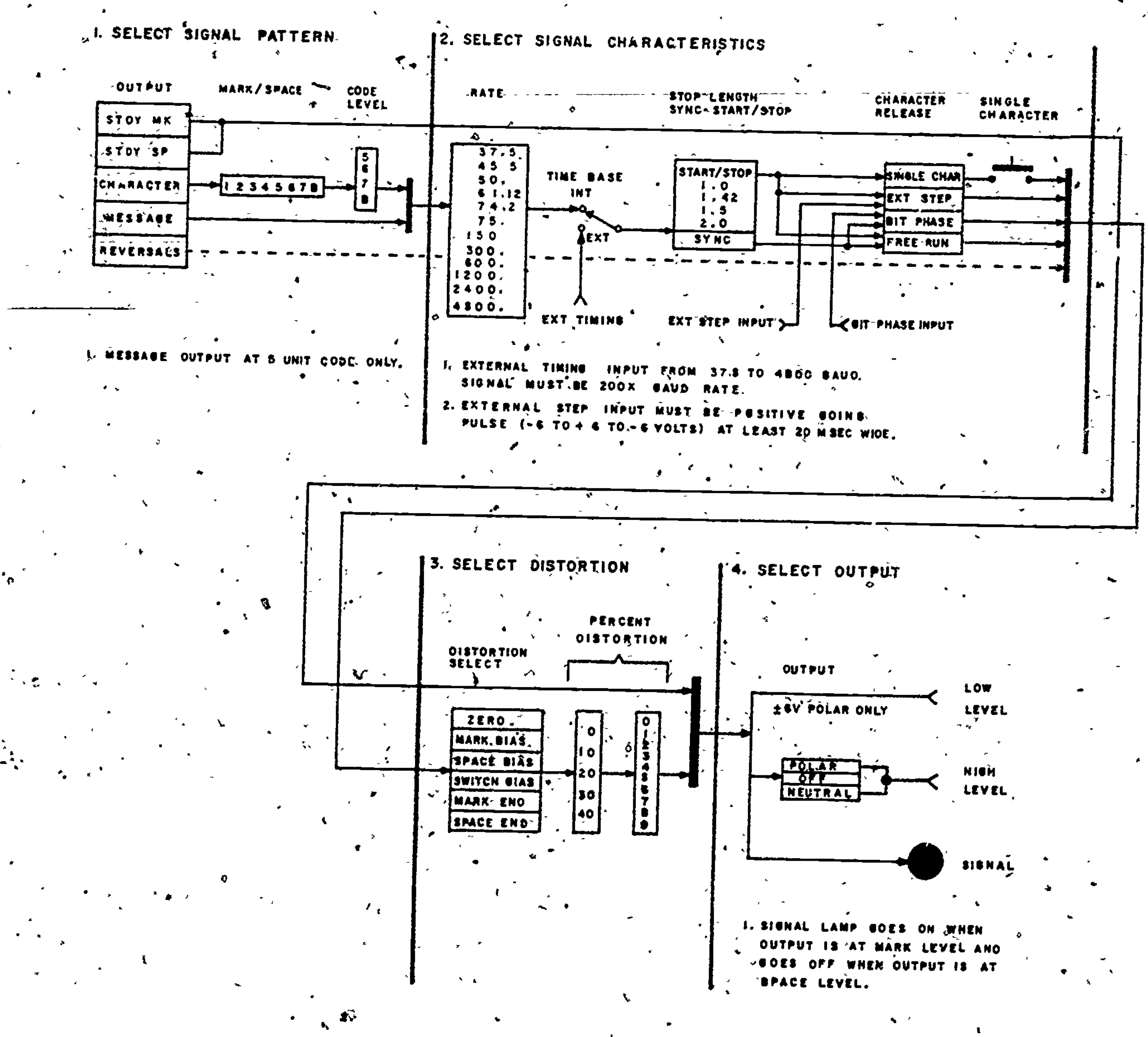

Figure A4-2.—Functional operation, signal generator.

> Neutral outputs: Connect test cable to signal generator before connecting test cable to signal loop (station provides loop voltage).

OPERATOR'S MAINTENANCE

Maintenance required by the operator is limited to replacement of the lamps and fuses in the signal generator.

SECTION II
ANALYZER-OSCILLOSCOPE

ANALYZER-OSCILLOSCOPE OPERATING DATA

The following procedures and instructions apply to both the analyzer and oscilloscope. If the analyzer is used without the oscilloscope, the instructions that apply to the oscilloscope

