NONRESIDENT TRAINING COURSE

July 1997

Electronics Technician

Volume 3—Communications Systems

NAVEDTRA 14088

Although the words "he," "him," and "his" are used sparingly in this course to enhance communication, they are not intended to be gender driven or to affront or discriminate against anyone.

PREFACE

By enrolling in this self-study course, you have demonstrated a desire to improve yourself and the Navy. Remember, however, this self-study course is only one part of the total Navy training program. Practical experience, schools, selected reading, and your desire to succeed are also necessary to successfully round out a fully meaningful training program.

COURSE OVERVIEW: After completing this course, you should be able to: recall the basic principle and the basic equipment used for rf communications; recognize frequency bands assigned to the Navy microwave communications, the single audio system (SAS), and the basics of the Navy tactical data system. Analyze the operation of the Navy's teletypewriter and facsimile system, the basics of the TEMPEST program, and the basic portable and pack radio equipment used by the Navy. Identify basic satellite communications fundamentals, fleet SATCOM subsystem, shore terminals, and basic SATCOM equipment and racks. Identify the composition of the Link-11 system, and problems in Link-11 communications. Recognize the functions of the Link 4-A systems, new technology in data communications, and local-area networks.

THE COURSE: This self-study course is organized into subject matter areas, each containing learning objectives to help you determine what you should learn along with text and illustrations to help you understand the information. The subject matter reflects day-to-day requirements and experiences of personnel in the rating or skill area. It also reflects guidance provided by Enlisted Community Managers (ECMs) and other senior personnel, technical references, instructions, etc., and either the occupational or naval standards, which are listed in the *Manual of Navy Enlisted Manpower Personnel Classifications and Occupational Standards*, NAVPERS 18068.

THE QUESTIONS: The questions that appear in this course are designed to help you understand the material in the text.

VALUE: In completing this course, you will improve your military and professional knowledge. Importantly, it can also help you study for the Navy-wide advancement in rate examination. If you are studying and discover a reference in the text to another publication for further information, look it up.

Sailor's Creed

"I am a United States Sailor.

I will support and defend the Constitution of the United States of America and I will obey the orders of those appointed over me.

I represent the fighting spirit of the Navy and those who have gone before me to defend freedom and democracy around the world.

I proudly serve my country's Navy combat team with honor, courage and commitment.

I am committed to excellence and the fair treatment of all."

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SUMMARY OF THE
ELECTRONICS TECHNICIAN
TRAINING SERIES

This series of training manuals was developed to replace the *Electronics Technician 3 & 2* TRAMAN.

The nine volumes in the series are based on major topic areas with which the Electronics Technician should be familiar. Volume 1, *Safety,* provides an introduction to general safety as it relates to the ET rating. It also provides both general and specific information on electronic tag-out procedures, man-aloft procedures, hazardous materials (i.e., solvents, batteries, and vacuum tubes), and radiation hazards. Volume 2, *Administration,* discusses COSAL updates, 3-M documentation, supply paperwork, and other associated administrative topics. Volume 3, *Communications Systems,* provides a basic introduction to shipboard and shore-based communication systems. Systems covered include man-pac radios (i.e., PRC-104, PSC-3) in the hf, vhf, uhf, SATCOM, and shf ranges. Also provided is an introduction to the Communications Link Interoperability System (CLIPS). Volume 4, *Radar Systems,* is a basic introduction to air search, surface search, ground controlled approach, and carrier controlled approach radar systems. Volume 5, *Navigation Systems,* is a basic introduction to navigation systems, such as OMEGA, SATNAV, TACAN, and man-pac systems. Volume 6, *Digital Data Systems,* is a basic introduction to digital data systems and includes discussions about SNAP II, laptop computers, and desktop computers. Volume 7, *Antennas and Wave Propagation,* is an introduction to wave propagation, as it pertains to Electronics Technicians, and shipboard and shore-based antennas. Volume 8, *Support Systems,* discusses system interfaces, troubleshooting, sub-systems, dry air, cooling, and power systems. Volume 9, *Electro-Optics,* is an introduction to night vision equipment, lasers, thermal imaging, and fiber optics.

INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

The text pages that you are to study are listed at the beginning of each assignment. Study these pages carefully before attempting to answer the questions. Pay close attention to tables and illustrations and read the learning objectives. The learning objectives state what you should be able to do after studying the material. Answering the questions correctly helps you accomplish the objectives.

SELECTING YOUR ANSWERS

Read each question carefully, then select the BEST answer. You may refer freely to the text. The answers must be the result of your own work and decisions. You are prohibited from referring to or copying the answers of others and from giving answers to anyone else taking the course.

SUBMITTING YOUR ASSIGNMENTS

To have your assignments graded, you must be enrolled in the course with the Nonresident Training Course Administration Branch at the Naval Education and Training Professional Development and Technology Center (NETPDTC). Following enrollment, there are two ways of having your assignments graded: (1) use the Internet to submit your assignments as you complete them, or (2) send all the assignments at one time by mail to NETPDTC.

Grading on the Internet: Advantages to Internet grading are:

- you may submit your answers as soon as you complete an assignment, and
- you get your results faster; usually by the next working day (approximately 24 hours).

In addition to receiving grade results for each assignment, you will receive course completion confirmation once you have completed all the assignments. To submit your assignment answers via the Internet, go to:

http://courses.cnet.navy.mil

Grading by Mail: When you submit answer sheets by mail, send all of your assignments at one time. Do NOT submit individual answer sheets for grading. Mail all of your assignments in an envelope, which you either provide yourself or obtain from your nearest Educational Services Officer (ESO). Submit answer sheets to:

> COMMANDING OFFICER
> NETPDTC N331
> 6490 SAUFLEY FIELD ROAD
> PENSACOLA FL 32559-5000

Answer Sheets: All courses include one "scannable" answer sheet for each assignment. These answer sheets are preprinted with your SSN, name, assignment number, and course number. Explanations for completing the answer sheets are on the answer sheet.

Do not use answer sheet reproductions: Use only the original answer sheets that we provide—reproductions will not work with our scanning equipment and cannot be processed.

Follow the instructions for marking your answers on the answer sheet. Be sure that blocks 1, 2, and 3 are filled in correctly. This information is necessary for your course to be properly processed and for you to receive credit for your work.

COMPLETION TIME

Courses must be completed within 12 months from the date of enrollment. This includes time required to resubmit failed assignments.

PASS/FAIL ASSIGNMENT PROCEDURES

If your overall course score is 3.2 or higher, you will pass the course and will not be required to resubmit assignments. Once your assignments have been graded you will receive course completion confirmation.

If you receive less than a 3.2 on any assignment and your overall course score is below 3.2, you will be given the opportunity to resubmit failed assignments. **You may resubmit failed assignments only once.** Internet students will receive notification when they have failed an assignment--they may then resubmit failed assignments on the web site. Internet students may view and print results for failed assignments from the web site. Students who submit by mail will receive a failing result letter and a new answer sheet for resubmission of each failed assignment.

COMPLETION CONFIRMATION

After successfully completing this course, you will receive a letter of completion.

ERRATA

Errata are used to correct minor errors or delete obsolete information in a course. Errata may also be used to provide instructions to the student. If a course has an errata, it will be included as the first page(s) after the front cover. Errata for all courses can be accessed and viewed/downloaded at:

http://www.advancement.cnet.navy.mil

STUDENT FEEDBACK QUESTIONS

We value your suggestions, questions, and criticisms on our courses. If you would like to communicate with us regarding this course, we encourage you, if possible, to use e-mail. If you write or fax, please use a copy of the Student Comment form that follows this page.

For subject matter questions:

E-mail: n315.products@cnet.navy.mil
Phone: Comm: (850) 452-1001, Ext. 1713
            DSN: 922-1001, Ext. 1713
            FAX: (850) 452-1370
            (Do not fax answer sheets.)
Address: COMMANDING OFFICER
            NETPDTC N315
            6490 SAUFLEY FIELD ROAD
            PENSACOLA FL 32509-5237

For enrollment, shipping, grading, or completion letter questions

E-mail: fleetservices@cnet.navy.mil
Phone: Toll Free: 877-264-8583
            Comm: (850) 452-1511/1181/1859
            DSN: 922-1511/1181/1859
            FAX: (850) 452-1370
            (Do not fax answer sheets.)
Address: COMMANDING OFFICER
            NETPDTC N331
            6490 SAUFLEY FIELD ROAD
            PENSACOLA FL 32559-5000

NAVAL RESERVE RETIREMENT CREDIT

If you are a member of the Naval Reserve, you may earn retirement points for successfully completing this course, if authorized under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 9 points. (Refer to *Administrative Procedures for Naval Reservists on Inactive Duty,* BUPERSINST 1001.39, for more information about retirement points.)

Student Comments

Course Title: *Electronics Technician, Volume 3—Communications Systems*

NAVEDTRA: 14088   **Date**:

We need some information about you:

Rate/Rank and Name: SSN: Command/Unit

Street Address: City: State/FPO: Zip

Your comments, suggestions, etc.:

CHAPTER 1

FUNDAMENTALS

INTRODUCTION

Communications in general, and especially in systems, covers a broad spectrum, from a simple single-channel voice circuit, to the fastest growing field of electronics—satellite communications. This training manual will provide you with knowledge applicable to questions and situations that arise on the job. Chapter 1 is a refresher course in basic communications systems and terminology. Chapters 2 and 3 will lead you through many of the systems and equipments in use today. Chapter 4 will discuss the Link-11 system, chapter 5 will cover the Link-11 Fault Isolation, chapter 6 will discuss Link 4-A, chapter 7 will introduce you to the new technology in data communications and the Link-16 system, and chapter 8 will discuss local-area networks.

The Electronics Technician rating is extremely diverse. Many ETs never get the opportunity to work in the communications field. Those who do are often locked into one particular system for many years. This assignment pattern sometimes causes ETs to feel overwhelmed or lost in their career. The massive amount of information ETs can be questioned on and expected to know can be frustrating. But the goal **YOU** and every ET must have is to become as knowledgeable as possible to be better. prepared for all future challenges.

After completing this chapter, you should be able to:

- **Identify the basic principles of rf communications**

- **Recognize the basic equipment used for rf communications**

- **Determine the frequency spectrum allocated to rf communications**

RADIO COMMUNICATIONS

Navy ships, planes, and shore bases operate as a team working together to accomplish a specific task. Radio equipment is used to coordinate the activities of the many fleet units by linking them with each other and with shore stations.

Radio can be defined as the transmission and reception of electronic impulses or signals through space by means of electromagnetic waves. Usually, the term is used in referring to the transmission of intelligence code and sound signals, although television and radar also depend on electromagnetic waves.

At one time, the term *radio communications* brought to mind telegraphy (CW), voice (AM), and possibly teletype communications. Today's radio communications has become a highly sophisticated field of electronics. You, the technician, need to become familiar with the diverse systems in use today.

The primary means of communicating between ships and between ships and stations is known as *telecommunications.* Telecommunications refers to communications over a distance and includes any transmission, emission, or reception of signals, writing, images, and sounds. Intelligence produced by visual or oral means or by wire, radio, or other electromagnetic systems is also included. Electrical, visual, and sound telecommunications are all used by the Navy. In this volume we will discuss electrical types of telecommunications.

COMMUNICATIONS SYSTEMS

A communications system consists of two or more units, each having its own separate identity, arranged and interconnected to perform a circuit operation that cannot be performed by one of the individual units alone. Navy communications systems vary from simple to very complex, depending upon the circuit operations involved. Each system requires the integrated use of various types of equipment, so flexibility is of the utmost importance. This flexibility is provided through a complex arrangement of interconnections that allow the physically separated sets, groups, and units to be selectively switched (patched) into the different circuit configurations.

Most shipboard communication equipments do not operate independently. A particular piece of electronic gear may be designated "primary" and still be used in many different system operations. You need to understand all the associated equipment in a system to identify problems correctly and to make repairs promptly. Thorough knowledge of system operations will enable you to say with complete confidence, this communications suite is operational.

SAFETY

Hazards encountered in servicing electronic equipment and the precautions to be taken against them are covered thoroughly in *Electronics Technician Volume 1, Safety,* NAVEDTRA 12411, and the *General Handbook* (NAVSHIPS 0967-000-0100) of the EIMB series.

Safety is everyone's responsibility. Observance of safety precautions will keep your equipment operating, help your career in the Navy, and possibly determine whether or not you survive. Always follow the appropriate safety precautions!

Note: Equipment that we cover in this and other chapters is intended to be merely representative of equipment that you may encounter on board your command. We will not attempt to include all the possible equipment or equipment configurations.

BASIC SYSTEM REQUIREMENTS

Radio equipment can be divided into three broad categories: transmitting equipment, receiving equipment, and terminal equipment. Transmitting
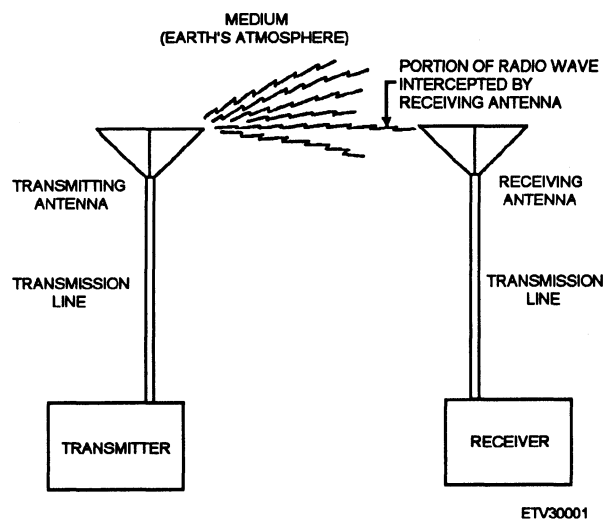

Figure 1-1.—Basic radio communication system.

equipment generates, amplifies, and modulates a transmitted signal. Receiving equipment receives a radio wave, then amplifies and demodulates it to extract the original intelligence. Terminal equipment is used primarily to convert the audio signals of encoded or data transmission into the original intelligence.

A basic radio communications system may consist of only a transmitter and a receiver, connected by the medium through which the electromagnetic waves travel (see figure 1-1). The transmitting equipment creates a radio-frequency (rf) carrier and modulates it with audio intelligence to produce an rf signal. This rf signal is amplified and fed to the transmitting antenna, which converts it to electromagnetic energy for propagation.

The receiving antenna converts the portion of the electromagnetic wave it receives into a flow of alternating rf currents. The receiver then converts these currents into the intelligence that was contained in the transmission.

Terminal equipment is used primarily where coded transmissions are employed, to convert the modulated signal into the original intelligence. Systems you will encounter in the fleet use terminal equipment, such as AN/UCC-l, AN/URA-17, and CV-2460.

THE FREQUENCY SPECTRUM

Figure 1-2 shows the overall electromagnetic frequency spectrum as defined by the International Telecommunications Union. Pay particular attention to the part used for communications. Rapid growth in the quantity and complexity of communications equipment and increased worldwide international requirements for radio frequencies have placed large demands upon the rf spectrum. These demands include military and civilian applications, such as communications, location and ranging, identification, standard time, industrial, medical, and other scientific uses.

The military has modified the frequency spectrum for its use as shown in table 1-1. A few general characteristics are described in the following paragraphs.

The extremely-low-frequency (elf), very-low-frequency (vlf), and low-frequency (lf) bands require high power and long antennas for efficient transmission (antenna length varies inversely with the frequency). Transmission of these frequencies is normally limited to shore stations.

The commercial broadcast band extends from about 550 kHz to 1700 kHz. This limits naval use to the

Table 1-1.—Frequency Bands.

FREQUENCY	DESCRIPTION
30-300 GHz	extremely-high-frequency
3-30 GHz	super-high-frequency
300 MHz-3 GHz	ultra-high-frequency
30-300 MHz	very-high-frequency
3-30 MHz	high-frequency
300 kHz-3 MHz	medium-frequency
30-300 kHz	low-frequency
3-30 kHz	very-low-frequency
300 Hz-3 kHz	voice frequency
Up to 300 Hz	extremely-low-frequency

upper and lower ends of the medium frequency (mf) band.

Long-range shipboard communications were conducted exclusively in the high-frequency (hf) band, so a large percentage of shipboard transmitters and receivers are designed to operate in this band. On board your command, you may find satellite communications has pushed hf into aback-up role.

A significant portion of the very-high-frequency (vhf) band is assigned to the commercial television industry. Some naval uses of the vhf band are mobile communications, repeater operation, navigation, amphibious and special operations, short range line-of-sight (LOS) communications, and satellite communications.

The ultra-high-frequency (uhf) band is used extensively by the Navy for LOS and satellite communications. Mobile communications, radar (over 400 MHz), and special operations are some other uses.

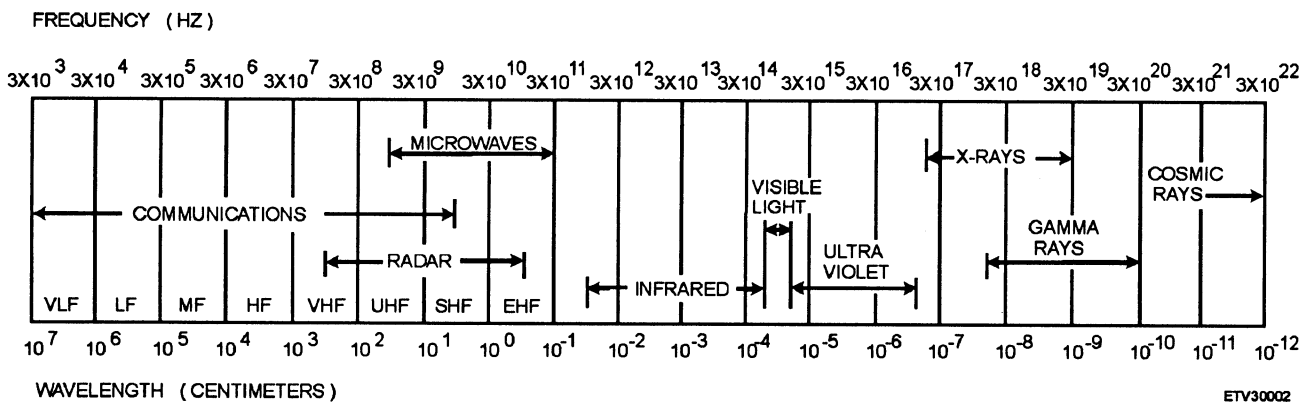The super-high-frequency (shf) band is the workhorse of microwave communications. LOS communi-

Figure 1-2.—Frequency spectrum.

1-3

cations, terrestrial, and satellite relay links, radar, and special operations are some other uses.

Experimental use of the extremely-high-frequency (ehf) band is ending. The Fleet Satellite (FLTSAT) Ehf Package **(FEP)** is attached to two modified uhf FLTSATs. The FEP is currently providing ehf communications capability to Army, Navy, and Air Force ground, airborne, and oceangoing terminals. We will discuss the FEP and its purpose in chapter 3.

Infrared devices and lasers use even higher frequency ranges. Information on equipment using these frequencies can be found in *Electro-Optics,* volume 9, of this training series.

RADIO EMISSIONS

The emission class of an rf transmitter is determined by the type of modulation used. The international designation system for AM and FM emissions is shown in table 1-2. It designates the rf emission by type, mode, and supplemental characteristics.

We will now discuss the basic equipment required for communications.

TRANSMITTERS

For rf communications to take place, a signal has to be generated. Generating the signal is the job of the transmitter. The following paragraphs will very briefly discuss basic transmitters and transmitter fundamentals.

TRANSMITTER FUNDAMENTALS

Equipment used for generating, amplifying, and transmitting an rf carrier is collectively called a radio transmitter. Transmitters may be simple, low-power units, for sending voice messages a short distance or highly sophisticated, using thousands of watts of power for sending many channels of data (voice, teletype, telemetry, t.v., etc.,) over long distances.

Basic transmitters are identified by their method of modulation: continuous wave (CW), amplitude modulation (AM), frequency modulation (FM), or single-sideband (ssb). We will first describe the types of modulation. We will then describe briefly the basic transmitters themselves.

Table 1-2.—Types of Radio Emissions

A∅	F∅	No modulation intended to carry intelligence.
A1	F1	On-off or mark-space keying without the use of a modulating tone.
A2	F2	On-off or mark-space keying of a modulating audio frequency, or of the modulated emission.
A3	F3	Voice-frequency modulating, including simplex AFTS RATT.
A3A		Single-sideband, reduced carrier (SSB).
A3B		Two indpendent sidebands (ISB).
A3H		Single-sideband, full carrier (compatible SSB).
A3J		Single-sideband, suppressed carrier (SSSC).
A4	F4	Facsimile, with modulation of main carrier directly or by a frequency-modulated subcarrier.
A4A		Facsimile using single-sideband, reduced carrier.
A5	F5	Television.
A5C		Television, vestigial sideband.
	F6	Four-frequency diplex telegraphy (RFCS RATT).
A7		Multichannel voice-frequency telegraphy (AFTS MUX).
A7A		Multichannel voice-frequency telegraphy (AFTS MUX) using single-sideband, reduced carrier.
A7B		Multichannel voice-frequency telegraphy (AFTS MUX) using two independent sidebands.
A7J		Multichannel voice-frequency telegraphy (AFTS MUX) using single-sideband, suppressed carrier.
A9	F9	Cases not covered by above (e.g., a combination of telephony and telegraphy).
A9B		Combinations using two independent sidebands.

MODULATION

Modulation is the process of varying some characteristic of a periodic wave with an external signal. The voice frequencies (about 110-3,000 Hz) are contained

in the audio frequency spectrum, 10-20,000 Hz. In naval communications the terms *voice communications* and *audio communications* are sometimes used interchangeably. The audio signal is impressed upon the rf carrier because it is impractical to transmit frequencies in the audio range due to their excessive wavelength.

Three characteristics of the carrier wave may be varied, or modulated, at an external signal rate: amplitude, frequency, and phase. The following paragraphs discuss each type of modulation.

Amplitude Modulation (AM)

Amplitude modulations the process of combining audio frequency and radio frequency signals so that the *amplitude* of the radio frequency waves varies at an audio frequency rate.

Frequency Modulation (FM)

Frequency modulation is a process in which the *frequency* of the carrier wave is made to vary. An FM signal should remain constant in amplitude and change only in frequency.

Frequency-Shift Keying (FSK)

Frequency-shift keying is considered a form of FM. It is a digital mode of transmission commonly used in radioteletype applications. In FSK the carrier is present all the time. In a keyed condition, the carrier frequency changes by a predetermined amount called

the *mark frequency.* The unkeyed state is called a space.

Phase-Shift Keying (PSK)

Phase-shift keying is similar to FSK except that the phase, not the frequency, is shifted. The primary advantage of PSK is that it can be accomplished in an amplifier stage.

Pulse Modulation

Pulse modulation is accomplished by varying the characteristics of a series of pulses. This can be done by varying the amplitude, duration, frequency, or position of the pulses. It can also be done through coding. Pulse modulation is especially suited for use with communications systems incorporating time-division mutiplexing.

BASIC TRANSMITTERS

Remember, transmitters are generally divided according to their type of modulation. In the discussion below, we describe very briefly how each type operates to help you differentiate between them.

CW Transmitter

A basic CW transmitter is shown in figure 1-3. CW is one of the oldest and least complicated forms of communications. Two advantages of CW are a *narrow bandwidth,* which requires less power out, and *clarity,* even under high noise conditions. The major disadvan-
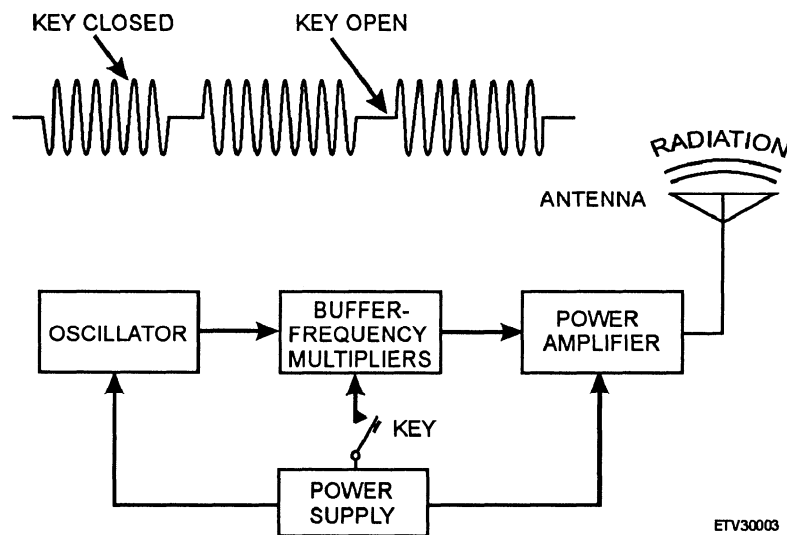

Figure 1-3.—Continuous-wave transmitter.

tage of a CW transmitter is that it must be turned on and off at specific intervals to produce Morse code keying (dots and dashes). This method is very slow by modern day standards. A better method of transmitting is AM.

AM Transmitter

Figure 1-4, a block diagram of an AM transmitter, shows you what a simple AM transmitter looks like. The microphone converts the audio frequency input to electrical energy. The driver and modulator amplify the audio signal to the level required to modulate the carrier fully. The signal is then applied to the power amplifier (pa). The pa combines the rf carrier and the modulating signal to produce the AM signal for transmission.

FM Transmitter

A block diagram of an FM transmitter is shown in figure 1-5. The transmitter oscillator is maintained at a constant frequency by a quartz crystal. This steady signal is passed through an amplifier, which increases the amplitude of the rf subcarrier. The audio signal is applied to this carrier phase-shift network. Here, the frequency of the carrier shifts according to audio signal variations. The FM output of the phase-shift network is

fed into a series of frequency multipliers that increase the signal to the desired frequency. The signal is then amplified in the power amplifier and coupled to the antenna.

Two important things to remember are (1) the amount of variation from the carrier frequency depends on the magnitude of the modulating signal and (2) the rate of variations in carrier frequency depends on the frequency of the modulating signal.

The FM transmitter is better than an AM transmitter for communications purposes because FM is less affected by static and other types of interference. An even better transmitter is the single-sideband transmitter, or ssb. Let's look at some of the advantages of ssb transmitters.

SINGLE-SIDEBAND TRANSMITTER

In ssb communications, the carrier is suppressed (eliminated) and the sideband frequencies produced by the carrier are reduced to a minimum. This means no carrier is present in the transmitted signal. It is removed after the signal is modulated and reinserted at the receiver during demodulation. Since there is no carrier, all the energy is concentrated in the sideband(s).
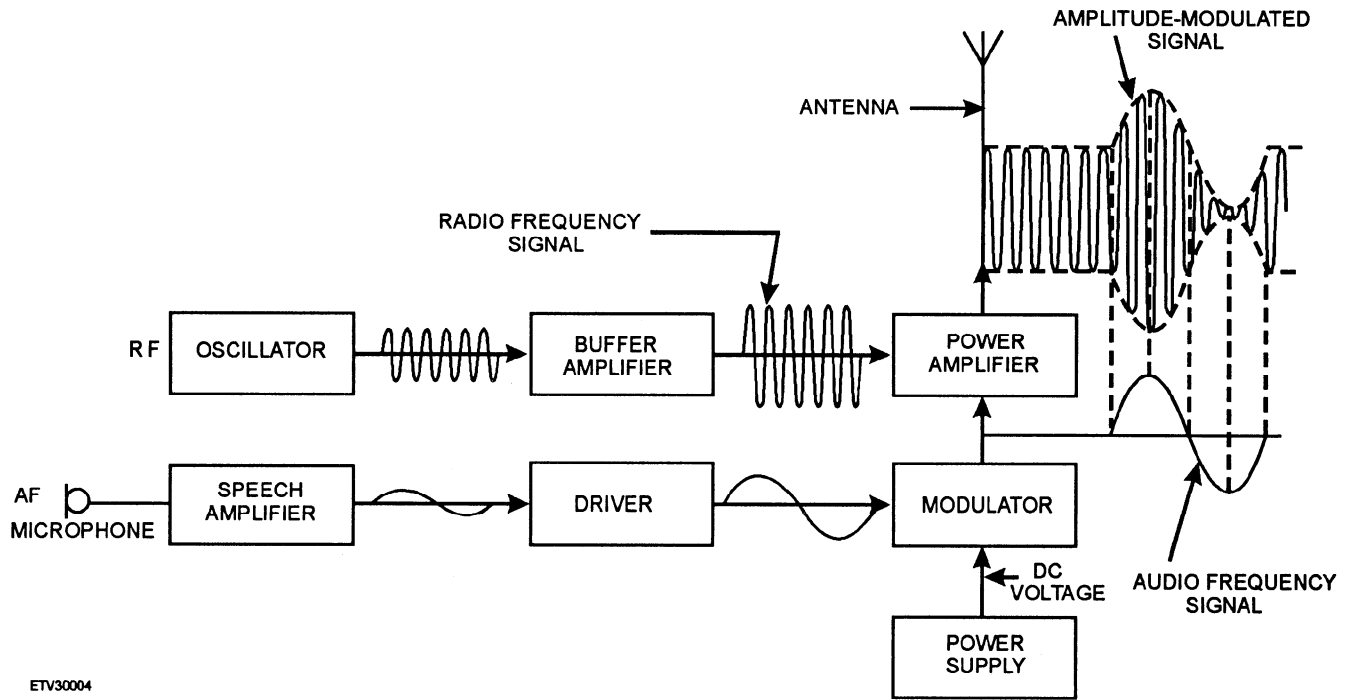

Figure 1-4.—AM transmitter block diagram.
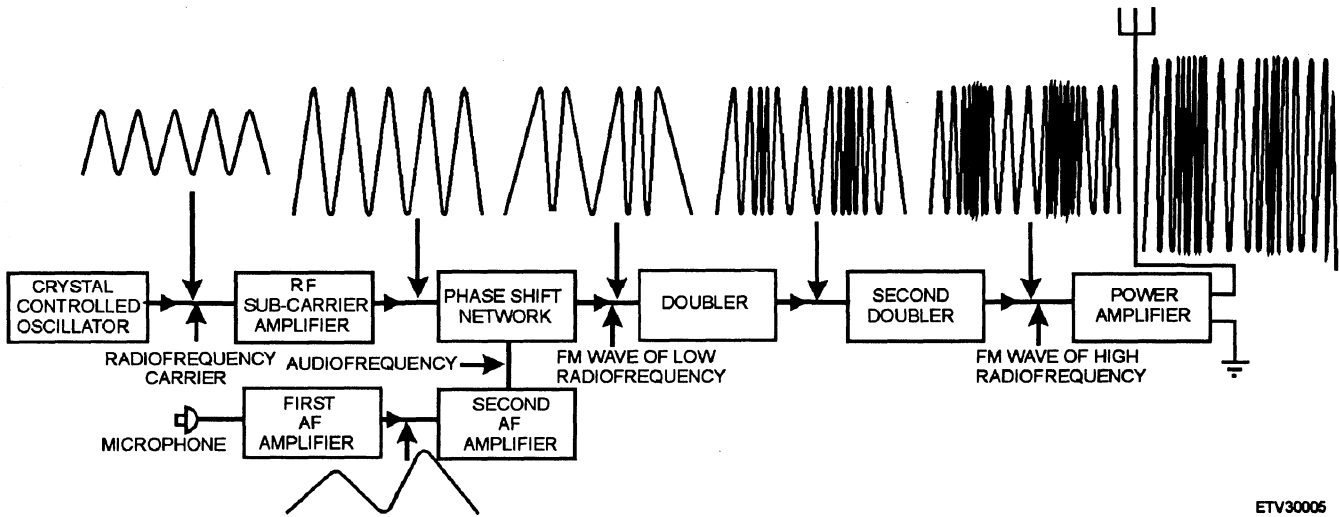
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1-6

Figure 1-5.—FM transmitter block diagram.

We can make ssb even more efficient by removing one of the sidebands. By filtering out one of the sidebands before it reaches the power amplifier, all the transmitter energy is concentrated into one sideband instead of being split between the carrier and two sidebands. This allows us to use less power for transmission. Other advantages are a narrower receiver bandpass and the ability to place more signals in a small portion of the frequency spectrum. Figure 1-6 is a block diagram of a ssb transmitter.

RECEIVERS

Earlier you were introduced to one link in a communications system, the transmitter. All that is needed to complete the system is a radio receiver. A receiver processes modulated signals and delivers, as an output, a reproduction of the original intelligence. The signal can then be applied to a reproducing device, such as a loudspeaker or a teletypewriter.

RECEIVER FUNCTIONS

To be useful, a receiver must perform certain basic functions. These functions are reception, selection, detection, and reproduction.

Reception

Reception occurs when a transmitted electromagnetic wave passes through the receiver antenna and induces a voltage in the antenna.
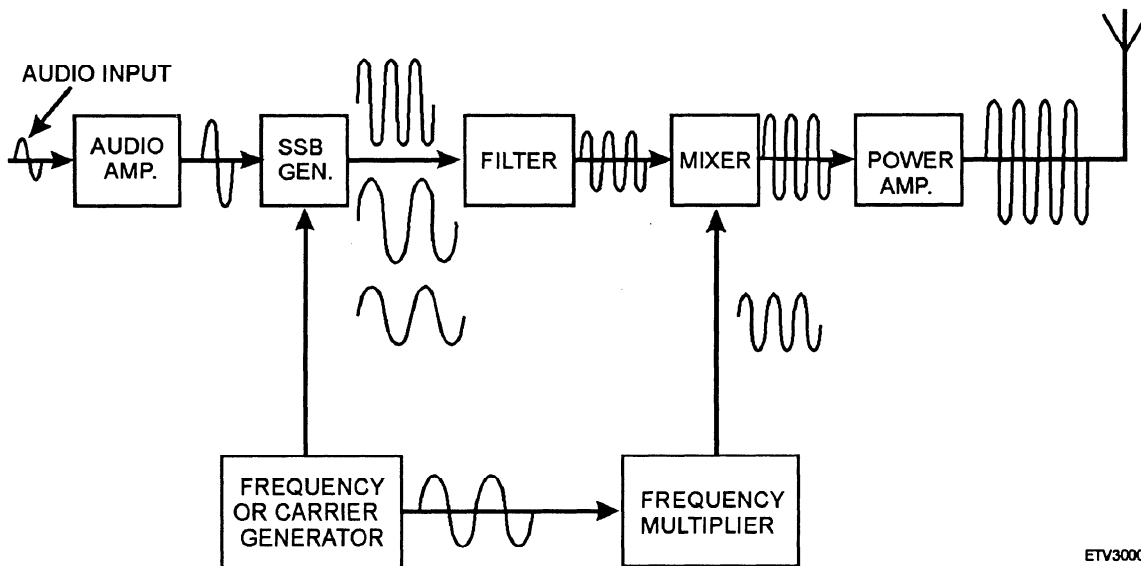

Figure 1-6.—SSB transmitter block diagram.

1-7

Selection

Selection is the ability to distinguish a particular station's frequency from all other station frequencies appearing at the antenna.

Detection

Detection is the extraction of the modulation from an rf signal. Circuits that perform this function are called detectors. Different forms of modulation require different detector circuits.

Reproduction

Reproduction is the action of converting the electrical signals to sound waves that can be interpreted by the ear.

RECEIVER CHARACTERISTICS

Understanding receiver characteristics is mandatory in determining operational condition and for comparing receivers. Important receiver characteristics are sensitivity, noise, selectivity, and fidelity.

Sensitivity

Sensitivity is a measure of receiver's ability to reproduce very weak signals. The weaker the signal that can be applied and still produce a certain signal-to-noise (S/N) ratio, the better that receiver's sensitivity rating. Usually, sensitivity is specified as the signal strength in microvolts necessary to cause a S/N ratio of 10 decibels, or 3.16:1.

Noise

All receivers generate noise. Noise is the limiting factor on the minimum usable signal that the receiver can process and still produce a usable output. Expressed in decibels, it is an indication of the degree to which a circuit deviates from the ideal; a noise figure of 0 decibels is ideal.

Selectivity

Selectivity is the ability of a receiver to distinguish between a signal at the desired frequency and signals at adjacent frequencies. The better the receiver's ability to exclude unwanted signals, the better its selectivity. The degree of selectivity is determined by the sharpness of resonance to which the frequency determining components (bandpass filters) have been engineered
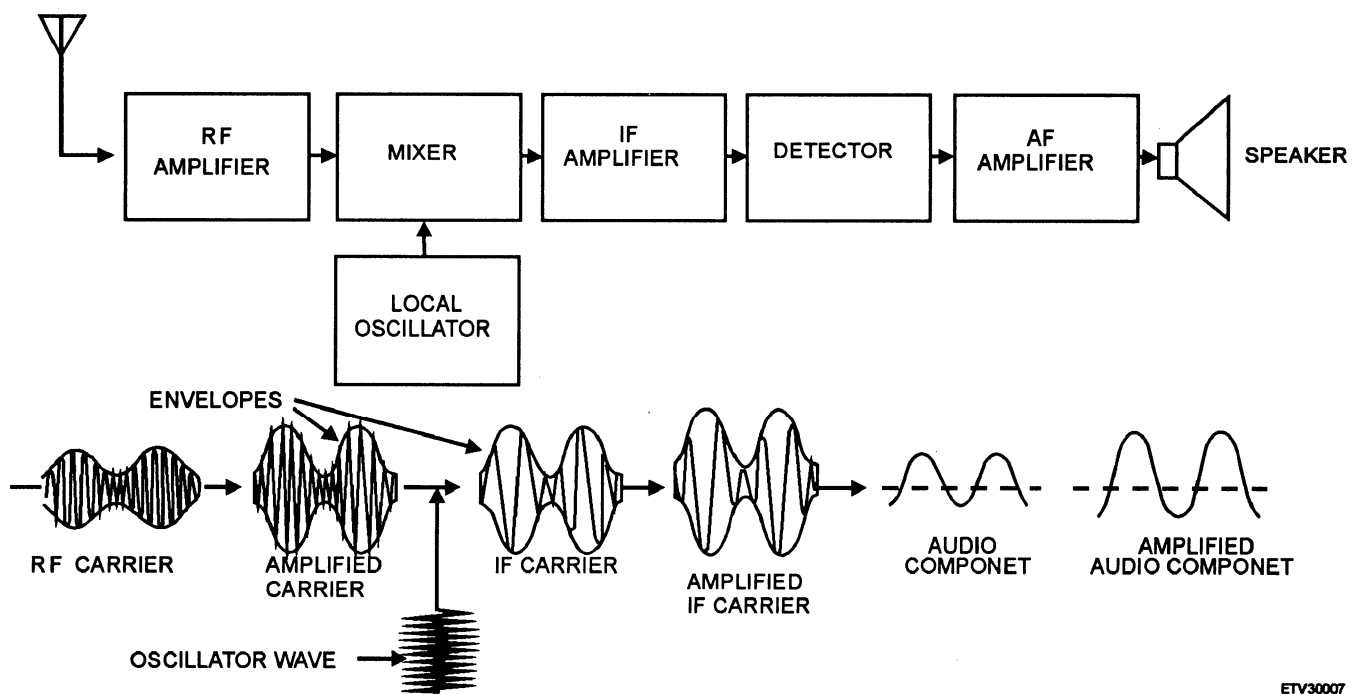

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Figure 1-7.—AM superheterodyne receiver and waveforms.

1-8

and tuned. Measurement of selectivity is usually done by taking a series of sensitivity readings in which the input signal is stepped along a band of frequencies above and below resonance of the receiver's circuits. As the frequency to which the receiver is tuned is approached, the input level required to maintain a given output will fall. As the tuned frequency is passed, the input level will rise. Input levels are then plotted against frequency. The steepness of the curve at the tuned frequency indicates the selectivity of the receiver.

Fidelity

Fidelity is a receiver's ability to reproduce the input signal accurately. Generally, the broader the bandpass, the greater the fidelity. Measurement is taken by modulating an input frequency with a series of audio frequencies and then plotting the output measurements at each step against the audio input. The curve will show the limits of reproduction.

Good *selectivity* requires a narrow bandpass. Good *fidelity* requires a wider bandpass to amplify the outermost frequencies of the sidebands. Knowing this, you can see that most receivers are a compromise between good selectivity and high fidelity.

AM SUPERHETERODYNE RECEIVER

The superheterodyne receiver was developed to overcome the disadvantages of earlier receivers. A block diagram of a representative superheterodyne receiver is shown in figure 1-7. Superheterodyne receivers may have more than one frequency-converting stage and as many amplifiers as needed to attain the desired power output.

FM SUPERHETERODYNE RECEIVER

Fundamentally, FM and AM receivers function similarly. However, there are important differences in component construction and circuit design because of differences in the modulating techniques. Comparison of block diagrams (figures 1-7 and 1-8) shows that electrically there are two sections of the FM receiver that differ from the AM receiver: the discriminator (detector) and the accompanying limiter.

FM receivers have some advantages over AM receivers. During normal reception, FM signals are static-free, while AM is subject to cracking noise and whistles. Also, FM provides a much more realistic reproduction of sound because of the increased number of sidebands.
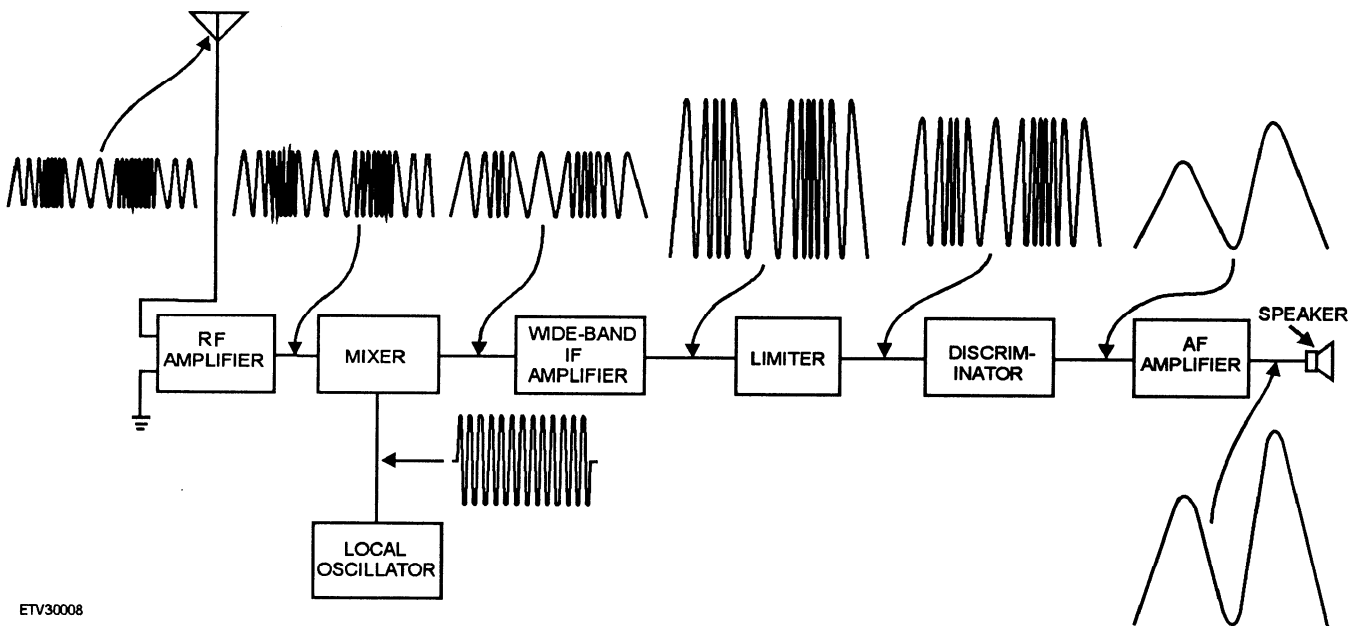

ETV30008

Figure 1-8.—FM superheterodyne receiver and waveforms.

SINGLE-SIDEBAND (SSB)

Figure 1-9 is a block diagram of a basic ssb receiver. Though the ssb receiver is not significantly different from a conventional AM superheterodyne receiver, it must use a special type of detector and a carrier reinsertion oscillator. The oscillators in a ssb receiver must be extremely stable. In some cases, a frequency stability of plus or minus 2 hertz is required. You can see that frequency stability is the most important factor of ssb equipment.

Ssb receivers may use additional circuits that enhance frequency stability, improve image rejection, or provide automatic gain control (age). However, the circuits shown in figure 1-5 will be found in all single-sideband receivers.

AMPLIFICATION

Because the incoming signal may be weak and because a certain minimum voltage level is required for the auxiliary equipment to operate, considerable amplification must take place before the receiver output is used to drive speakers, headphones, or terminal equipment. This is usually called the *gain* of the receiver. Gain is a term used to describe an increase in current, voltage, or power. For example, if the detector, which removes the desired intelligence, requires 1 volt to operate and if the input to the receiver is 1 microvolt, a total amplification of 1 million is required before detection. If the loudspeaker requires 10 volts, another voltage amplification of 10 is necessary between the detector and the loudspeaker.

The gain of an amplifier is expressed in decibels (dB). The decibel is a means of measuring relative levels of current, voltage, or power. Most often it is used to show the *ratio* between input power and output power. This ratio is expressed as gains and losses, where a minus (–) sign placed before dB indicates a loss and a plus (+)(or no sign at all) indicates a gain. The number of decibels change between two power values can be computed by the formula:

$$db = \log_{10} \frac{P1}{P2}$$

The comparison of dB's to power ratio is shown in table 1-3. You can see instantly the reason behind using the decibel system. It is much easier to say the signal level has increased 40 dB than to say it has increased 10,000 times.

Examining table 1-3 again, you can see that an increase of 3 dB indicates a doubling of power. The reverse is also true. If a signal decreases by 3 dB, half the power is lost. For example, a 100-watt signal *decreased* by *3* dB will equal *50* watts, while the same 100-watt signal *increased* by *3* dB will equal 200 watts. It's important to understand that **no matter how much power is involved,** a loss or gain of 3 dB always represents a halving or doubling of the output power.

Technically, the dB level of a signal is a logarithmic comparison between the input and output signals. Table 1-4 shows the common logarithms used to calculate dB. Normally the input signal is used as a reference. However, sometimes a standard reference signal is used. The most widely used reference level is a 1 milliwatt signal. Decibels measured in reference to 1 milliwatt are abbreviated dBm. A signal level of 3 dBm is 3 dB above 1 milliwatt and a level of -3dBm is 3 dB below 1 milliwatt. The formula for dBm is a variation of the dB power formula:

$$dbm = 10 \log \frac{actual\ power\ (P2)}{.001\ watt\ (P1)}$$

As a Navy technician, you will use the dBm system of measurement often to perform receiver sensitivity tests. For example, a receiver rated at -110 dBm will detect a signal 110 dB below 1 milliwatt. Suppose the
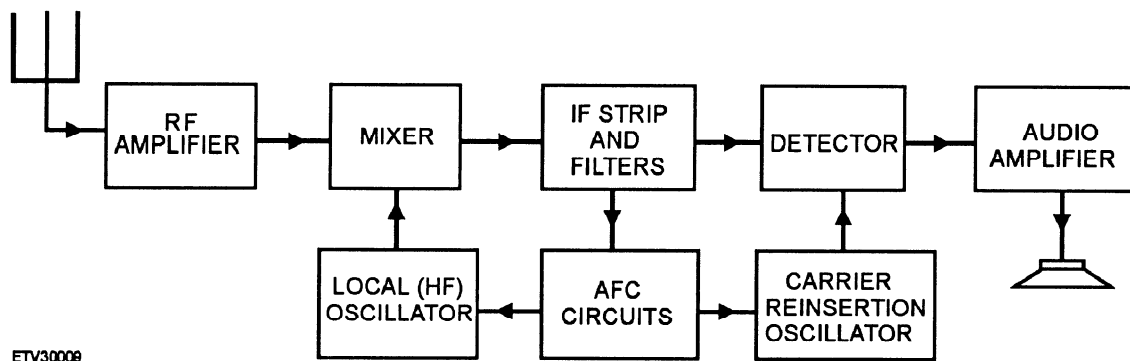
ETV30009

Figure 1-9.—Basic ssb receiver.

Table 1-3.—Decibel to Power Ratio

DB Loss or Gain		Power Ratio Loss or Gain
1	=	1.3
3	=	2.0
5	=	3.2
6	=	4.0
7	=	5.0
10	=	10
20	=	100
30	=	1000
40	=	10,000
50	=	100,000
60	=	1,000,000

Table 1-4.—Logarithms

LOG 1 = 0.0000	LOG 8 = 0.9031
LOG 2 = 0.3010	LOG 9 = 0.9542
LOG 3 = 0.4771	LOG 10 = 1.0000
LOG 4 = 0.6021	LOG 20 = 1.3010
LOG 5 = 0.6990	LOG 30 = 1.4771
LOG 6 = 0.7782	LOG 40 = 1.6021
LOG 7 = 0.8451	LOG 50 = 1.6990
	LOG 60 = 1.7782

receiver's sensitivity drops to -107 dBm. Since a loss of 3 dB reduces the sensitivity by 1/2, the input signal will have to be twice as large to be detected.

TRANSCEIVERS

A transceiver is a unit, usually enclosed in a single case, that combines a transmitter and receiver using a common frequency control. Transceivers are used extensively in two-way radio communications at all frequencies, and in all modes.

The primary advantage of using a transceiver rather than a separate transmitter and receiver is cost. In a transceiver, many of the components can be shared during both transmit and receive operations. Another advantage is that transceivers can be tuned more easily than separate units.

A disadvantage of using a transceiver is that while duplex operation is not possible with most transceivers, communication must sometimes be carried out on two different frequencies. Although this is a

problem with most transceivers, some do have provisions for separate transmit and receive operations, allowing them to overcome the problem.

ANCILLARY EQUIPMENT

Now that we have looked at the basic components of a communications system, let's identify some of the ancillary equipment required to make a transmitter and receiver useful.

HANDSET

A handset converts acoustical (sound) energy into electrical energy, which is used to modulate a transmitter. It also converts electrical energy into acoustical energy for the reproduction of the received signal.

To **key** a transmitter, the push-to-talk button is depressed, closing the dc keying circuit, which places the transmitter on the air. The handset is normally connected to a radio set control but can be used locally at the transmitter. Using the "local" option is a good way to determine whether a problem exists in the transmitter or remote equipment.
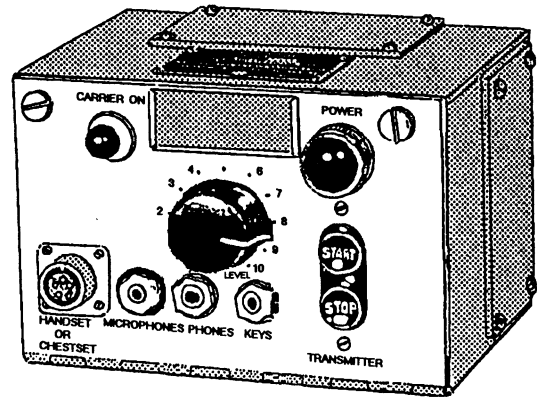
RADIO SET CONTROL

The radio set control provides the capability to control certain transmitter functions and the receiver output from a remote location. Some control units contain circuits for turning the transmitter on and off, voice modulating the transmission, keying when using CW, controlling receiver output, and muting the receiver when transmitting.

A representative radio set control unit is shown in figure 1-10. As many as four of these units maybe paralleled to a single transmitter/receiver group to provide additional operating positions. This setup is often found aboard ship when a transmitter or receiver is controlled from various locations like the bridge or combat information center.
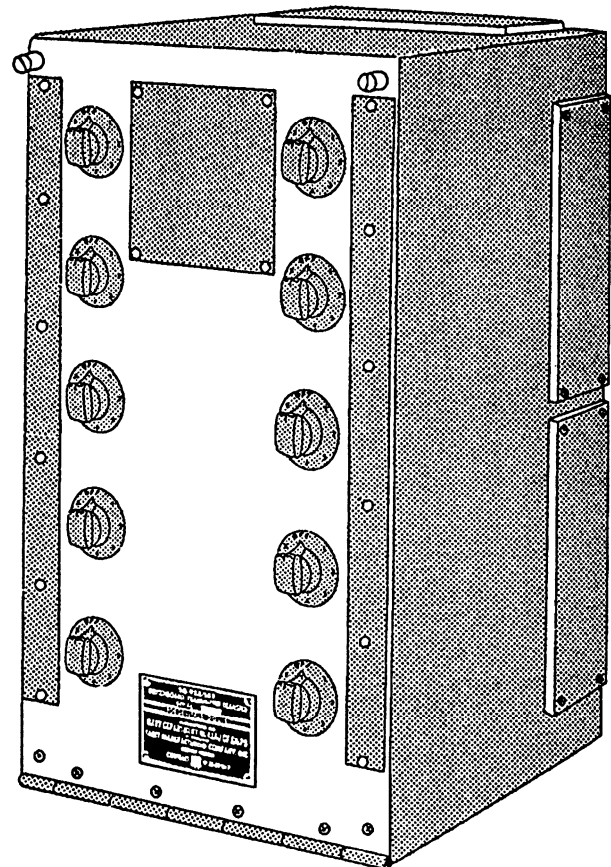
TRANSMITTER TRANSFER SWITCHBOARD

The transmitter transfer switchboard allows the remote control station functions and signals to be transferred selectively to the transmitters. Figure 1-11 shows a transfer switchboard that allows the functions and controls of anyone, or all, of 10 remote control station functions and signals to be transferred selectively to any one of six transmitters. Each knob corresponds

ETV30010

Figure 1-10.—Radio set control

ETV30011

Figure 1-11.—Transmitter Transfer Switchboard (SB-988/SRT).

to a remote control station and has 8 operating positions. Positions 1 through 6 correspond to attached transmitters. The seventh position (X) allows for switching of the transmitters to another switchboard. The eighth position (OFF) removes the remote from the system.

RECEIVER TRANSFER SWITCHBOARD

The receiver switchboard allows the audio outputs from the receivers to be transferred to remote control station audio circuits. A representative receiver transfer switchboard is shown in figure 1-12. This switchboard contains 10 seven-position switches. Each switch corresponds to a remote control station and each switch position (1 through 5) represents a receiver. Position X allows the circuits attached to the switch to be transferred to another switchboard.

ANTENNAS

An antenna is a conductor or system of conductors that radiates or intercepts energy in the form of electromagnetic waves. An antenna can be simply apiece of wire; but in practice, other considerations make the design of an antenna system complex. The height above ground, conductivity of the earth, antenna shape and dimensions, nearby objects, and operating frequency are just a few of the factors affecting the radiation field pattern.

Information on antenna theory, basic antennas, and wave propagation will be available in *Antennas & Wave Propagation,* volume 7, of this training series. Currently, you can find information in Navy Electricity and Electronics Training Series (NEETS), Module 10, *Introduction to Wave Propagation, Transmission Lines, and Antennas,* NAVEDTRA 172-10-00-83.

SYNCHROS AND SERVOS

In many electromechanical systems, the angular position of a shaft must be transmitted from one location to another without an actual mechanical linkage. You have seen examples of this in mast-mounted rotating directional antennas and the automatic tuning function of receivers and transmitters from remote locations. A widely used method employs ac machines that operate as single-phase transformers. These machines are called *synchros.*

Synchro receivers contain sets of gears that do the actual moving of the device to which the synchro is attached. These receivers are light-duty devices, de-
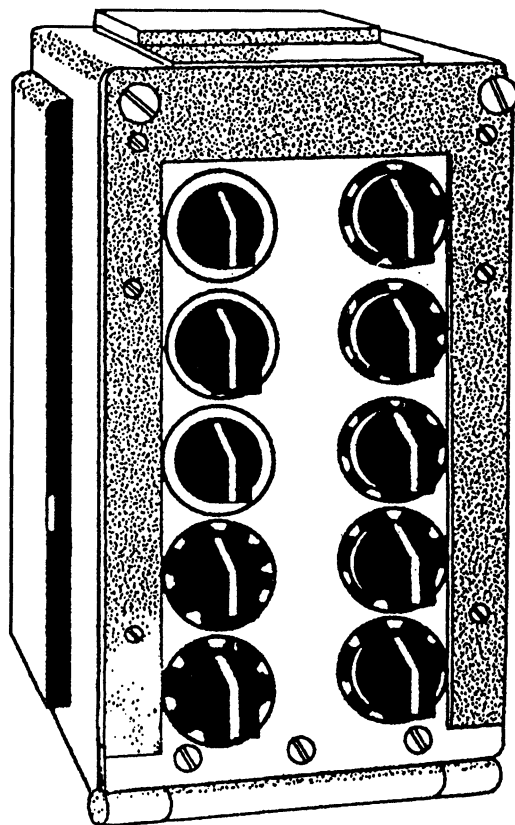
ETV30012

Figure 1-12.—Receiver Transfer Switchboard (SB-973/SRT).

signed to move small loads or to produce small amounts of torque. When the shaft to be driven at the remote location is connected to an indicating device or some light load, the synchro receiver is capable of developing the necessary torque. But, if the load is a heavy load and more torque is required, torque (power) amplification is required. A control system capable of delivering larger amounts of power or torque is known as a servo mechanism, or *servo.*

You will encounter many systems that use sychros and servos. You can find detailed information about these devices in the *Military Standards Handbook,* MIL-HDBK-225 and NEETS, Module 15, *Synchros, Servos, and Gyros,* NAVEDTRA 172-15-00-85.

CHAPTER 2

SYSTEMS EQUIPMENT CONFIGURATIONS

INTRODUCTION

In chapter 1, we discussed basic system requirements. In this chapter, we will look at each equipment configuration. We will then link them together, forming a block diagram of the systems covered. We will discuss naval equipment from extremely-low-frequency through super-high-frequency. We also will look at microwave communications, the Single Audio System, teletype equipment, portable and pack radio equipment, and the Communications Link Interface Planning System.

At various points in the chapter, we review basic principles associated with the larger topic. The purpose of those reviews is to refresh your memory, in case you have not worked in the area for sometime.

After completing this chapter, you should be able to:

- **Identify system equipment configurations and how they link together**

- **Recognize various extremely-low-frequency through super-high-frequency naval equipment**

- **Compare a simplex relay system with a duplex relay system in microwave communications**

- **Identify teletype equipment and portable and pack radio equipment**

- **Identify the Communications Link Interface Planning System**

SHIPBOARD COMMUNICATIONS OVERVIEW

Shipboard communications are now highly sophisticated. Nearly all the communications requirements for a ship can be met with fewer, more versatile, pieces of equipment. This versatility came about through improved equipment design and installation.

As communications equipment became more capable and complex, the need for an orderly process of identifying equipment by designation became apparent. The process that was developed identified equipment from the system level down to the part level. The highest level designator, *system,* describes

pieces of equipment that work together for a specific function. The lowest level designator, *part,* describes one piece, like a resistor. The following paragraphs describe the various levels in greater detail.

SYSTEM

Recall from chapter 1 that a communications system is a collection of equipment used together to satisfy a specific communications requirement. Further, as the following paragraphs explain, a *system* is a combination of *sets, units, assemblies, subassemblies,* and parts. The requirement placed on the system could be to send or receive voice, cw, or teletype information.

Figure 2-1 illustrates the equipment included in a typical system to meet these communication requirements.

SET

A *SET* consists of a unit or units and the assemblies, subassemblies, and parts connected to perform a specific function. Two examples are radio receiving sets and radio transmitting sets.

GROUP

A *GROUP* is a collection of units, assemblies, subassemblies, and parts that (1) is a subdivision of a set or system and (2) cannot perform a complete operational function. A good example is an antenna coupler group.

UNIT

A *UNIT* is a combination of parts, subassemblies, and assemblies mounted together that can normally operate independently of other equipment. An example of a unit is the power supply.

ASSEMBLY/SUBASSEMBLY

An *ASSEMBLY* is a combination of two or more subassemblies joined to perform a specific function. A *SUBASSEMBLY* consists of two or more parts that form a portion of an assembly. It can be replaced as a whole, but some of its parts can be replaced individually.

The distinction between an assembly and a subassembly is not always clear. An assembly maybe considered a subassembly when it is part of a larger or more complex assembly. A computer keyboard is a good example. By itself, it is an assembly. However, it is also a subassembly in a total computer system. Another example you are very familiar with is a circuit card.
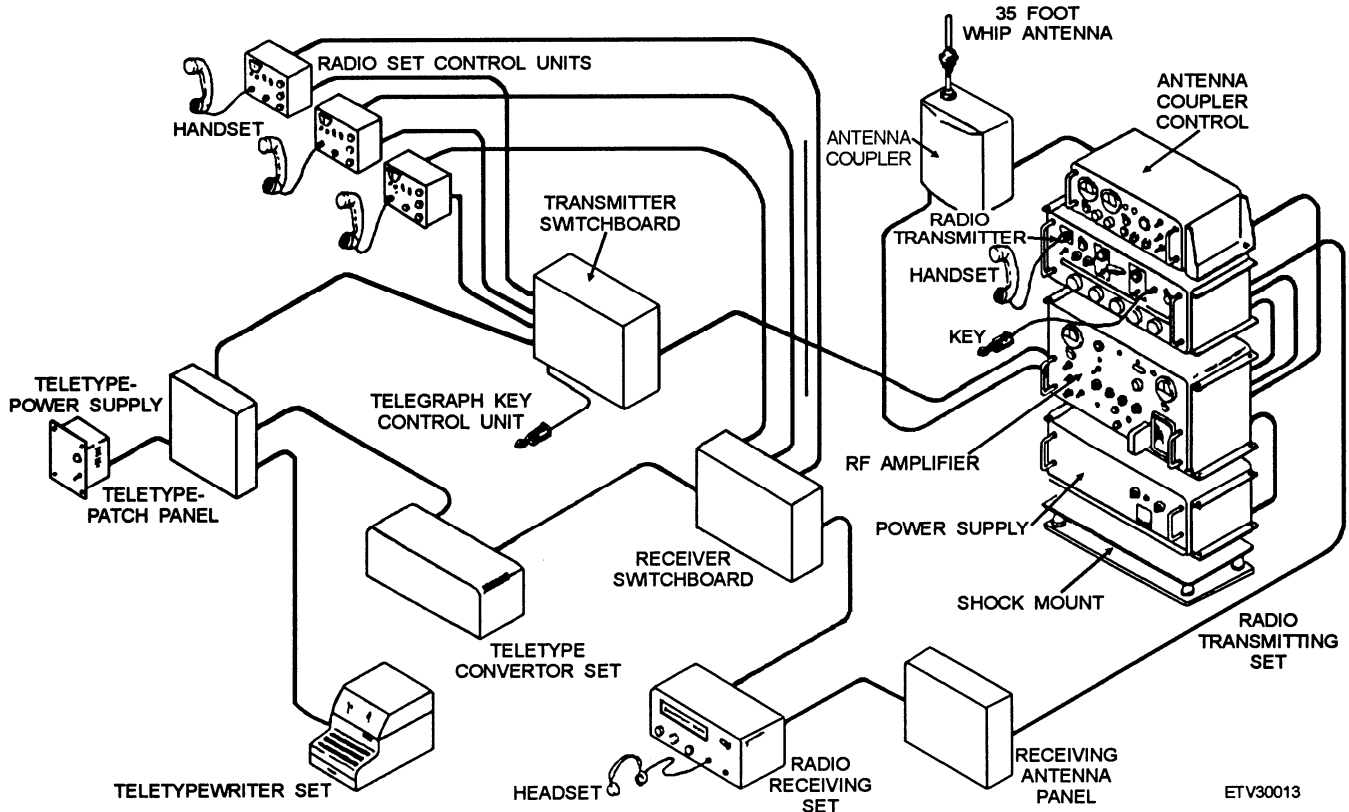

Figure 2-1.—Communications system pictorial view.

PART

A *PART* is one component or a combination of two or more components. A part cannot normally be disassembled without being destroyed. Resistors, capacitors, and transistors are examples of parts.

EQUIPMENT CONFIGURATIONS

The wide variety of communications equipment aboard ship can be overwhelming. This section separates that equipment into types of systems and identifies typical equipment associated with each type of system.

EXTREMELY-LOW-FREQUENCY/ VERY-LOW-FREQUENCY COMMUNICATIONS

The extremely-low-frequency (elf) communications system is used to send short "phonetic letter spelled out" (PLSO) messages from the Continental United States (CONUS) to submarines operating at normal mission speeds and depths. Elf can penetrate ocean depths to several hundred feet with little signal loss. This allows submarines to operate below the surface, improving their survivability by making detection more difficult.

The elf system is a one-way communications system from CONUS to at-sea submarines. The large size of elf transmitters and antennas makes transmission from submarines impractical.

The principal use of the very-low-frequency (vlf) communications system is to provide fleet broadcasts to the submarine fleet and associated ships and activities thorughout the world. Additional uses are in long-range navigation and time and frequency broadcasts.

Vlf Transmit

Vlf transmission is normally considered a broadcast; that is, a one--way transmission, with no reply required. The extent and location of the area to be covered determine the transmitter location and power out.

For worldwide coverage, the Navy has installed seven transmitters whose power out ranges from 0.25 to 2.0 megawatts. These transmitters, such as the AN/FRT-87, can operate in either the interrupted continuous wave (icw) or frequency shift keying (fsk) mode. A typical vlf radio transmitting station is shown in figure 2-2.

Vlf Receive

The vlf receive system receives fsk and icw radio transmissions and then reproduces the intelligence that was broadcast. Receivers used for vlf communications are the AN/BRR-3, AN/FRR-21, AN/WRR-3, and
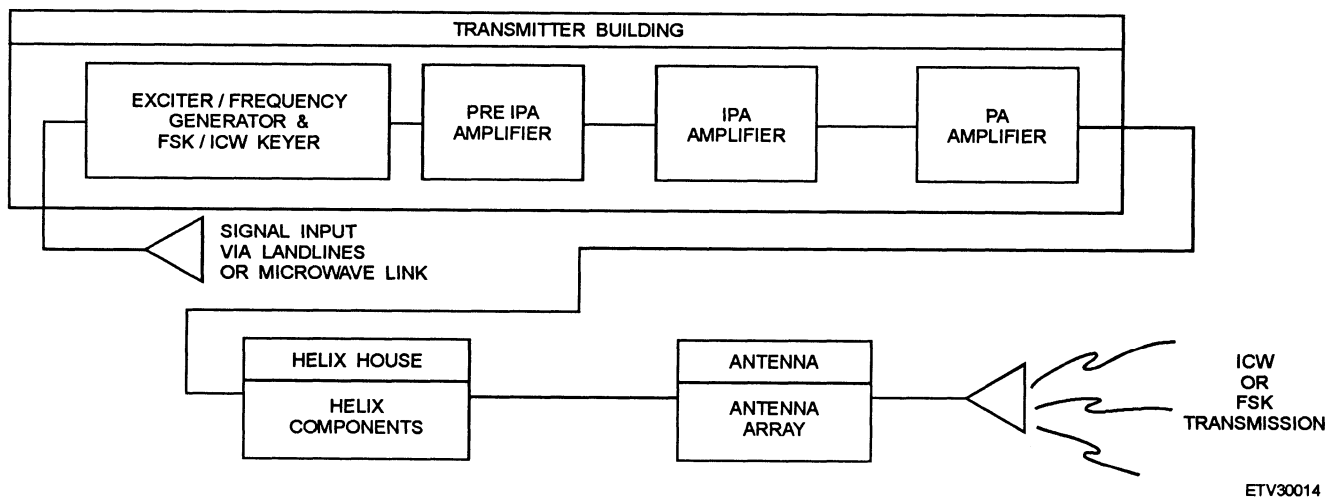

Figure 2-2.—Vlf radio transmitting station block diagram.

URR-R389. Figure 2-3 illustrates a typical vlf receiving system, using the AN/BRR-3 receiver. Most surface ships no longer receive vlf broadcasts. However, you will probably find one of these receivers mounted somewhere in your message center or radio room.

LOW-FREQUENCY COMMUNICATIONS

The low-frequency (lf) band occupies a very small portion of the radio frequency spectrum. However, the Navy's requirement to provide the best possible communications to the fleet requires operation on all frequency bands. The low-frequency band is used for long-range direction finding, encrypted medium- and long-range communications, and aeronautical radio navigation.

Lf Transmit

The low-frequency transmitter is a part of the Fleet Multichannel Broadcast System, operating at high
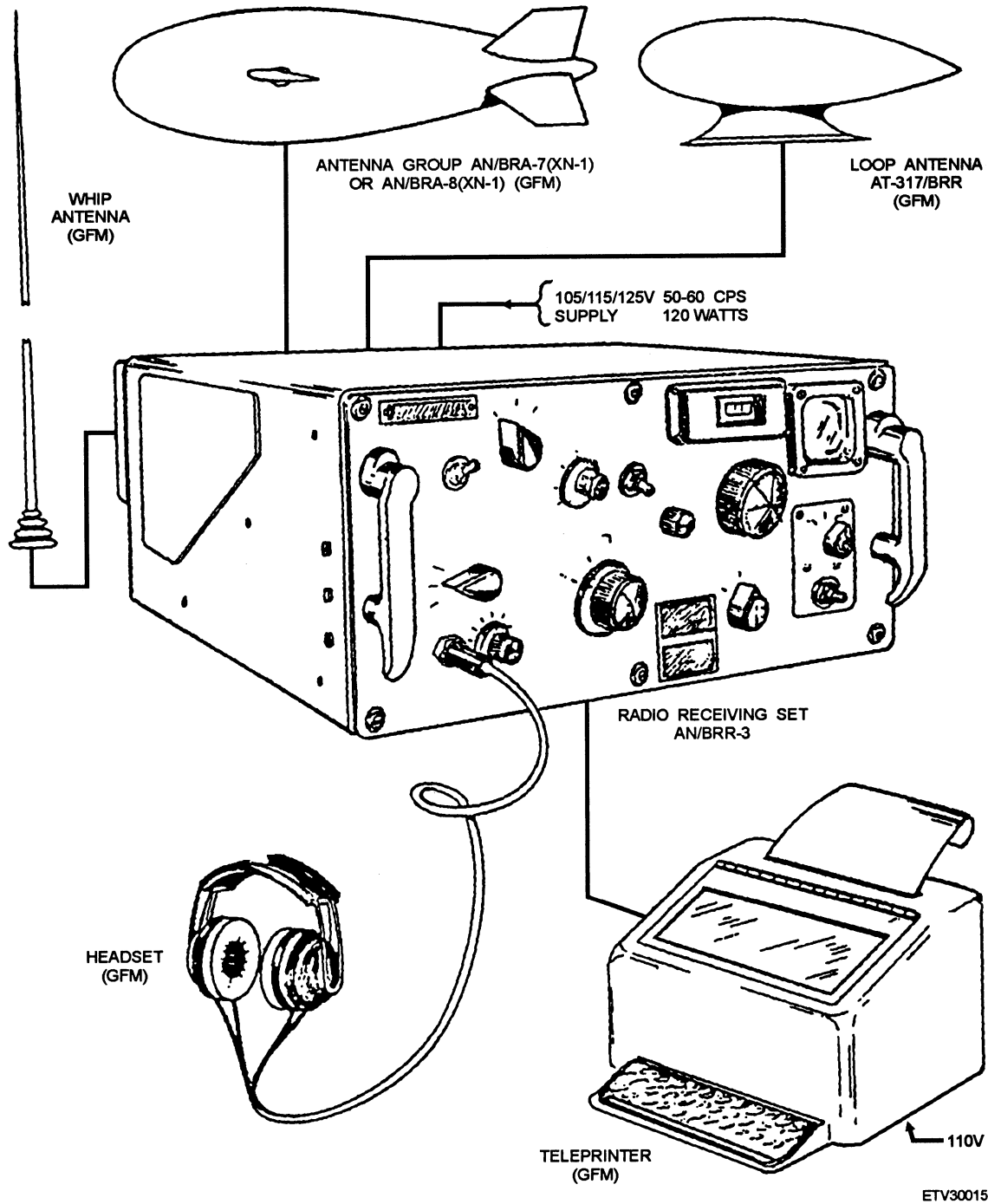

Figure 2-3.—Typical vlf receiving system.

2 - 4

power over long distances. It provides eight channels of frequency-division multiplex rtty traffic on each transmission. The AN/FRT-72 transmitter is designed specifically for this purpose. It produces 50-kW peak-envelope power (25-kW average power) and covers a frequency range of 30 to 150 kHz. Low-frequency transmitters are normally used only on shore stations.

Lf Receive

The low-frequency receive system receives lf broadcasts and reproduces the intelligence that was transmitted. A typical lf receive system is shown in figure 2-4. The antennas receive the lf signal and send it to the multicoupler and patch panel. The multicoupler and patch panel (AN/SRA-17 and AN/SRA-49) allow the operator to select different antennas and connect them to various receivers. In the system shown in figure 2-4, the receiver can be either the AN/SRR-19A or the R-2368A/URR. These receivers operate in the frequency ranges of 30 to 300 kHz and 14 kHz to 30 MHz, respectively.

The receiver audio is fed to the SB-973/SRR receiver transfer switchboard. As we explained earlier, this allows the received audio to be connected to numerous pieces of equipment. In figure 2-4, the audio is connected to either an AN/URA-17 or CV-2460 convertor comparator, which converts the received signal to dc for use by the teletype (tty) equipment. From the convertor, the dc signal is fed to a dc patch panel (SB-1203/UG). The signal can then be sent to any crypto equipment attached to the patch panel. The crypto equipment decrypts the signal and routes it to the red patch panel (SB-1210/UGQ). The signal can

then be patched to a teletype printer for plain text printing, or to a reperforator, where a paper tape will be punched and stored for later printing.
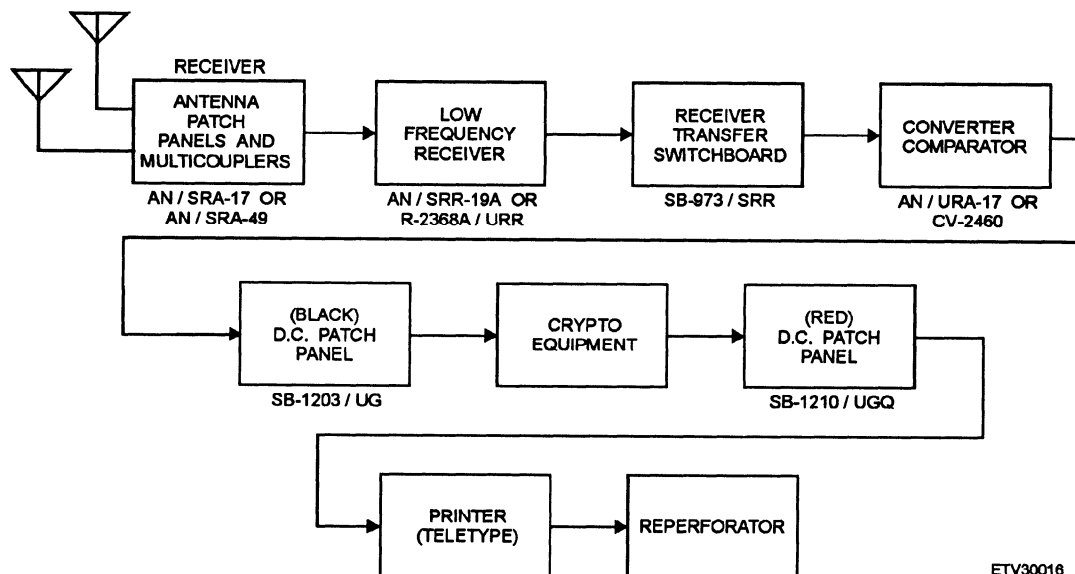
HIGH-FREQUENCY COMMUNICATIONS

The high-frequency (hf) band is shared by many domestic and foreign users. Portions scattered throughout the band are assigned to the military. The Navy's communications requirements have grown rapidly, severely taxing its portion of the spectrum. Satellite communications has relieved some of this congestion and, for some types of service, has replaced hf for long-distance communications, pushing hf into a back-up role. However, even with the use of satellite communications, hf will continue to be in high demand for sometime. We will cover satellite communications in chapter 3.

Naval communications within the hf band are grouped into four general types: point-to-point, ship-to-shore, ground-to-air, and fleet broadcast. All but the fleet broadcast are normally operated two-way.

Point-to-Point

Point-to-point systems provide communications over long-distance trunks or via links between fixed terminals. A *trunk* is normally a message circuit between two points using cable, fiber, or telephone circuits. A *link* is a transmitter/receiver system connecting two locations. The two locations normally use directional, high-gain antennas that increase the effective radiated power, reduce the chance of interference, and boost the sensitivity of the

Figure 2-4.—Lf receive.

receiving system. With the path length and direction fixed, propagation factors are simplified. This provides highly reliable hf communications.

Ship-to-Shore

High-frequency atmospheric communications between shore stations are relatively easy because shore stations have sufficient space for efficient omnidirectional antennas or arrays that provide hf coverage of large areas. Ship-to-shore hf communications are more difficult because the ship is moving and constantly changing direction. This change of direction and severe space limitations aboard ships make the installation of large, efficient hf antennas impractical.

To overcome these problems, ship-to-shore systems have two major differences from point-to-point systems. First, shipboard antennas are omnidirectional. Second, several frequencies are usually assigned for each circuit. If one frequency starts to drop out, another can be selected to match the propagation path conditions between the ship and the shore terminal.

Ground-to-Air

The use of hf radio for ground-to-air communications is similar to its use for ship-to-shore communications. An additional problem is that an aircraft moves much more rapidly than a ship. This rapid movement (plus additional space limitations) requires that all major circuit im-provements be made at the ground stations. Examples of improvements that can only be made to the ground station are higher powered transmitters, lower noise receivers, and more efficient antennas.

Fleet Broadcast

As the name implies, this service involves broadcast area coverage from shorebased transmitters to ships at sea. To overcome propagation problems, messages are sent on several frequencies at the same time (frequency-diversity). Space-diversity with physically separated receive antennas also helps overcome propagation problems.

Now let's look at typical shipboard high-frequency transmit and receive systems.

Shipboard HF Transmit

The high-frequency transmit signal can contain either voice or teletype information. Figure 2-5 shows a typical shipboard high-frequency transmit system.

The same equipment used to receive teletype messages on low frequencies (teletype, DC Patch Panel SB-1210/UGQ, crypto equipment, and DC Patch Panel SB-1203/UG) are used to send teletype messages on the high-frequency system; but of course, in reverse order.

An AN/UCC-1(V) or CV-2460 telegraph terminal converts a dc signal into a tone signal. This signal is fed to the SB-988/SRT transmitter transfer switchboard. A C1004 transmit keying and control/teletype is used to key the transmitter during tty operation. Voice communications also can be connected to the SB-988/SRT switchboard. The voice communications are developed at a handset connected to the C-1138 radio
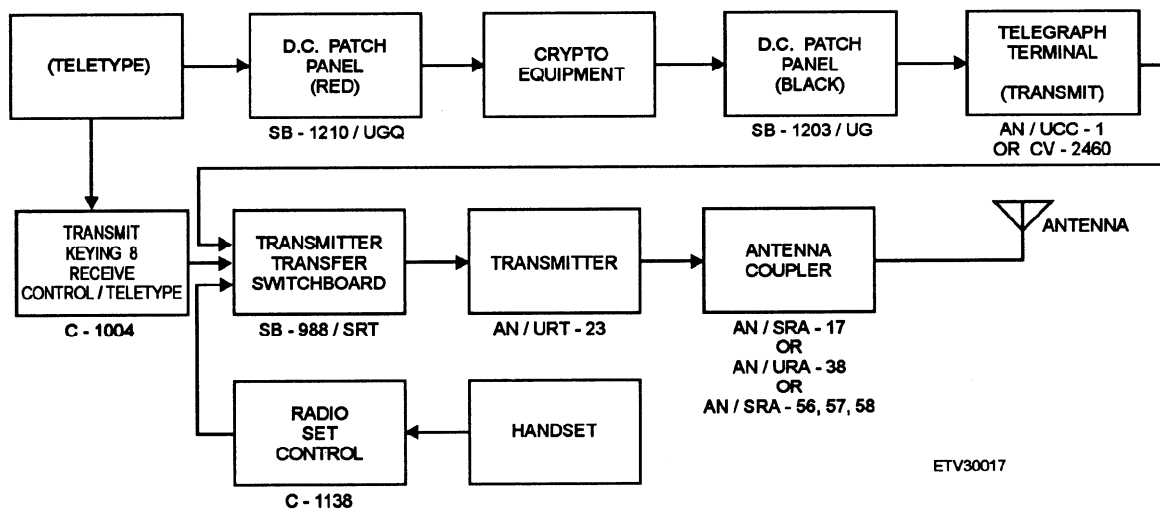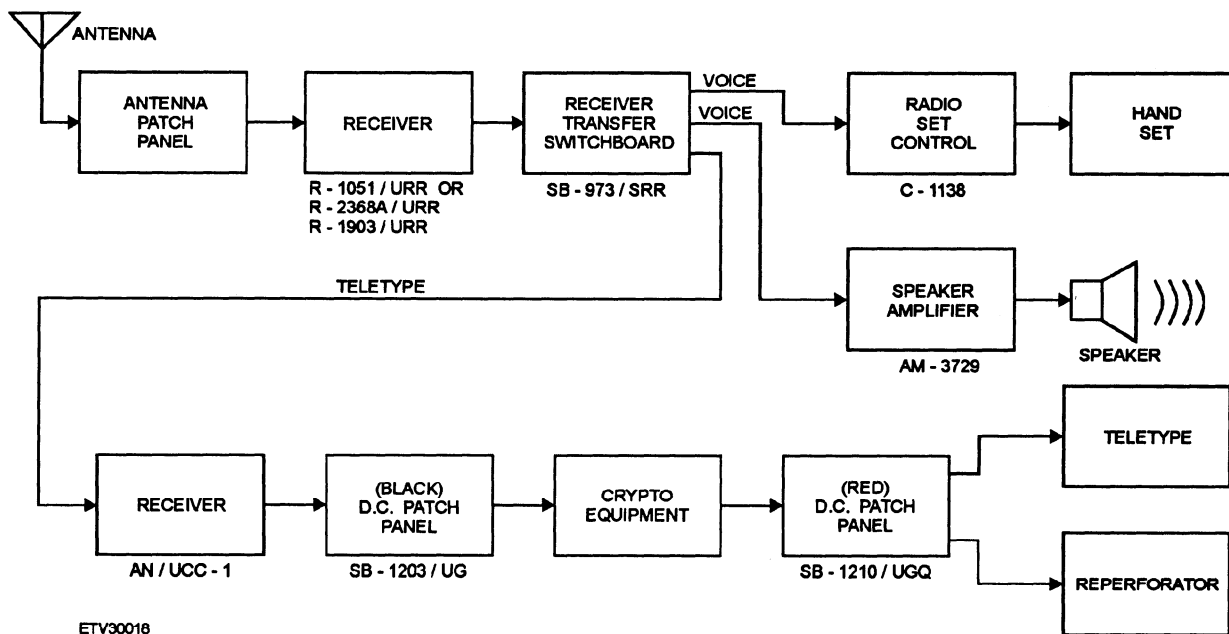

Figure 2-5.—Shipboard hf transmit system.

Figure 2-6.—Shipboard hf receive system.

set control. The output of the radio set control is then fed to the switchboard.

The transmitter transfer switchboard allows operators to select the proper transmitter for the selected frequency. The AN/URT-23 transmitter receives its input from the switchboard and changes the signal to a modulated rf signal that is fed to the AN/SRA-34, 56, 57, 58, or AN/URA-38 antenna coupler. The antenna coupler matches the output impedance of the transmitter to the input impedance of the antenna. Antenna couplers also allow more than one transmitter to be connected to the same antenna as long as certain conditions are met. When the signal reaches the antenna, it is radiated into the atmosphere.

Shipboard Hf Receive

A typical shipboard hf receive system is shown in figure 2-6. A transmitted signal similar to the one previously discussed is received by the antenna and converted from electromagnetic energy to electrical energy. The signal is fed to an antenna patch panel where it can be distributed to any number of receivers.

In figure 2-6, a receiver (R-1051/URR, R-2368/URR, or R-1903/URR) converts the rf signal into either a teletype signal (fsk) or voice. The receiver output is then fed to the SB-973/SRR receiver transfer switchboard. The teletype signal from the switchboard follows the same path used by the low-frequency signal we discussed earlier. Identical pieces of equipment are used. The voice signal from the receiver switchboard is sent to the C-1138 radio set control and
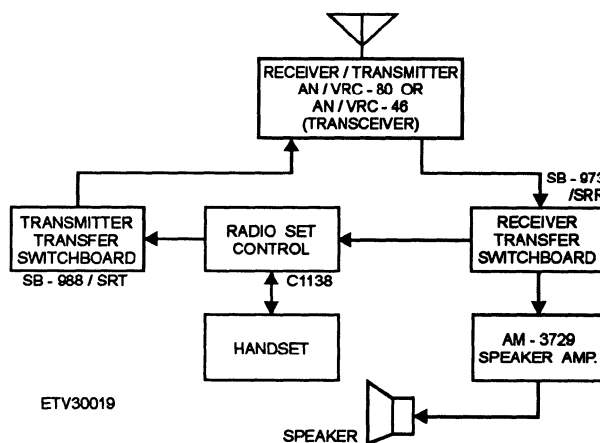
Figure 2-7.—Vhf transmit and receive system.

fed to a handset. The voice signal also can be sent from the switchboard to an AM-3729 remote speaker amplifier and then to a speaker. This allows the user to listen to the signal without having to hold the handset.