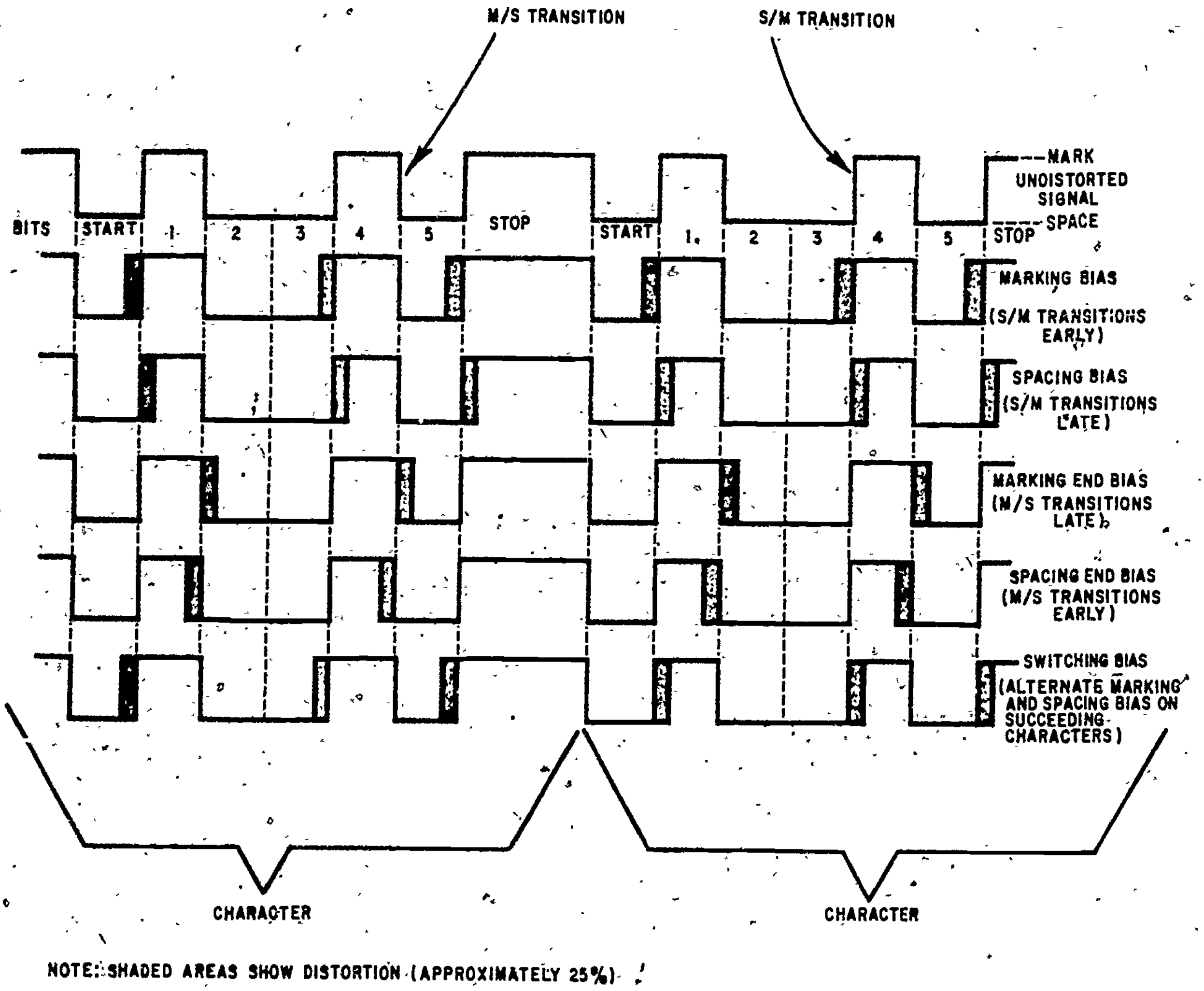

Figure A4-3.—Examples of telegraph distortion.

may be disregarded. Separate operation of the oscilloscope is not recommended.

a. CONTROLS AND INDICATORS.—The controls and indicators for the analyzer and oscilloscope are shown in figures A4-4 and A4-5 and listed in tables A4-2 and A4-3.

b. ANALYZER-OSCILLOSCOPE TURN-ON PROCEDURE.—Perform the following procedure to turn on the analyzer-oscilloscope units:

(1) On analyzer, set POWER switch (14) to ON; check that POWER lamp (9) goes on.

(2) Set analyzer controls as follows:

(a) MODE switch (18) to type of signal to be measured.

(b) RATE switch (4) to rate of signal to be measured.

(c) POLARITY switch (6) to polarity sense of signal to be measured.

(d) RESET switch (19) to OFF.

(e) FILTER switch (8) to OUT.

(f) TIME BASE switch (2) to INT.

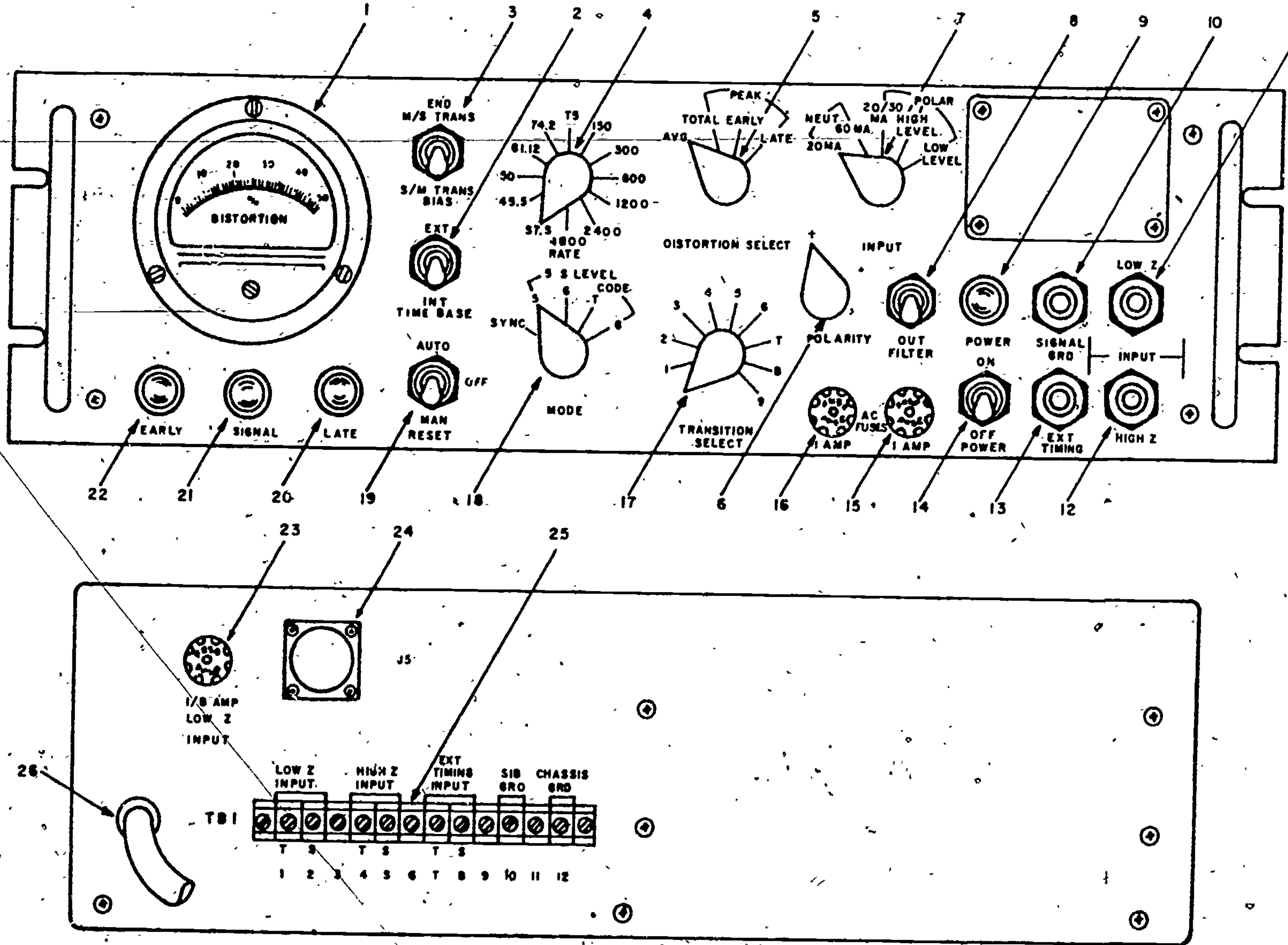

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Figure A4-4.—Analyzer controls and indicators.

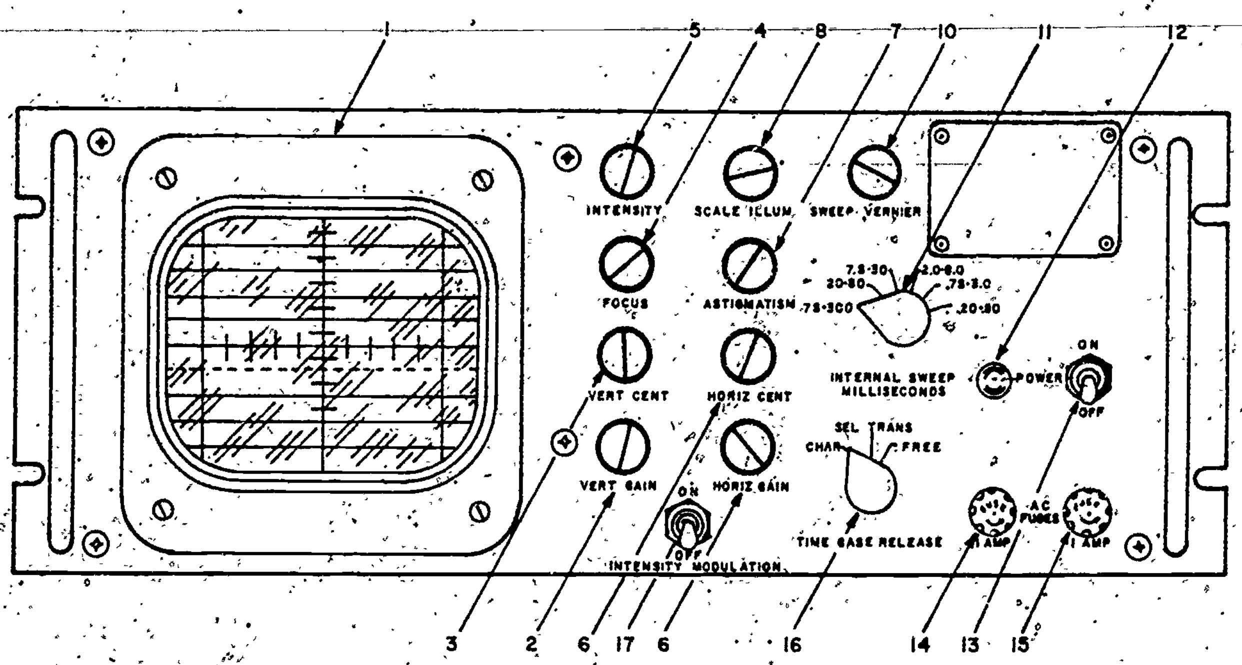

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Figure A4-5.—Oscilloscope controls and indicators.

> **NOTE**
>
> If external timing signal is to be used in lieu of internal time base generator of analyzer, connect external signal to EXT TIMING jack (13) and set TIME BASE switch to EXT.

(3) On oscilloscope, set POWER switch (13, figure A4-5) to ON; check that POWER lamp (12) goes on.

(4) Adjust following oscilloscope controls as required to obtain a clean centrally positioned trace on oscilloscope CRT (1):

(a) INTENSITY control (5).
(b) SCALE ILLUMINATION (8).
(c) FOCUS control (4).
(d) ASTIGMATISM control (7).
(e) VERT CENT control (3).
(f) HORIZ CENT control (6).
(g) HORIZ GAIN control (9).

(5) Set oscilloscope controls to initial settings:

(a) VERT GAIN control (2) to midposition.

(b) INTENSITY MODULATION switch (17) to OFF.

(c) INTERNAL SWEEP MILLISECONDS switch (11) to approximate rate of signal to be measured.

(d) SWEEP VERNIER control (10) to midposition.

(e) TIME BASE RELEASE switch (16) to CHAR.

(6) Set INPUT switch (7, figure A4-4) to required position.

> **CAUTION**
>
> Always connect test cable to analyzer before connecting test cable to signal loop.

(7) Connect analyzer to signal loop as follows:

(a) For current signals, connect analyzer in series using INPUT LOW Z jack (11).

Table A4-2.—Analyzer controls and indicators

FIGURE A4-4 INDEX NO.	CONTROL OR INDICATOR	FUNCTION
1	% DISTORTION Meter	Measures percentage distortion from 0 to 50 in 1% increments
2	TIME BASE Switch	Selects either external or internal time base. The external timing signal is connected through EXT TIMING jack
3	END M/S TRANS-S/M TRANS BIAS Switch (M/S-S/M Switch)	Selects either mark-to-space or space-to-mark transitions for analysis of end distortion and bias distortion, respectively
4	RATE Switch	Selects baud rate from 37.5 to 4800 of internal time base
5	DISTORTION SELECT Switch	Selects type of distortion (average or peak) for analysis. Also selects total, early, and late for peak distortion measurements
6	POLARITY Switch	Reverses polarity of input signal
7	INPUT Switch	Selects either polar or neutral input circuits. The two neutral positions are current inputs at 20 and 60 ma, respectively. The 20-30 ma position is the polar current input and the high and low level polar positions are the high and low voltage inputs, respectively
8	FILTER Switch	Connects filter used to remove spikes and holes in input waveform. Usable up to 150 baud
9	POWER Indicator Lamp	Illuminates when ac power is applied to the analyzer
10	SIGNAL GRD Jack	Connector for signal ground
11	INPUT - LOW Z Jack	Input connector for current signals
12	INPUT - HIGH Z Jack	Input connector for all voltage signals
13	EXT TIMING Jack	Input connector for all external timing signals