VERY-HIGH-FREQUENCY COMMUNICATIONS

The Navy uses the very-high-frequency (vhf) band for mobile communications such as bridge-to-bridge, among boat crews, and for amphibious operations and landing parties.

Vhf Transmit

A typical vhf transmit and receive system is shown in figure 2-7. On the transmit side, the operator, at a remote location, talks into the handset. The handset is

connected to radio set control, C-1138. The radio set control output is fed to transmitter transfer switchboard, SB-988/SRT. The switchboard performs the same function as it does in the lf and hf systems. The output of the switchboard is connected to the transmit side of the transmitter/receiver (transceiver), AN/VRC-46 or AN/VRC-80. The transceiver converts the input signal to an rf signal for transmission and the rf is radiated into the atmosphere by the antenna.

Vhf Receive

Again, look at figure 2-7. The incoming signal is picked up by the antenna. This signal is fed to the receive side of the transceiver. The transceiver output is fed to the receiver transfer switchboard. The switchboard output is connected to either radio set control or to a speaker amplifier, AM-3729, or both, depending on the user's preference. The output of the radio set control is fed to the handset and the speaker amplifier output is routed to the speaker.

ULTRAHIGH-FREQUENCY COMMUNICATIONS

The ultrahigh-frequency (uhf) band is used for line-of-sight (short range) command and control communications. As we stated earlier, line-of-sight means that both antennas are aimed at one another, with no obstruction in between.

This band is also used for satellite communications. Satellite communications are line-of-sight communications because the antennas remain in sight of each other, though the distance traveled by the signal is much greater than for surface communications.

The uhf system uses a transceiver. However, we will still describe the transmit and receive functions separately. Although this description pertains to voice communications, uhf equipment can process tty data in the same way that the hf system does.

Uhf Transmit

A basic block diagram of a uhf transmit system is shown in figure 2-8. On the transmit side of the *nonsecure* voice system, the operator at a remote location talks into the handset. The handset is connected to a C-1138 radio set control. The radio set control is connected to an SB-988/SRT transmitter transfer switchboard, which is connected to the transmitter.

On the transmit side of the *secure* voice system, the operator talks into the secure voice remote phone unit (RPU). The RPU is connected to the secure voice matrix, which is the tie point for the connection of multiple remote phone units. The matrix output is fed to the secure voice equipment that encrypts the information. This encrypted information is then fed to an SB-988/SRT transmitter transfer switchboard.

The transmitter switchboard performs the same function we described for previous systems. The switchboard output is connected to the transmit side of the AN/SRC-20/21 or AN/WSC-3, which is connected
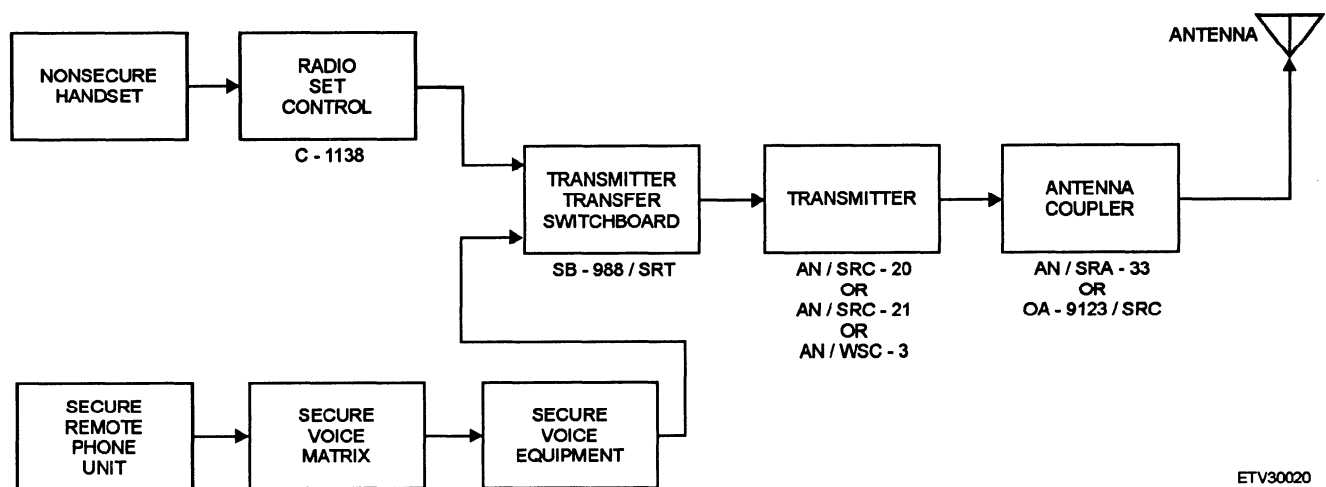
Figure 2-8.—Uhf transmit.

to an AN/SRA-33 or OA-9123 antenna coupler. The coupler output is then fed to an antenna.

Uhf Receive

A basic block diagram of a uhf receive system is shown in figure 2-9. Most of the components are the same as those used in the transmit function. We will, therefore, identify by specific designator only the components that are unique to the receive function. The receive signal is picked up by the antenna and fed to the receive side of the transceiver through the antenna coupler. The receiver output is connected to an SB-973/SRR receiver transfer switchboard. It is then connected to either the nonsecure or secure voice system, depending upon the received transmission mode.

When a nonsecure signal is received, the output of the receive transfer switchboard is fed to either the radio set control or to the AM-3729 speaker amplifier, or both, depending on user preference.

If a secure voice transmission is received, the output of the switchboard is connected to the secure voice equipment and decrypted. This output is fed to the secure voice matrix. The secure voice matrix output is fed to the RPU, where the signal is converted back to its original form.

SUPERHIGH-FREQUENCY COMMUNICATIONS

As we discussed in the previous chapter, two primary uses of the superhigh-frequency (shf) band are microwave and satellite communications. The AN/FSC-79 SHF terminal and satellite communications will be covered in the next chapter. In the following paragraphs, we will discuss line-of-sight and tropospheric scatter microwave communications.

MICROWAVE COMMUNICATION SYSTEMS

Microwave systems, such as the AN/FRC-84 and AN/FRC-170(V), are used to relay multiplex signals from point to point. A simplex relay system provides one-way communications and consists of a transmitting terminal, a certain number of repeaters,
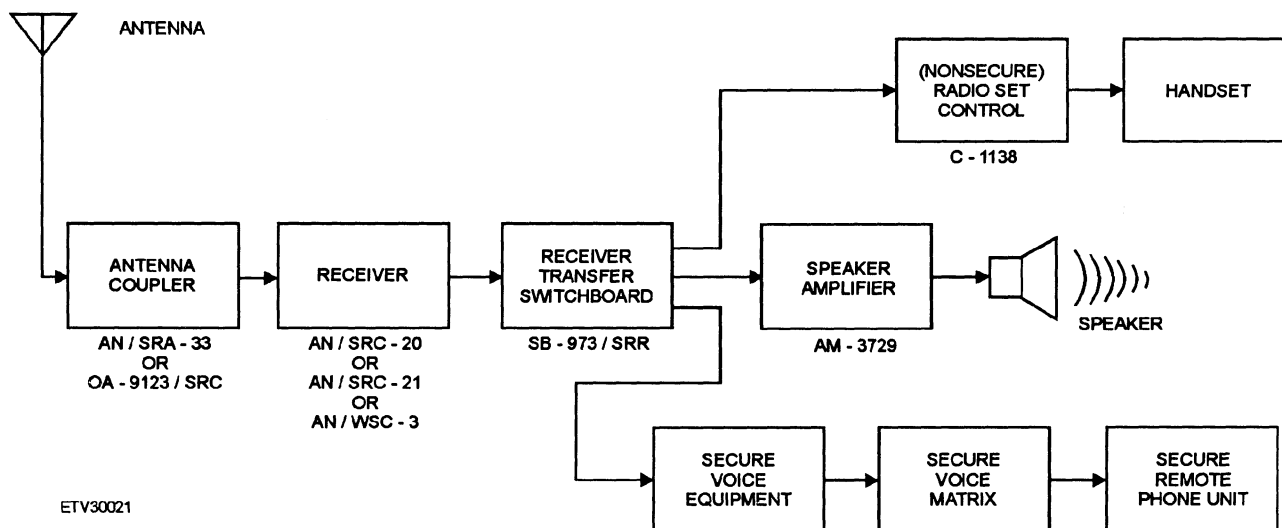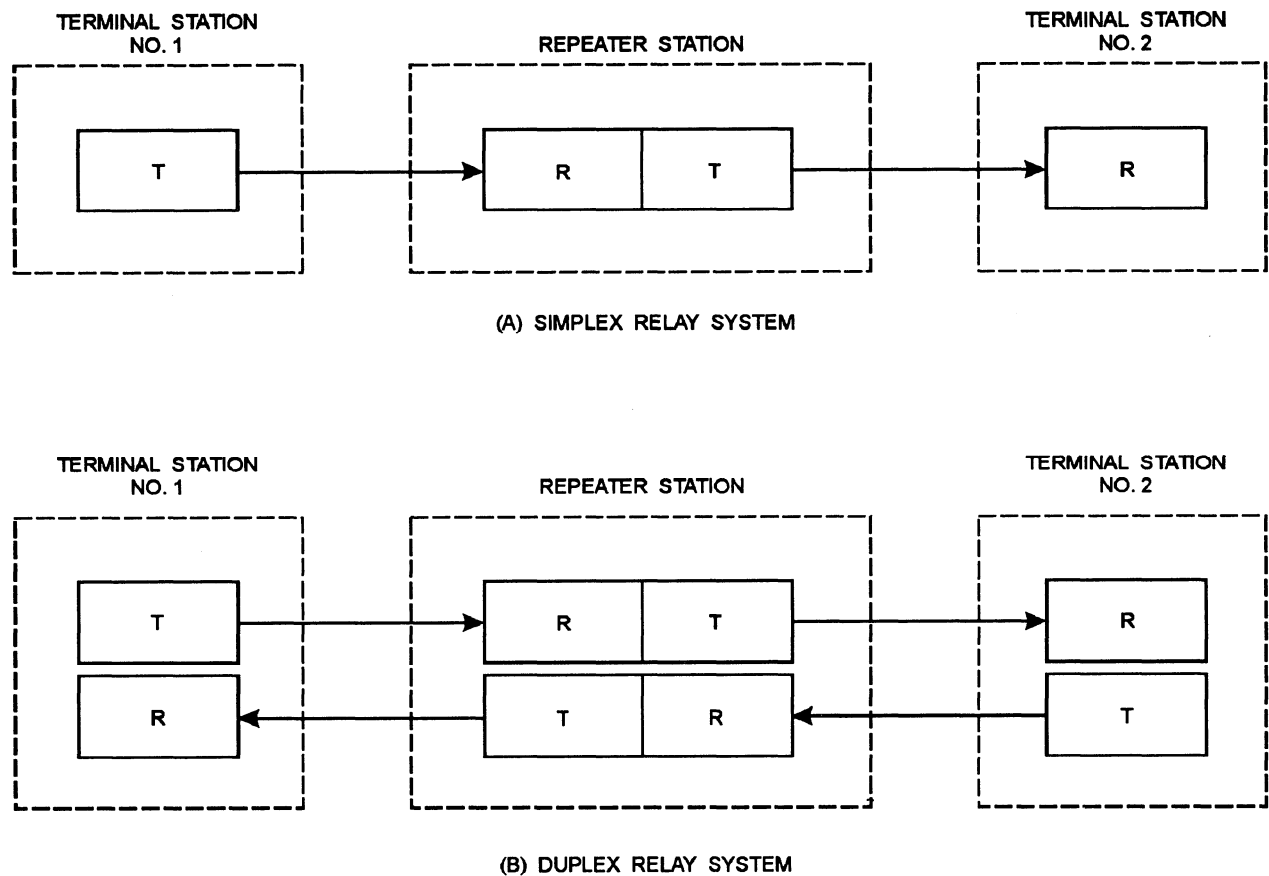
Figure 2-9.—Uhf receive.

TERMINAL STATION
NO. 1

REPEATER STATION

TERMINAL STATION
NO. 2

| T | → | R | T | → | R |

(A) SIMPLEX RELAY SYSTEM

TERMINAL STATION
NO. 1

REPEATER STATION

TERMINAL STATION
NO. 2

| T | → | R | T | → | R |
| R | ← | T | R | ← | T |

(B) DUPLEX RELAY SYSTEM

NOTE:
R IS ABBREVIATION FOR RECEIVER
T IS ABBREVIATION FOR TRANSMITTER

ETV30022

Figure 2-10.—Basic microwave relay system.

and a receiving terminal. Figure 2-10A shows you such a system. A duplex relay system (figure 2-10B) provides two-way communications by using two simplex systems, one transmitting in one direction and the other transmitting in the opposite direction. The duplex system is further refined by using a single antenna for transmitting and receiving. This is done by using different transmitting and receiving frequencies and by using a duplexer in the transmission line.

The rf equipment in terminal and repeater stations are basically the same. Terminal equipment can be converted to repeater equipment and vise versa. Let's take a look at a typical microwave transmitter and receiver.

MICROWAVE TRANSMITTER

A typical microwave transmitters shown in figure 2-11. In operation, the output of a telephone multiplex terminal, which consists of a frequency multiplexed AM carrier signal, is applied to the terminal transmitter. This input signal (baseband signal) also could be a television signal or any other form of signal to be transmitted. A pre-emphasis network accentuates the high frequencies, relative to the low, to improve the
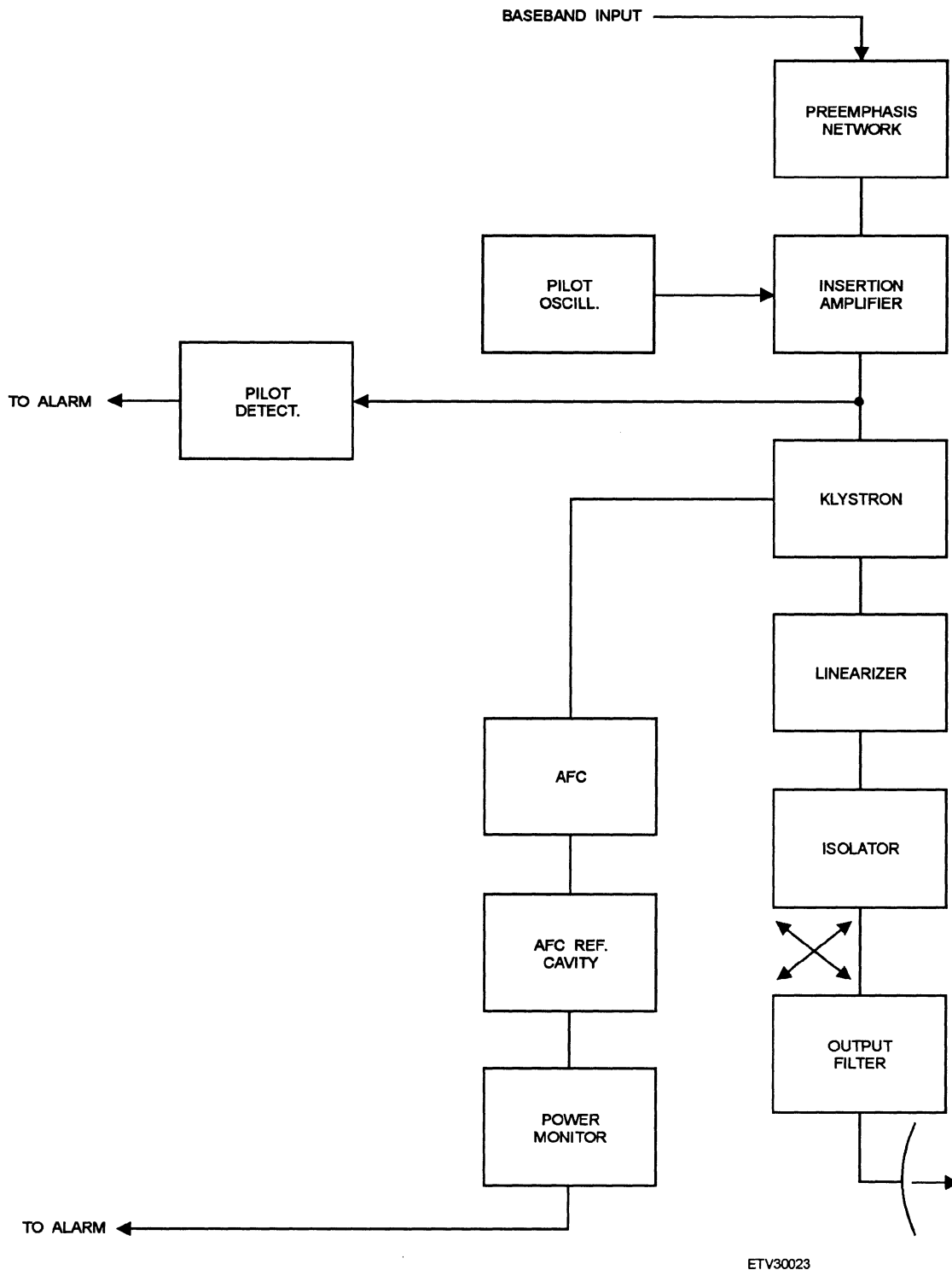
Figure 2-11.—Typical microwave transmitter.

signal-to-noise ratio. The insertion amplifier accepts the signal, amplifies it, and then applies the signal to the klystron oscillator. With this method, the input signal directly modulates the carrier frequency, resulting in a frequency-modulated wave. The "linearize" couples a portion of the output power back to the klystron to compensate for its nonlinearity. This technique allows for optimum performance with modulation densities as high as 1200 channels. You should be aware that solid-state devices are replacing most klystrons.

MICROWAVE RECEIVER

A typical microwave receiver is shown in figure 2-12. Though not shown, sensing and alarm functions are integral to all microwave communications equipment.

During system operation, the signal from the antenna passes through a waveguide preselector that eliminates interference from adjacent rf channels. The signal then enters a waveguide filter tuned to its frequency, which rejects all other unwanted frequencies. Next, the signal passes through an isolator that minimizes intermodulation noise and holds the VSWR below 1.2:1. The signal is then mixed with the local oscillator (LO) output to produce the standard 70-MHz intermediate frequency (IF). The IF output is amplitude-limited and applied to an automatic frequency control (afc) discriminator, which controls the frequency of the LO. The signal is also applied to an IF discriminator, a de-emphasis circuit, and a squelch circuit that disconnects the baseband amplifier and demultiplexing equipment if noise increases above a preset level. After the squelch circuit, the signal passes through a baseband amplifier and then to the demultiplexing equipment, where the original intelligence is retrieved.

Microwave communications systems operating in the shf portion of the frequency spectrum use the principle that propagation approaches an optical straight-line path. Propagation takes place in the lower atmosphere and is affected by meteorological factors. Communications in this medium are usually either line-of-sight or tropospheric scatter.

LINE-OF-SIGHT (LOS)

A line-of sight microwave system consists of one or more point-to-point hops. Each hop is designed to be integrated into a worldwide communications network. Los system characteristics are as follows:

● Propagation—Free space as affected by the troposphere.

● Communications Capacity/Bandwidth—Up to 600-4kHz voice channels; wideband, can accept TV.

● Range—Usually 50 to 150 km (31 to 95 statute miles). This depends upon antenna height, earth curvature, and intervening terrain.

● RF Power—Usually less than 10 watts.

● Antennas—Both transmitting and receiving antennas are horn-driven paraboloids, providing high gain and narrow beam widths. In some applications, plane reflectors are used with the paraboloids.
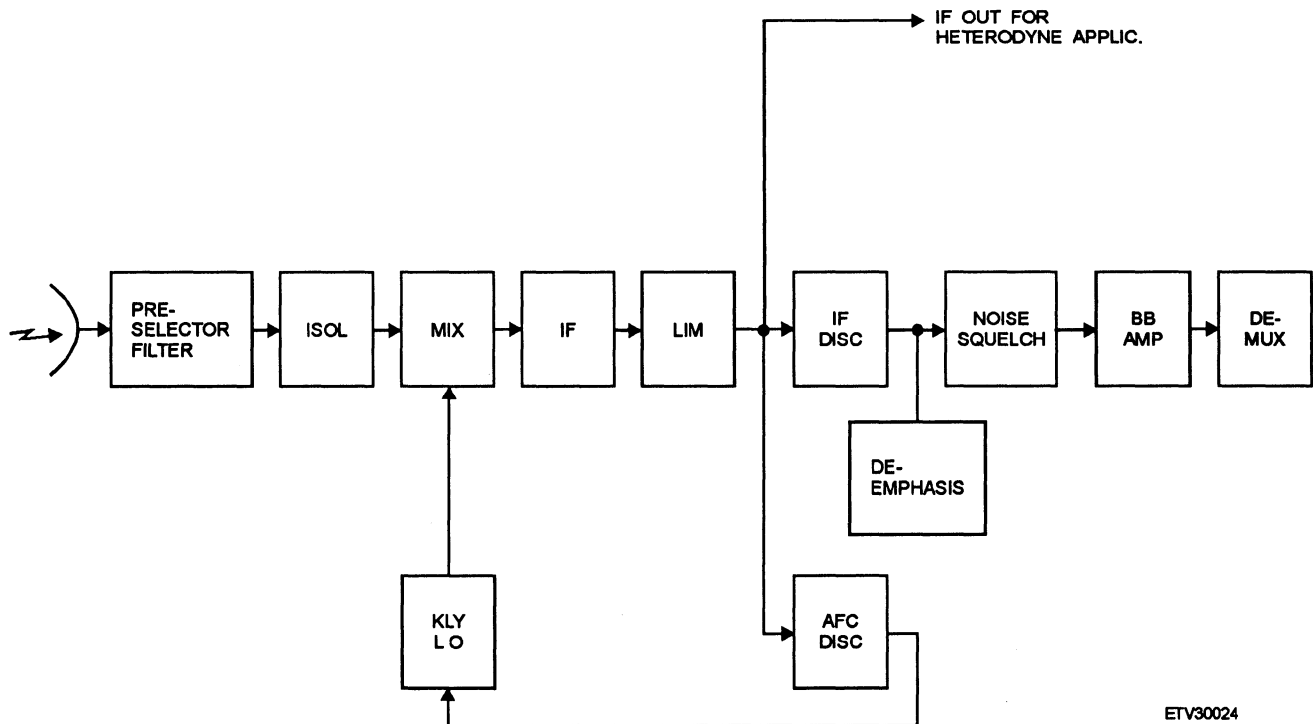

Figure 2-12.—Typical microwave receiver.

● Reliability—Designed to be operational more than 99% of the time, including the periods of poor propagation.

● Countermeasures—Because of antenna directivity, the system is difficult to jam. Additionally, the system should not be susceptible to nuclear disturbances of the ionosphere.

● Application—Because of the bandwidth capability and minimum site requirements, los is well adapted to moderate distance point-to-point multichannel communications (with repeaters), transmission of closed circuit TV, transmission of radar information from outlying sites, communications relay between locations in congested areas, and "antenna farms."

TROPOSPHERIC SCATTER SYSTEM

At microwave frequencies, the atmosphere has a scattering effect on electromagnetic fields that allows for over-the-horizon communications. This type of communications is called tropospheric scatter, or *troposcatter* for short. Troposcatter takes place mostly at low altitudes, but some effect takes place at altitudes of up to 10 miles. Under the right conditions, troposcatter can take place over hundreds of miles.

A tropospheric scatter microwave system consists of one or more point-to-point hops (or sections). Each hop is designed so it can be integrated into the worldwide communications network of the Defense Communications System (DCS). Troposcatter links have the following characteristics:

● Propagation—Free space as affected by the troposphere.

● Communications capacity/bandwidth—Up to 600 4-kHz voice channels; wideband, can accept TV.

● Range—Up to 800 km (500 statute miles).

● RF Power—High; up to 75 kilowatts depending upon bandwidth, quality, and range.

● Coverage—Point-to-point only.

● Antennas—Both transmitting and receiving antennas are horn-driven paraboloids providing high gain and narrow beam widths.

● Reliability—Designed to be operational more than 99% of the time, including periods of poor propagation.

● Countermeasures—Extremely difficult to jam. Should not be susceptible to nuclear disturbances of the ionosphere.

● Application—Meets the communications requirements between HF sites within its minimum skywave one-hop distance of about 400 miles and line-of-site of about 30 miles. It is especially useful where conditions prevent the use of line-of-sight communications or if adverse propagation conditions interfere with other transmission methods.

MULTIPLEXING

As we mentioned earlier, the rf spectrum has become very congested. The maximum number of transmissions taking place in the rf spectrum is being increased through the use of *multiplexing*. Multiplexing refers to the simultaneous transmission of two or more messages over the same medium or channel at the same time. Multiplexing may be achieved in various ways, but the most common methods are time-division multiplexing (tdm) and frequency-division multiplexing (fdm). Although several types of multiplexing equipment are available in the fleet today, the AN/UCC-1D is the most common.

TIME-DIVISION MULTIPLEXING

Time-Division Multiplexing (Tdm) is a method of combining analog signals for serial transfer. The signals are sampled at intervals and interwoven for transmission. The speed of this multiplexed signal is faster than the original individual channel speed by a multiple equal to the number of combined signals. For example, if 5 signals are multiplexed, the data speed of each signal must be multiplied by 5 to keep the signals in synchronization. Tdm also results in an increase in the signal bandwidth because of the increased data speed.

Time-division multiplexing also can be used with digital signals, but this method is usually called *synchronous* multiplexing.

FREQUENCY-DIVISION MULTIPLEXING

Unlike tdm, which samples a portion of the sine wave, frequency-division multiplexing (fdm) transmits and receives for the full 360 degrees of the sine wave. A channel is subdivided into smaller segments of equal size, called *subchannels*. Each subchannel carries a separate signal. Fdm used by the Navy can generally be divided into two categories, voice and tty communications. You can find more information on multiplexing in NEETS, volume 17.

SINGLE AUDIO SYSTEM (SAS)

The Single Audio System (SAS) was developed to fulfill the requirement for an integrated secure/non-secure shipboard voice communications system. It consists of telephone sets, voice-signal switching devices, various control devices, and field changes to existing equipment, in conjunction with other elements of the overall shipboard radio communications system. The SAS is essentially the baseband (AM and/or FM) hf, vhf, or uhf audio subset of the shipboard exterior communications system. It incorporates voice communications circuits, user control over the operating mode (both secure and nonsecure), and various degrees of operator control over voice circuit selection. Figure 2-13 shows the major equipment groups, subsystems, and their interrelationship.

There are two versions of SAS: an automated system (ASAS) and a manual system (MSAS). The voice switching equipment and means provided for user control over circuit selection are the two primary differences. Information in this section applies to both ASAS and MSAS, unless otherwise specified.

There is no specific list of equipment that makeup every SAS installation. There can be different types and quantities of equipment in each of the groups identified in figure 2-13. Equipment types and quantities are dictated by the communications requirements of individual ships and ship classes. The publication, *Operation and Maintenance Instructions, Single Audio System,* NAVELEX EE109-CA-OMI-010/El10 SAS, identifies, in tables 1-1 and 1-2, the SAS equipment commonly used in the fleet.
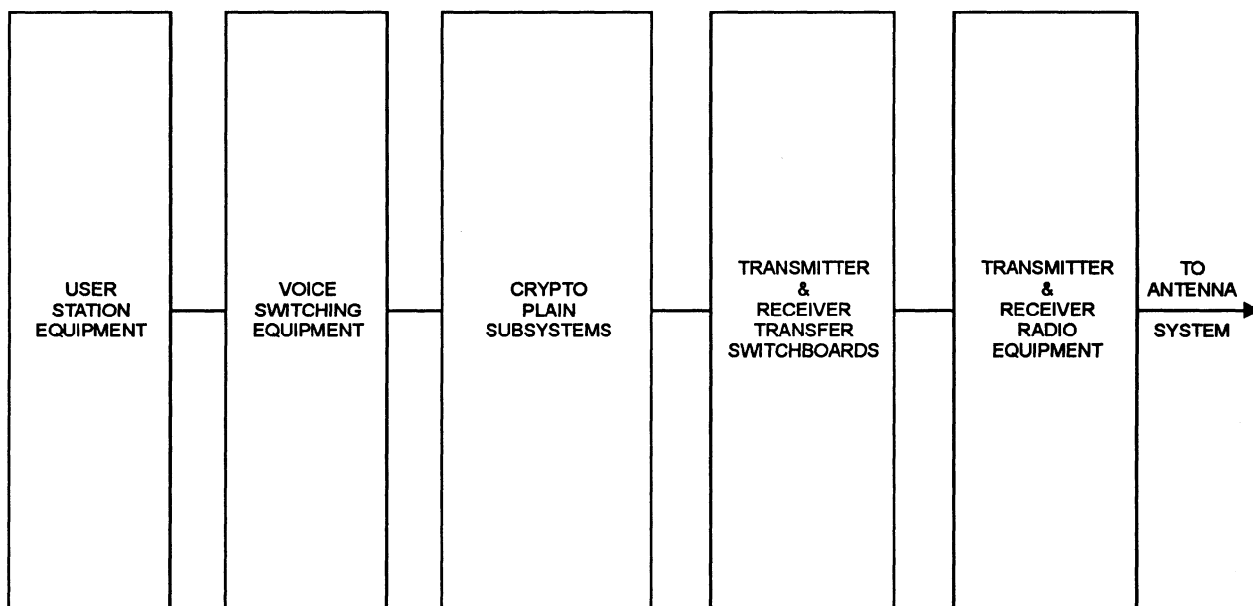
SYSTEM CAPABILITIES

The SAS incorporates basic capabilities for setting up and operating voice communications circuits. An SAS installation provides the unique capability to communicate in a secure or nonsecure mode, at the discretion of the operator, from a single telephone or NTDS device. This single audio interface with various crypto or plain subsystems is the essence of the SAS. The SAS provides the following options:

* The user can select the transmit operating mode except for FLTSATCOM secure voice and PLAIN configurations.

* The system can notify the user of the transmit operating mode selected, both visually and with audio indications.

* The system can notify the user by visual indication if the voice station equipment is not connected to a crypto or plain subsystem.

* The system can notify the user of any incoming secure (CIPHER) signals by both visual and audio indications except for the FLTSATCOM secure voice configuration.

* The user can select a voice channel and have it indicated visually.

In addition to these capabilities, the ASAS version has the following features:

* A processor controlled, programmable voice

Figure 2-13.—Single Audio System (SAS).

| USER STATION EQUIPMENT | VOICE SWITCHING EQUIPMENT | CRYPTO PLAIN SUBSYSTEMS | TRANSMITTER & RECEIVER TRANSFER SWITCHBOARDS | TRANSMITTER & RECEIVER RADIO EQUIPMENT | TO ANTENNA SYSTEM |

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- A voice switch self-test and fault location read-out (built-in test).

- An audio indication to the user when the voice switch built-in-test (BIT) detects a trunk line short.

- A technical control monitor phone, incorporated into the voice switch, which can access all voice channels.

SYSTEMS EQUIPMENT AND LOCATION

The following paragraphs provide a brief description of the major equipment included in a typical SAS installation. Figure 2-13 illustrates the audio path of the system and the order in which we will discuss the equipment.

User Station Equipment

User station equipment is located in operations centers throughout the ship, like the bridge, combat information center (CIC), flag plot, secondary corm, and other stations where exterior voice communications are required by the ship's mission. This equipment consists of telephone sets, audio amplifiers, loudspeakers, headsets, recorders, audio jackboxes, Naval Tactical Data System (NTDS) consoles and intercom units, and local switching devices for added system flexibility.

Voice Switching Equipment

The voice switching equipment is a major component of the SAS. It is the interface and primary switch between the user's equipment and all crypto and plain subsystems. It is designed for very high interchannel isolation, which is a TEMPEST requirement for all equipment that handle both secure and nonsecure signals at the same time. (The ASAS and MSAS use different switches for this purpose.)

Crypto and Plain Subsystems

The various crypto and plain subsystems are located in the main communications spaces. Cryptographic devices and other "red" equipment are located in a secure area within these spaces. There are five crypto and plain subsystems used within the SAS: NESTOR, VINSON, PARKHILL, FLTSATCOM secure voice, and PLAIN ONLY. Additional classified information on these subsystems is available on a need-to-know basis.

Transmitter and Receiver Transfer Switchboards

These equipment are part of the overall exterior communications switching system and are located in the main communications spaces, generally in the vicinity of the technical control working area. The switchboard equipment group interconnects crypto and plain subsystem equipment with the appropriate radio equipment. You should recall from chapter 1 that these switchboards are also the interconnecting points for other subsystems within the overall exterior communications system. Therefore, they are not unique to the SAS.

Transmit and Receive Radio Equipment

These equipment may be located in both the main communications spaces and in separate rooms located in various parts of the ship. This equipment group consists of the various transceivers, transmitters, and receivers used for voice nets. The more common transceivers you will encounter are the AN/SRC-20 series, AN/VRC-46, AN/WSC-3(V)3 and (V)7, AN/URC-93, and AN/WSC-6. Common transmitters include the AN/URT-23, AN/URT-24, T-1322/SRC, and AN/GRT-21. Common receivers are the R-1051 series, R-1903, and AN/GRR-23. For additional information on individual equipment, refer to that equipment's technical manual.

TELETYPEWRITER/FACSIMILE EQUIPMENT

In chapter 1, we discussed different methods of voice communications. Sometimes, the message is too long for practical transmission by voice, so to get your message or idea across, you may need to use a chart, map, or photograph. Teletype (tty) and facsimile (FAX) equipment allow us to do this.

In the following paragraphs, we will discuss some common terms associated with tty and FAX equipment. We will then look at some basic systems.

MODES OF OPERATION

There are two basic modes of teletypewriter operation: asynchronous (start-stop) and synchronous. The *asynchronous* mode is the most common. The *synchronous* mode is used primarily in high-speed data systems.

Asynchronous Mode

In this mode, the receiving device is only allowed to run for one character and is then stopped to await the start signal for the next character. Any differences in speed between the transmitting and receiving devices can only accumulate during the time assigned to one

character. There is a penalty for this advantage. Character length is increased to include the start (space) and stop (mark) signals. These start and stop signals are part of the five unit code (BAUDOT CODE) shown in figure 2-14.

Synchronous Mode

Synchronous systems have an advantage over asynchronous systems. The start and stop elements are not used. This allows more room for information transmission. Time is not wasted on start and stop units. Additionally, this mode has a higher capacity to accept distorted signals because it does not depend on the start and stop signals for timing.

MODULATION RATE

The terms used in referring to tty modulation rates or signaling speeds are *baud, words per minute (wpm),* and *bits per second (bps).* Baud is the only term that is technically accurate. The others are either approximations or require explanation.

Baud

By definition, the word *baud* is a unit of modulation rate. To find the modulation rate of a signal in bauds, divide 1 by the time interval of the shortest unit in the signal. For example, 22 milliseconds (.022 see) is the time interval of the shortest unit in the five-unit code at 60 wpm. To find the number of bauds equal to 60 wpm, divide 1 by .022. Rounding off the results provides the figure 45.5, which is the baud equivalent of 60 wpm. You can see that increasing the wpm means the unit time interval has decreased.

The most common baudot data speeds range from 45.45 to 100 bauds, or about 60 to 133 wpm. Higher speeds are obtained using the American National Standard Code for Information Exchange (ASCII). This is a seven-unit digital code used for the transmission of teleprinter information. ASCII is used primarily with computer systems, but it is also used in some teletypewriter applications. The Defense Communications System standard speed for teletype operation is 100 wpm or 75 baud.
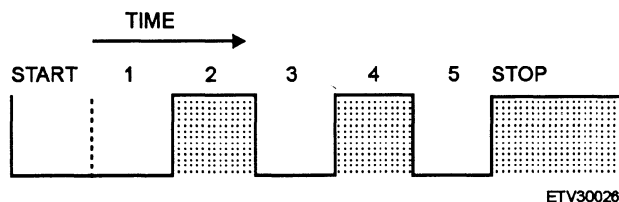

Figure 2-14.—Mark and space signals in the teletypewriter-character R.

Words per minute is used only when speaking in general terms about an approximation of speed. At a speed of 100 wpm, 100 five-letter words with a space between them can be transmitted in a 60-second period. But, you can also get this wpm rate by varying the modulation rate or the length of individual characters. Because of this, the baud method of reference rather than wpm is used.

Bit

In binary signals, the term *bit* is equivalent to one place in a binary number. Because of the influence of computer language, modulation rate is sometimes expressed as *bits per second (bps).* When it is expressly understood that each unit in the baudot character is the same length, the modulation rate expressed in bps is the same as the modulation rate expressed in baud.

DC CIRCUITS

The two most common methods of creating the mark and space conditions are *neutral* and *polar* operation. In neutral operation, current flow represents the mark and no current flow represents the space. In polar operation, current impulses of one polarity represent the mark and impulses of the opposite polarity represent the space.

Neutral circuits use the presence or absence of current flow to convey information. These circuits use high level (60/20 milliamperes) as the line current value. (Low level operation uses (±6 vdc at 20 micro-amps and can be balanced or unbalanced). A neutral teletypewriter circuit consists of a transmitting device, a current source, a variable resistor to control current, a receiving device, and a transmission line.

Polar operation differs from neutral operation. In a polar system information is always present in either a positive or negative condition. The circuit composition is the same, but polar operation requires an additional current source. This current source is usually a solid-state dc power supply that provides variable current to the teletypewriters. The extra current source normally provides current from the positive side for marks and current from the negative side for spaces.

There are some advantages to using polar circuits rather than neutral circuits. In a polar circuit, it is almost impossible to distort a signal by high reactance, low-line currents, or random patching of circuits or equipment. A big advantage for the ET is that a complete loss of current (a zero reading on the milliamme-

ter) quickly indicates line or equipment trouble. Using neutral signaling, this may only indicate that a steady space is being transmitted. This condition is known as *running open.* The teletype appears to be running because it is decoding the constant spaces that cause the type hammer to continually strike the type box, but there is no printing or movement across the page.

BASIC SYSTEMS

When teletypewriters are wire-connected (looped), the exchange of information between them is direct. When they are not physically joined, exchange of information is more complex. Dc mark and space intervals cannot be sent through the air. The gap between the machines must be bridged using transmitters and receivers. The transmitter carrier

wave is used to carry the mark and space information. A *keyer* is used to change the dc pulses from the tty into mark and space modulation for the transmitter carrier wave. The receiver and a *convertor* are needed to change the rf signal back to dc pulses.

RADIO ACTUATED TELETYPE (RATT) SYSTEMS

The Navy's two basic RATT systems are the tone modulated system known as *audio frequency tone shift* (AFTS), and the carrier frequency shift system known as *radio frequency carrier shift (RFCS).* The RFCS system is commonly called *frequency shift keying* (fsk).

For fsk systems, the transmitter provides a source of rf excitation. Figure 2-15 illustrates a basic fsk
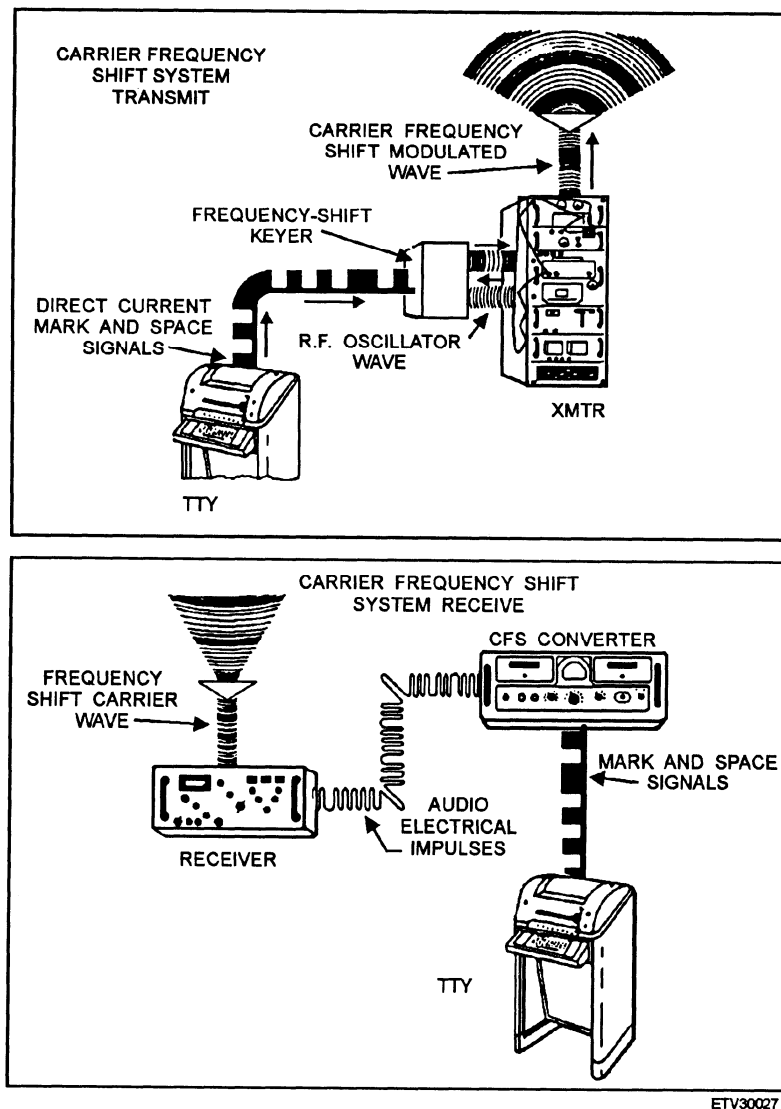

Figure 2-15.—Basic carrier frequency shift (RFCS) system.

system. You will find that the keyer is part of the transmitter in modern systems. The keyer shifts the signal below or above the assigned frequency, corresponding to the mark or space required for tty transmission. Usually, the keyer is adjusted for 850 Hz (425 Hz above and 425 Hz below the assigned frequency). A space will be 425 Hz above and a mark will be 425 Hz below the operating frequency.

AFTS systems use amplitude modulation to change dc mark and space pulses into audio. A basic tone-modulated system is shown in figure 2-16. The audio conversion is done by an audio oscillator in the tone convertor. Varying the tone according to the characters transmitted from the tty equipment amplitude-modulates the transmitter carrier wave. The receiver demodulates this signal, separating the audio signal from the carrier.