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Table A4-2.--Analyzer controls and indicators--continued

FIGURE A4-4 INDEX NO.	CONTROL OR INDICATOR	FUNCTION
14	POWER Switch	Ac power switch for analyzer
15	AC FUSES - 1 AMP Fuse	1-ampere 250-volt fuse connected to one side of input power line
16	AC FUSES - 1 AMP Fuse	1-ampere 250-volt fuse connected to one side of input power line
17	TRANSITION SELECT Switch	Selects either all or 1 of 9 specific transitions for analysis and display
18	MODE Switch	Selects synchronous or start/stop mode. Also selects 5-, 6-, 7-, or 8- unit codes.
19	RESET Switch	Selects automatic or manual reset of output meter. Center position is off
20	LATE Indicator Lamp	Illuminates during average distortion measurements to indicate marking end and spacing bias distortion
21	SIGNAL Indicator Lamp	Illuminates to show presence and type of signal. Glows steadily for steady mark, remains off for steady space, and blinks for keying signal
22	EARLY Indicator Lamp	Illuminates when making average distortion measurement to indicate marking bias or spacing end distortion
23	LOW Z INPUT fuse	Fuses low impedance input line
24	J5 connector	Connector for Analyzer to Oscilloscope cable
25	TB1 terminal board	Provides connection for input signals
26	Input power cable	Provides for connection of input power

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Table A4-3.—Oscilloscope controls and indicators

FIGURE A4-5 INDEX NO.	CONTROL OR INDICATOR	FUNCTION
1	Cathode Ray Tube (CRT)	Displays digital waveforms
2	VERT GAIN Control	Controls height of trace on CRT
3	VERT CENT Control	Controls vertical position of trace on CRT
4	FOCUS Control	Adjusts focus (spot size) of electron beam
5	INTENSITY Control	Adjusts intensity of trace on CRT
6	HORIZ CENT Control	Controls horizontal position of trace on CRT
7	ASTIGMATISM Control	Adjusts astigmatism (spot shape) of electron beam
8	SCALE ILLUMINATION Control	Controls illumination of engraved scale (graticule)
9	HORIZ GAIN Control	Controls width of trace on CRT
10	SWEEP VERNIER Control	Fine adjustment control of internal sweep oscillator
11	INTERNAL SWEEP MILLI-SECONDS Switch	Selects one of six sweep ranges
12	POWER Indicator Lamp	Illuminates when ac power is applied to the oscilloscope
13	POWER Switch	Ac power switch for oscilloscope
14	AC FUSES - 1 AMP Fuse	1-ampere 250 volt fuse connected on one side of input line
15	AC FUSES - 1 AMP Fuse	1-ampere 250 volt fuse connected on one side of input line
16	TIME BASE RELEASE Switch	Selects synchronizing signal for oscilloscope sweep. In CHAR, the oscilloscope sweep is triggered for each character. In SEL TRANS, the sweep is triggered for separate transitions as measured on the analyzer. In FREE, no trigger is applied. The CHAR and SEL TRANS signals are applied to the oscilloscope from the analyzer.
17	INTENSITY MODULATION Switch	Connects intensity modulating signal from analyzer to Z-axis input of oscilloscope

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(b) For voltage signals, connect analyzer across loop using INPUT HIGH Z jack (12).

(8) On analyzer, check SIGNAL lamp (21) and verify that:

(a) For steady mark signal, the lamp glows steadily.

(b) For steady space signal, the lamp remains off.

(c) For keying signal, the lamp blinks on (for marks) and off (for spaces).

(9) On oscilloscope, verify presence of signal on CRT. Adjust oscilloscope controls for best presentation of waveform.

c. BIAS DISTORTION MEASUREMENT.—Bias distortion is the average displacement of the space-to-mark transition from its normal position referred to the start mark-to-space transition. The distortion is called marking bias if the transition occurs early and spacing bias if the transition occurs late. The analyzer is capable of measuring the average bias distortion for the overall signal and also for signal transitions (in Start/Stop signals). Measure bias distortion as follows:

(1) Perform turn-on procedure.

(2) Set analyzer controls as follows:

(a) TRANSITION SELECT switch (17) to ALL (or to selected transitions).

(b) DISTORTION SELECT switch (5) to AVG.

(c) M/S-S/M switch (3) to S/M.

(3) Observe % DISTORTION meter (1) and EARLY, LATE, and SIGNAL lamps (22, 20, and 21) for following:

(a) % DISTORTION meter—indicates amount of distortion (average).

(b) EARLY lamp—if on, indicates mark bias distortion.

(c) LATE lamp—if on, indicates space bias distortion.

(d) SIGNAL lamp—blinks to indicate that signal is keying.

d. END DISTORTION MEASUREMENT.—End distortion is the average displacement of the mark-to-space transition from its normal position referred to the start mark-to-space transition. The distortion is called spacing end distortion if the mark-to-space transition is early and marking end if the transition is late. The analyzer is capable of measuring the average end distortion for the overall signal and also for single transitions (in Start/Stop signals). Measure end distortion as follows:

(1) Perform turn-on procedure.

(2) Set analyzer controls as follows:

(a) TRANSITION SELECT switch (17) to ALL (or selected transition).

(b) DISTORTION SELECT switch (5) to AVG.

(c) M/S-S/M switch (3) to M/S.

(3) Observe % DISTORTION meter (1) and EARLY, LATE, and SIGNAL lamps (22. 20, and 21) for following:

(a) % DISTORTION meter—indicates amount of average distortion.

(b) EARLY lamp—if on, indicates spacing end distortion.

(c) LATE lamp—if on, indicates marking end distortion.

(d) SIGNAL lamp—blinks to indicate that signal is keying.

e. PEAK DISTORTION MEASUREMENT.—Total peak distortion is the highest amount of distortion that occurs on a signal during a given period of time. The distortion may occur on mark-to-space transitions or space-to-mark transitions and may occur either early or late. The analyzer is capable of measuring the total peak distortion, early peak distortion (both M/S and S/M) and late peak distortion (both M/S and S/M).

> **NOTE**
>
> The percent distortion shown on the % DISTORTION meter represents the peak value obtained during the measuring period. The meter displays the peak reading indefinitely until changed to a higher value or reset to zero by the RESET switch. The RESET switch offers two options: manual reset mode, in which the momentary switch must be manually pressed down to reset the meter; and the automatic reset mode, in which the analyzer continuously resets the meter at 5-second intervals.

(1) TOTAL PEAK MEASUREMENTS.–Measure the total peak distortion as follows:

(a) Perform turn-on procedure.

(b) Set analyzer controls as follows:

(1) TRANSITION SELECT switch (17) to ALL (or to selected transition).

(2) DISTORTION SELECT switch to TOTAL.

(3) RESET switch (19) to AUTO if automatic reset feature is desired. Otherwise set switch to OFF.

(c) Observe % DISTORTION meter (1) and SIGNAL lamp (21) for following:

(1) % DISTORTION meter–indicates peak value of distortion.

(2) SIGNAL lamp–blinks to indicate signal is keying.

(2) EARLY PEAK DISTORTION–Measure early peak distortion (peak marking bias and peak spacing end) as follows:

(a) Perform turn-on procedure.

(b) Set analyzer controls as follows:

(1) TRANSITION SELECT switch (19) to ALL (or to selected transition).

(2) DISTORTION SELECT switch (5) to EARLY.

(3) RESET switch (19) to AUTO if automatic reset feature is desired. Otherwise set switch to OFF.

(4) M/S-S/M switch (3) to either M/S or S/M depending upon type of transition to be measured. Set to S/M to measure marking bias, M/S to spacing end.

(c) Observe % DISTORTION meter (1) and SIGNAL lamp (21) for following:

(1) % DISTORTION meter–indicates peak value of marking-bias and spacing end distortion for S/M or M/S transitions.

(2) SIGNAL lamp–blinks to indicate that signal is keying.

(3) LATE PEAK DISTORTION.–Measure late peak distortion (peak marking end and peak spacing bias) as follows:

(a) Perform turn-on procedure.

(b) Set analyzer controls as follows:

(1) TRANSITION SELECT switch (19) to ALL (or to selected transition).

(2) DISTORTION SELECT switch (5) to LATE.

(3) RESET switch (19) to AUTO if automatic reset feature is desired. Otherwise set switch to OFF.

(4) M/S-S/M switch (3) to either M/S or S/M depending upon type of transition to be measured. Set to M/S for marking end and S/M for spacing bias.

(c) Observe % DISTORTION meter (1) and SIGNAL lamp (21) for following:

(1) % DISTORTION meter–indicates peak value of marking end and spacing bias distortion for M/S or S/M transitions.

(2) SIGNAL lamp–blinks to indicate that signal is keying.

OPERATING PRECAUTIONS

The following summary of operating precautions and general information is provided for use by the operator:

a. The input filter of the analyzer is usable only up to modulation rates of 150 baud. Set FILTER switch to OUT position when operating the analyzer above 150 baud.

b. The external timing input signal to the analyzer must be 200 times the desired baud rate. The external timing signal must be a square wave having an amplitude of ±6 volts.

c. Use LOW Z connector when measuring current signals.

d. Use HIGH Z connector when measuring voltage signals.

e. Always connect test cable to analyzer before connecting cable to signal loop.

OPERATOR'S MAINTENANCE

The maintenance required by the operator is limited to replacement of lamps and fuses.

APPENDIX V
OPERATING SIGNALS

Table A5-1.—Operating signals

Signal	Question	Answer, Advice, or Order
QRK	What is the readability of my signals (or those of________)?	The readability of your signals (or those of________) is________(1 to 5).
QRM	Are you being interfered with?	I am being interfered with.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRU	Have you anything for me?	I have nothing for you.
QSA	What is the strength of my signals (or those of________)?	The strength of your signals (or those of________) is________(1 to 5).
QSV	Shall I send a series of Vs on this frequency [or ____kHz (or MHz)]?	Send a series of Vs on this frequency [or ____kHz (or MHz)].
QSY	Shall I change to transmission on another frequency?	Change to transmission on another frequency [or on ____ kHz (or MHz)].
ZAR	. . . .	This is my____request (or reply). [(1) First, (2) second, (3) third, etc.]
ZBK	Are you receiving my traffic clear?	I am receiving your traffic________[(1) clear; (2) garbled].
ZDK	Will you repeat message________(or portion ________)? Or, rerun No.______?	Following repetition (of______) is made in accordance with your request.
ZEC	Have you received message__________?	Message________[(1) not received, (2) unidentified, give better identification data].
ZEN	. . . .	This message has been delivered by other means or by a separate transmission to the addressee(s) immediately following this operating signal.
ZEX	. . . .	This is a book message and may be delivered as a single address message to addressees for whom you are responsible.
ZFH	. . . .	This message (or message______) is being (or has been) passed to you (or____) for________[(1) action, (2) information, (3) comment].
ZFI	Is there any reply to message__________?	There is no reply to message__________.
ZIA	. . . .	This message (or message______) is being (or has been) passed out of proper sequence of station serial numbers.
ZII	What was____of your (or____'s) number____? [(1) date-time group, (2) filing time].	My (or____'s) number____had following____ [(1) date-time group, (2) filing time].
ZKP	Are you (or is ____) radio guard for________ [on ____ kHz (or MHz)]?	I am (or ____is) radio guard for____ on ____kHz (or MHz)].
ZNB	What is authentication of______ [(1) message______, (2) last transmission, (3) ______]?	Authentication (of____) is______ [(1) message______, (2) last transmission, (3) ________].
ZOC	. . . .	Station(s) called relay this message to addressees for whom you are responsible.
ZON	. . . .	Place this message (or message______) on broadcast indicated by numerals following______(numeral may be followed by specific broadcast designator) [(1) NSS; (2) NPG; (3) NPM; (4) NBA; (5) NPN; (6) NPO; (7) NHY; (8) NAM; (9) NAF; (10) NPL; (11) NDT].
ZOV	. . . .	Station designation preceding this operating signal is the correct routing for this message rerouted by______.
ZUE	. . . .	Affirmative (Yes).
ZUG	. . . .	Negative (No).
ZUI	. . . .	Your attention is invited to ______________.
ZUJ	. . . .	Standby.

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APPENDIX VI

DSSCS OPERATING SIGNALS

Some of the most commonly used operating signals are listed in Appendix V. Remember that the Q code is used internationally, and speaks of "telegrams" where a U.S. Navy communicator would say "message."