In both the RFCS and AFTS systems, the tty signals pass through the panel that controls looping current. Looping current is the current supplied by the tty solid-state power supply. The tty panel integrates the tone-modulated and carrier-frequency shift systems. By allowing the tty equipment to be set up in any configuration desired, this panel gives the operators maximum operational flexibility with the least amount of circuitry and equipment.
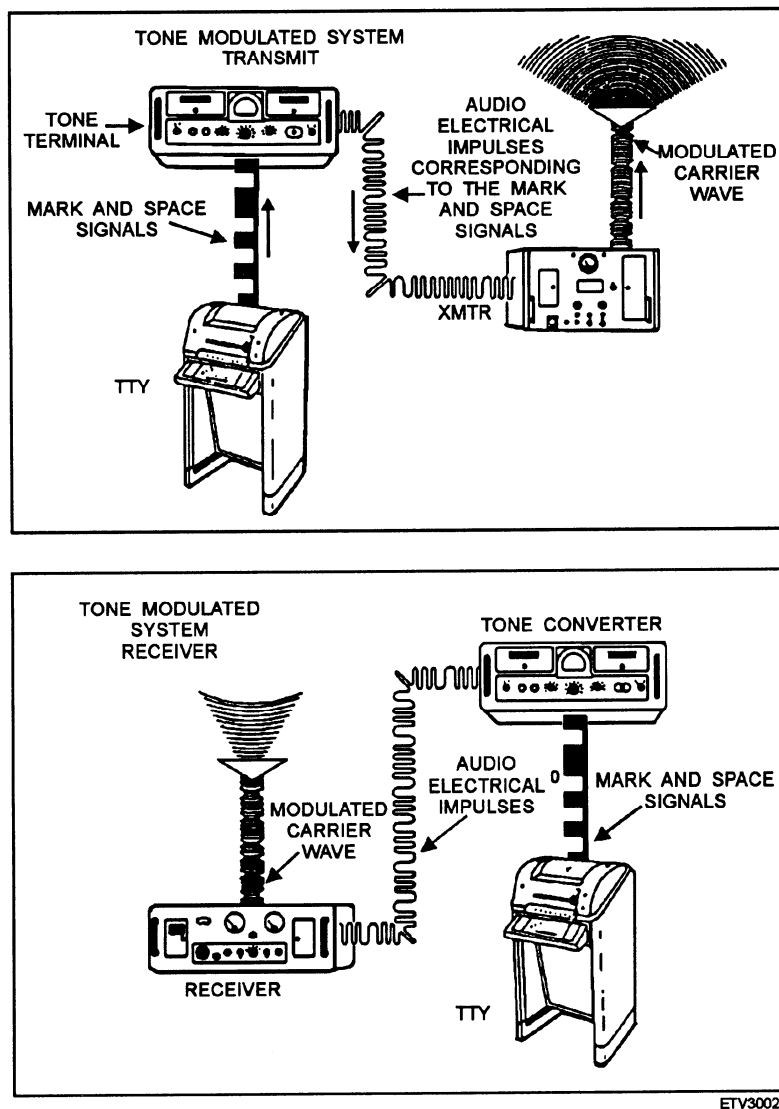

Figure 2-16.—Basic tone-modulated (AFTS) system.

SIMPLEX RFCS TELETYPE SYSTEM

A simplex communications circuit consists of a single channel, which may have two or more stations communicating over it. However, they cannot communicate at the same time. The stations have to alternate using the channel.

RFCS teletype systems are used in the lf to hf band for long-range communications. To reduce fading and interference, the Navy uses two methods of diversity reception called *space diversity* and *frequency diversity.* In space diversity reception, the transmitted signal is received by two or more antennas spaced at distances greater than one wavelength. Because of the spacing requirements, space diversity is normally limited to shore stations. In frequency diversity, two or more signals are transmitted on differing frequencies, but carry the same intelligence. Another type of frequency diversity is called *af diversity* or *tone diversity* and is used with multichannel broadcasts.

A simplified block of a simplex RFCS system is shown in figure 2-17.
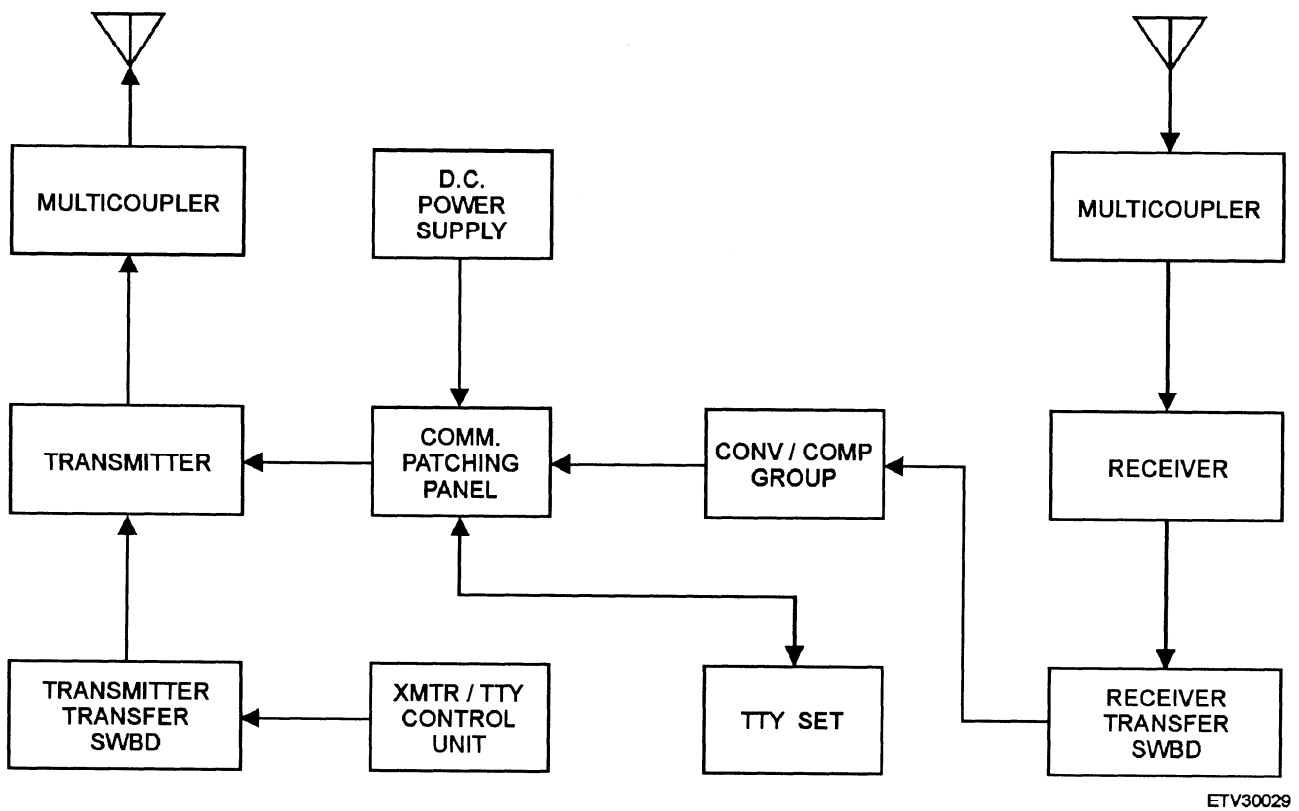

Figure 2-17.—Simplex RFCS system.

RFSC SEND

In the following paragraphs, we will discuss the equipment shown in the RFCS transmit (send) system in figure 2-18.

Teletypewriter Sets

The Model 28 family and the AN/UGC-143 series are the two tty sets currently used by the Navy. Although the AN/UGC-143 is not shown in figure 2-17, we will discuss its characteristics later. There are several tty sets included in the Model 28 family with varying weights and sizes. They feature high operating speeds, quiet operation, and are particularly suited for shipboard use under the severe conditions of roll, vibration, and shock.

Model 28 tty's may be composed of the following components, depending upon their specific function: a cabinet, keyboard, page printer, typing perforator, transmitter distributor, typing reperforator, power distribution panels, and power supply.

All equipment components are housed in the cabinet. Transmissions are initiated through the keyboard or transmitter distributor. Received signals are printed on the page printer. Monitored transmissions can also be printed on the page printer. The typing perforator and reperforator are used for preparing tapes that can be stored for future transmission through the transmitter distributor.

The AN/UGC-143A(V) is also known as the Navy Standard Teleprinter (NST) and has the following characteristics:

- Fully automated

- Accepts Baudot code or ASCII

- Bulk storage unit contains tape drives similar to those found in the AN/USH-26

- Can be configured to interface with Navy standard personal computers

- Fully compatible with current crypto devices

- Capable of supporting paper tape operations

Patch Panels

Tty panels SB-1203/UG and SB-1210/UGQ are used for interconnection and transfer of shipboard tty equipment. The SB-1203/UG is a general-use panel and the SB-1210/UGQ is intended for use with crypto. In addition, tty panels furnish a central point for connecting the dc supply into the teletypewriter circuits. So, one source of supply can be used for all the circuits passing through a particular panel.

One procedural note: Anyone patching or unpatching circuits from a tty panel must be sure to pull the plug from the looping jack before removing the other plug from the set (machine) jack. Pulling the set jack first interrupts all tty message traffic on that channel. **IT ALSO PRODUCES A DANGEROUS DC VOLTAGE ON THE EXPOSED PLUG!**

Cryptographic Equipment

Cryptographic equipment is used to encode and decode messages that require security handling. To do this, the crypto equipment must be compatible on both the transmit and receive ends.
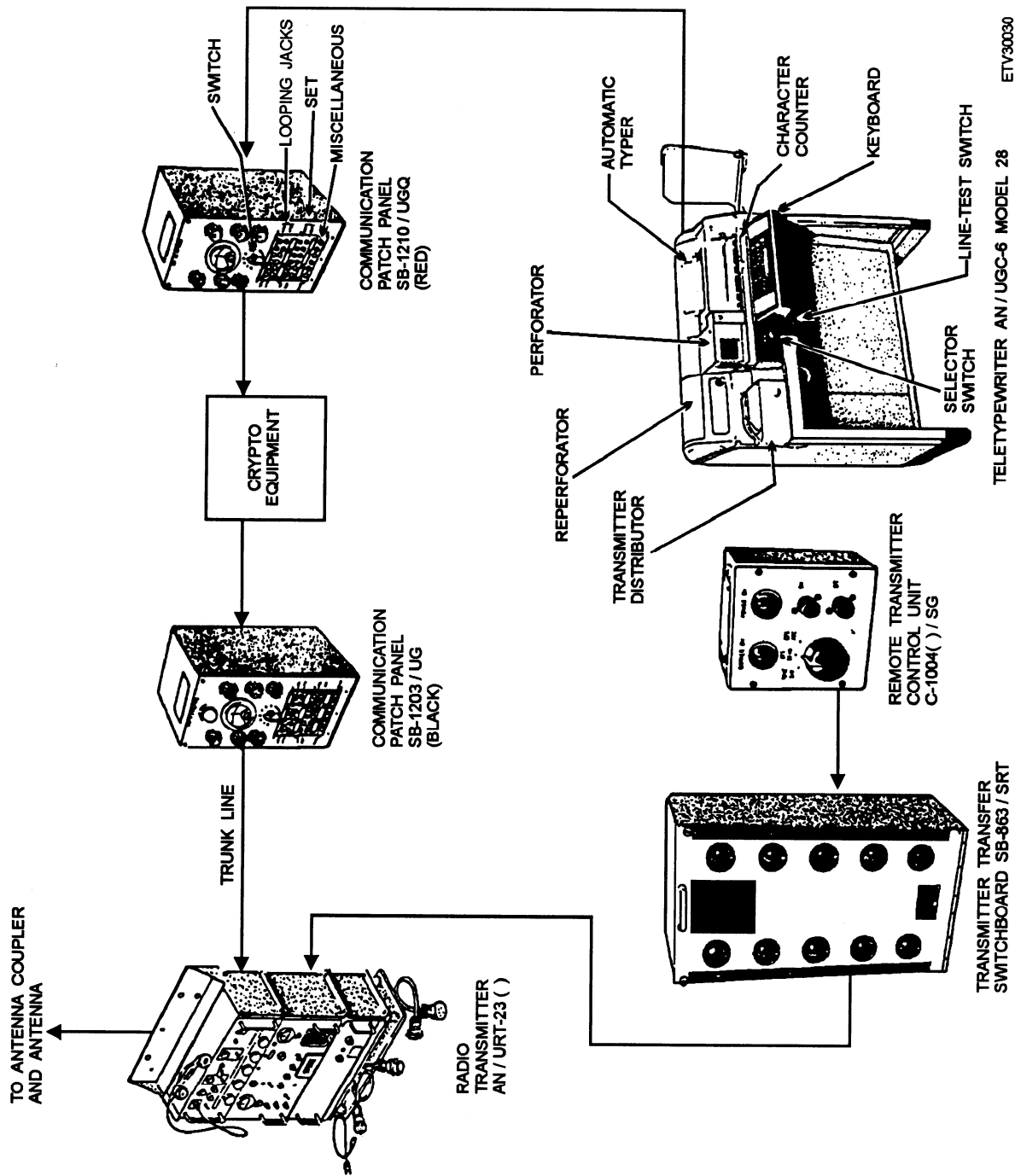
Remote Transmitter Control

The remote transmitter control unit is mounted close to the tty keyboard, and permits remote control of the transmitter. For RFCS operation, the operator sets the three-position rotary switch to CFS SEND to transmit and CFS REC for receiving. The TONE S/R position is used for AFTS transmit and receive.

Transmitter Switchboard

The SB-863/SRT switchboard is used in this system to connect the remote transmitter control to the transmitter to be used.

Transmitter

The transmitter is used to transmit the RFCS signal. It is important that the operator tune the transmitter to the proper frequency.

SWITCH

LOOPING JACKS

SET

MISCELLANEOUS

COMMUNICATION
PATCH PANEL
SB-1210 / UGQ
(RED)

AUTOMATIC
TYPER

CHARACTER
COUNTER

KEYBOARD

LINE-TEST SWITCH

TELETYPEWRITER AN / UGC-6 MODEL 28

PERFORATOR

SELECTOR
SWITCH

REPERFORATOR

TRANSMITTER
DISTRIBUTOR

CRYPTO
EQUIPMENT

REMOTE TRANSMITTER
CONTROL UNIT
C-1004( ) / SG

COMMUNICATION
PATCH PANEL
SB-1203 / UG
(BLACK)

TRANSMITTER TRANSFER
SWITCHBOARD SB-863 / SRT

TRUNK LINE

TO ANTENNA COUPLER
AND ANTENNA

RADIO
TRANSMITTER
AN / URT-23 ( )

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Figure 2-18.—RFCS transmit (send) system.

RFCS RECEIVE SYSTEM

The RFCS receive system shown in figure 2-19 is used to receive the transmitted signal and convert it back to a usable tty output.

Antenna Filter

The antenna filter receives the rf signal from the antenna and filters out any unwanted signals so only the proper band of frequencies are passed on to the receiver.

Radio Receiver

The receiver translates the rf signal to an audio signal.

Receiver Transfer Switchboard

The switchboard is used to connect the receiver to any one of the convertors in the convertor group.

Convertor/Comparator Group

The convertor/comparator group is used with receivers in either space diversity or frequency diversity operation to convert the frequency shift af signal from the receiver into dc pulses that open and close the dc loop according to the mark and space characters received. When the system is not using diversity operation, each convertor can be used with a separate receiver.
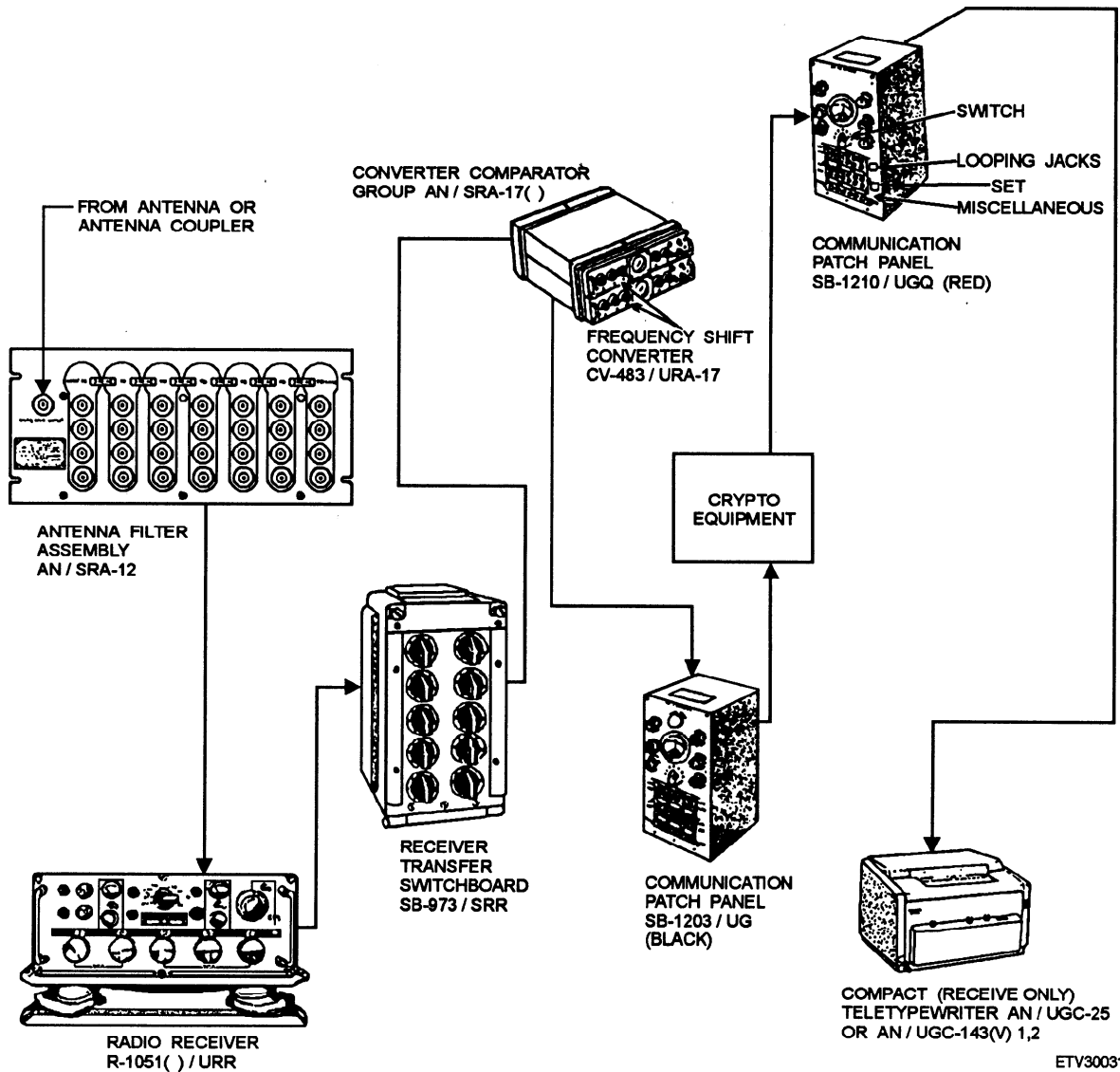

Figure 2-19.—RFCS receive system.

The comparator section of the convertor compares the signals received in the diversity mode and allows only the stronger signal to be passed on to the communication patch panel.

Communication Patch Panel

The communication patch panel performs the same function on the receive side as it does on the transmit side.

Crypto Equipment

The crypto equipment decodes the received signal so it can be printed out in its original form.

Teletype

The tty equipment converts the dc pulses from the patch panel to a printed copy of the original message. The tty shown is a page printer only and does not have transmit capability.

AFTS SYSTEM

Figure 2-20 is a block diagram of a half-duplex uhf system. Half-duplex communication can be in either direction, but cannot happen at the same time. The term *half-duplex* is qualified by adding *send only, receive only,* or *send or receive.*

AFTS Transmit

Dc signals from the tty are sent to the communications patch panel where they are fed to the tone terminal set. The tone terminal set converts the dc signals into audio tone-shift signals. The audio tone-shift signals are patched to the transmit side of the transceiver through the transmitter transfer switchboard. The audio tone-shift signals are then used to modulate the rf carrier for transmission.

AFTS Receive

The rf tone-modulated signals are received at the antenna and then patched, via the multicoupler, to the receive side of the transceiver, where demodulation to audio tone-shift signals takes place. The signals are then patched to the tone terminal set through the receiver transfer switchboard, where they are converted back to dc signals. The dc signals are then patched through the communication patch panel to the tty.

FACSIMILE

Facsimile (FAX) is a method of transmitting still images over a communications system. The images may be weather maps, photographs, sketches, typewritten or printed text, or handwriting. Military use of FAS is primarily limited to transmission and reception of weather maps. Because of long transmission times, its tactical uses are limited.

TEMPEST

Compromising emanations, generally called TEMPEST, are unintentional data-related or *intelligence-bearing signals which, if intercepted or analyzed, can disclose the classified information transmitted, received, handled, or otherwise processed by electrical information processing equipment or systems.*

The Navy uses MIL-STD-1680 (SHIPS), *Installation Criteria for Shipboard Secure Electrical Processing Systems,* as the guide for TEMPEST. Within communications centers, ETs must understand and be familiar with both **RED** and **BLACK** designated systems and equipment. The RED and BLACK designations are explained in the following paragraphs.

RED CRITERIA

The RED designation applies to all crypto equipment, subscriber terminal equipment, and interconnecting conductors involved in processing classified plain language information. It also applies
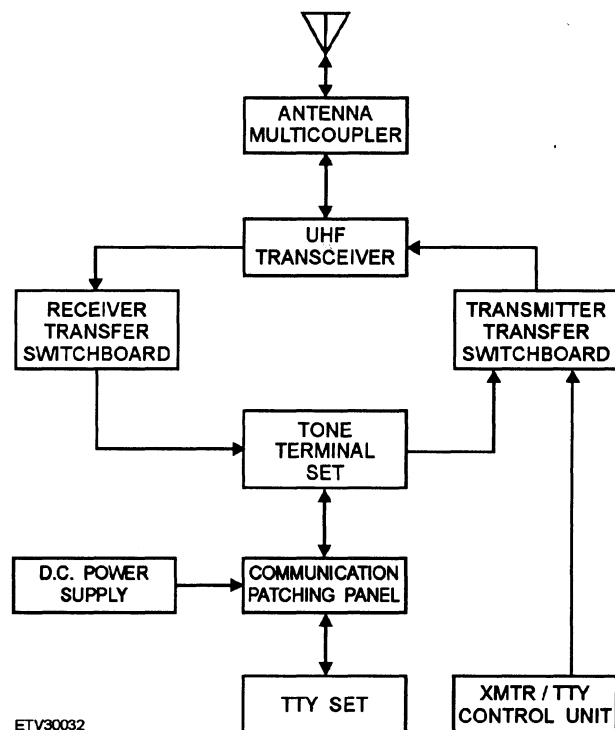
ETV30032

Figure 2-20.—Half-duplex AFTS teletype system.

to primary power circuits, dc circuits, control wiring, and ground conductors serving cryptographic equipment and subscriber terminal equipment that are designated RED.

The RED designation also applies to junction boxes, distribution frames, terminal boxes, conduit, ducts, cable racks and hangers, patching and switching panels, cabinets, power distribution panels (both ac and dc), and other ancillary equipment serving the conductors and equipment mentioned above.

Primary Red

Any conductor intended to carry classified plain language terminating in RED equipment or the RED side of crypto equipment is designated PRIMARY RED.

Secondary Red

Any conductor, other than PRIMARY RED, that connects to RED equipment, the RED side of crypto equipment, or the RED side of isolation devices, and does not intentionally carry classified information, but because of the coupling mechanism with the RED equipment *might* carry compromising information, is designated SECONDARY RED. Some examples you are probably familiar with are indicator lines, and control and timing lines. Power distribution panels and grounding systems serving RED conductors are also designated SECONDARY RED.

BLACK CRITERIA

The BLACK designation applies to all conductors and equipment involved in handling or processing unclassified plain language and encrypted information in electrical form. It also applies to all facilities and circuits that are not designated RED.

PORTABLE AND PACK RADIO EQUIPMENT

Because portable and pack radio sets must be lightweight, compact, and self-contained, they are usually battery- or generator-powered, have low output power, and are either transceivers or transmitter-receivers. Navy ships and Special Forces carry a variety of these radio sets for amphibious and emergency communications, with the equipment type varying according to the needs of the ship or command. The following paragraphs introduce some of these equipment.

AN/CRT-3A

Radio transmitter AN/CRT-3A, popularly known as the "Gibson girl," is a rugged emergency transmitter carried aboard ships and aircraft for use in lifeboats and liferafts. Shown in figure 2-21, it operates on the
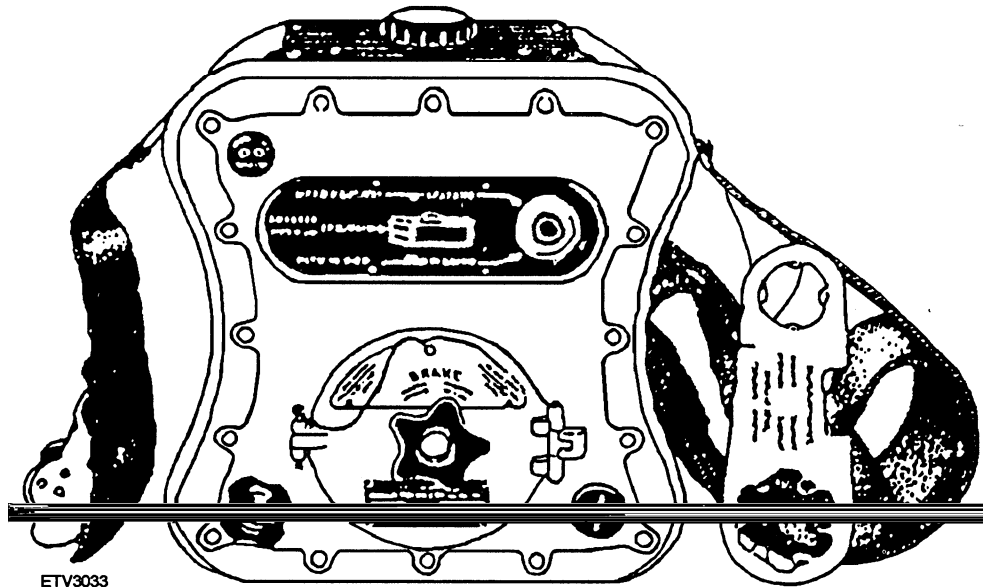

ETV3033

Figure 2-21.—Emergency Transmitter AN/CRT-3A.

international distress frequency (500 kHz) and the survival craft communication frequency (8363 kHz). No receiving equipment is included.

AN/PRC-70

The AN/PRC-70 is a multimode (FM, CW, FSK, SSB, AM) manpack radio set operating in the 2.0-to 75.9999-MHz frequency range.

AN/PRC-77

The AN/PRC-77, shown in figure 2-22, is an FM, short-range, 920 channel vhf radio operating in the 30- to 75.95-MHz frequency range. Figure 2-22 (view A) shows the pack frame, the handset, and accessory pouch. View B shows the transmitter-receiver. When not in use, the equipment is stored in a special aluminum case.
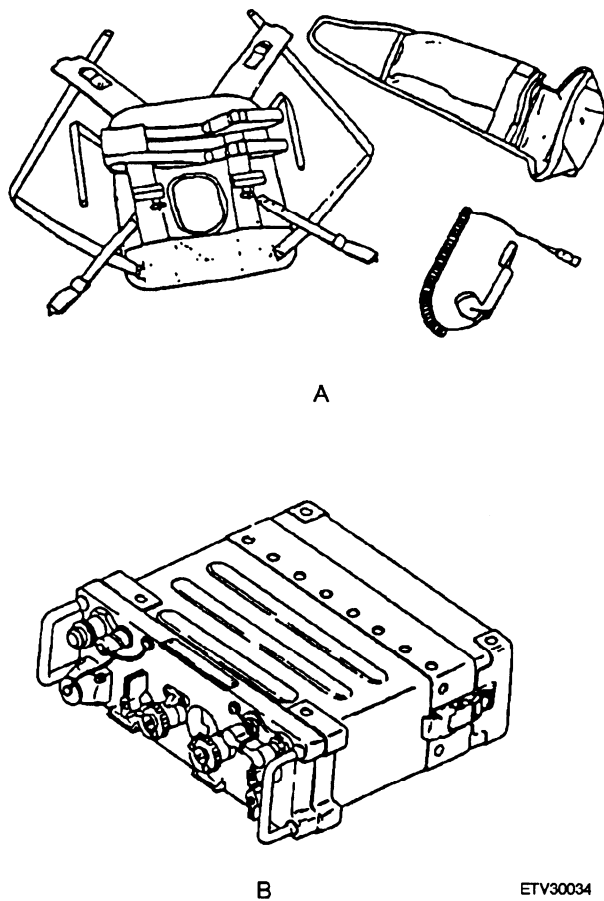
AN/PRC-96

The AN/PRC-96 portable transceiver, shown in figure 2-23, is dual-channeled, battery-powered, and provides homing and two-way voice communications between liferafts and searching ships and aircraft, on the 121.5 and 243 MHz "guard" channels.

AN/PRC-104

The AN/PRC-104, shown in figure 2-24, is a lightweight radio transceiver that operates in the hf band and can be tuned from 2.0 to 29.9999 MHz. It operates in the ssb (usb or lsb) modes for voice communications, CW for Morse code, and FSK for
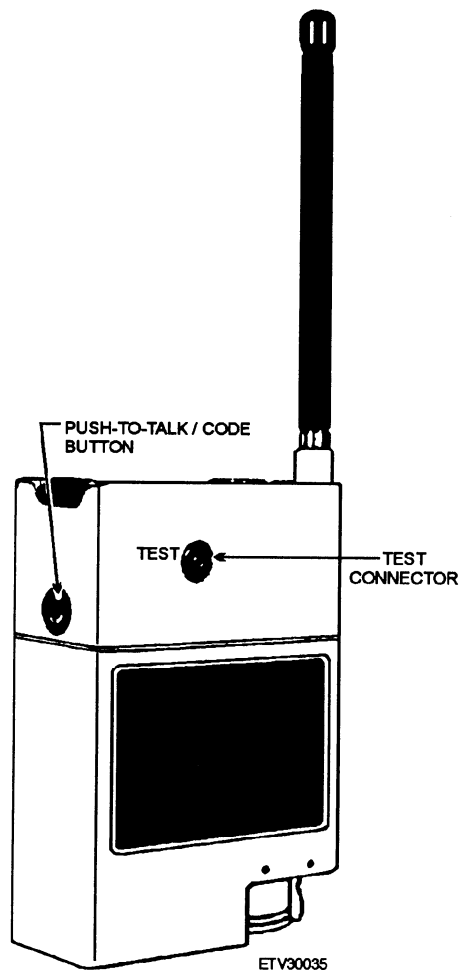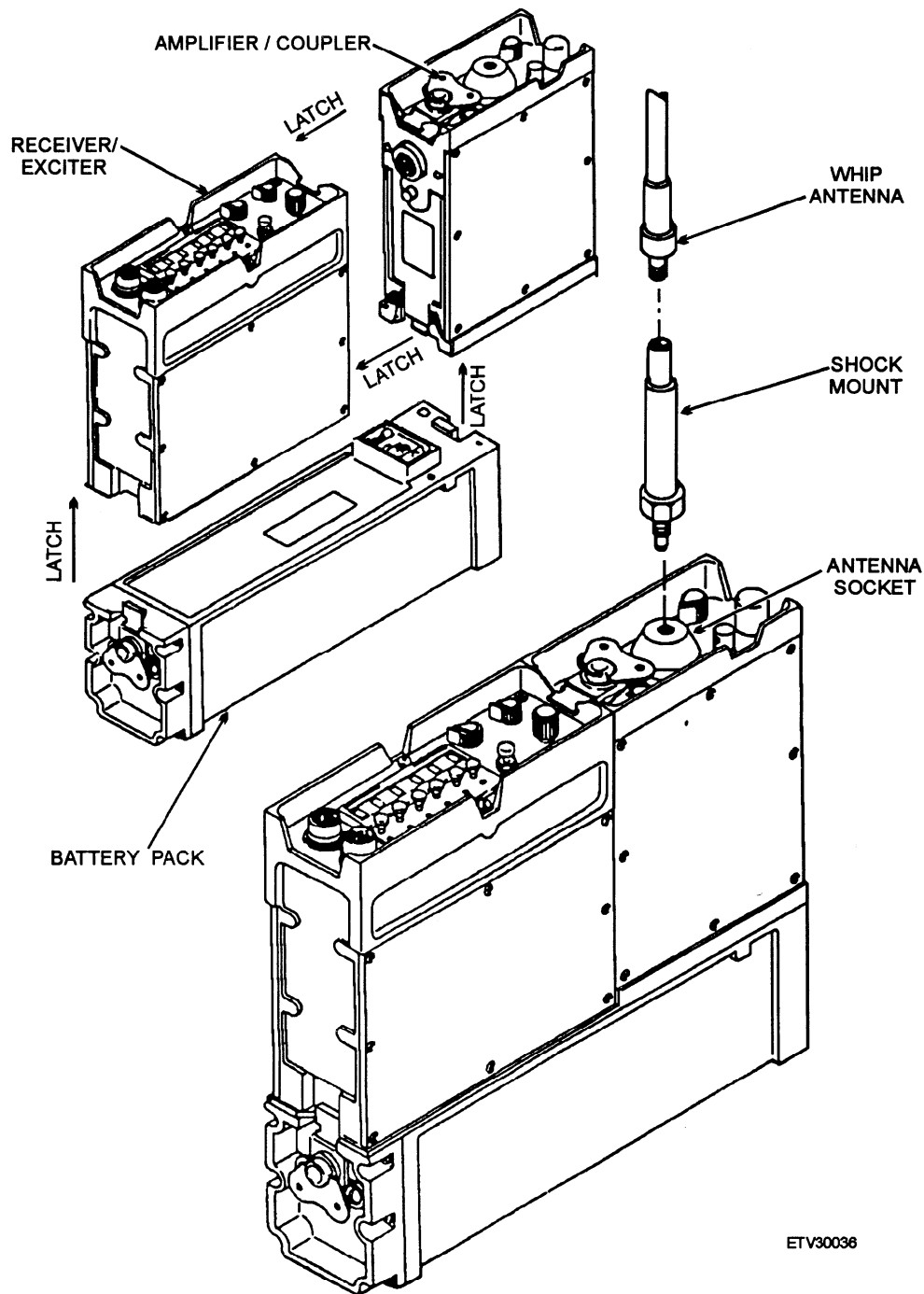
A

B   ETV30034

Figure 2-22.—Radio Set AN/PRC-77.

PUSH-TO-TALK / CODE BUTTON

TEST   TEST CONNECTOR

ETV30035

Figure 2-23.—Transceiver AN/PRC-96.

Figure 2-24.—Transceiver AN/PRC-104.

transmission of tty or other data. It can be used in the man-pack configuration or can be configured for vehicular or fixed station operation.

Unlike older radio sets, there are no front panel meters or indicator lights on the AN/PRC-104. All functions are monitored by the radio itself and communicated through the handset in the form of audio tones. This is extremely useful during tactical black-out operations. Newer versions of the AN/PRC-104 have modified the R/T section of the radio, but the above information still applies.

AN/PRC-113

The AN/PRC-l13 is a two-band (vhf and uhf) amplitude modulated transmitter-receiver, which operates at 116.0 through 149.975 MHz in the vhf band and 225.0 through 399.975 Mhz in the uhf band. When interfaced with TSEC/KY-57 crypto

equipment, this radio can operate in AM voice, or AM secure voice.

AN/PRC-117

The AN/PRC-117 Full-Band Frequency-Hopping VHF-FM Manpack Transceiver with integrated COMSEC, shown in figure 2-25, operates in the 30-to 89.975-MHz frequency range and contains a built-in COMSEC capability that is compatible with VINSON KY-57/58 equipment.

Frequency-hopping is an advanced method of ECCM (Electronic Counter-Counter-Measure). You should remember that a standard FM transmission is centered on a specific carrier frequency, which means it can be easily detected, monitored, or jammed. In
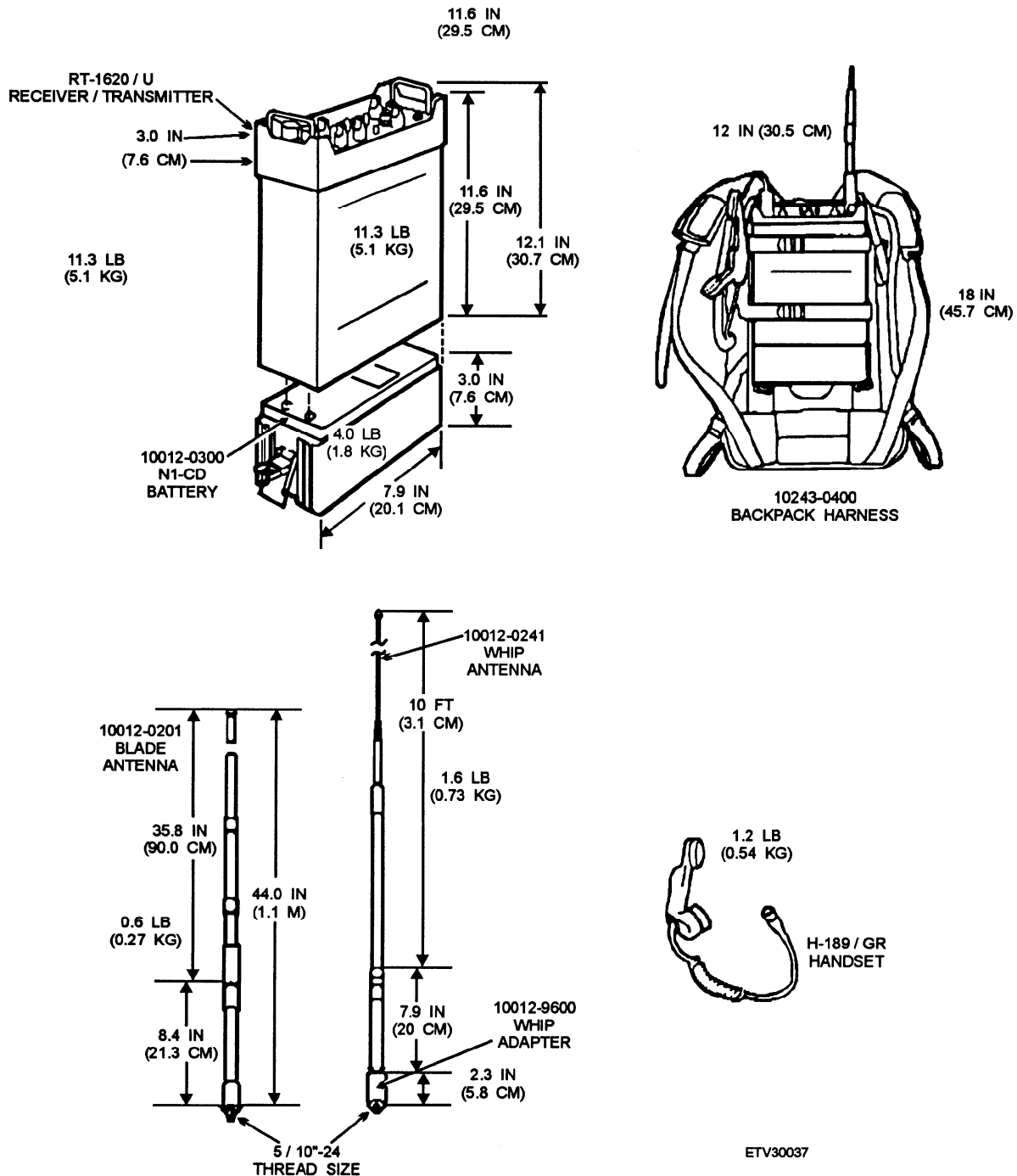

Figure 2-25—Transceiver AN/PRC-117.

2-27

frequency hopping, no single carrier is used. Instead, the transmitter hops around the band in a random pattern, spending only a few milliseconds on any one frequency. This makes the signal difficult to detect and extremely difficult to monitor or jam.

AN/PSC-3

Backpack radio set AN/PSC-3 is a portable, battery-powered, half-duplex uhf transceiver operating in the 225.0- to 399.995-MHz range. It provides two-way voice (secure and plain) and data communications via satellite relay (SAT) or line-of-sight (los) modes. Radio set AN/PSC-3 components are shown in figure 2-26.

One important feature of the AN/PSC-3 is its ability to interface directly with the AN/PRC-70, AN/PRC-77, and other vhf-capable radios, which provides a satellite link for vhf tactical equipment. This provides away to retransmit vhf information from one of these radios by (1) converting vhf to uhf, (2) transmitting through a satellite to another AN/PRC-3, (3) demod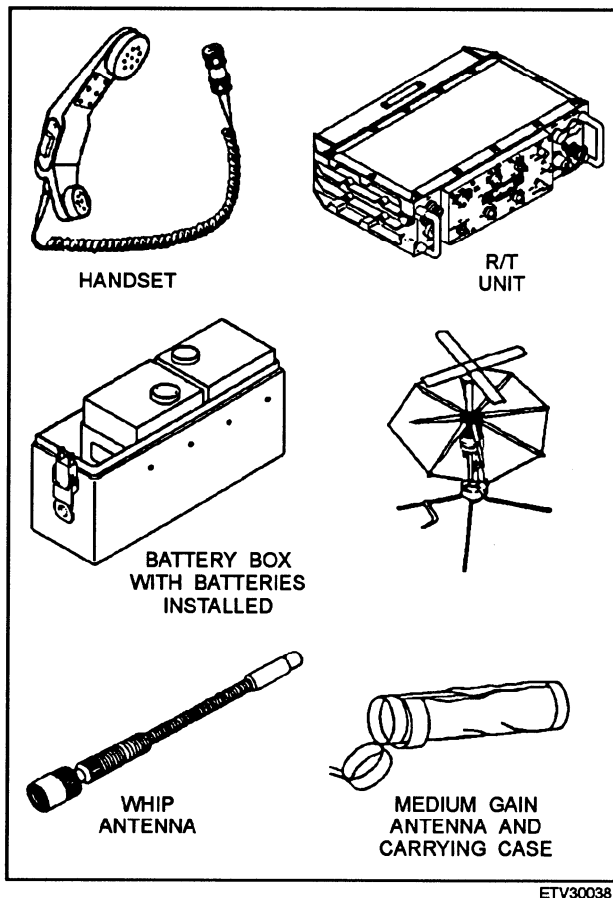ulating it and passing it directly to another AN/PRC-70/77, which could then (4) retransmit the information as vhf. This greatly enhances communications capability and extends the communications range. A basic retransmission setup is shown in figure 2-27.