In addition to operating signals which are assigned meanings in the current edition of ACP 131, the following signals and assigned meanings are authorized for use in DSSCS; however, they should not be used outside the DSSCS community.

SIGNAL	MEANING
ZCA	This is an exact duplicate of a message which has been forwarded via physical means.
ZCA1	This is an exact duplicate of a message which has been forwarded via physical means to____.
ZEM	Used in the message format as a symbol for machine recognition of the start of text (SOT) indicator which prevents the incoming line sensing device from reacting to certain machine sequences during the textual portion of a message.
ZNZ1	Originator has indicated that this message should be forwarded without service action on the text at relay or addressee stations, as the information contained is perishable. (For use by message originators on specific types of traffic the text of which is non-literal. ZNZ1 messages will only be serviced for garbles in the message heading to insure proper handling.)
ZPO	The text of this message is to be relayed in precisely the same format as that in which it is received. No characters or machine functions are to be added, inserted or deleted, and the relative positions of the groups are to be retained. Normally used on those messages requiring computer processing. ZPO messages may be serviced for obvious garbles in the heading and text.
ZRJ	Urgent Operating Condition (defined in ACP-131 as "Will you check your . . . ?"). In DSSCS the operating signal is used to attract the attention of a distant station. Receipt of this signal will activate an alarm at those stations where incoming circuits are equipped with the model

28 printer. To avoid unnecessary alarms, use of this operating signal must be limited to conditions of urgency.

ZYH Used in the message format as a high precedence indicator which activates an alarm upon receipt of a CRITIC or message assigned FLASH or IMMEDIATE precedence.

ZYO This message originated by Navy afloat or Navy mobile unit. All service message and retransmission requests will be addressed to the routing indicator following this operating signal. (Used during certain periods to preclude significant delay to service requests when the Naval afloat units do not terminate full period communications either because of emission control orders or other operational factors.) ZYO will appear in message format line 4, immediately following the TCC and separated by a space, followed by routing indicator of the station to which any subsequent service action should be directed. Instructions for application of ZYO will be issued by COMNAVSECGRU to cognizant Naval activities.

ZYS Do not transmit via OPINTEL broadcast.

ZZR The text of this message employs a code which presents a garbled appearance on standard teletypewriter equipments: approximate length is . . . (1. 300 groups; 2. 600 groups; 3. 900 groups.)

ZZS This is a voluntary correction; disregard previous transmission.

APPENDIX VII

THE METRIC SYSTEM

The metric system was developed by French scientists in 1790 and was specifically designed to be an easily used system of weights and measures to benefit science, industry, and commerce. The metric system is calculated entirely in powers of 10, so one need not work with the various mathematical bases used with the English system, such as 12 inches to a foot, 3 feet to a yard, and 5280 feet to a mile.

The system is based on the "metre" which is one ten-millionth of the distance from the Equator to the North Pole. It is possible to develop worldwide standards from this base of measurement. The metric system of weights is based on the gram, which is the weight of a specific quantity of water.

Soon after the system was developed scientists over the world adopted it and were able to deal with the mathematics of their experiments more easily. The data and particulars of their work could be understood by other scientists anywhere in the world. During the early 19th century many European nations adopted the new system for engineering and commerce. It was possible for these countries to trade manufactured goods with one another without worrying whether it would be possible to repair machinery from another country without also buying special wrenches and measuring tools. Countries could buy and sell machine tools and other sophisticated and precision machinery without troublesome modifications or alterations. It was much easier to teach the metric system, since metres can be changed to kilometres or centimetres with the movement of a decimal point, which is roughly like being able to convert yards to miles or inches by adding zeros and a decimal instead of multiplying by 1760 or dividing by 36.

With the exception of the United States, all the industrialized nations of the world have adopted the metric system. Even England and Canada are changing from their traditional systems of measure, and the metric system will be almost universal by 1980.

Although the metric system has not been officially legislated by the Congress, the metric system is becoming more prominent in this country. Most automobile mechanics own some metric wrenches to work on foreign cars or foreign components in American cars. Almost all photographic equipment is built to metric standards. Chemicals and drugs are usually sold in metric quantities, and "calorie counters" are using a metric unit of thermal energy.

Because we are allied with countries who use the metric system, much of our military information is in metric terms. Military maps use meters and kilometers instead of miles, and many weapons are in metric sizes, such as 7.62 mm, 20 mm, 40 mm, 75 mm, and 155 mm. Interchange of military equipment has caused a mixture of metric and English measure equipment since World War I when the army adopted the French 75 mm field gun, and World War II when the Navy procured the Swedish 40 mm Bofors and the Swiss 20 mm Oerlikon heavy machineguns.

It is inevitable that the United States will officially adopt the metric system. Exactly when this happens and how rapidly the changeover will depend on economics, since the expense of retooling our industry and commerce to new measurements will be very great. The cost of conversion will be offset by increased earnings from selling machinery and products overseas. Another benefit is that scientists use the metric system, but their calculations now have to be translated into English measure to be used by industry. With adoption of the metric system ideas can go directly from the drawing board to the assembly line.

The Navy will be using the metric system more during the next few years. Although you will find it easier to solve problems using this system, at first you will find it difficult to visualize or to estimate quantities in unfamiliar units of measure.

Fortunately, many metric units can be related to equivalent units in the English system.

The metre, which is the basic unit, is approximately one-tenth longer than a yard.

The basic unit of volume, the litre, is approximately one quart. The gram is the weight of a cubic centimeter, or millilitre, of pure water, and is the basic unit of weight. As a common weight though, the kilogram, or kilo, which equals the weight of a litre of water, weighs 2.2 pounds. The centimetre is used where we would use the inch, and where we measure by the fluid ounce, the metric system employs the millilitre (ml). For power measure the metric system uses the kilowatt (kW), which is approximately 1.3 horsepower.

In terms of distance, a land mile is eight-fifths of a kilometre, and a nautical mile is 1.852 kilometres, or nearly 2 kilometres.

A basic metric expression of pressure is the kilogram per square centimetre, which is 14.2 psi, nearly 1 atmosphere of pressure.

When working on foreign machinery, you may notice that your half-inch, three-quarter inch, and one-inch wrenches will fit many of the bolts. These sizes correspond to 13 mm, 19 mm, and 26 mm respectively in the metric system, and are very popular because they are interchangeable. The 13/16-inch spark plug wrench, which is standard in this country, is intended to fit a 20 mm nut.

The basic quantities of the metric system are multiplied or divided by powers of 10 to give other workable values. We cannot easily measure machine parts in terms of a metre, so the millimetre, or one-thousandth of a metre is used. For very fine measure the micron, also called the micrometre, can be used. It is one-millionth part of a metre, or one-thousandth of a millimetre. For small weights the milligram, one-thousandth of a gram is used. All of these multiples are expressed with standard prefixes taken from Latin:

micro	= 1/1,000,000
milli	= 1/1,000
centi	= 1/100
*deci	= 1/10
*deca	= 10
*hecto	= 100
kilo	= 1,000
*myria	= 10,000
mega	= 1,000,000

* Rarely used

Over the next few years the metric system will become more used by the Navy as well as by the civilian world. You will find it easy to work with once you have mastered the basic terms. It will be difficult to translate values from our present system to the metric system, but this operation will become unnecessary once the new measurements are totally adopted.

Tables of equivalent English measure and metric equivalents are essential when you work simultaneously with both systems. The table which follows shows the equivalent measures of the two systems. The columns on the left have the equivalent values which are accurate enough for most work, and on the right are the multiples used to convert the values with a high degree of accuracy.

U.S. CUSTOMARY AND METRIC SYSTEM UNITS OF MEASUREMENTS

* IN FEBRUARY OF 1960, THE U.S. BUREAU OF STANDARDS ANNOUNCED ITS POLICY TO THENCEFORTH USE THE UNITS OF THE INTERNATIONAL SYSTEM FOR WEIGHTS AND MEASURES, REPLACING WHAT HAD BEEN CALLED THE METRIC SYSTEM. THE ABBREVIATION USED FOR THE INTERNATIONAL SYSTEM IS (SI).

Multiples and Submultiples	Prefixes	Symbols
1 000 000 000 000 = 10^{12}	tera (tĕr'à)	T
1 000 000 000 = 10^{9}	giga (jĭ'gà)	G
1 000 000 = 10^{6}	mega (mĕg'à)	M
1 000 = 10^{3}	kilo (kĭl'ô)	k
100 = 10^{2}	hecto (hĕk'tô)	h
10 = 10	deka (dĕk'à)	da
0.1 = 10^{-1}	deci (dĕs'ĭ)	d
0.01 = 10^{-2}	centi (sĕn'tĭ)	c
0.001 = 10^{-3}	milli (mĭl'ĭ)	m
0.000 001 = 10^{-6}	micro (mī'krô)	μ
0.000 000 001 = 10^{-9}	nano (năn'ô)	n
0.000 000 000 001 = 10^{-12}	pico (pē'kô)	p
0.000 000 000 000 001 = 10^{-15}	femto (fĕm'tô)	f
0.000 000 000 000 000 001 = 10^{-18}	atto (ăt'tô)	a

Multiply	By	To Obtain
Acres	40.47	Ares
Acres	4,047	Centares
Acres	10	Square chains
Acres	43,560	Square Feet
Acres	4,840	Square Yards
Ares	0.02471	Acres
Ares	100	Centares
Ares	1,076	Square Feet
Ares	119.6	Square Yards
Barrels (U.S., dry)	3.281	Bushels
Barrels (U.S., liquid)	4.21	Cubic Feet
Barrels (U.S., liquid)	31.5	Gallons
Board Feet (1' x 1' x 1')	144	Cubic inches
Cable lengths (U.S.)	120	Fathoms
Cable lengths (U.S.)	720	Feet
Cable lengths (U.S.)	240	Yards
Centares	10.76	Square feet
Centares	1.196	Square Yards
Centimeters	0.3937	Inches
Cubic Centimeters	0.06102	Cubic Inches
Chains	66	Feet
Chains	100	Links
Chains	4	Rods
Cubic Feet	1,728	Cubic Inches
Cubic Feet	0.02832	Cubic Meters
Cubic Feet	0.03704	Cubic Yards
Cubic Feet	6.229	Gallons (British)
Cubic Feet	7.481	Gallons (U.S.)
Cubic Feet	28.316	Liters
Cubic Inches	16.39	Cubic Centimeters
Cubic Inches	0.0005787	Cubic Feet
Cubic Inches	0.003606	Gallons (British)
Cubic Inches	0.004329	Gallons (U.S.)
Cubic Inches	0.01639	Liters
Cubic Meters	35.31	Cubic Feet
Cubic Meters	1.308	Cubic Yards
Cubic Yards	27	Cubic Feet
Cubic Yards	0.7646	Cubic Meters
Cubic Yards	764.6	Liters
Degrees (C.)+ 17.8	1.8	Degrees (F.)
Degrees (F.)−32	0.5556	Degrees (C.)
Degrees	0.01745	Radians
Fathoms	0.00833	Cable Lengths (U.S.)
Fathoms	6	Feet
Fathoms	1.8288	Meters

Multiply	By	To Obtain
Feet	30.48	Centimeters
Feet	0.1667	Fathoms
Feet	0.3048	Meters
Feet per Minute	0.01136	Miles per Hour
Feet per Second	0.5921	Knots
Feet per Second	18.288	Meters per Minute
Feet per Second	0.6818	Miles per Hour
Furlongs	10	Chains
Furlongs	660	Feet
Furlongs	40	Rods
Furlongs	220	Yards
Gallons (British)	4,546.1	Cubic Centimeters
Gallons (British)	0.1605	Cubic Feet
Gallons (British)	277.274	Cubic Inches
Gallons (British)	1.2009	Gallons (U.S.)
Gallons (British)	4.546	Liters
Gallons (British)	4	Quarts (British)
Gallons (U.S.)	0.03175	Barrels (liquid, U.S.)
Gallons (U.S.)	3,785.4	Cubic Centimeters
Gallons (U.S.)	0.13368	Cubic Feet
Gallons (U.S.)	231	Cubic Inches
Gallons (U.S.)	0.8327	Gallons (British)
Gallons (U.S.)	3.785	Liters
Gallons (U.S.)	4	Quarts (U.S.)
Grams	15.43	Grains
Grams	0.001	Kilograms
Grams	1,000	Milligrams
Grams	0.03527	Ounces (avoirdupois)
Hands	10.16	Centimeters
Hands	4	Inches
Hectares	2.471	Acres
Hectares	100	Ares
Hectoliters	0.1	Cubic Meters
Hectoliters	26.417	Gallons (U.S.)
Hectoliters	100	Liters
Hogsheads	2	Barrels (Liquid, U.S.)
Hogsheads (U.S.)	63	Gallons (U.S.)
Hundredweights	0.508	Quintals (metric)
Inches	72	Points
Inches	6	Picas
Inches	6	Ems
Inches	12	Ens
Inches	2.54	Centimeters