DIGITAL MESSAGE DEVICE GROUP (DMDG)

The DMDG is part of the Special Forces Burst Communications System. It is used with radio sets AN/PRC-70/74 and AN/PSC-3 to send and receive messages. Messages are typed on the KY-879/P keyboard (shown in figure 2-28), which displays the message as it is being typed and stored in memory. When the message is ready to be sent, the operator selects the proper mode and the device converts the message to digital information. The digital information is sent to one of the above radios for transmission. After the information is received at the other end, it is sent to another KY-879/P, where the message can be read on the device's display screen.

The device can send messages at 300 or 1200 baud in the satellite mode and 266.6 baud when connected to the AN/PRC-70/74.

INTRODUCTION TO COMMUNICATIONS LINK INTERFACE PLANNING SYSTEM (CLIPS)

The Communications Link Interface Planning System (CLIPS) was introduced to the Joint Special Operations Community in 1986. CLIPS is a system designed to help the communications planner
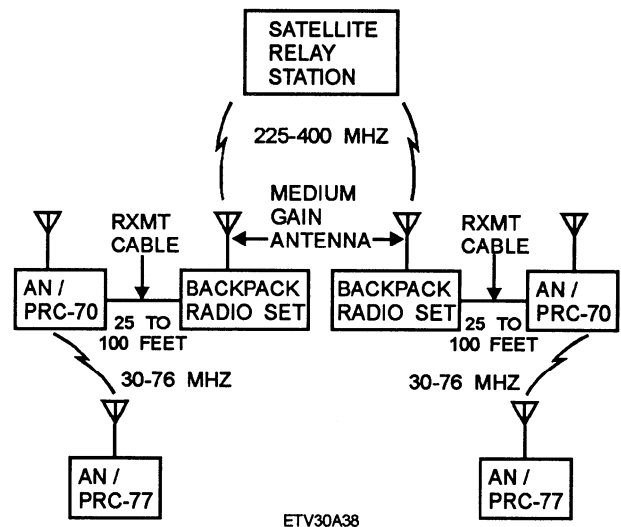

Figure 2-26.—Radio Set AN/PSC-3.

Figure 2-27.—Basic retransmission scheme.

GROUNDING SCREW   **COMMAND KEYS**   **CURSOR**   **PRESSURE SCREW**

LCD DISPLAY   **LED'S**

ENTER   SEND   READ   MSG REC'D   ACK   POWER

SCROLL LEFT   **SPACE BAR**   **DELETE KEY**

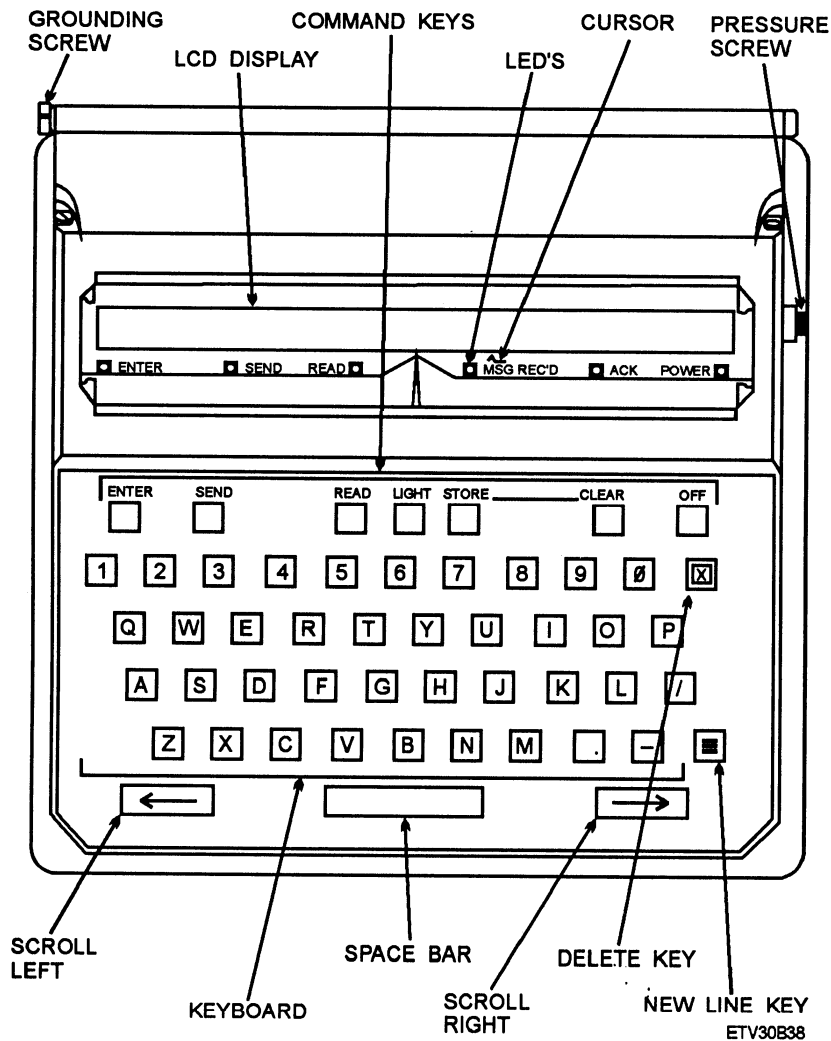**KEYBOARD**   **SCROLL RIGHT**   **NEW LINE KEY**

ETV30B38

Figure 2-28.—KY-879/P keyboard.

determine interoperability in joint operations involving single-channel tactical radio equipment.

Equipment planning in the Special Operations Community is complicated by the wide variety of equipment used and the highly variable and rapidly changing nature of the operational settings. Because most communications requirements for this community are satisfied by single-channel, full-duplex radio links, CLIPS was designed primarily to help plan this type of communications link. Equipment covered under CLIPS is specifically limited to radios, modems, crypto devices, input/output data terminals, and packet controllers normally used to establish these radio links.

The CLIPS program is designed for use with IBM PC or compatible computers using MS-DOS. It is designed to provide solutions to equipment planning and link configuration problems by considering all the factors involved and automatically determining the "best" system to be used by each participant in the communications link. The CLIPS program incorporates the knowledge of experienced communications personnel, equipment specifications, circuit planning rules, and equipment inventories in a way that makes communications planning straightforward, easy, and objective.

CHAPTER 3

SATELLITE COMMUNICATIONS

INTRODUCTION

In the past, the Navy relied upon hf communications as its primacy method of sending messages. With the overcrowding of the hf spectrum, the need for new and advanced long-range communications became apparent. Satellite communications **(SATCOM)** systems have shown they can provide survivable, reliable, high-capacity, secure, and cost-effective telecommunications for the military.

In this chapter, you will be introduced to satellite communications fundamentals, fleet SATCOM subsystems, shore terminals, current and future satellites, and some specific SATCOM equipment and racks. SATCOM is a natural outgrowth of modern technology and the continuing demand for greater capacity and high-quality communications. This information will be crucial to you in understanding the communications technology of both today and the future.

After completing this chapter, you should be able to:

- **Recognize satellite communications fundamentals**

- **Identify fleet SATCOM subsystems and shore terminals**

- **Evaluate specific SATCOM equipment and racks**

SATELLITE COMMUNICATIONS FUNDAMENTALS

A typical SATCOM link uses an **active** satellite that receives and retransmits, and two earth terminals. (A **passive** satellite simply reflects radio signals back to earth.) One station transmits to the satellite on the *uplink* frequency. The satellite translates the signal to the *downlink* frequency, amplifies the signal, then transmits it to the receiving terminal. Figure 3-1 shows
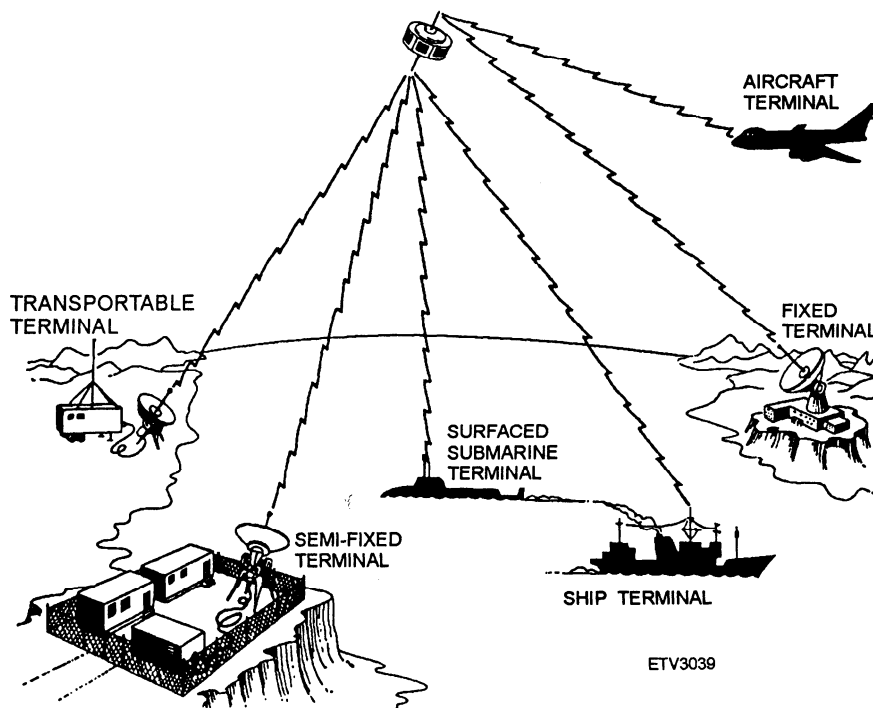

Figure 3-1.—Satellite communications system.

some of the various earth terminals and how they interface. The end use or purpose determines the system's complexity and how the system is used.

ROLE OF SATELLITE COMMUNICATIONS

SATCOM links, one of several kinds of long-distance communications links, interconnect communications centers located strategically throughout the world. These SATCOM links are part of the Defense Satellite Communications System **(DSCS)** and Fleet Satellite Communications.

Satellite communications systems are very important to the worldwide military communications network for two primary reasons. First, they continue to operate under conditions that cause problems for other methods of communication. Second, they provide reliable and secure communications to previously inaccessible areas. In many cases, these communications requirements can <u>only</u> be satisfied by sophisticated satellite communications systems. By satisfying such needs, SATCOM makes a significant contribution to the improved reliability of naval communications.

ADVANTAGES OF SATELLITE COMMUNICATIONS

Some of the unique advantages SATCOM has over conventional long-distance communications are as follows:

- SATCOM links are unaffected by the propagation problems associated with hf radio communications.

- SATCOM links are free from the high-attenuation problems of facilities that use wire or cable for routing communications.

- SATCOM links span long distances.

- The numerous repeater stations required for line-of-sight and troposcatter systems are not needed.

As you can see, satellite links provide the required flexibility and reliability needed to support military operations. In the following paragraphs, we will look at SATCOM capacity, reliability, vulnerability, flexibility, and limitations.

Capacity

Currently, military SATCOM systems can provide communications between backpack, shore, airborne, and shipboard terminals. These SATCOM systems can handle thousands of communications channels at the same time.

Reliability

SATCOM frequencies are only slightly affected by atmospheric phenomena and do not depend on reflection or refraction. Reliability is based on the skill of operators and maintenance personnel and the condition of the satellite communications equipment.

Vulnerability

Communications satellites are relatively safe from threats of harm. Because these satellites are in such high orbits, any attempt to disable or destroy them from the Earth would be difficult and expensive. However, Earth terminals are a different story. They offer a more attractive target for destruction by conventional methods. But these terminals can be protected by the same methods taken to protect other vital installations. So overall, the satellite system is nearly free from harm by an enemy.

Operationally, highly directional earth terminal antennas provide a high degree of freedom from jamming. The wideband system can use antijamming techniques, which also reduces vulnerability.

Flexibility

Mobile military satellite earth terminals with trained crews can be deployed and put into operation anywhere in the world within hours.

Limitations

The technical characteristics of the satellite and its orbital parameters are the main limitations to a satellite communications system. Two additional limiting factors for active satellites are transmitter power and receiver sensitivity. Energy for electricity is limited to whatever can be produced by the solar cells, which limits the satellite's output power. This problem is made worse by users who increase their output power to the satellite, causing the satellite to try to retransmit at the new power level, at the expense of reducing signals to other users.

FLEET SATELLITE
COMMUNICATIONS

The Fleet Satellite Communications **(FLTSATCOM)** System provides communications, via satellites, between designated mobile units and shore sites. These links provide worldwide coverage between the latitudes of 70 degrees north and 70 degrees south. Three satellites are currently in use with a fourth to come online soon: GAPFILLER, LEASAT, FLTSATCOM, and UHF Follow-on (UFO).

System installations are located on ships, submarines, mobile vans, aircraft, and shore stations. Though these installations could operate separately, integrating the system provides message traffic and voice communications to all DOD long-range communications networks. In addition, certain shore stations provide a back-up capability to other users in case of an outage of any kind, which maintains net connectivity.

The Navy SATCOM system consists of information exchange subsystems that use the satellites as (1) relays for communications and control, and (2) quality monitoring subsystems that provide data required to manage satellite resources. Each subsystem is structured for specific naval communications requirements. The following subsystems make up most of the Navy's FLTSATCOM system.

- Fleet Satellite Broadcast Subsystem. This is an expansion of the "Fleet Broadcast," which has been the central communications medium for operating naval units.

- Common User Digital Information Exchange Subsystem **(CUDIXS)** and Navy Modular Automated Communications Subsystem **(NAVMACS).** These two installations form a communications network for transmitting general-service message traffic between ships and shore installations.

- Submarine Satellite Information Exchange Subsystem **(SSIXS).** This subsystem compliments other communications links between SSBN and SSN submarines and shore terminals.

- Secure Voice Subsystem. This is a narrowband uhf subsystem that links voice communications between ships and connects with wide-area shore voice networks.

- Tactical Intelligence Subsystem **(TACINTEL).** This subsystem is specifically designed for special intelligence communications.

- Teletypewriter Subsystem. This subsystem is an extension of terrestrial teletypewriter transmission networks.

- Tactical Data Information Exchange Subsystem **(TADIXS).** This is a one-way broadcast of tactical information from command centers ashore to afloat units primarily in support of over-the-horizon targeting **(OTH-T).**

- Officer in Tactical Command Information Exchange Subsystem **(OTCIXS).** This subsystem continues to provide inter-and intra-battle group communications and is now also designated as the return path for ship-to-shore OTH-T communications.

- Demand Assigned Multiple Access **(DAMA)** Subsystem. This subsystem was designed to multiplex several subsystems, or users, on one satellite channel, allowing more satellite circuits to use a single uhf satellite channel.

- Control Subsystem. This subsystem is a communications network that provides status reporting and management of system assets

The installation of subsystem baseband equipment and rf terminals aboard ships is driven by communications traffic levels, type of communications, and mission requirements. For example, Fleet Broadcast, a common subsystem in naval communications, is received by many different types of ships. Atypical suite on a large ship may include Fleet Broadcast, CUDIXS, NAVMACS, Secure Voice, TADIXS, OTCIXS, Teletypewriter, and TACINTEL equipment.

Most subsystems have very rigid control and accountability of message and data-link traffic. All subsystems have some form of backup mode. Within the constraints of equipment capability, each subsystem addresses the unique requirements of the user and the environment in which the user operates. On board your ship, you may not use all these systems, but during your career you will probably come across all of them. Now that we have identified the satellite communications subsystems, we need to provide you

with a basic understanding of how they operate. But first, we need to discuss FLTSATCOM Shorebased Terminals.

FLTSATCOM SHOREBASED TERMINALS

SATCOM installations at shore terminals operate from existing naval communications centers and certain command operations centers. Four Naval Computer and Telecommunications Area Master Stations **(NCTAMS)** have primary responsibility for naval communications via satellite. They are:

- NCTAMS LANT, Norfolk, Virginia

- NCTAMS MED, Naples, Italy

- NCTAMS WESTPAC, Finegayan, Guam

- NCTAMS EASTPAC, Wahiawa, Hawaii

The Naval Computer and Telecommunications Station (NCTS), San Diego, California, as part of TADIXS, provides connectivity between NCTAMS EASTPAC and NCTAMS LANT.

Ten NCTSs are used to retransmit Fleet Broadcast message traffic via hf links. In addition, an rf terminal at Yokosuka, Japan, transmits SSIXS and Secure Voice communications to the western Pacific and Indian Oceans. Also, there is landline connection between Japan and NCTAMS WESTPAC to support TADIXS and OTCIXS transmissions.

Within these facilities, each subsystem consists of two parts: the baseband equipment (used to collect and control the transmitted or received communications) and the rf terminal (used by the baseband system to transmit and receive via satellite link). Some subsystems have the baseband equipment and rf terminals in the same building, while others have the baseband equipment installed at a remote facility located some distance from the rf terminal. Most subsystems use a common rf terminal. However, the Fleet Broadcast has an rf terminal specifically designed for that subsystem.

FLEET SATELLITE BROADCAST SUBSYSTEM

The Fleet Satellite Broadcast Subsystem provides the capability to transmit Fleet Broadcast message traffic in a high-level jamming environment. The subsystem has 15 subchannels of encrypted message traffic at an input data rate of 75 bps per channel. These subchannels are time-division multiplexed and are transmitted in a one-way rf transmission at 1200 bps. The shore terminal transmits this data on a direct-sequence, spread-spectrum shf signal to the satellite, where the signal is translated to uhf and down-linked to the subscriber. Figure 3-2 shows a block diagram of the Fleet Satellite Broadcast Subsystem.

The High-Speed Fleet Broadcast **(HSFB)** is a planned upgrade to the Fleet Satellite Broadcast Subsystem. This upgrade will improve broadcast transmission speed, information through-put (capability of equipment to process or transmit data during a specific period of time), and flexibility.

Message Traffic Input

The Fleet Satellite Broadcast message traffic is queued and/or channel selected by two processor-controlled message switching systems before transmission. These systems are the Naval Communications Processing and Routing System **(NAVCOMPARS)** for general service message traffic, and **STREAMLINER** for special intelligence message traffic. Fleet weather data from Naval Oceanographic Command Centers is also transmitted on nonprocessor controlled channels.

Rf Transmission

The FLTSATCOM satellites have two rf channels allocated for Fleet Satellite Broadcast message traffic. The primary channel is configured for an shf uplink to the satellite and for translation within the satellite for transmission as uhf in the downlink. The second rf channel is designed for backup use only.

Since two channels are available, and several different modulation techniques are used for the uplink, there are seven different modes in which the rf link can be transmitted.

In modes 1 through 6, the shf transmissions are made by the Satellite Communications Terminal AN/FSC-79. Mode 7 operates the rf uplink and downlink at ultra-high frequencies and uses the uhf transceiver AN/WSC-5(V).

Reception

Subscribers receive the uhf downlink signal through the AN/SSR-1 receiver system, which demodulates and demultiplexes the signal. The demuxed signal is decrypted and read into the
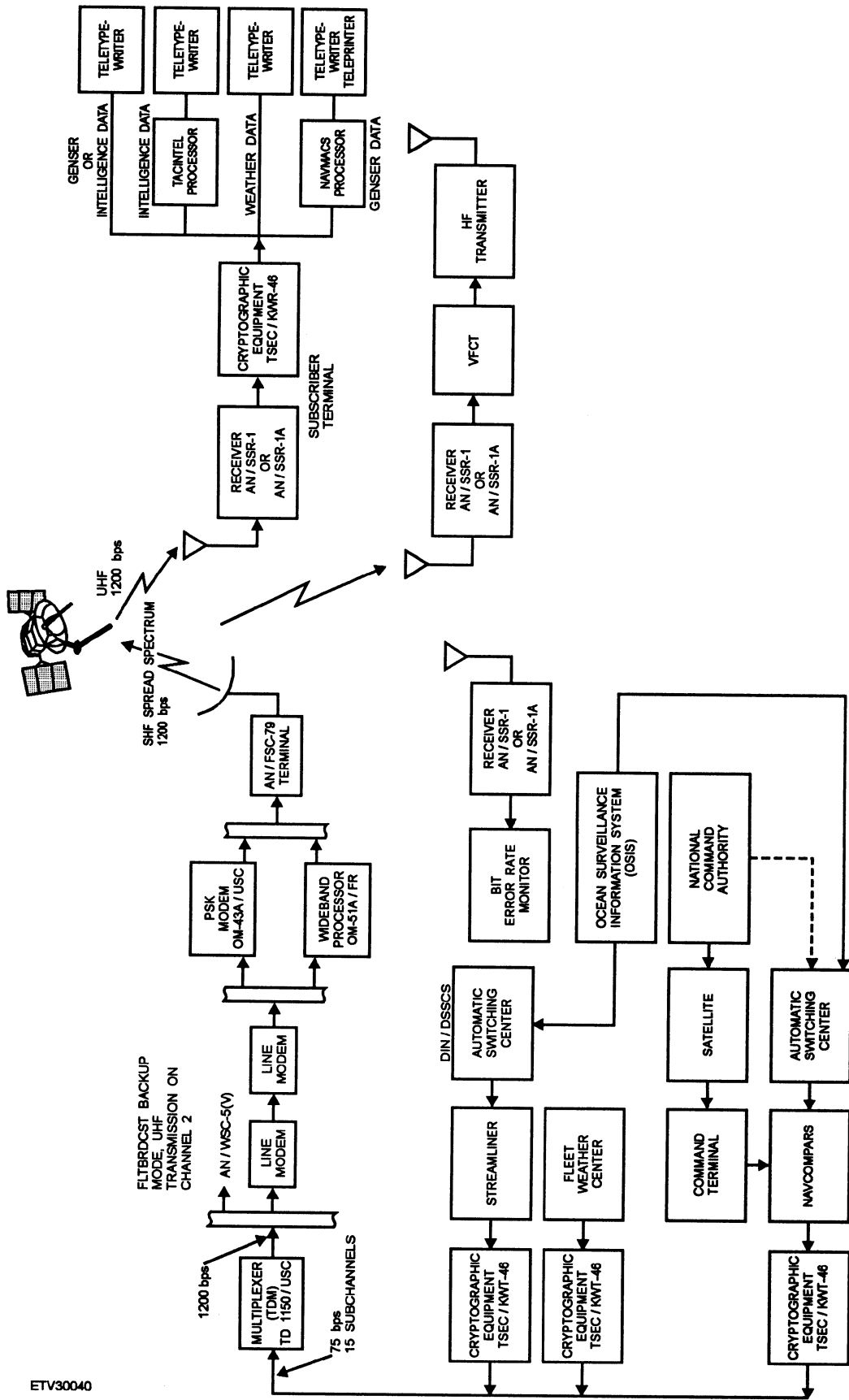
Figure 3-2.—Fleet Satellite Broadcast Subsystem.

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3-5

NAVMACS and TACINTEL processors for message screening and printing. (Refer to the discussion of these two systems.) Weather data is sent directly to printers after decryption. Ships not equipped with one or both of these systems will normally output the broadcast to teletypewriters.

Fleet Broadcast Retransmission

At selected shore stations, fleet Broadcast message traffic is retransmitted on hf links. These stations receive the tdm data directly via cable or satellite.

CUDIXS/NAVMACS

The CUDIXS subsystem is a shorebased installation of processors and peripheral equipment that provides K link control of the network and processing at shore installations. Figure 3-3 shows a typical CUDIXS installation.

NAVMACS is a shipboard message processing system that automatically guards a minimum of four broadcast channels, serves as an automated shipboard terminal for CUDIXS, and provides accountability for all incoming and outgoing message processing needs for ships of the fleet.

NAVMACS subscriber terminal equipment is similar to CUDIXS terminal equipment.

The NAVMACS program is designed to address the growth requirements in existing installations and the unique requirements of ships having a high volume of message traffic. In ships that have a message processing and distribution system (**MPDS**), the NAVMACS processor interacts with the MPDS processor. A basic NAVMACS system is shown in figure 3-4.

NAVMACS reads the headings of incoming message traffic and separates all messages addressed to the ship or commands for which it is guarding. The system compares every addressee on each incoming first run message against entries in its command guard list (**CGL**). When the system finds one or more matches between addresses on the first run message and the entries of the CGL, the message is printed (copied) onto a line printer. If an emergency or Flash precedence message on a first run is received, it is printed completely, regardless of whether or not a match is found. For nonmatches of messages with precedence lower than Flash, only the heading of the message is printed.

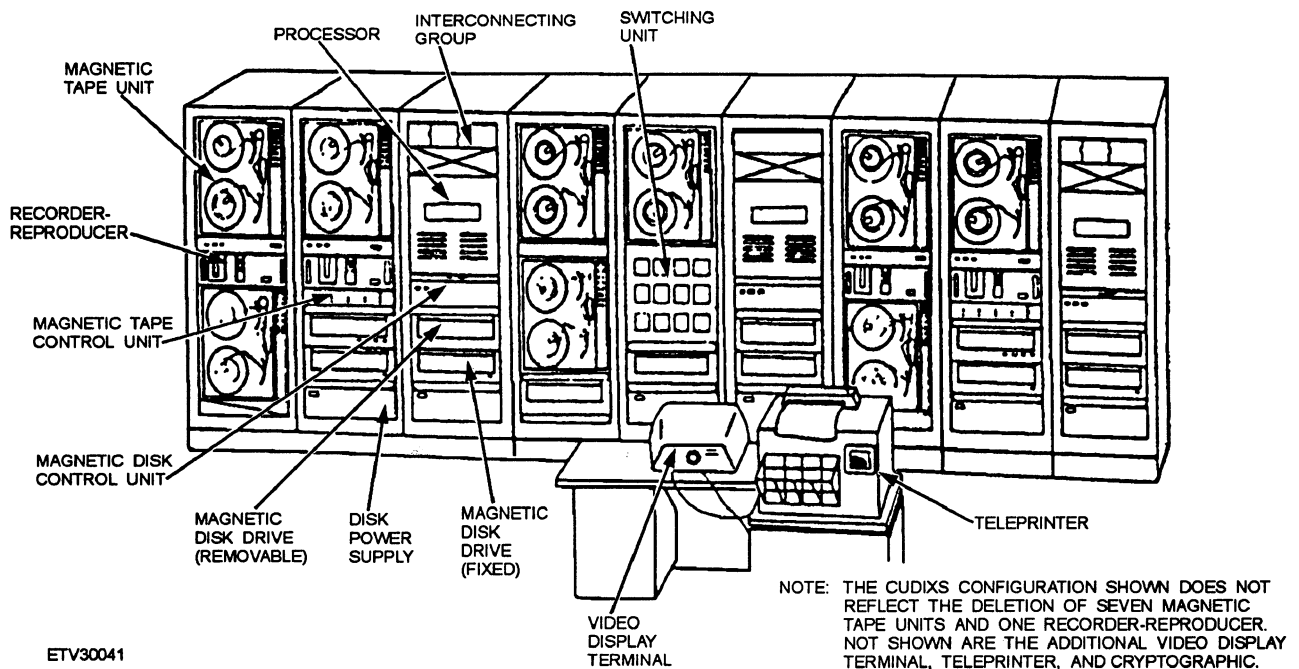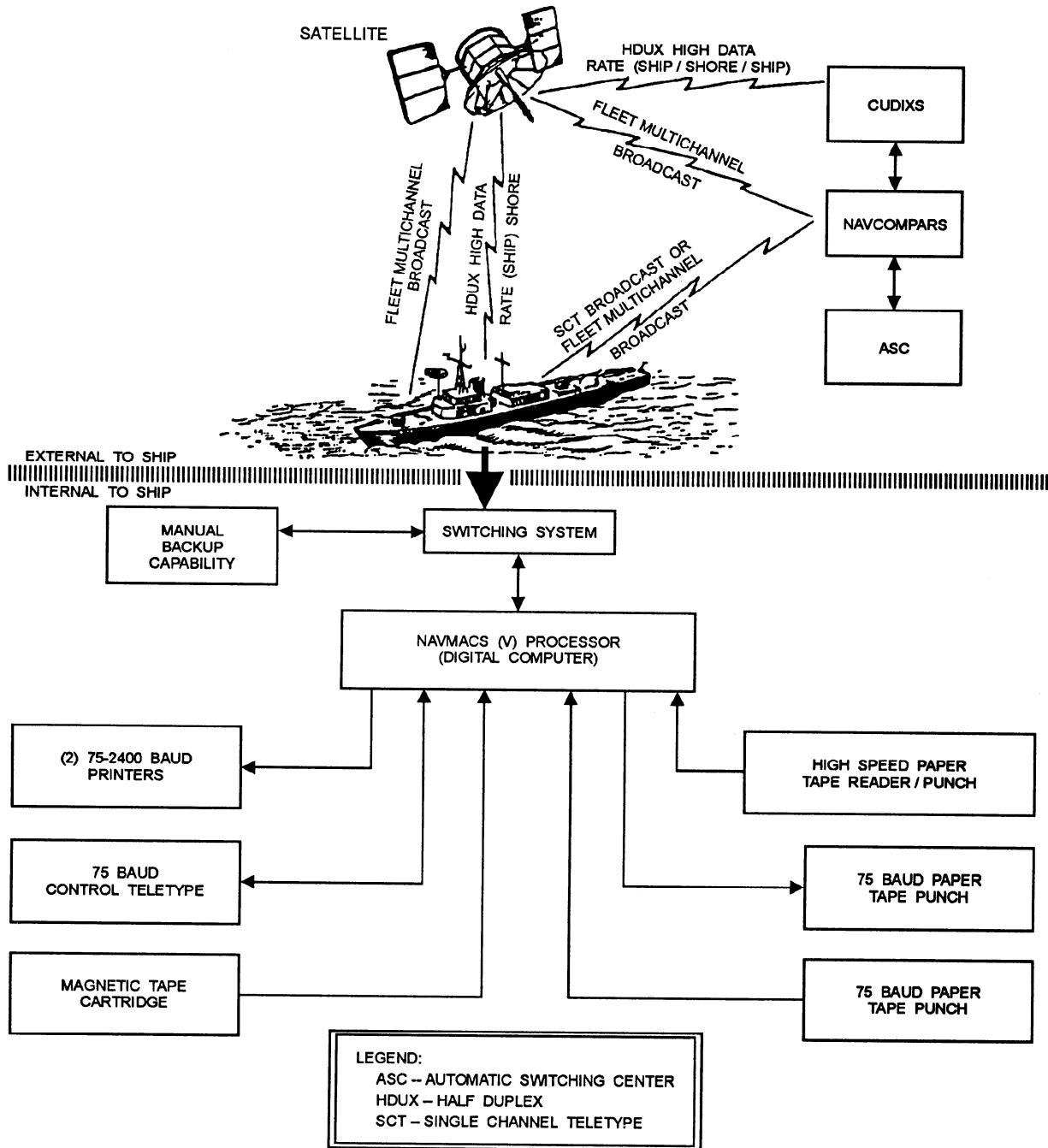Together, CUDIXS and NAVMACS provide improved ship-to-shore and shore-to-ship operational

Figure 3-3.—CUDIXS equipment configuration.

SATELLITE

HDUX HIGH DATA
RATE (SHIP / SHORE / SHIP)

FLEET MULTICHANNEL
BROADCAST

FLEET MULTICHANNEL
BROADCAST

HDUX HIGH DATA
RATE (SHIP) SHORE

SCT BROADCAST OR
FLEET MULTICHANNEL
BROADCAST

CUDIXS

NAVCOMPARS

ASC

EXTERNAL TO SHIP

INTERNAL TO SHIP

MANUAL
BACKUP
CAPABILITY

SWITCHING SYSTEM

NAVMACS (V) PROCESSOR
(DIGITAL COMPUTER)

(2) 75-2400 BAUD
PRINTERS

HIGH SPEED PAPER
TAPE READER / PUNCH

75 BAUD
CONTROL TELETYPE

75 BAUD PAPER
TAPE PUNCH

MAGNETIC TAPE
CARTRIDGE

75 BAUD PAPER
TAPE PUNCH

LEGEND:
  ASC -- AUTOMATIC SWITCHING CENTER
  HDUX -- HALF DUPLEX
  SCT -- SINGLE CHANNEL TELETYPE

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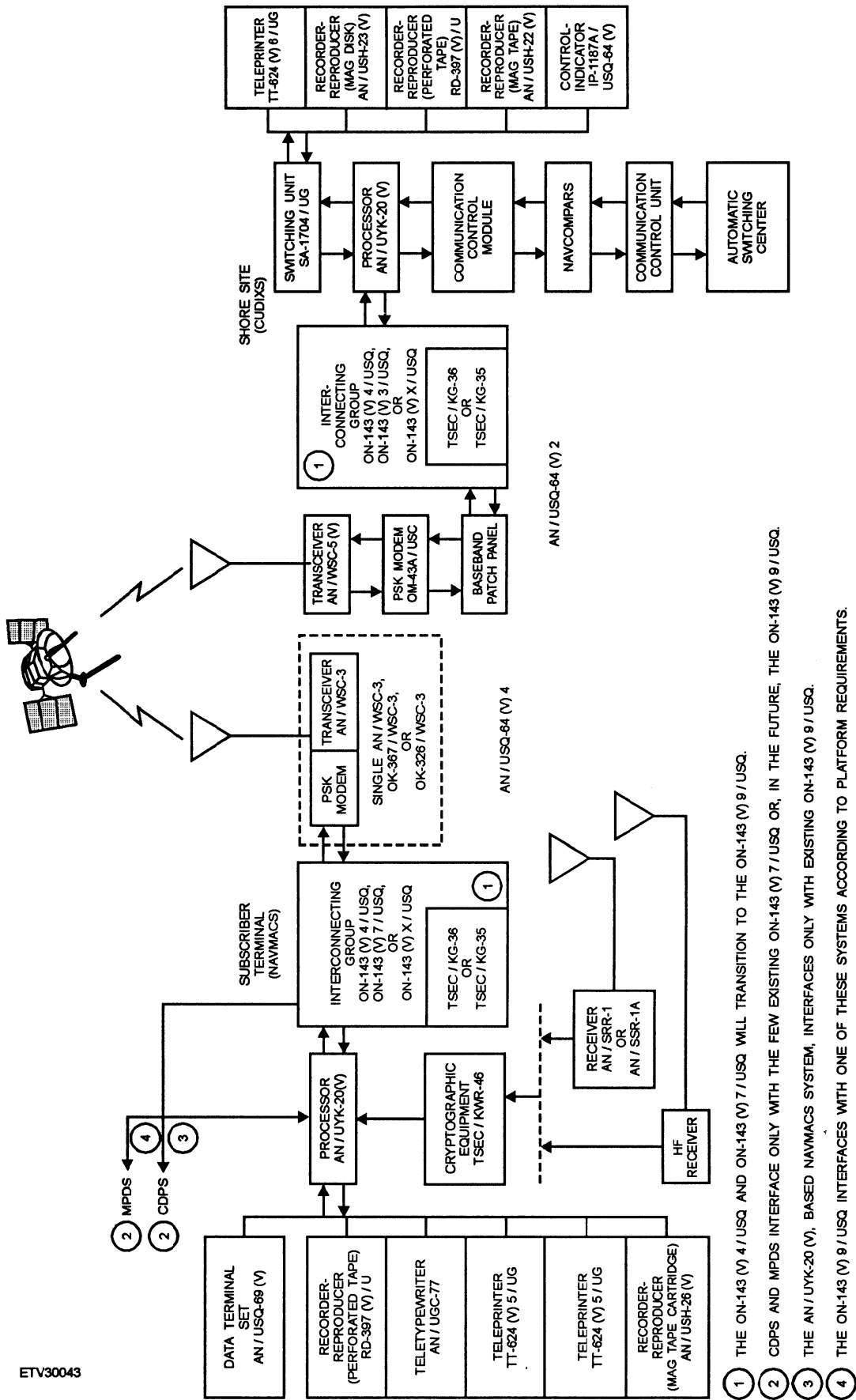Figure 3-4.—NAVMACS (V) communications interface.

Figure 3-5.—CUDIXS/NAVMACS subsystem (non-DAMA).

ETV30043

communications. These improvements help increase message traffic through-put rates and traffic volume, and improve link reliability. Figure 3-5 shows both sides of the CUDIXS/NAVMACS subsystem.

Message Traffic Input

At shore facilities, the primary collection point for message traffic to be transmitted or received on the CUDIXS/NAVMACS rf link is NAV-COMPARS.

Rf transmission Link Control (Non-DAMA)

The CUDIXS baseband equipment shares a common rf terminal with other subsystems. At the shore facilities this terminal is a uhf transceiver, AN/WSC-5(V). Aboard ship, NAVMACS uses a uhf transceiver, AN/WSC-3(V). All uhf satellites have 25-kHz-wide channels allocated for CUDIXS/NAVMACS transmissions. Each channel is operated as a half-duplex uhf link, with a data transmission rate of 2400 bps. The rf modulation is differential encoded phase-shift keying (DPSK).

SUBMARINE SATELLITE INFORMATION EXCHANGE SUBSYSTEM (NON-DAMA)

SSIXS was designed to compliment vlf and mf/hf communication links between shorebased submarine broadcast control authorities (BCAs) and submarines. Figure 3-6 shows a SSIXS subsystem.

This subsystem provides the submarine commander the ability to receive messages transmitted via satellite at scheduled intervals ("Group Broadcasts"). Between Group Broadcasts, submarines may transmit messages to the BCA, including a request for messages held in queue. The shore terminal responds with acknowledgements for the received messages and transmits all messages addressed to that particular submarine. Two modes, Group Broadcast and Query/Response, permit the submarine to be active or passive, depending on what the submarine commander wants. One 25-kHz wideband channel on each of the four FLTSATCOM satellites has been allotted to SSIXS. A single SSIXS network may have up to 120 submarine subscribers.
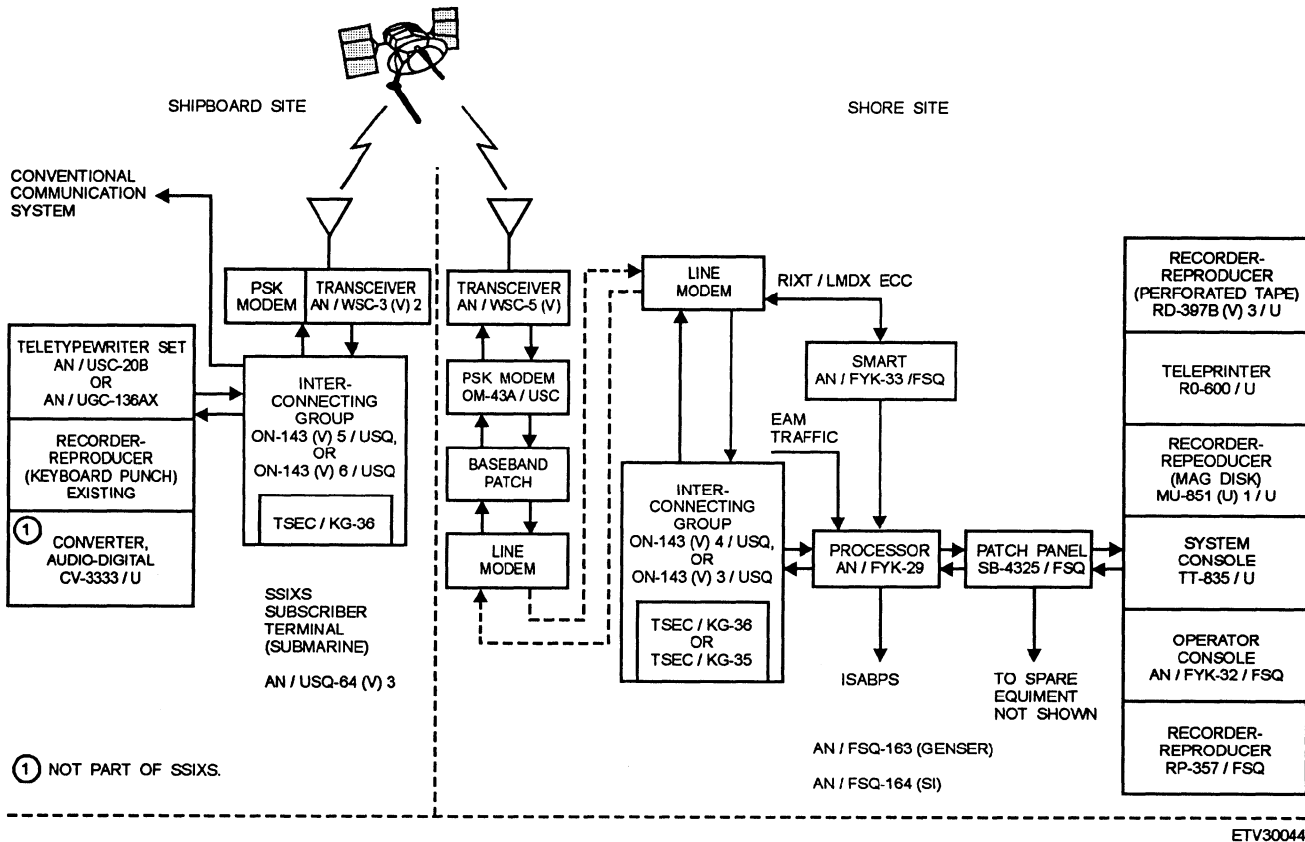

Figure 3-6.—SSIXS subsystem.

3-9

SSIXS has undergone an upgrade (SSIXS II) that replaces the SSIXS shore equipment with new computer equipment.

Message Traffic Input

At the broadcast control authority (BCA), the console keyboard operator, high-speed paper tape reader, or Submarine Message Automated Routing Terminal **(SMART)** enters into the SSIXS shore terminal messages addressed to submarines that have been received from AUTODIN, NAVCOMPARS, or locally over the counter in the message center. Aboard the submarine, message traffic is input via the teletypewriter or tape reader equipment. SSN submarines that have the Data Link Control System **(DLCS)** installed have an additional input/output capability via the sensor interface unit (SIU) for over-the horizon targeting (OTH-T messages.

Rf Transmission Link Control

Ashore, the SSIXS subsystem shares access to the same satellite rf terminal equipment as the other uhf SATCOM subsystems, with the exception of COMSUBGRU SEVEN, Yokosuka, Japan, which is equipped with dedicated AN/WSC-3 transceivers.

Since each BCA is located some distance away from the Naval Computer and Telecommunications Area Master Station **(NCTAMS),** line modems and land lines are required for interconnection. The submarine uhf rf terminal is the single-channel, half-duplex AN/WSC-3. SSIXS transmissions are at 4800 bps. The capability to operate SSIXS in the DAMA net (see the section on DAMA) has been successfully demonstrated and will be used in the future. Each subscriber to a SSIXS network is assigned a unique identification number that is used in all transmissions to or from the subscriber. The identification numbers are stored within the shore station and subscriber processors and are used for the following purposes:

● At the shore stations, the subscriber identification number, when combined with broadcasts, determines the number of times message traffic is transmitted to the subscriber.

● When a subscriber makes a transmission to the shore station, the identification number is included. The shore station will not acknowledge a transmission without receiving the identification number.

● The subscriber uses the number to screen incoming message traffic. Any data that is not addressed to that particular subscriber is discarded.

SECURE VOICE SUBSYSTEM

The Secure Voice subsystem enables the transmission of ship-to-ship, ship-to-shore, and shore-to-ship voice communications via satellite relay. Figure 3-7 shows a Secure Voice subsystem. (AUTOSEVOCOM has been replaced by radio wireline interface (RWI) at all NCTAMS shore activities.) The subsystem transmits and/or receives secure voice communications via a half-duplex, push-to-talk satellite link. Channels on each of the four FLTSATCOM satellites have been allocated for use by the Secure Voice subsystem. Control of the voice channels is maintained by the Secure Voice controller at the responsible NCTAMS/ NCTS.

The subsystem uses digitized voice at a data rate low enough to be compatible with a 3-kHz voice channel and is considered narrowband. The sound of Narrowband Secure Voice is very distinctive. Once you hear it, you won't forget it. The system uses special analog-to-digital processing of the speech signal at the handset terminal and the rf transmission rate is 2400 bps.

The Secure Voice subsystem has dedicated rf channels on the uhf SATCOM satellites as well as dedicated DAMA time slots where DAMA nets have been established.

Voice Transmission

The rf terminal installations on mobile platforms determine the manner in which a Secure Voice transmission is made. These mobile platforms maybe categorized into two types:

● 'The small ship/submarine that share a single-channel AN/WSC-3(V) uhf transceiver and cryptographic equipment between NAVMACS or SSIXS and a Secure Voice terminal.

● Larger ships that have two or more AN/ WSC-3(V) uhf transceivers and cryptographic equipment are installed. This installation normally has a transceiver dedicated to Secure Voice.

Secure Voice use is accomplished by either of two methods. In the first method, ships access a Secure Voice channel if the channel is not in use. The ship contacts another ship directly by using the available channel. When coordination of voice communications with shore commands is required, the ship contacts the voice controller who, in turn, tells the recipient(s) of an incoming voice transmission.
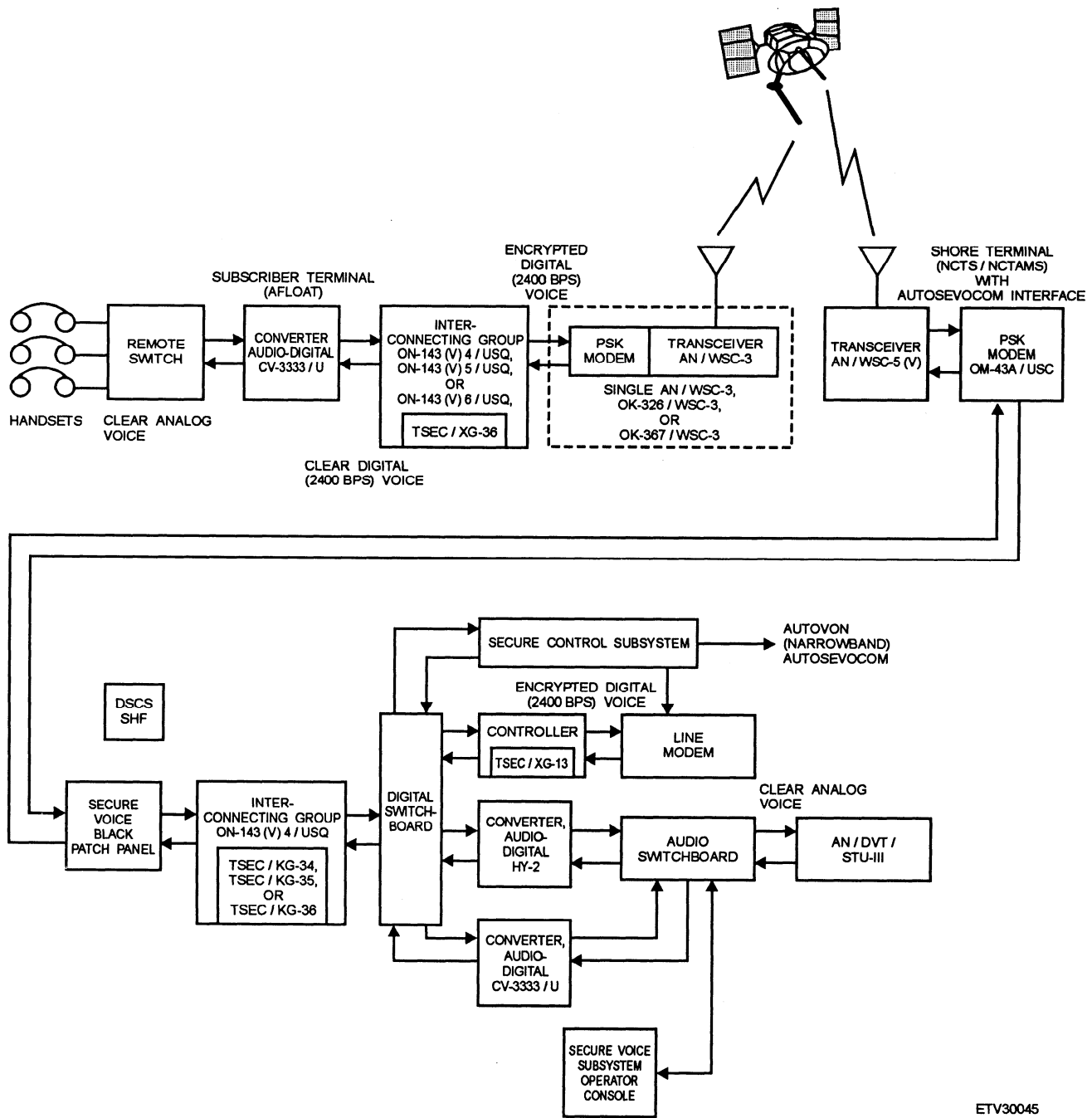
Figure 3-7.—Secure Voice subsystem.

The second method requires a different process and is used if the channels are busy or if procedures require this method. For the small ship or submarine, a voice transmission request must be sent by message to the Secure Voice controller. A small ship uses the CUDIXS/NAVMACS network for the message. The submarine may transmit a voice-channel request during a random-access time period in the SSIXS. In both cases, the request is passed from the reception point ashore to the voice controller. The voice controller coordinates the voice transmission by assigning a voice channel, contacting the unit that will receive the voice transmission, and following through with the transmission.

Radio Wireline Interface

The Radio Wireline Interface (**RWI**) was developed to access and interconnect existing and future Secure Voice subsystems and equipment. It provides the capability to connect shorebased worldwide

3-11
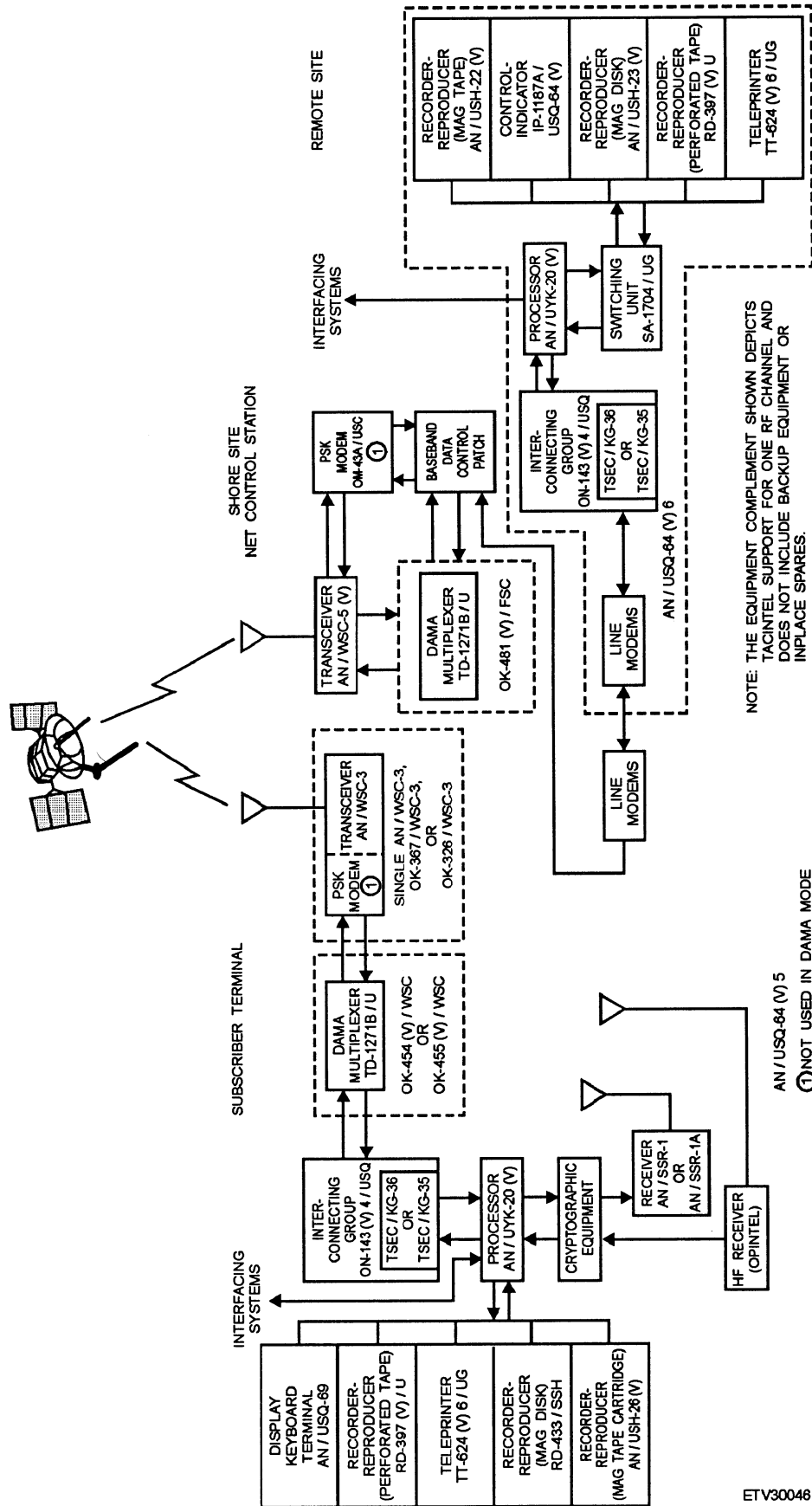
Figure 3-8.—DAMA-configured TACINTEL subsystem.

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terrestrial **(wireline)** systems with the SATCOM, Defense Satellite Communications Systems, and alternate hf systems. This system extends shore communications seaward and gives commands at sea the same Secure Voice telephone communications currently provided to the worldwide shore establishment. The RWI provides interconnection among the Secure Voice Improvement Program (SVIP) channels **(STU-III** units), a RED telephone bus, the Advanced Narrowband Digital Voice Terminal, SATCOM radio terminals (uhf, shf, and in the future, ehf), and hf radio links.

TACTICAL INTELLIGENCE SUBSYSTEM

The Tactical Intelligence subsystem (TACINTEL) is used to transmit special-intelligence communications. A link-control protocol has been adapted to a format required for communication across a DAMA-supported channel using a polling scheme that can support a net membership of 23 subscribers. A portion of a DAMA 25-kHz channel on each of the FLTSATCOM satellites has been allocated for TACINTEL. A TACINTEL subsystem is shown in figure 3-8.

TACINTEL also processes time-sensitive sensor data and other data essential to Indications and Warnings and OTH-Targeting. In addition, this system, unlike CUDIXS/NAVMACS, can be used for direct ship-to-ship interchange of this data.

Rf Transmission

TACINTEL baseband equipment uses an rf terminal in common with other subsystems at both shore facilities and subscriber terminals. Shore facilities use an AN/WSC-5(V); subscribers use an AN/WSC-3(V). The TACINTEL channel operates as a half-duplex uhf link at 1200, 2400, or 4800 bps. Modulation is DPSK

Subscriber Reception

Each subscriber has an identification number recognized by the subscriber processor. This number serves as the initial basis for incoming message screening. Screened message traffic is sent to the TACINTEL peripheral equipment (printer) or the interfacing systems. The remaining message traffic is discarded without release.

Future TACINTEL

The TACINTEL II program will upgrade the existing TACINTEL and incorporate state-of-the-art hardware and software. It will be a computer-based message communications system, enabling automatic receipt and transmission of Special Intelligence communications for both ashore and afloat users. During the transition, it will be compatible with the present TACINTEL.

TELETYPEWRITER SUBSYSTEM

The Teletypewriter Subsystem expands existing teletypewriter communications networks by using satellites as relay stations.

The Navy continues to have numerous uses for the 75-bps tty. These include dedicated full-time terminations for beyond-line-of-sight tactical and report-back circuits and as backup connectivity for networks such as CUDIXS/NAVMACS and TACINTEL. A non-DAMA-configured teletypewriter subsystem is shown in figure 3-9.
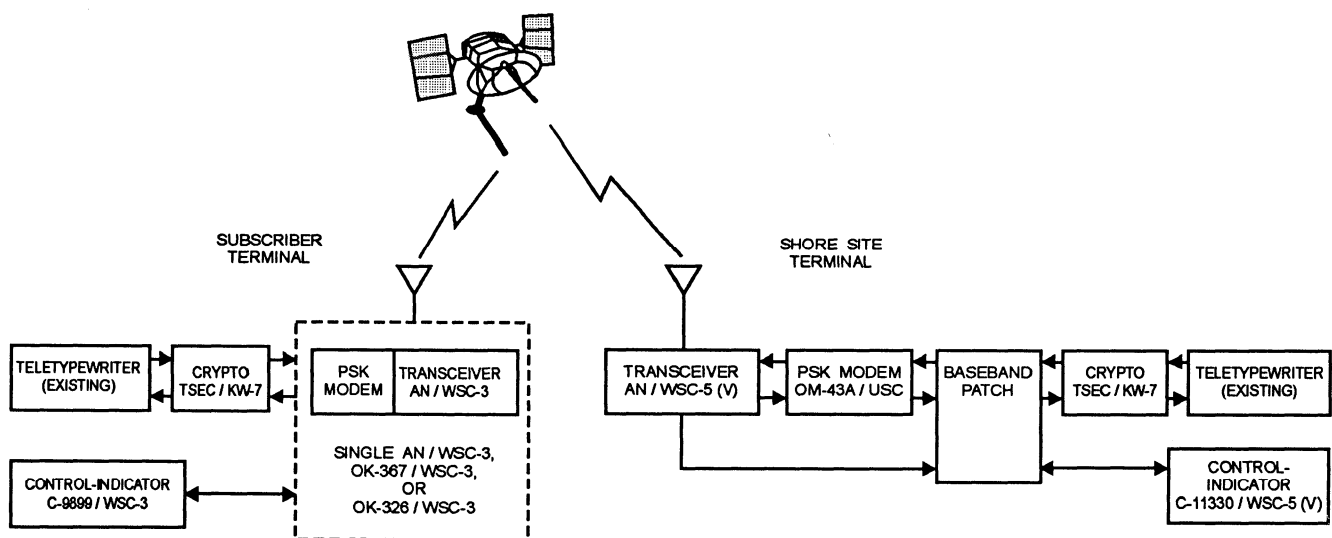
Figure 3-9.—Teletypewriter subsystem-non DAMA.

TADIXS/OTCIXS

TADIXS supports the exchange of Over-the-Horizon Targeting **(OTH-T)** information between shore and fleet-based computer systems that support Navy cruise missile operations. Surface ships and submarines operate in a TADIXS receive-only mode. OTH-T data from the fleet destined for shore or other fleet users is sent by the afloat Tactical Data Processors **(TDPs)** through the TADIXS ON-143(V)6/USQ to the OTCIXS ON-143 (V)6/USQ for transmission over the OTCIXS satellite. A TADIXS surface ship installation is shown in figure 3-10. Each OTCIXS-equipped surface ship or submarine can enter both out-going teletype and TDP traffic simultaneously.

Rf Transmission Link Control

The TADIXS satellite link network operates in a half-duplex manner at a data rate of 2400 bps in a permanently assigned time slot of a uhf DAMA channel. Control of message traffic transmission is
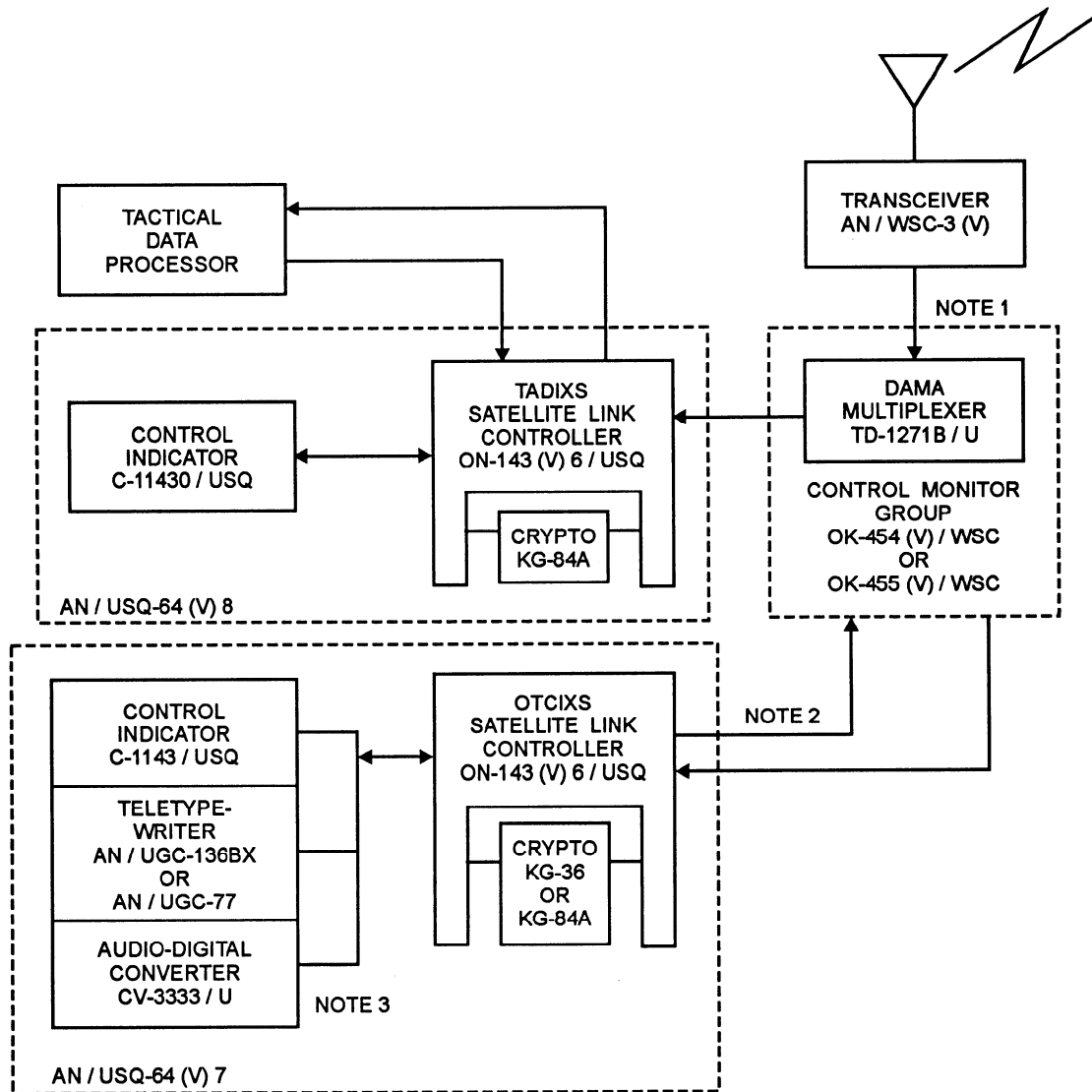
NOTES:

1. TADIXS IS RECEIVE ONLY FOR AFLOAT PLATFORMS.

2. CONFIGURATION SHOWN IS FOR AN OTCIXS DAMA NETWORK IN THE NON-DAMA CONFIGURATION. THE OK-143 (V) 8 / USQ CONNECTS DIRECTLY WITH A SECOND AN / WSC-3 (V).

3. NOT PART OF AN / USQ-64 (V) 7, BUT CAN BE INSTALLED FOR FLTSATCOM SECURE VOICE OPERATIONS.

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Figure 3-10.—TADIXS surface ship installation.

achieved by a polling and controlled access protocol installed in the TADIXS radio controller (shore) software and the TADIXS satellite link controller (afloat) software.

In the non-DAMA mode, OTCIXS operates in a half-duplex manner at a data rate of 2400 bps using a dedicated uhf channel. When functioning in the DAMA mode, OTCIXS operates at a data rate of 1200 or 2400 bps in a permanently assigned time slot of a uhf DAMA channel. Control of message traffic transmission is achieved by a demand-assigned access protocol installed in the OTCIXS radio controller (shore) and satellite link controller (afloat) software.

Message Traffic Reception

Each subscriber in the TADIXS network has a unique identification number recognized by the subscriber processor. This number serves as the initial basis for incoming message traffic screening. TADIXS or OTCIXS satellite link controllers (on afloat units) compare redundant receptions for accuracy and form the most accurate composite of the traffic received.

For surface ship and submarine users, screened message traffic is sent to the teletypewriter or TDP system, as applicable. The rest of the traffic is discarded. The reception of traffic does not make the satellite link controller send an acknowledgement. This allows afloat platforms to receive traffic while operating in an emission control (**EMCON**) environment.

DEMAND-ASSIGNED MULTIPLE ACCESS (DAMA) SUBSYSTEM

The uhf DAMA subsystem was developed to multiplex several baseband systems or users on one 25-kHz satellite channel. This had the effect of adding more satellite circuits per channel to the uhf Satellite Communications System. Without uhf DAMA, each satellite communications subsystem requires a separate satellite channel.

DAMA equipment accepts encrypted data streams from independent baseband sources and combines them into one continuous serial output data stream. DAMA interfaces the Navy uhf SATCOM subsystems and the AN/WSC-5(V) and DAMA-compatible AN/WSC-3(V) transceivers. The DAMA unit (TD-1271B/U multiplexer) includes a modem, eliminating the need to use a separate modem at the AN/WSC-5(V) or the modem within the AN/WSC-3(V). The baseband equipment input or output (**I/O**) data rate

with DAMA equipment can be 75, 300, 600, 1200, 2400, 4800, or 16,000 bps. The DAMA transmission rate on the satellite link (**burst rate**) can be 2400, 9600, 19,200, or 32,000 symbols per second (**sps**). CUDIXS/NAVMACS, Secure Voice, and OTCIXS currently use 2400 bps. TACINTEL operates at 2400 or 4800 bps, depending upon the ocean area.

The DAMA multiplexed data stream is divided into frames, with each frame being 1,386 seconds long. Each frame is subdivided into time slots as shown in figure 3-11. Most of the DAMA frame formats are derived from this basic format. In the following paragraphs, we will name and describe the purpose of each slot.

Channel Control Order Wire (CCOW) Slot

This slot is used to transmit system timing and control information from the channel controller to subscriber units only. It provides subscriber units with system timing, configuration, and satellite rf control information. It occurs at the beginning of each frame.

Return Channel Control Order Wire (RCCOW) Slot

This time slot provides limited order wire capability for DAMA-related subscriber-to-channel controller communications. It is used for transmission from the subscriber to the channel controller.

Ranging Time Slot

This is the time slot during which the user's TD-1271B/U determines the range between the user terminal and the satellite to set the transmitter synchronization required for timing. All DAMA multiplexer transmit times are referenced to the satellite.

Link Test Slot

The link test slot is used to evaluate the performance of the satellite link. Each subscriber is able to transmit a fixed data stream through the satellite, receive that bit stream, and then perform error analysis automatically.
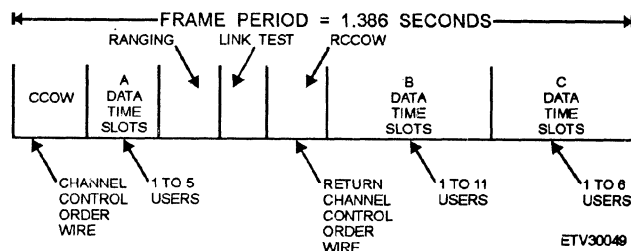

Figure 3-11.—Basic DAMA frame format.

Data Time Slots

These are the time slots during which users transmit or receive data. There are three segments of time slots in each frame, designated A, B, and C. Segment A may contain from one to five circuits; B may contain from one to eleven circuits; and C may contain from one to six circuits. The number of circuits in each group depends on the baseband data rate, the forward correction rate, and the transmission burst rate, as influenced by the radio frequency interference **(RFI)** environment.

Current Operation

For communications on the eastern Pacific satellite, a master control station is installed at NCTAMS EASTPAC. This same pattern of DAMA equipment installations has been followed at NCTAMS LANT, MED, WESTPAC, and NTCS. Each master control station has multiple multiplexer installed, and each TD-1271B/U multiplexer can accommodate up to four circuits. The number of multiplexer installed aboard each ship varies according to platform requirements.

Any DAMA-equipped platform with full-duplex capability can be designated a channel controller. This capability provides an emergency backup for the shorebased master controller terminals. A DAMA subscriber who is designated a channel controller will provide all the required CCOW functions for DAMA system control of a particular rf channel.

Operationally, the user terminal will have its baseband port automatically connected to a data time slot when the proper slot number is keyed into the multiplexer front panel keyboard. Each SATCOM subsystem that uses DAMA will have a specific slot number. Circuits will normally be operated on a netted basis, and circuit numbers will be assigned by COMNAVTELCOM and/or FLTCINC.

Transition

Transition to DAMA is taking place in a manner that allows subscribers converted to DAMA to communicate with those who have not been converted. During the transition period, equipment installed at shorebased master stations will form gateways between DAMA and non-DAMA circuits. In the following paragraphs, we will discuss subsystems that are either currently undergoing conversion to DAMA or are planned for conversion, so you will know what to expect in the future.

Secure Voice —DAMA is now being phased into the Secure Voice Subsystem. A DAMA-configured Secure Voice Subsystem is shown in figure 3-12.

CUDIXS/NAVMACS —NAVMACS platforms will be gradually transitioned to DAMA. This transition will start when CUDIXS shore and CUDIXS/NAVMACS ship hardware and software have been modified for compatibility with DAMA. At that time, a transition will begin allowing DAMA or non-DAMA ships to communicate with the CUDIXS shore terminal. A DAMA-configured CUDIXS/ NAVMACS subsystem is shown in figure 3-13.

Teletypewriter —Teletypewriter capability via DAMA becomes available as DAMA is installed on each platform. To provide maximum flexibility during the transition, capability is provided at the shorebased master control stations to interface non-DAMA and DAMA users. Figure 3-14 shows a DAMA-configured teletypewriter subsystem.

CONTROL SUBSYSTEM

The Control Subsystem is structured to perform the following tasks:

- Sense and collect system status information in a defined geographical area and on a worldwide scale.

- Control system resources and the degradation of system capability.

The Control Subsystem is a combination of several areas and levels of command. The major players are listed below:

- The Chief of Naval Operations is the executive authority for all SATCOM system.

- The Commander, Naval Space Command is responsible for the operational control and management of these systems and for the effective operation and maintenance of assigned Navy resources for the Department of Defense.

- The Naval Computer and Telecommunications Command performs the required functions to provide day-to-day control and operation of naval satellite communications assets. With coordination, system resources can be adjusted to meet operational needs.
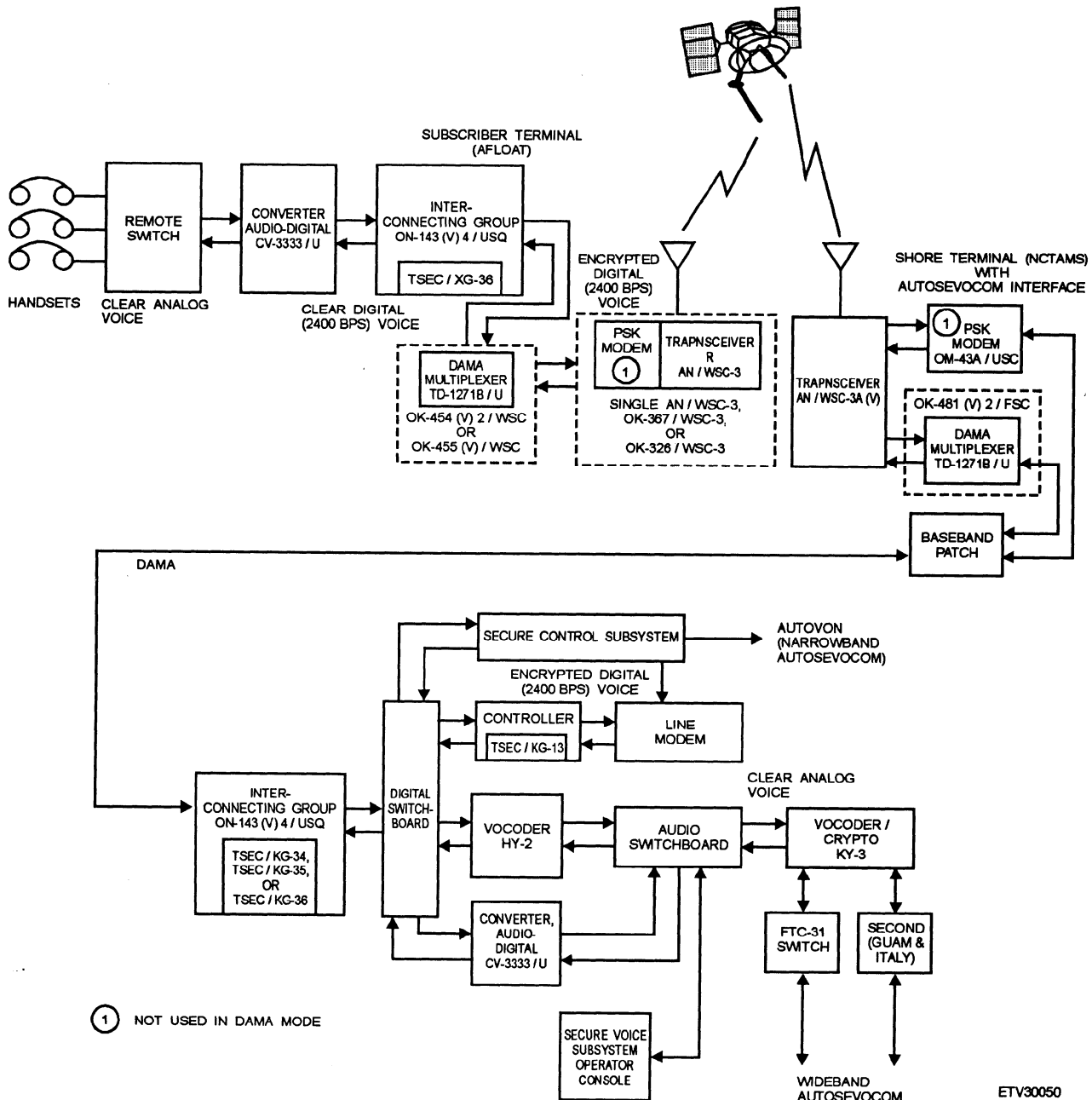
Figure 3-12.—DAMA-configured Secure Voice Subsystem.

• Supporting the control subsystem are NCTAMS, NCTS, the USAF Satellite Operations Center, and contractor-operated control facilities.

The key to controllability lies in having many points for sensing the status of subsystems and equipment operation. Status data may be collected by operators or by special facilities or equipment. There are many points within each subsystem where subsystem and equipment operational status is collected. Also, several subsystems/systems have the ability to provide a printout of status information.

Transmission of status data from the NCTAMS, NCTS, and USAF Satellite Operations Center is via teletypewriter order wire. The Naval Computer and Telecommunications Command maintains a substantial quantity of updated status data in computer files. A diagram of the Control Subsystem is shown in figure 3-15.
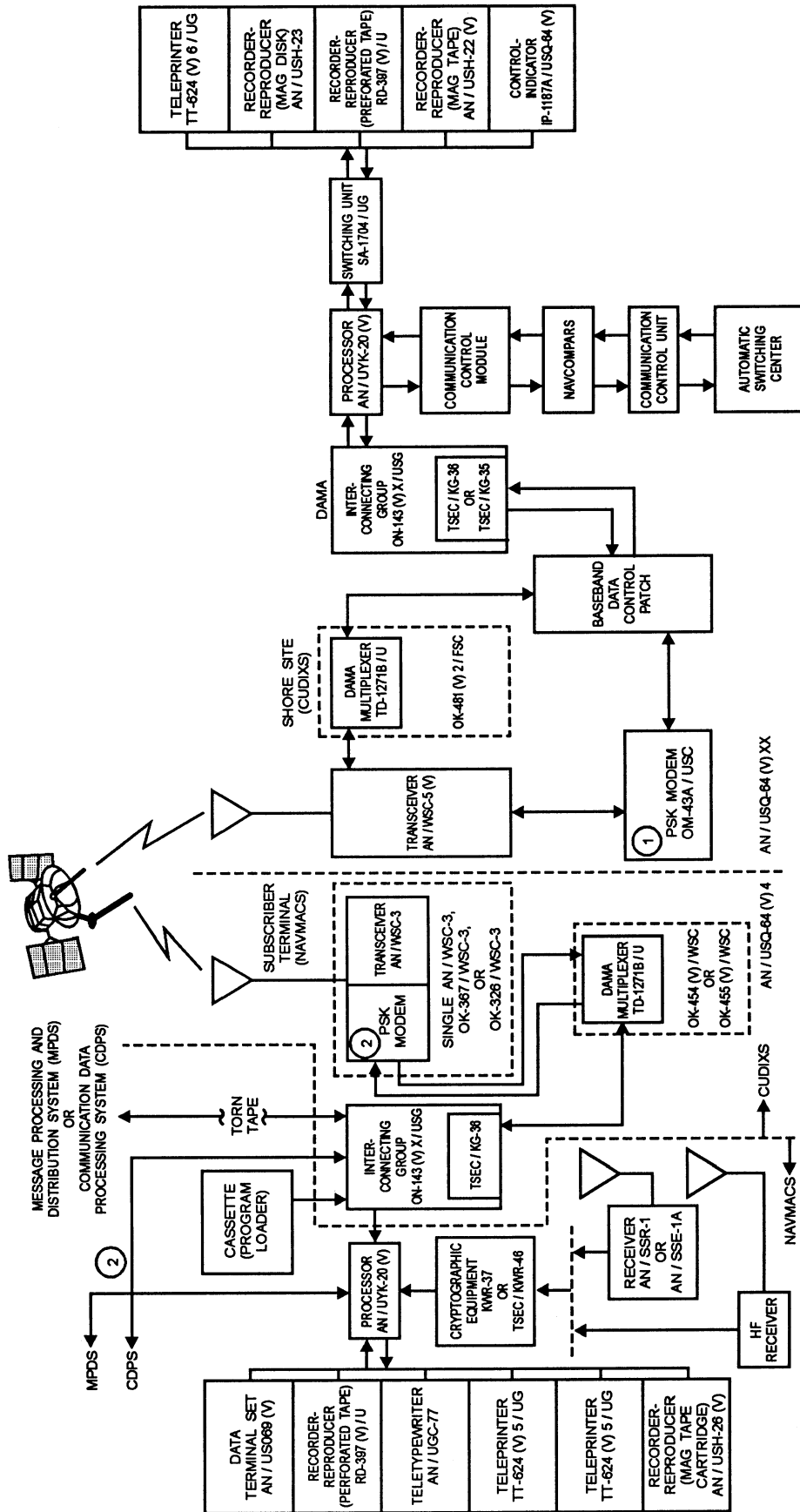
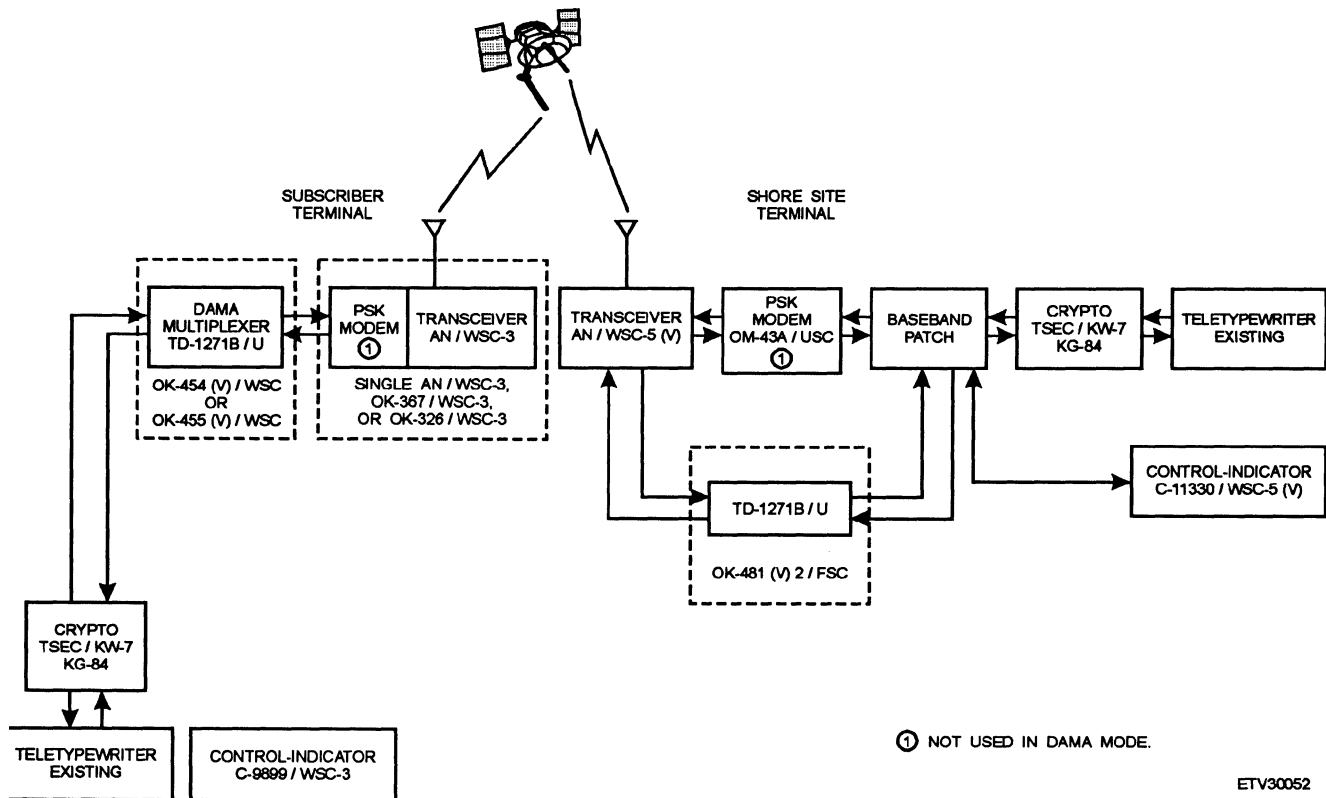Figure 3-13.—DAMA-configured CUDIXS/NAVMACS subsystem.

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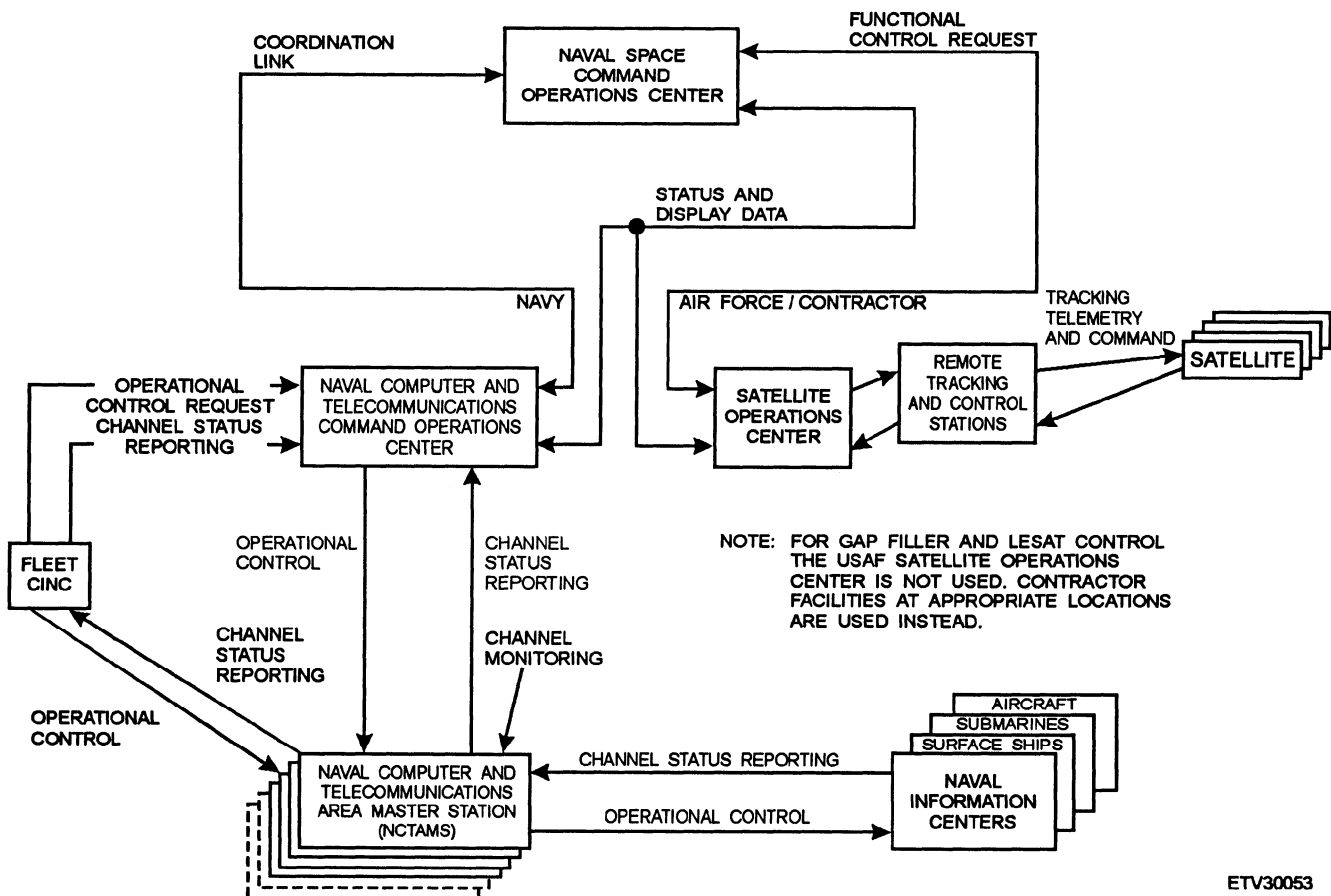Figure 3-14.—DAMA-configured teletypewriter subsystem.