Multiply	By	To Obtain	Multiply	By	To Obtain
Inches	0.0833	Feet	Miles, Nautical	6,076.1	Feet
Inches	1,000	Mils	Miles, Nautical	72,963	Inches
Inches	0.0277	Yards	Miles, Nautical	1.8532	Kilometers
Inches of Mercury	0.49131	Pounds per Square Inch	Miles, Nautical	1,853.2	Meters
Kilograms	1,000	Grams	Miles, Nautical	1.1508	Miles, Statute
Kilograms	2.2046	Pounds (Avoirdupois)	Miles, Nautical	1	Minutes of Latitude
Kiloliters	1	Cubic Meters	Miles, Nautical	2,026.8	Yards
Kiloliters	1.308	Cubic Yards	Miles per Hour (Statute)	88	Feet per Minute
Kiloliters	264.18	Gallons (U.S.)			
Kiloliters	1,000	Liters	Miles per Hour (Statute)	1.467	Feet per Second
Kilometers	4.557	Cable Lengths			
Kilometers	3,280.8	Feet	Miles per Hour	0.8684	Knots
Kilometers	39,370	Inches	Miles, Statute	7.33	Cable Lengths
Kilometers	1,000	Meters	Miles, Statute	5,280	Feet
Kilometers	0.5396	Miles, Nautical	Miles, Statute	8	Furlongs
Kilometers	0.62137	Miles, Statute	Miles, Statute	63,360	Inches
Kilometers	1,093.6	Yards	Miles, Statute	1.6093	Kilometers
Knots	1.1516	Statute Miles per Hour	Miles, Statute	1,609.3	Meters
			Miles, Statute	0.8689	Miles, Nautical
Knots	1.688	Feet per Second	Miles, Statute	1,760	Yards
Leagues, Nautical	25.33	Cable Lengths	Millier (See Tons—Metric)		
Leagues, Nautical	5.5597	Kilometers			
Leagues, Nautical	3	Miles, Nautical	Milliradians	206.265	Seconds of Arc
Leagues, Statute	4.8280	Kilometers	Mils	0.001	Inches
Leagues, Statute	3	Miles, Statute	Myriameters	10	Kilometers
Links	7.92	Inches	Ounces (avoirdupois)	28.3495	Grams
Liters	1,000	Cubic Centimeters	Pint (Liquid, U.S.)	4	Gills (U.S.)
Liters	61.025	Cubic Inches	Pint (Liquid, Br.)	4	Gills (British)
Liters	0.21998	Gallons (British)	Pint (Liquid, Br.)	0.56825	Liters
Liters	0.26418	Gallons (U.S.)	Pint (Liquid, U.S.)	0.4732	Liters
Liters	0.8799	Quarts (British)	Pounds (avoirdupois)	7,000	Grains
Liters	0.908	Quarts (U.S., dry)	Pounds (avoirdupois)	453.59	Grams
Liters	1.0567	Quarts (Liquid, U.S.)	Pounds (avoirdupois)	0.4536	Kilograms
			Pounds (avoirdupois)	16	Ounces
Meters	100	Centimeters	Pounds (avoirdupois)	1.2153	Pounds (troy)
Meters	0.001	Kilometers	Pounds (troy)	0.8229	Pounds (avoirdupois)
Meters	1.0936	Yards			
Meters	3.281	Feet	Pounds per Square Inch	2.03537	Inches of Mercury
Meters	39.37	Inches			
Meters	1,000	Millimeters	Quart (British)	1.1365	Liters
Meters	1.0936	Yards	Quart (British)	2	Pints (British)
Meters per Minute	0.0547	Feet per Second	Quart (Liquid, U.S.)	0.9463	Liters
Meters per Second	2.237	Miles per Hour	Quart (U.S.)	2	Pints (U.S.)
Microns	0.001	Millimeters	Quintals (Metric)	1.97	Hundredweights
Miles, Nautical	8.44	Cable Lengths	Quintals (Metric)	100	Kilograms

Multiply	By	To Obtain	Multiply	By	To Obtain
Radians	57.30	Degrees	Square Miles, Statute	259	Hectares
Rods	16.3	Feet	Square Miles, Statute	2.59	Square Kilometers
Rods	25	Links	Square Yards	0.8362	Centares
Square Centimeters	0.1550	Square Inches	Square Yards	9	Square Feet
Square Feet	0.0929	Centares	Square Yards	1,296	Square Inches
Square Feet	929	Square Centimeters	Tons (Long)	1.016	Metric Tons
Square Feet	144	Square Inches	Tons (Long)	2,240	Pounds (Avoirdupois)
Square Feet	0.1111	Square Yards			
Square Inches	6.452	Square Centimeters	Tons (Metric) (Millier)	1,000	Kilograms
Square Inches	0.006944	Square Feet			
Square Kilometers	100	Hectares	Tons (Metric) (Millier)	2,204.6	Pounds (Avoirdupois)
Square Kilometers	0.3861	Square Miles (Statute)			
			Tons (Short)	0.9072	Metric Tons
Square Meters (See Centares)			Tons (Short)	2,000	Pounds (Avoirdupois)
Square Miles, Statute	640	Acres	Yards	91.44	Centimeters
Square Miles, Statute	25,900	Ares	Yards	0.9144	Meters

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MODIFICATIONS

Pages 370 - 375 of this publication has (have) been deleted in adapting this material for inclusion in the "Trial Implementation of a Model System to Provide Military Curriculum Materials for Use in Vocational and Technical Education." Deleted material involves extensive use of military forms, procedures, systems, etc. and was not considered appropriate for use in vocational and technical education.