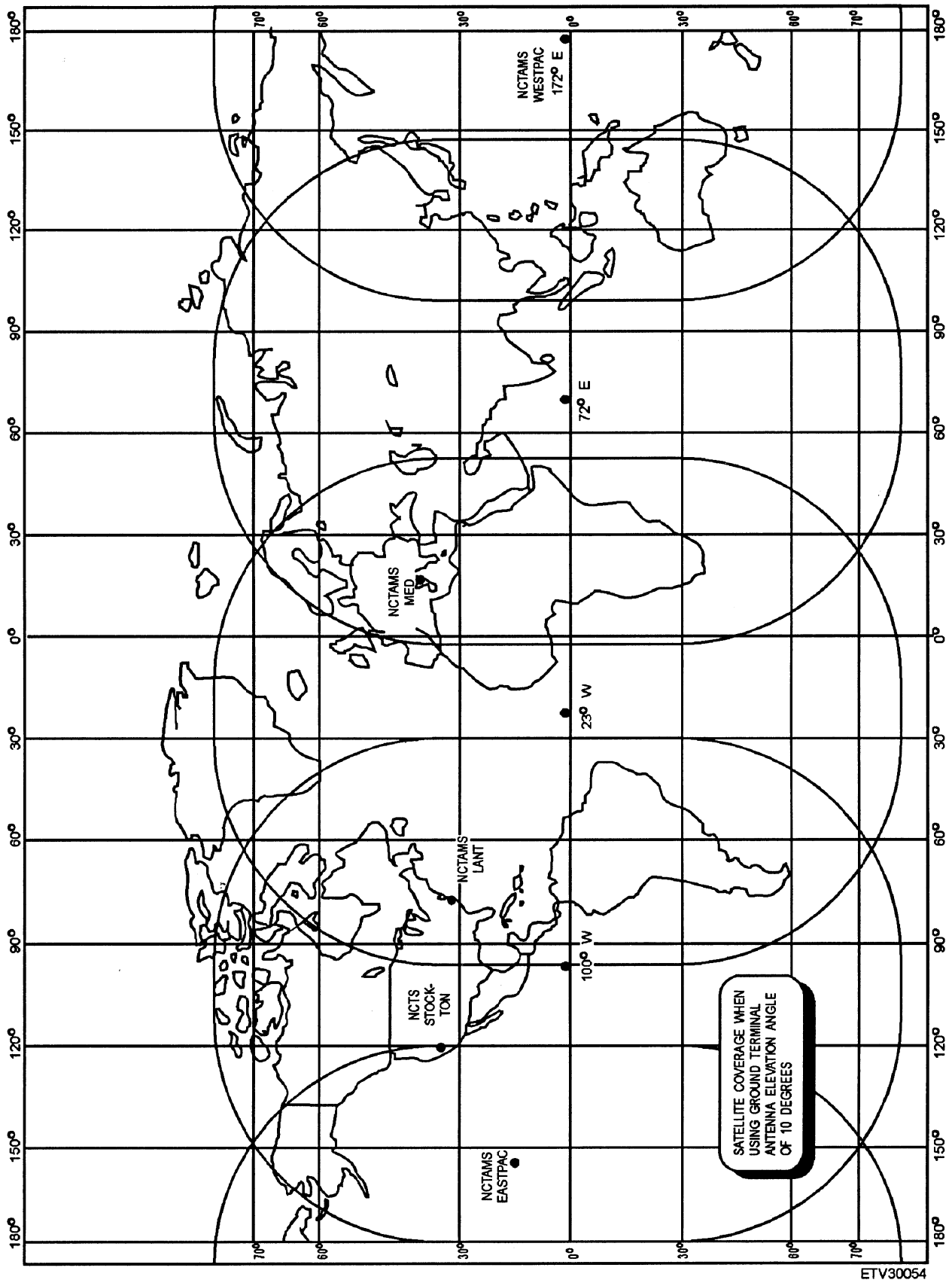Figure 3-15.—Control Subsystem functional diagram.

Figure 3-16.—Uhf satellite coverage areas.

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SATELLITES

In 1976, three satellites were placed into orbit over the Atlantic, Pacific, and Indian Oceans. These satellites, called **MARISATs,** were procured by and are managed by the COMSAT General Corporation. Each satellite has three uhf channels for military use (one wideband 500-kHz channel and two narrowband 25-kHz channels). The uhf section of each satellite is leased to the Navy for communications. To distinguish the special management and control functions for communications on these uhf channels, the Navy has given the leased MARISAT satellite assets the name **GAPFILLER.**

Current planning calls for no Navy use of GAPFILLER satellites after the mid-1990's. Satellite coverage will then be provided by a combination of **FLTSAT** and **LEASAT** until the new **UHF FOLLOW-ON (UFO)** satellites are placed into service. The Navy plans to have two operational satellites in each of four satellite coverage areas. Each satellite coverage area can be terminated in at least two NCTAMS, allowing around-the-world connectivity. You can see this connectivity in figure 3-16.

FLTSATCOM SATELLITE

The FLTSATCOM satellite consists of two major parts: a payload module that includes the antennas and a space craft module with a solar array. The payload module contains the uhf, shf, and S-band (tracking, telemetry, and command) communications equipment antennas. The communications equipment is mounted internally on side panels that cover this section of the satellite.

The space craft module contains nearly all other subsystem equipment, including sensors, attitude and velocity control, telemetry, tracking and command, and electrical power distribution. The spacecraft is stabilized on three axes, and the body-fixed antennas are kept pointing at the sun by a clock drive. A FLTSATCOM satellite is shown in figure 3-17.

Each FLTSATCOM satellite can relay communications on 23 separate uhf channels. Of the 23 channels, 10 are 25-kHz channels, 12 are 5-kHz channels, and one is a 500-kHz channel. The ten 25-kHz channels are dedicated for Navy use. Each 25-kHz uhf down-link channel has a separate transmitter. Channel one, used in primary mode for Fleet Broadcast transmissions, incorporates signal processing within the satellite (the shf up-link signal is translated to uhf
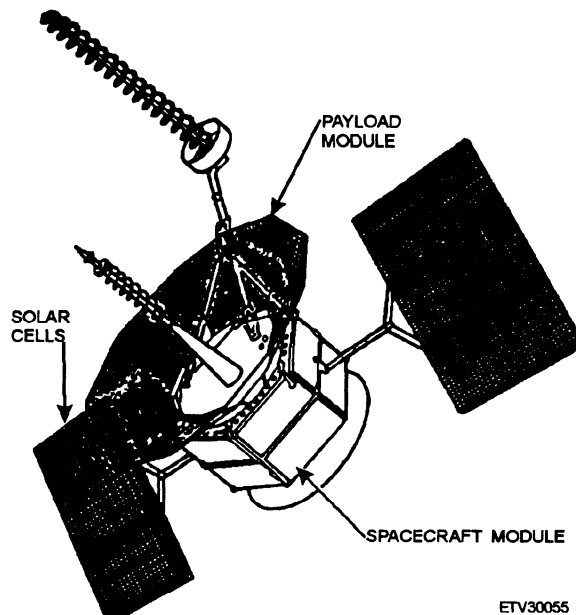
Figure 3-17.—FLTSATCOM satellite.

for down-link transmission). In addition, two of the FLTSATCOM satellites have ehf packages attached.

FLTSAT Extremely-High-Frequency Package (FEP)

The Fleet Satellite (FLTSAT) Extremely-High-Frequency (EHF) Package **(FEP)** provides ehf communications capability for Army, Navy, and Air Force ground, airborne, and ocean-going terminals. Two FEPs are currently in orbit, carried aboard two modified uhf FLTSATs, numbers seven and eight.

FEP operates at ehf frequencies of approximately 20-GHz on the down-link and 44-GHz on the up-link. It has two antenna beams: (1) a dual-frequency spot beam steerable by ground command, and (2) an earth coverage beam that uses separate horn antennas for transmit and receive.

LEASAT SATELLITE

The LEASAT satellite has seven 25-kHz uhf down-link channels, one 500-kHz wide-band channel, and five 5-kHz channels. One of the seven 25-kHz down-link channels is used for Fleet Broadcast. The broadcast up-link is shf, with translation to uhf taking place in the satellite. The remaining

six channels function as direct relay channels with separate repeaters. A LEASAT satellite is shown in figure 3-18.

Compared to FLSATCOM satellites, LEASAT satellites have a reduced number of 25-kHz channels. However, they can still serve expanding Navy SATCOM requirements by using the groundbased DAMA technique, effectively using each satellite channel more efficiently.

UHF FOLLOW-ON SATELLITE

The purpose of the Ultra-High-Frequency Follow-On Satellite System **(UHF F/O)** is to provide satellite communications for DOD and other government agencies through satellites in geosynchronous orbit. The current satellites, GAPFILLER, FLTSATCOM, and LEASAT are approaching the end of their normal mission life. UHF F/O will provide the needed replenishment satellites. The strategy for replacement is to use existing FLTSATCOM and LEASAT assets fully, while deploying the UHF F/O satellites to minimize communications disruptions as the FLTSATCOM and LEASAT satellites fail or reach the end of their useful life. An exploded view of a UHF F/O satellite is shown in figure 3-19.

Communications Capability

The uhf communications subsystem consists of receive and transmit antennas, a low-noise pre-amplifier, 25- and 5-kHz channel receivers and

Figure 3-18.—LEASAT satellite.

transmitters, and an output multiplexer. The shf communications subsystem provides shf anti-jam up-link capability for Fleet Broadcast (which is down-linked as uhf) and consists of receive and transmit antennas, the receiver, a dual channel processor, and the beacon transmitter. Signals received by the shf receive antenna are fed to the shf receiver. In turn, the processor provides Fleet Broadcast outputs that are fed to uhf communications subsystem for down-link. The multiplexed anti-jam broadcast capability of the UHF F/O permits up to three broadcast channels to be up-linked and down-linked simultaneously.

On the fourth and subsequent satellites deployed, an ehf communications subsystem will provide three ehf broadcast channel up-links and seven ehf communications channel up-links. Each of these ehf up-links will be capable of being down-linked as ehf only, uhf only, or simultaneously as uhf and ehf. UHF F/O will also have the capability of transmitting and receiving ehf telemetry and command data.

User interfaces for UHF F/O are identical to those of the current FLTSATCOM and LEASAT constellation. The uhf portion of the UHF F/O system is compatible with all existing Navy uhf terminals except those using frequency-hopping techniques.

Channel Allocations

The UHF F/O satellite channels are allocated and grouped as follows:

● Group I has a single 25-kHz bandwidth channel with a variable satellite translation frequency and a jam resistant shf up-link.

● Group II has nine 25-kHz bandwidth channels with a satellite translation frequency of 41 MHz.

● Group III has eight 25-kHz bandwidth channels with a satellite translation frequency of 33.6 MHz.

● Group IV has eight 5-kHz bandwidth channels with a satellite translation frequency of 73.1 MHz.

● Group V has thirteen 5-kHz bandwidth channels with a satellite translation frequency of 53.6 MHz.

MILSTAR

MILSTAR is a new generation Satellite Communications (SATCOM) system being developed by the Navy, Army, and Air Force for two primary purposes. First, it will provide a survivable
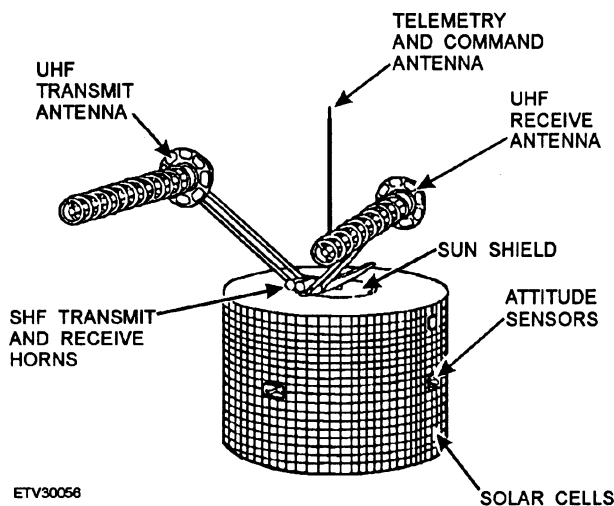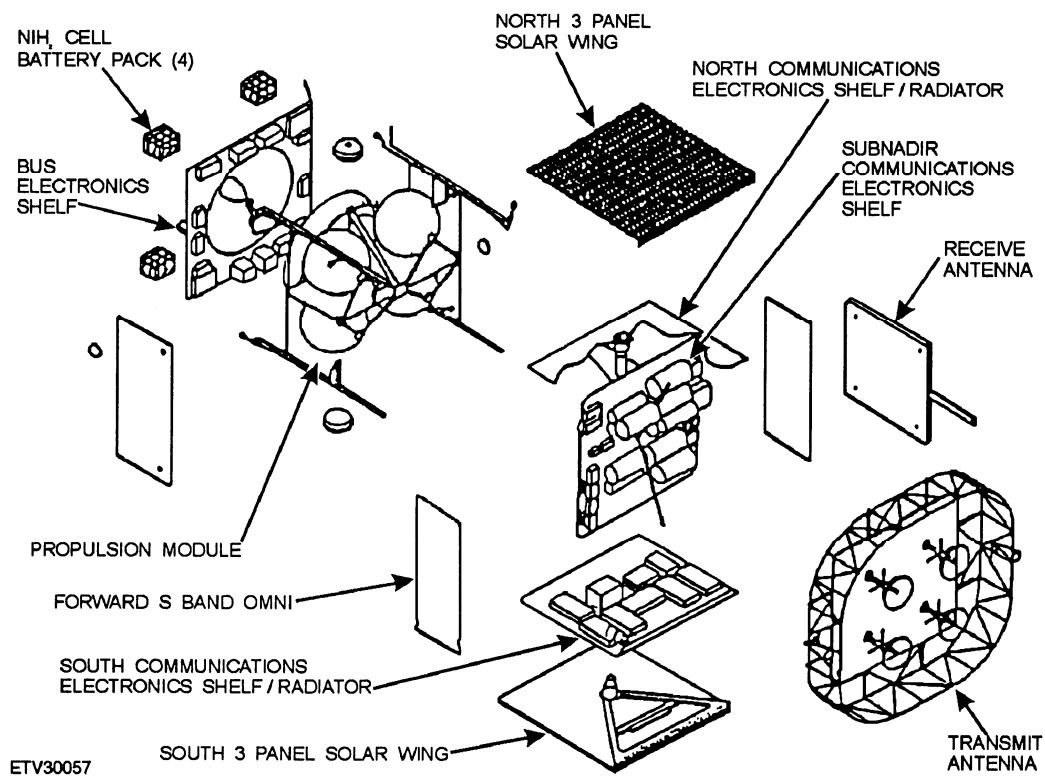
Figure 3-19.—UHF Follow-On satellite exploded view.

communications capability to the National Command Authority (NCA). Second, it will provide sufficient communications support for both strategic and tactical missions. The primary objective of the MILSTAR program is to develop and deploy an affordable, jam-resistant SATCOM system that will meet both long-haul and local communications needs.

MILSTAR will use communications terminals that will provide Secure Voice (SV), Teletype (TTY), data, and facsimile EHF SATCOM. MILSTAR terminals will be installed on aircraft, in fixed telecommunications centers, landbased tactical elements, shorebased telecommunications centers, surface ships, and submarines.

In the following paragraphs, we will look at some of the equipment associated with satellite communications.

SATELLITE EQUIPMENT

The equipment used in Navy SATCOM subsystems can be divided into two general groups, rf terminals and the baseband equipment common to a processor installation. The selection of specific equipment is determined by the operating en-

vironment—whether installation is to be aboard a ship, submarine, aircraft, or shore installation. In this chapter, we will limit our discussion primarily to commonly used shipboard and shore equipment.

Satellite Communications Terminal AN/FSC-79

The AN/FSC-79 terminal processes and converts 70-MHz signals to X-band (shf) transmitted signals. It also converts received signals from X-band to 70 MHz. This terminal can simultaneously transmit a spread spectrum carrier and receive a satellite beacon signal. The design of the terminal provides redundancy in many components to ensure a high degree of availability. The terminals are installed at NCTAMS LANT, MED, WESTPAC, EASTPAC, and NCTS, Stockton (contractor operated).

Uhf Transceiver AN/WSC-5(V)

The AN/WSC-5(V) transceiver provides an eight-circuit, full-duplex data operation or, as an alternative, six full-duplex data circuits and two FM audio or tone-group circuits. It also provides an interface for connectivity to the uhf DAMA
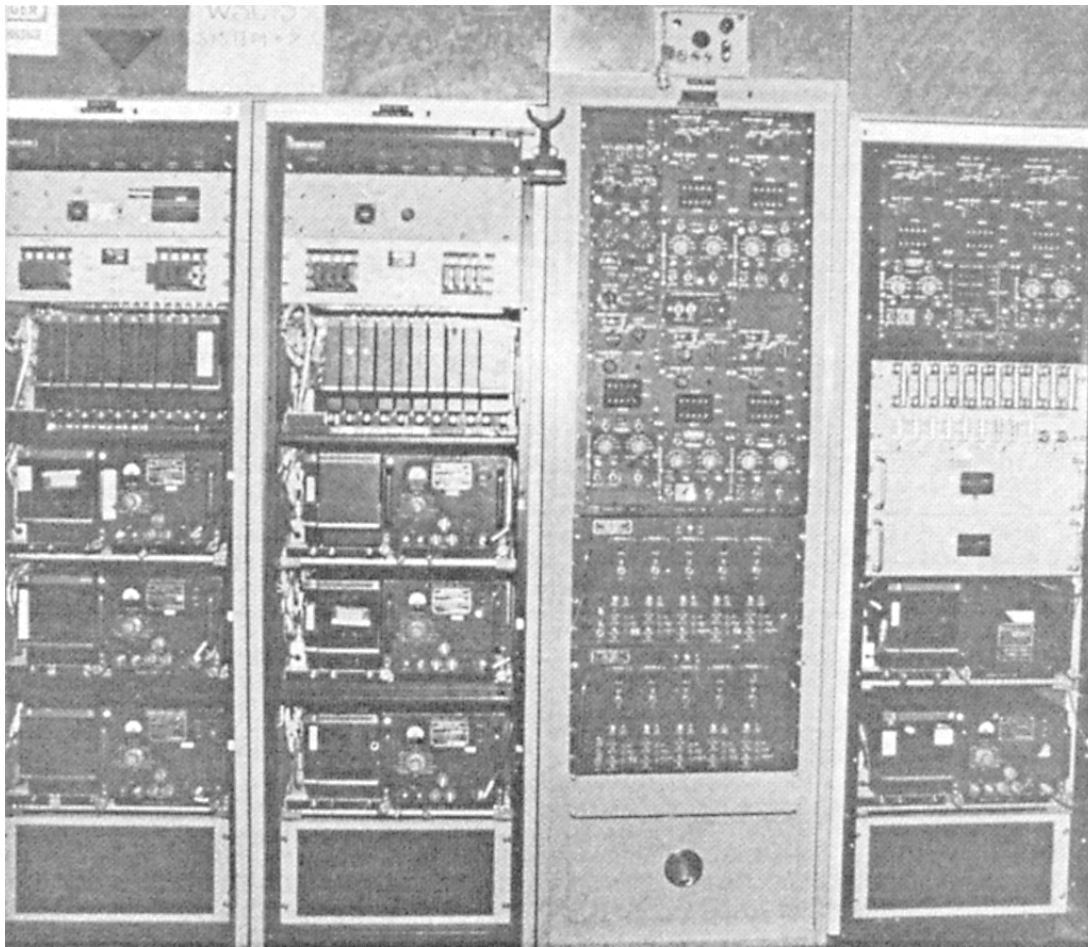
Figure 3-20.—Uhf transceiver AN/WSC-5(V).

equipment. Figure 3-20 shows an AN/WSC-5(V) transceiver installation.

This transceiver is capable of three types of modulation/demodulation:

• Frequency modulation/demodulation with pre-emphasis/ de-emphasis for voice transmission/ reception.

• Frequency modulation/demodulation without pre-emphasis/de-emphasis for tone-group transmission/ reception.

• Differentially encoded phase-shift keying using the OM-43A/USC modem. The transceiver has a 70-MHz interface for connection to either the modem or the TD-1271B/U DAMA multiplexer.

All four NCTAMS have AN/WSC-5(V) transceivers installed.

The C-11330/WSC-5(V) shown in figure 3-21 provides for remote control of the AN/WSC-5(V) for teletype operation. The C-11330/WSC-5(V) is similar to the C-9899/WSC-3, except that it uses +6 Vdc for the

keyline signal and indicator lamps. Both units have identical front panels.

Transceiver AN/WSC-3(V)

To be consistent in this discussion, we will refer to both the AN/WSC-3 and AN/WSC-3(V) transceivers
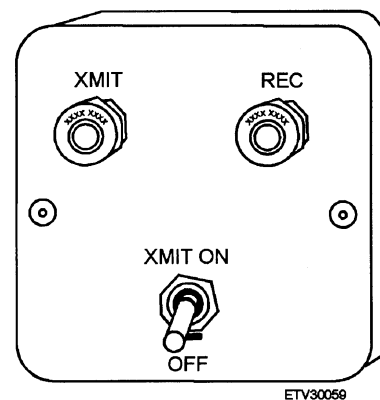
Figure 3-21.—Control-Indicator C-11330/WSC-5(V) or C-9899/WSC- 3.

3-24
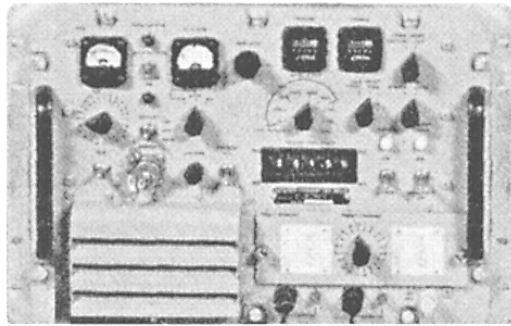
Figure 3-22.—Uhf radio RT-1107/WSC-3.

as AN/WSC-3. A single AN/WSC-3 (RT-1107/WSC-3) is shown in figure 3-22.

The AN/WSC-3 transceiver is used primarily aboard ship, at Marine Corps terminals, and at selected shore installations. It has various configurations designed to meet the particular requirements of these platforms. The configuration differences are identified in the AN/WSC-3 variations table, table 3-1.

The transceiver can be operated in either satellite or line-of-sight mode, either locally or remotely. A modulation control permits selection of PSK data rates from 75 to 9600 bps, FSK modulation at 75 bps, and FM or AM modulation for voice. The rf output is 30 watts AM and 100 watts for FM, PSK, and FSK

The AN/WSC-3A, AN/WSC-3A(V)2 and (V)3 have been modified for use with the DAMA subsystem. The AN/WSC-3(V)15, (V)17, and (V)19 are manufactured as DAMA-capable.

The transceiver has two control indicators for remote operations. The C-9351/WSC-3, shown in figure 3-23, provides for remote control of the AN/WSC-3 as described in the table 3-1 description. As we mentioned before, the C-9899/WSC-3 provides for remote teletype operation. Two built-in modems are included with the transceiver.

Receiver Systems AN/SSR-1 and 1A

You have probably seen this receiver since it is installed aboard most naval surface vessels. It enables ships to receive Fleet Satellite Broadcast. The received carrier may contain either FM or PSK modulation; the preferred demodulation is selected manually with a switch associated with the receiving set. The AN/SSR-1 can drive high-level teletype equipment. The AN/SSR-1A can drive both high- and
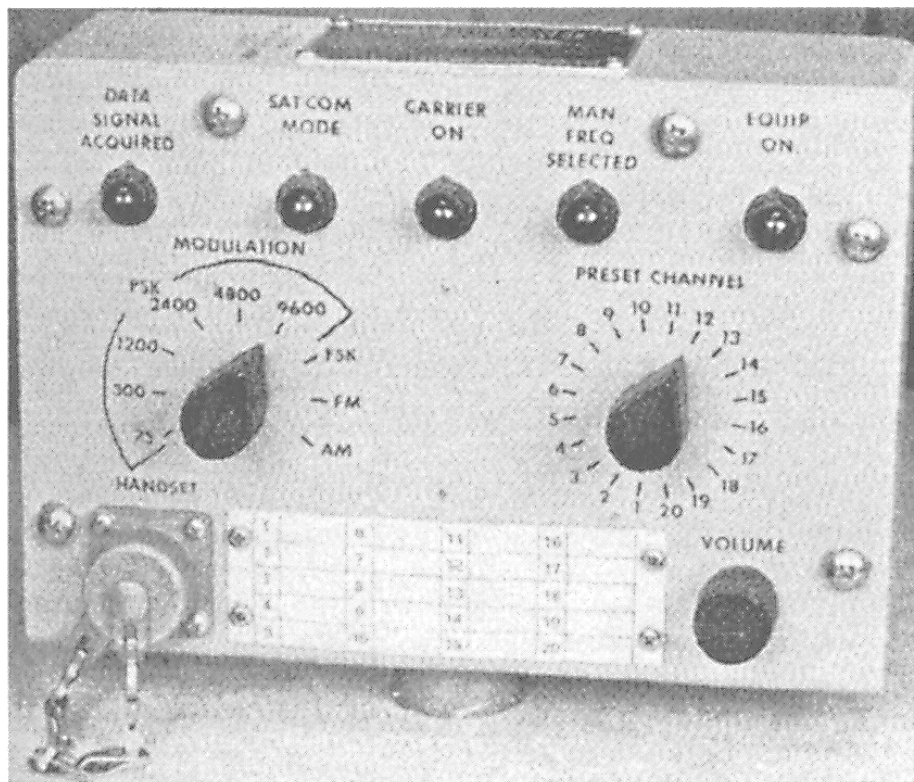
Figure 3-23.—Control-Indicator C-9351/WSC-3.

Table 3-1.—AN/WSC—3 Variations

Nomenclature	Description
AN/WSC-3 • RT-1107/WSC-3 • C-9351/WSC-3	AM Voice, AM Secure Voice, FM Voice, PSK Data at 75, 300, 1200, 2400, 4800, 9600 bps. FSK Data at 75 bps via satellite or LOS, selectable.
AN/WSC-3(V)1 • RT-1107(V)1/WSC-3(V) • C-9351/WSC-3	Similar to AN/WSC-3, SWR meter added. Chassis wired for FM Vinson Secure Voice, Link 11 and SAS but without FM Vinson S/V Link 11 or SAS modules. (SAS = Single Audio System).
AN/WSC-3(V)2 • RT-1107(V)2/WSC-3(V) • C-9351/WSC-3	Similar to (V)1 with FM Vinson S/V and Link 11 modules added. Standard Interface Module.
AN/WSC-3(V)3 • RT-1107(V)3/WSC-3(V) • C-9351/WSC-3	Similar to (V)2 but with SAS module.
AN/WSC-3(V)4	None produced.
AN/WSC-3(V)5	None produced.
AN/WSC-3(V)6 • RT-1107(V)6/WSC-3(V) • C-9351/WSC-3	Similar to (V)5. FM Vinson S/V, standard interface and Link 11 modules added.
AN/WSC-3(V)7 • RT-1107(V)7/WSC-3(V) • C-9351/WSC-3	Similar to (V)6, but with SAS I/O module
AN/WSC-3(V)8 • RT-1107(V)8/WSC-3(V) • C-9351/WSC-3	Similar to (V)7 with computer-compatible serial frequency and mode control. (USCG)
AN/WSC-3(V)9 • RT-1107(V)9/WSC-3(V) • C-9351/WSC-3	Similar to (V)3. Modified for 5-kHz channels vice 25 kHz. Provide 34,995 channels vice 7000.
AN/WSC-3(V)10 • RT-1107(V)10/WSC-3(V) • C-9351/WSC-3	Similar to (V)6 with AJ capability.
AN/WSC-3(V)11 • RT-1107(V)11/WSC-3(V) • C-9351/WSC-3	Similar to (V)7 with AJ capability.
AN/WSC-3(V)12 • RT-1107(V)12/WSC-3(V) • C-9351/WSC-3	Similar to (V)3 but modified for Trident SSBN IRR. Blower flow altered.
AN/WSC-3(V)13 • RT-1107(V)13/WSC-3(V) • C-9351/WSC-3	Similar to (V)2. Modified to operate from 400-Hz primary power.
AN/WSC-3(V)14 • RT-1107(V)14/WSC-3(V)	Similar to (V)7 but uses a bidirectional MIL-STD-1553B bus interfaced to an external controller.

Table 3-1.—AN/WSC—3 Variations—Continued

Nomenclature	Description
AN/WSC-3(V)15 • RT-1107(V)15/WSC-3(V) • C-9351/WSC-3	Similar to (V)2 or (V)3 but is DAMA compatible. Has a switchable audio interface module and can be switched from standard interface or SAS.
AN/WSC-3(V)16 • RT-1107(V)16/WSC-3(V) • C-9351/WSC-3	Similar to (V)2 but has an SSN AFSATCOM system (SAFS) interface drawer (A20) instead of the preset channel.
AN/WSC-3(V)17 • RT-1107(V)17/WSC-3(V) • C-9351/WSC-3	Similar to (V)15 but has modified transmit signal transient and preamble characteristics. (MTSC)
AN/WSC-3(V)18 • RT-1107(V)18/WSC-3(V) • C-9351/WSC-3	Similar to (V)12 but has modified transmit signal transient and preamble characteristics. (MTSC)
AN/WSC-3(V)19 • RT-1107(V)19/WSC-3(V) • C-9351/WSC-3	Similar to (V)17 but has the SAFS A20 drawer installed.
AN/WSC-3A • RT-1107A/WSC-3 • C-9351/WSC-3	Same as AN/WSC-3 but modified for use with UHF DAMA.
AN/WSC-3A(V)2 • RT-1107A(V)2/WSC-3(V) • C-9351/WSC-3	Modified for use with UHF DAMA.
AN/WSC-3A(V)3 • RT-1107A(V)3/WSC-3(V) • C-9351/WSC-3	Modified for use with UHF DAMA.
C-9351/WSC-3	Remote control for RT-1107. Contains preset channel control, modulation select, handset control, RT indicator lamps, and RT mode controls.
C-9351A/WSC-3	Similar to C-9351 and allows use of longer interface cables.
C-9899/WSC-3	Remote control for RT-1107/WSC-3, has a keyline switch, transmit and receive indicators. It is used for teletype circuit control; requires 28 volts dc for indicator lamps and provides a ground keyline.
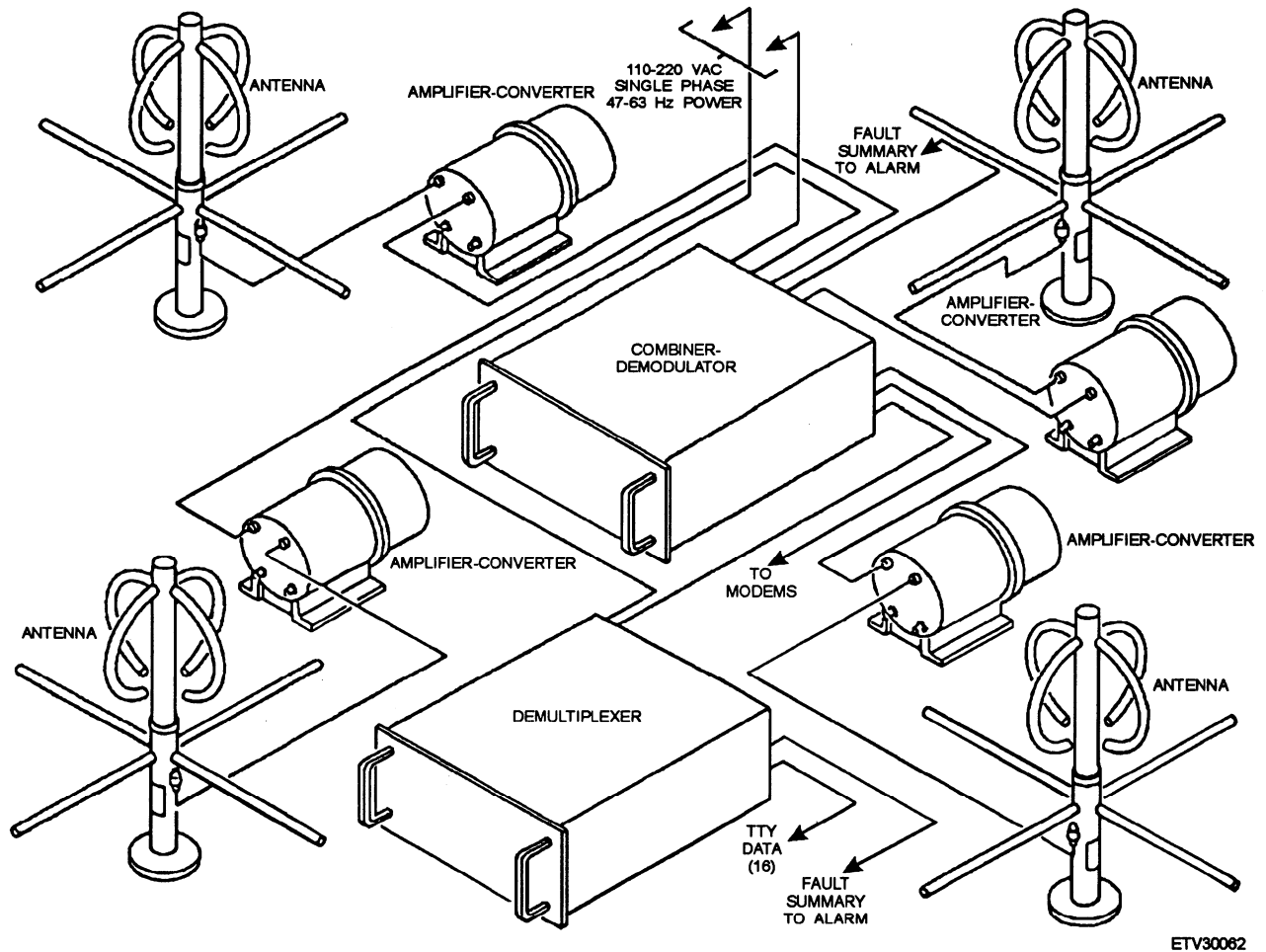
Figure 3-24.—Typical receive-only system.

low-level teletype equipment. A receive system is shown in figure 3-24.

The receiver system includes up to four AS-2815/SSR-1 antennas with an Amplifier Convertor AM/6534/SSR-1 (fig. 3-25). It also includes a Combiner-Demodulator MD-900/SSR-1 (fig. 3-26) and a Demultiplexer TD-1063/SSR-1 (fig. 3-27). The antenna and convertors are mounted above deck in positions that ensure that at least one antenna is always in view of the satellite. The combiner-demodulator and demultiplexer are mounted below deck.

The receiver accepts rf signals between 240 MHz and 340 MHz, a modulation bandwidth of 25 kHz. The combiner-demodulator demodulates the rf input from the amplifier convertor and provides a 1200-bps output for the demultiplexer. The demultiplexer accepts an input of 1200 bps and outputs 15 channels at 75 bps. The decrypted demultiplexer output is patched to NAVMACS, TACINTEL processors, or tele-typewriters.

Antennas

SATCOM antennas will be discussed in volume 7 of this training series.
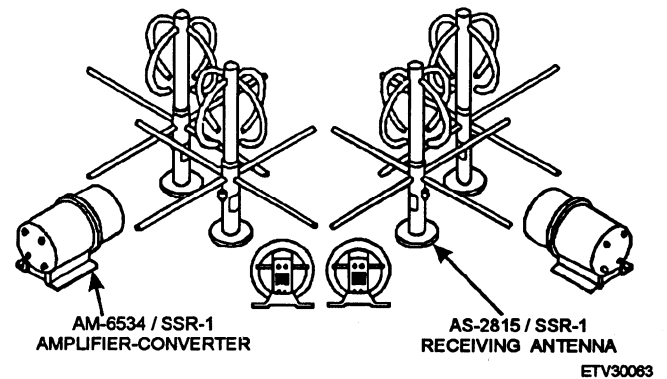
Figure 3-25.—Receiving Antenna AS-2815/SSR-1 and Amplifier Converters AM-6534/SSR-1.

3-28
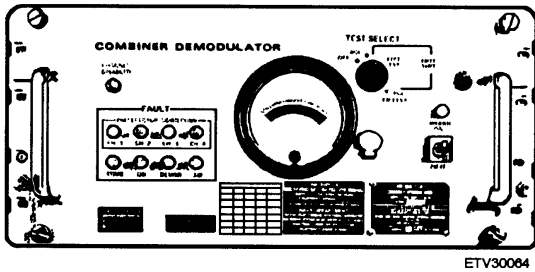
Figure 3-26.—Combiner-Demodulator MD-900/SSR-1.
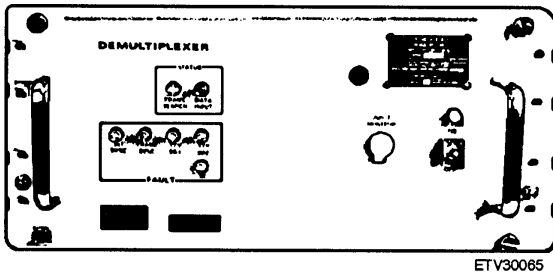
Figure 3-27.—Demu1tiplexer TD-1063/SSR-1.

Modem Group OM-43A/USC

The OM-43A/USC shown in figure 3-28 is used primarily with the AN/WSC-5(V) transceiver at shore installations. It performs differential phase-shift keying (DPSK) modulation and demodulation of a
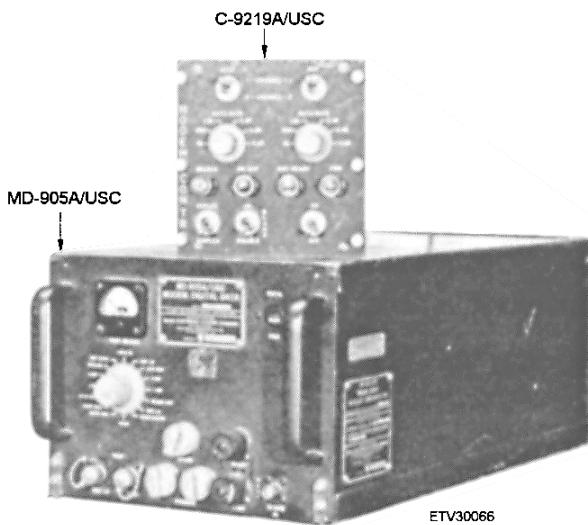
Figure 3-28.—Modem Group OM-43A/USC.

serial data stream at data rates of 75, 300, 1200, 2400, 4800, and 9600 bits per second. This modem can be operated in fill-duplex, although normal operation is half-duplex.

Modulator-Demodulator OM-51A/FR

This modem is an integral part of the Fleet Satellite Broadcast subsystem. It is a spread spectrum (wide bandwidth with frequency modulation of a transmitter and receiver in exact synchronization) type modem used with the AN/FSC-79 satellite communications terminal to provide rf transmission capability in a high-level jamming environment. Shown in figure 3-29, its basic function is to provide rf analog and digital conditioning circuits and frequency synthesizing for dual-redundant transmission and reception. It interfaces with the AN/FSC-79 terminal and the AM-6534/ SSR-1 amplifier-convertor.
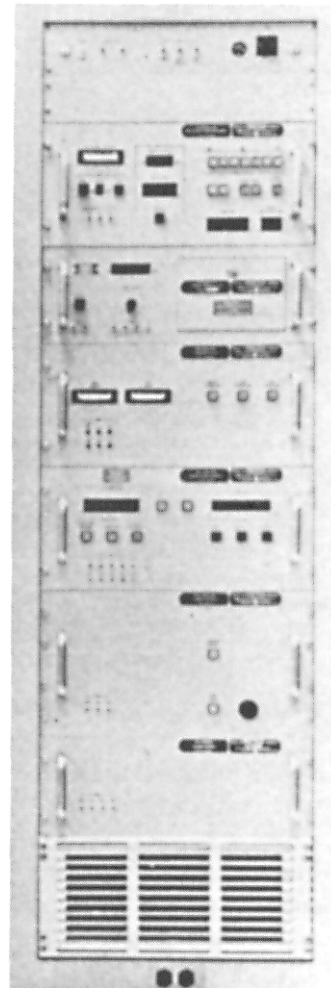
Figure 3-29.—Modulator-Demodulator Group OM-51A/FR.

Figure 3-30.—Data Processing Set AN/UYK-20(V).

This installation consists of a standard cabinet containing seven assemblies: a summary control panel, frequency synthesizer, receiver-synchronizer, coder-modulator, demodulator, and two power supplies.

Data Processing Set AN/UYK-20(V)

The AN/UYK-20(V), figure 3-30, is a general-purpose processor designed to meet the requirements of small and medium processor applications in shipboard or shore military facilities. The processor is used in the CUDIXS, NAVMACS, SSIXS (shore installations), and TACINTEL subsystems.

Data Processing Set AN/UYK-44(V)

The AN/UYK-44(V), figure 3-31, was designed to meet the same requirements as the AN/UYK-20(V), and to use AN/UYK-20(V) software with minimum modifications. It is used in the TADIXS subsystem,

Figure 3-31.—Data Processing Set AN/UYK-44(V).

Communication System Control Center AN/USQ-64(V)

This control center is used to pass satellite data traffic efficiently and bidirectionally between a ship and shore. It turns associated transmitters on and off according to a polling scheme. It also uses detection and correction and sends automatic requests for retransmission to improve received data accuracy. The ten AN/USQ-64(V) variations and their uses are as follows:

● (V)l—SSIXS shore installations

● (V)2—CUDIXS shore installations

● (V)3—SSIXS subscriber installations

● (V)4—NAWCS shore installations

● (V)5—TACINTEL ship subscriber, for passing Special Intelligence (S1) data traffic bidirectionally between a NCTS and fleet nets

● (V)6—TACINTEL shore installations, for the same purpose as (V)5

● (V)7—OTCIXS: fixed submarine or shipboard installations for passing TDP formatted data and teletypewriter traffic

● (V)8—TADIXS ship and submarine installations

● (V)9—TADIXS Gateway Facility (TGF)

● (V10)—Tactical Data Processor Controller

Interconnecting Group ON-143(V)/USQ

Each ON-143(V)/USQ configuration varies, depending on its particular use. It fits within limited spaces aboard small ships and submarines, performing a variety of functions related to several input-output channels of the control processor. It provides red-black isolation, synchronization of crypto units, level conversions, and crypto test and alarm signals. It also provides crypto control and interfaces baseband system components with rf link equipment. An ON-143(V) 4/USQ is shown in figure 3-32.

Data Terminal Set AN/USQ-69(V)

The Data Terminal Set shown in figure 3-33 has a 15-inch diagonal screen on which a 2000 character page can be displayed. The memory is available in two
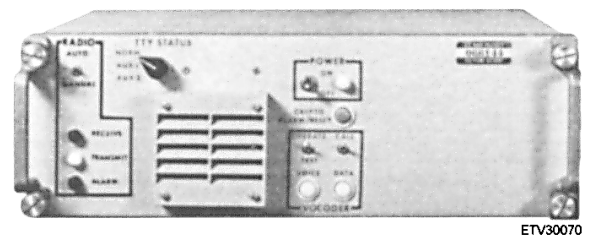
Figure 3-32.—Interconnecting Group ON-143(V)4/USQ.

sizes, 2000 and 6000 characters. When memory overflows as a result of computer output, a computer interrupt is initiated. Overflow as a result of operator input causes an audible alarm. This unit is currently used with TACINTEL (ship) and NAVMACS.

Figure 3-33.—Data Terminal Set AN/USQ-69(V).

Signal Data Recorder-Reproducer RD-397(V)/U

The RD-397(V)/U, figure 3-34, is used in baseband equipment installations with CUDIXS, NAVMACS, and TACINTEL (ship and shore). The (V)3 version is used at SSIXS shore locations. This tape perforator/reader can punch tape at 63.3 characters per secon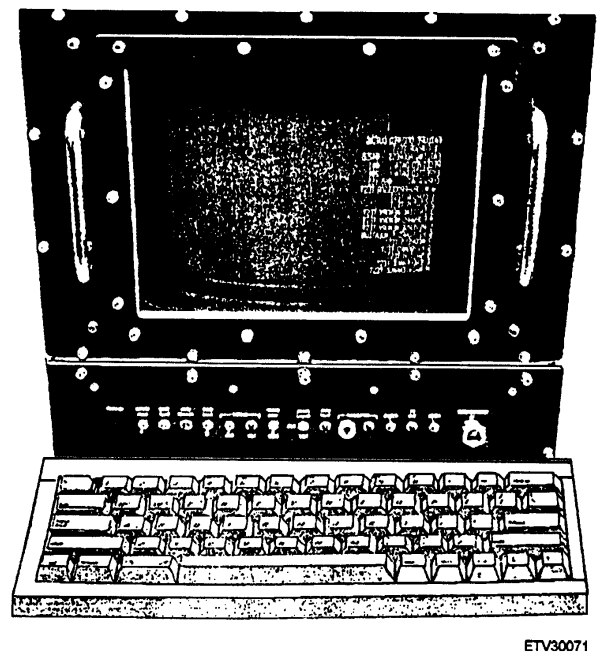d and read tape at up to 300 characters per second. The equipment is self-contained; that is, complete with control logic, buffering, and power supplies.

Navy Standard Teleprinter AN/UGC-143(V)

The Navy Standard Teleprinter **(NST)** is the standard teleprinter terminal set for surface platforms. The NST is used for netted circuits and for broadcast, ship-to-shore, and ship-to-ship communications circuits. The various configurations of the NST provide for information preparation, editing, printing and receiving of serial data, and buffering and storage of information. An AN/UGC-143A(V) 4 NST is shown in figure 3-35.
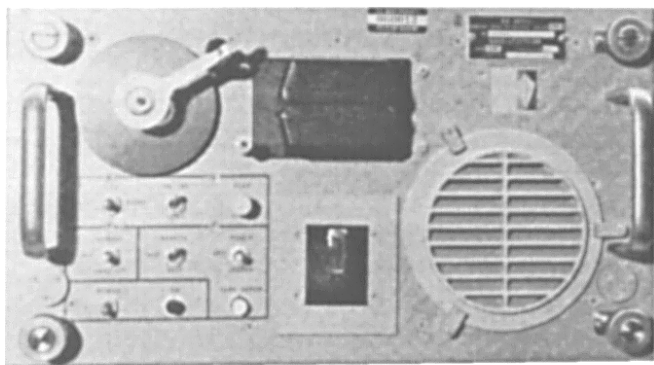
ETV30072

Figure 3-34.—Signal Data Recorder-Reproducer RD-397(V)/U.
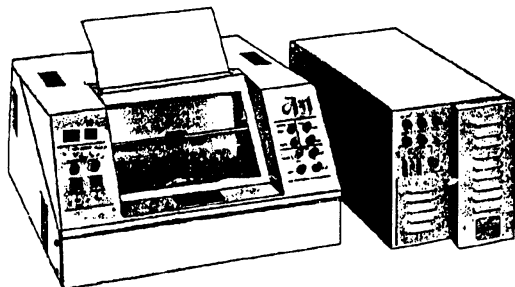
ETV30073

Figure 3-35.—NST AN/UGC-143(V).

Audio Digital Converter CV-3333/U

The Audio Digital Converter CV-3333/U is called a vocoder or voice digitizer. This unit is a solid-state, all-digital speech processor, providing speech output at a data rate of 2400 bps. It is capable of fill-duplex or half-duplex operation, figure 3-36. It can be used to provide a single digitized voice circuit, or have its output multiplexed with other data-bit streams to provide simultaneous voice and data transmission. It is used primarily as an analog-to-digital converter in Fleet Satellite Secure Voice communications.

Switching Unit SA-1704/UG

The Switching Unit SA-1704/UG is used in baseband equipment shore installations of SSIXS, CUDIXS, and TACINTEL subsystems. It is a passive patch panel that shows the equipment configuration in use. Each subsystem unit is slightly different. In CUDIXS, the switching unit maybe used to switch in equipment from the spare system; whereas in SSIXS, it is used to switch in standby equipment. The SB-4333/U Patching Switchboard is the planned replacement for this unit.

Time-Division Multiplexer TD-1150/USC

The TD-1150/USC time-division multiplexer is installed at broadcast keying stations ashore. It is used in the Fleet Satellite Broadcast subsystem and consists of two units, one online and the other in standby. It accepts up to fifteen 75-bps data channels and multiplexes this information into a single 1200-bps output data stream. A TD-1150/USC is shown in figure 3-37.

Multiplexer (DAMA) TD-1271B/U

The Multiplexer (DAMA) TD-1271B/U is used in the DAMA subsystem and provides time-division
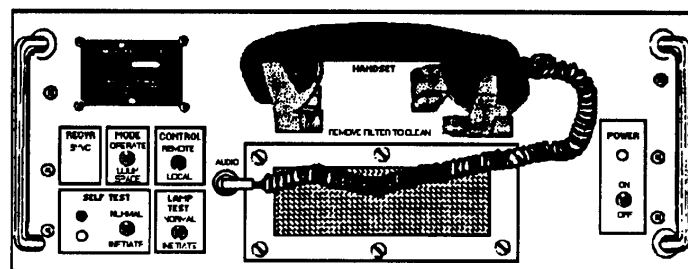
ETV30074

Figure 3-36.—Audio Digital Converter CV-3333/U.
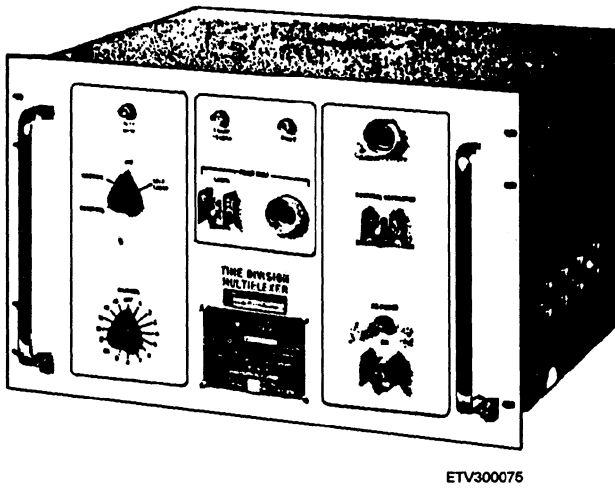
Figure 3-37.—Time-Division Multiplexer TD-1150/USC.

Figure 3-39.—Multiplexer (Mini-DAMA) AN/USC-42(V) prototype.

multiplexing of several digital data sources over one satellite channel. This allows platforms equipped with the TD-1271B/U and proper RT equipment to time-share the satellite channel. Each multiplexer has four I/O ports for connecting baseband equipment and four remote request and status display units. The TD-1271 B/U interfaces with RT equipment on a 70-MHz IF. Outputs from the unit also control the frequency and synchronize the transmit and receive timing of the radio. A TD-1271B/U is shown in figure 3-38.

Multiplexer (Mini-DAMA) AN/USC-42(V)1/(V)3

This unit is currently under development, with technical and operational evaluation to take place soon. Mini-DAMA is compatible and interoperable with the TD-1271B/U and will perform or eliminate all functions of the AN/WSC-3(V)2/(V)3. A Mini-DAMA unit is shown in figure 3-39.

Cryptographic Equipment

Several different models of cryptographic equipment are used in the FLTSATCOM system.

TSEC/KGV-11
LOCATION
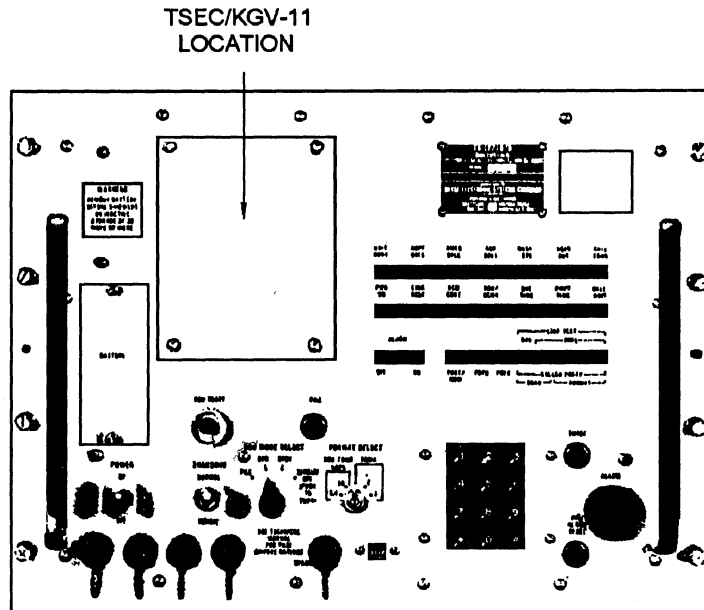
Figure 3-38.—Multiplexer (DAMA) TD-1271B/U.

Check your command's communications configuration for identification of this equipment. Specific information on this equipment is available on a need-to-know basis.

Electrical Equipment Rack CY-7597/WSC-3, CY-7597A/WSC-3

The CY-7597/WSC-3 (fig. 3-40) and CY-7597A/WSC-3 provide for mounting of one C-9597/WSC-1(V) antenna control, one C-10232/WSC-3, and up to four RT-1107/WSC-3s. These racks contain all the wiring required to interconnect these items. Connectors installed on the top panel provide system interface connections for baseband, teletype, frequency standard, external modem, and control-indicator equipment.

The C-9597/WSC-1(V) antenna controller provides a means of controlling the antennas in the OE-82 dual-

shipboard system. The control indicator 3-34 can switch the AN/WSC-3s for LOS or SATCOM use, monitor rf output power, and provide power on/off switching.

Electrical Equipment Cabinet CY-7971/WSC

The CY-7971/WSC (fig. 3-41), provides for mounting one MX-10342/WSC, two SB-4124/WSCs, and two TD-1271B/U multiplexer. The cabinet contains all wiring required to interconnect these pieces of equipment. Connectors installed on the top panel provide system interface connections for baseband, teletype, frequency standard, AN/WSC-3, and control-indicator equipment.

The MX-10342/WSC provides a means to monitor and test all functions. The SB-4124/WSCs are data-

ETV30078

Figure 3-40.—Electrical Equipment Rack CY-7597/WSC-3.
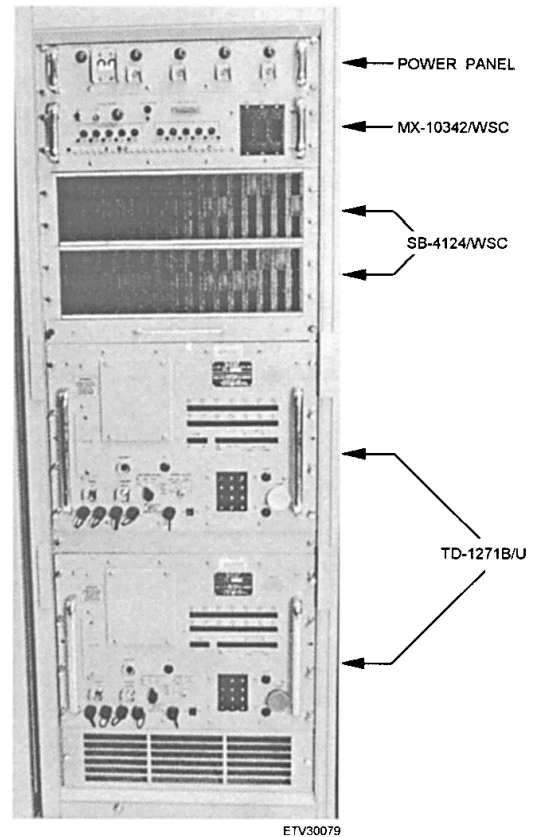
ETV30079

Figure 3-41.—Electrical Equipment Cabinet CY-7971/WSC.
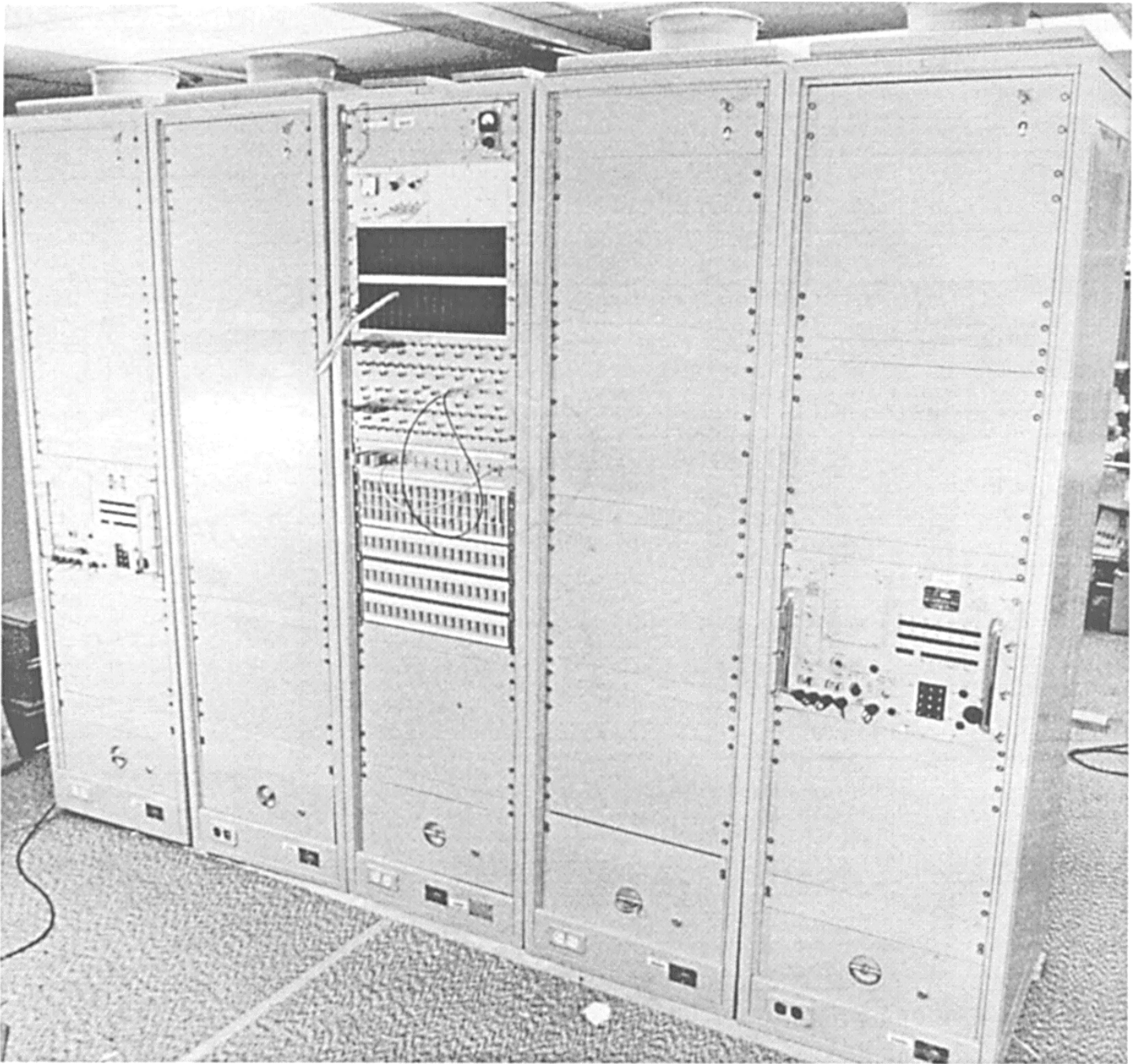
ETV30080

Figure 3-42.—Control Monitor Group OK-481(V)2/FSC.

and control-patching switchboards. Since we discussed the multiplexer in depth earlier, we will not go into detail here.

Control Monitor Group OK-481(V)2/FSC

The Control Monitor Group OK-481(V)2/FSC is a part of the Navy uhf satellite communications system.

This group provides for the interfacing of the TD-1271B/U multiplexer, the AN/WSC-5(V), and the baseband equipment used at DAMA shore installations. It provides for rapid reconfiguration and monitoring of interfaced equipment using digital, rf, and monitor patching facilities. It can accommodate up to 14 TD-1271lB/U's and can multiplex up to 56 baseband circuits. An OK-48l(V)2/FSC is shown in figure 3-42.

CHAPTER 4

THE LINK-11 SYSTEM

INTRODUCTION

Tactical data links are usually limited to a specific area of operation and are used for command and control of specific forces. Link-11 is the U.S. Navy shipboard version of Tactical Data Information Link-A (TADIL A). The Link-11 system is used to provide high-speed, computer-to-computer exchange of digital tactical information among ships, aircraft, and shore installations, as shown in figure 4-1.
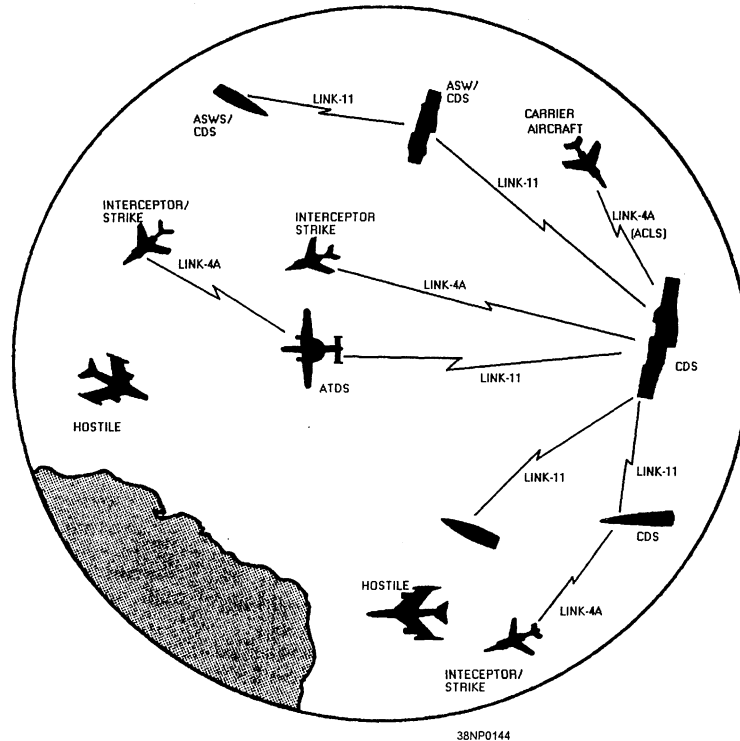
Figure 4-1.—Tactical digital information links.

Link-11 data communications can operate with either high-frequency (HF) or ultra-high-frequency (UHF) radios. In the HF band, Link-11 provides gapless omnidirectional coverage of up to 300 nautical miles from the transmitting site. In the UHF band, the Link-11 system is capable of line-of-sight omnidirectional coverage, approximately 25 nautical miles between ships and 150 nautical miles for ship-to-air links.

To understand the operation of the Link-11 system fully, you must be able to identify the hardware components that compose it and the functions they perform.

After completing this chapter you should be able to:

● **Describe the composition of a typical Link-11 system.**

● **Describe the operation of the Link-11 transmission and receive cycles.**

● **Describe the six operating modes of the Link-11 system.**

● **Describe the function of the Link-11 encryption (security) device.**

● **Describe the audio tones generated by the Link-11 Data Terminal Set.**

● **Describe the word formats used to transmit Link-11 tactical data.**

● **Describe the message formats used in the various Link-11 operating modes.**

● **Describe the Operation of the Link-11 Data Terminal Set.**

LINK-11 FUNDAMENTALS

To monitor the operation of and perform maintenance on the Link-11 system, you must understand how the different pieces of equipment interact with each other. Let's take a look at a basic Link-11 system.

LINK-11 SYSTEM OVERVIEW

A typical shipboard Link-11 communications system (figure 4-2) and consists of the following components: the CDS digital computer, a cryptographic device, the Link-11 data terminal set, the communications switchboard, and the HF or UHF radio set transceivers (transmitter-receiver), an antenna coupler, and an antenna. The data terminal set is the center of the Link-11 system and is covered in detail later in this chapter. The communications switchboard is used to select the desired HF or UHF transceiver. An external frequency standard is also part of many Link-11 systems. Additionally, the **Shipboard Gridlock System** (SGS) is installed on many ships. On SGS-equipped ships, an AN/UYK-20 is placed in the line between the CDS computer and the crypto device.

CDS Computer

The central processor of the Combat Direction System is the CDS computer. Keeping a data base of tracks is among the many functions of the operational
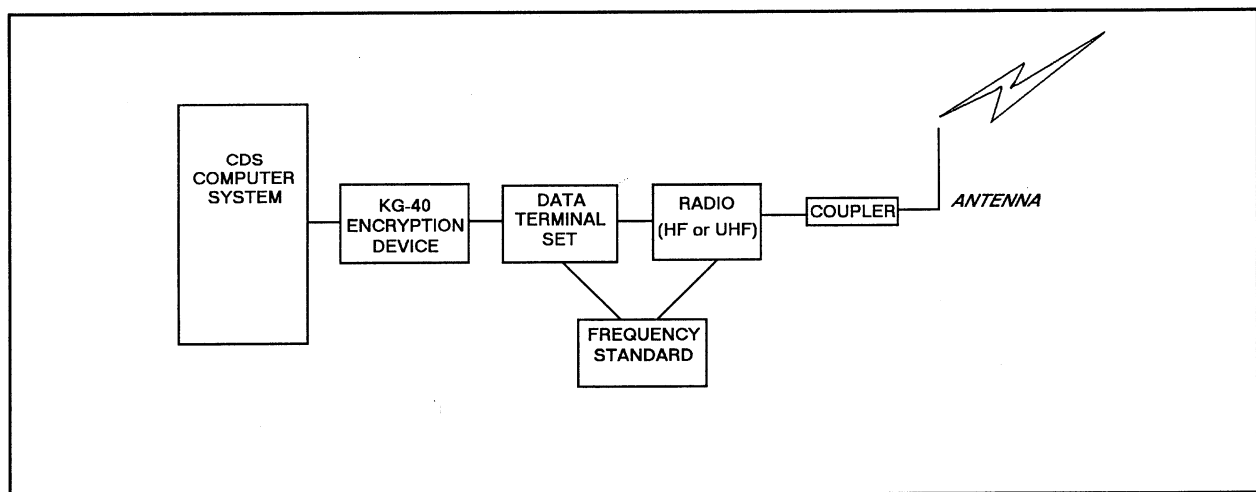
Figure 4-2.—The Link-11 communications system.

program. The information about these tracks can be transmitted to other units over the Link-11 net. The computer sends data to the data terminal set using 24-bit data words. The computer also receives information about remote tracks from other units in the net and displays these tracks through the display system.

Shipboard Gridlock System

Gridlock is the matching of track positions held by other ships with the tracks held by your own ship. Gridlock is a procedure for determining data registration correction by comparing remote tracks received from a designated reference unit to local data. Ideally, tracks received from remote units that are also displayed by onboard sensors should be transparent, that is, in the exact same position on the CRT. If the gridlock system does not provide correlation between local and remote tracks, the remote tracks may be painted twice and overlap each other, as shown in figure 4-3.

38NP0145
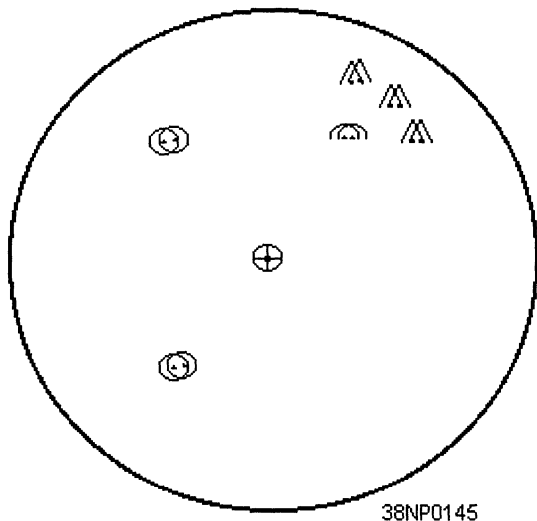
Figure 4-3.—Tracks out of gridlock.

Failure to maintain gridlock may be the result of inaccurate positioning data from a ship's sensor, from the Ship's Inertial Navigation Systems (SINS), or from the ship's gyro. Failure to maintain gridlock may also be the result of an inaccurate operator entry.

The SGS computer performs continuous automatic gridlock calculations. In the event of an SGS computer failure, the flow of Link-11 data to the CDS computer is interrupted. To restore Link-11 data

flow, all SGS installations have switches installed that allow the technician to bypass the SGS computer until the fault is corrected.

Link-11 Security Device

A standard model security device, such as the TSEC/KG-40, commonly referred to as the KG-40, is used with the Link-11 system. When the DTS is transmitting data, the KG-40 receives parallel data from the CDS computer, encrypts the data, and sends it to the DTS. When the participating unit (PU) is receiving data, encrypted data is received from the DTS, decrypted, and sent to the CDS computer.

Because of the specialized training and security requirements of cryptographic equipment, we will not cover the internal operation and controls of the security device.

Data Terminal Set (DTS)

The data terminal set (DTS) is the heart of the Link-11 system. The DTS is the system modulator/demodulator (MODEM). the CDS computer sends 24 bits of data to the DTS via the SGS computer and the encryption device. The DTS adds six bits of data for error detection and correction. These six bits are called **hamming** bits. The 30 bits of data are phase shift modulated into 15 audio tones. These 15 data tones and a Doppler correction tone are combined into a composite audio signal, which is sent to either the UHF or HF radio for transmission.

The DTS receives the composite audio signal from the radio and separates the 15 data tones and the Doppler correction tone. The 15 data tones are demodulated into 30 data bits. The six hamming bits are checked for errors and the 24 data bits are sent to the CDS computer via the encryption device and the SGS computer.

Link-11 Communications Switchboard

The communications switchboard provides for manual switching of the data terminal set and individual HF and UHF radios. The communications switchboard provides system flexibility and casualty

recovery capabilities. A typical switchboard will provide the following interconnections:

● The Link-11 data terminal set to one or more HF radio sets to provide the standard HF Link-11 capability

● A Link-11 data terminal set to one or more UHF radios sets to provide UHF Link-11 capability

The same communications switchboard may also be used for connecting a Link-4A data terminal set to one or more UHF radios to provide standard UHF Link-4A (TADIL C) capability. Link-4A is covered in detail later in this book.

Radios

The Link-11 system can operate with either an HF radio or a UHF radio. Long-range communications are achieved by the use of the HF system. UHF communications are limited to line of sight. "Line of sight" means the radio wave will not bend over the horizon; therefore, the use of an antenna mounted high on the mast will increase the range of UHF communications.

Antenna Couplers

Antenna couplers are used to connect a specific radio set to a specific antenna. The coupler provides for the correct impedance matching of the antenna and the radio set. For many of the multicouplers to work properly, it is extremely important that the correct frequency spacing be observed. A general rule is to ensure a frequency spacing of 15 percent. Frequencies that are too close together can cause interference and distortion, increasing the signal-to-noise ratio and causing bit errors in the data.

Antennas

In oversimplifying the theory of antenna operation, an antenna is just a piece of wire that radiates electromagnetic energy from the radio into the atmosphere and converts atmospheric electromagnetic radiation into RF current to be processed by the radio. As electromagnetic energy from the atmosphere passes through this wire, it induces a current in the wire. This current is fed to the radio receiver. If the receiver is tuned to the same frequency as the received signal, the signal can be processed. The same wire will radiate an electromagnetic field if current is flowing through it.

The frequency at which a radio operates determines what size antenna is most suitable for transmitting and receiving. The higher the frequency, the smaller the antenna will be. Lower frequencies require larger antennas. For example, the full-wave length of an antenna designed to operate at 4 MHz is about 250 feet long. Since this length is too large for shipboard application, antennas are designed in submultiple lengths. These include half-wave and quarter-wave antennas. An antenna can be tuned by introducing a capacitive or inductive load. This loading effectively changes the electrical length of the antenna and can be used to extend the frequency range of the antenna. For more information on antenna design and operation, refer to the Navy Electricity and Electronics Training Series, Module 10, *Introduction To Wave Propagation, Transmission Lines, and Antennas,* NAVEDTRA B72-10-00-93.

Transmission Cycle

The data flow for the Link-11 transmission cycle is shown in figure 4-4. The CDS computer receives data from the various ship's sensors, navigation systems, and operator entries, and stores this data in a data base. When a Link-11 transmission is required, the computer outputs parallel digital data through the SGS computer to the cryptographic device. The cryptographic device encrypts the data and sends the encrypted data to the data terminal set (DTS). The DTS converts the digital data to analog audio tones, keys the transmitter using the radio set keyline, and passes the audio tones, via the communications switchboard, to the transmitter for modulation to the RF carrier signal. The radio set keyline is a signal that switches the radio to transmit mode when the set and receive mode when clear.

When you are using the HF band, the radio frequency signal modulation uses amplitude modulation independent sideband; that is, the upper sideband (USB) and lower sideband (LSB) are transmitted independently in an effort to overcome propagation-caused signal losses. The UHF radio

Figure 4-4.—Link-11 data flow for the transmit cycle.

transmitted independently in an effort to overcome propagation-caused signal losses. The UHF radio uses frequency modulation; therefore, only the USB is used.

Receive Cycle

When a transmitted signal is received, the receiver demodulates the audio tones from the RF carrier and passes them via the communications switchboard to the DTS. The DTS demodulates and demultiplexes the audio tones into digital data. The digital data is sent to the cryptographic device where it is decrypted and sent to the CDS computer for processing.

LINK-11 NET OPERATING MODES

Before we look into the actual operation of the data terminal set, you need to have some knowledge of the Link-11 modes of operation and how the messages are formed. Link-11 employs networked (net) communications techniques for exchanging digital information among airborne, land-based, and shipboard systems. As you have seen, the amount of hardware required to support Link-11 operations is relatively small; however, establishing and maintaining a successful link can be very complex.

Establishing a Link-11 Net

The establishment of a successful link involves the interaction and teamwork of the operators and technicians of several units working toward the common goal. If one unit is having trouble with the link radio, data terminal set, or other equipment, it can make the entire link unreliable.

When a task force is about to deploy, the task force commander will issue a message that has the necessary information required to establish Link-11 communications. The information in this message includes a list of primary and secondary frequencies, designation of the initial net control station, initial gridlock reference unit (GRU) designation, PU identification and addresses, initial data link reference point (DLRP), and other required operating procedures. Voice communications are also required for net control and coordination during initialization.

When the task force is formed, the picket stations inform the net control station (NCS) of their readiness to establish link operations. Upon establishing communication with all units, NCS transmits Net Synchronization (Net Sync). If the NCS is using corrected timing (normal mode), the Net Sync verifies the communications path between NCS and all picket units. If a picket unit cannot receive Net Sync, it cannot participate in the net. Net Test should follow Net Sync. Net Test is used to confirm connectivity between the Link-11 units. Units having difficulty in receiving Net Sync or Net Test should report to NCS that they are not able to participate in the net and then begin corrective action.

When Net Test is completed, all picket stations report their status to NCS. Then NCS directs all PUs to switch to the Roll Call mode and initiate link operations. Net Synchronization and Net Test are used in the initialization of the net. The normal mode of operation is Roll Call.

The above scenario has introduced you to several new terms and modes of operation. These are explained in detail in the following paragraphs.

The following are the six modes of Link-11 operation:

- Net Synchronization

- Net Test

- Roll Call

- Broadcast

- Short Broadcast

- Radio Silence

Net Synchronization

The Net Sync mode of operation is used to establish a uniform time base from which all net data communications normally initiate. The Net Sync mode is usually initiated when establishing a link net after all operator entries have been properly completed. The Net Sync transmission is manually started by the operator on the NCS platform and continuously transmits the Link-11 **preamble** until stopped by the operator.

The preamble consist of two tones–the 605-Hz tone and the 2,915-Hz tone. During the transmission of Net Sync, the 2,915-Hz tone is periodically phased shifted 180 degrees. The time between these shifts is determined by the selected data rate and is called a **frame.**

Each PU is equipped with a very accurate time base in the form of a frequency standard (internal or external). When the NCS transmits Net Sync, each unit receiving the transmission synchronizes its individual time base with the Net Sync signal. If the picket station is operating in the corrected sync mode, as is normally the case, the picket will check to see that it can recognize the Net Sync signal as a means of verifying that a good radio link has been established. If a picket is going to operate in the stored sync mode, it will align its stored frame timing to the timing of the NCS, using the received Net Sync signal. Since stored sync timing locks the picket to the time base of the NCS, data from other pickets may be lost.

Therefore, this mode should only be used during times of poor radio propagation or signal jamming. After the completion of Net Sync, the next operation performed in establishing a link is usually Net Test.

Net Test

Net Test provides an overall evaluation of the net and equipment performance. When you are operating in this mode, NCS will broadcast canned test data to all pickets within the net. The data terminal set contains a code generator that generates twenty-one 30-bit data words. Once all the words in the word table have been generated, the process automatically starts over and keeps running until stopped by the operator.

Net Test will test the connectivity between all units and the operation of the DTS. Since it is a local test, Net Test does not check the interface between the CDS computer and the DTS. Net Testis also helpful to the technician for setting the audio input and output levels of the DTS or radio set.

Roll Call

Roll call is the normal mode of operation. In this mode, the operator on the NCS platform enters ownship's address and an assigned address (PU number) for each PU in the proper switch position. When the link is initiated, each PU is polled for data. Polling consists of sending a **call-up** message. If the PU fails to respond, the call-up is repeated. If the PU still does not respond, it is skipped and the next PU is polled. When a PU recognizes its own address, the PU will transmit its data to all the participants in the link. When the NCS recognizes the end of the PU reply, it automatically switches to the transmit mode and calls up the next PU address. After all the units in the net have been polled, the NCS transmits its own data and the process is continuously repeated. The roll call mode provides all PUs with continuous, near real-time exchange of tactical information.

Broadcast

When the broadcast mode is used, one PU will continuously send a series of data transmissions to all

the members of the net. Once manually initiated, the transmission will continue to be sent automatically until the operator manually stops it. Through the use of the broadcast mode, other picket stations can receive real-time tactical information without breaking radio silence.

Short Broadcast

In the Short Broadcast mode, a picket station or the NCS sends a data transmission to the other members of the net. The transmission is initiated by the operator depressing the TRANSMIT START button on the DTS control panel and is terminated automatically when the computer has finished sending the DTS data. This mode is used only when no other unit is transmitting.

Radio Silence

In the Radio Silence mode, the radio set key line and the data terminal set audio output are disabled. The receive capability of the DTS is not affected. The Radio Silence mode is manually initiated and terminated.

BUILDING A LINK-11 MESSAGE

Information transmitted from the DTS originates from two sources. Tactical data always originates from the CDS computer. Other information, including the **preamble, phase reference, start** and **stop codes,** and **address frames,** originates within the data terminal set. These additional special-purpose frames are added to the data frames to form the proper messages.

For the DTS to control the net properly, strict adherence to the correct message format and net protocol are required. Every Link-11 message has a specific format and function. Each Link-11 message generated by the DTS begins with a header consisting of the **preamble** (five frames) and the **phase reference frame** (one frame). Control codes, such as the start code, the picket stop code, and the control stop code, are also required.

Preamble

The preamble, as previously covered, consists of a two-tone signal. The two tones are the 605-Hz Doppler tone and the 2,915-Hz sync tone. The preamble is five frames long and is transmitted at four times the normal power, as shown in figure 4-5. Normal power for the 605-Hz Doppler tone is +6 dB and the data tones, including the 2,915-Hz tone, is 0 dB. During the preamble, the 605-Hz tone is transmitted at +12 dB, and the 2,915-Hz sync tone is transmitted at +6 dB. The sync tone is shifted 180 degrees for each frame to allow the receiving DTS to detect frame transitions.
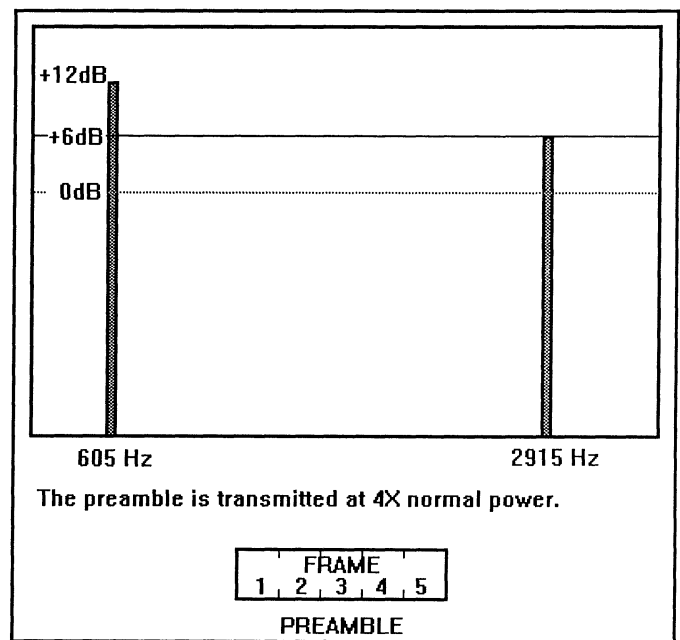
Figure 4-5.—The Link-11 preamble power levels and frame count.

Phase Reference Frame

The phase reference frame follows the preamble and is shown in figure 4-6. This frame is composed of the normal 16-tone composite signal with the data tones transmitted at 0 dB and the Doppler tone transmitted at +6 dB. Since the two bits of data stored in a tone is based on a certain phase shift in respect to the preceding frame, the phase reference frame provides the reference for the first frame of data. Each succeeding frame becomes the phase reference for the following frame.

4-7
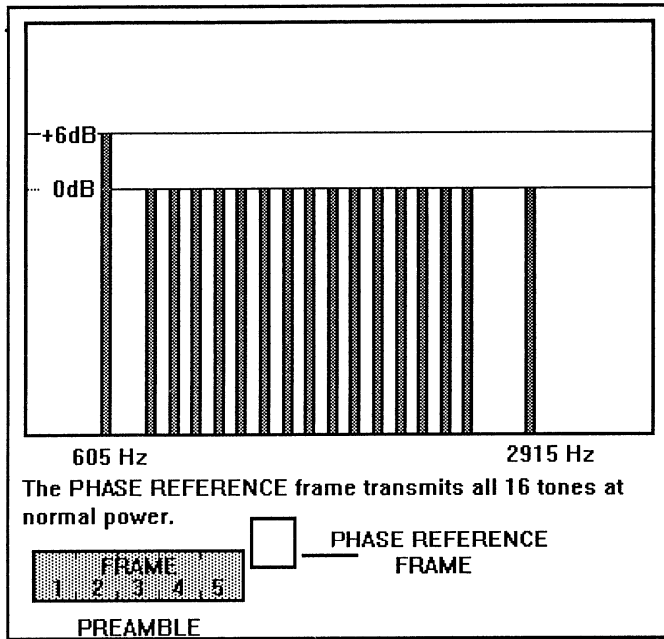
Figure 4-6.—The phase reference frame added to the preamble with normal data tone levels.

Information Segment

The information segment of the Link-11 message is composed of control code frames and message data frames. Control code frames consist of a start code, a stop code, and an address code. Each control code is two frames in length and performs a specific function. Control codes are not sent to the CDS computer.
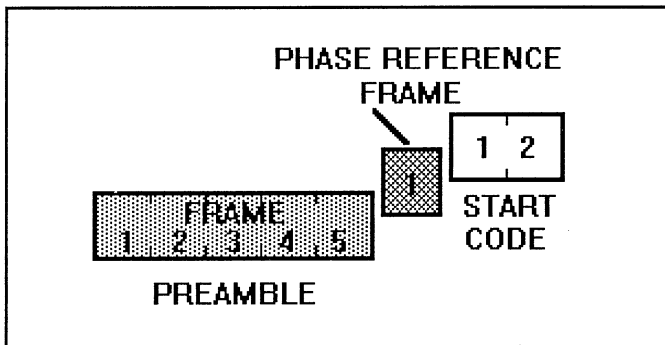
Figure 4-7.—The start code added to the Link-11 transmission.

START CODE. —The start code is a two-frame code that follows the phase reference frame, as shown in figure 4-7. When sensed by the DTS, the start code causes the DTS to send the **Prepare-to-Receive Data interrupt** to the CDS computer.

MESSAGE DATA FRAMES. —Message data frames contain the tactical data being disseminated and follow the start code, as shown in figure 4-8. The number of message data frames depends on the amount of tactical information the unit transmits. The 24 bits of data contained in each frame is sent to the CDS computer.
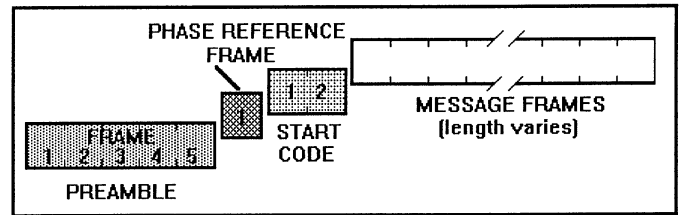
Figure 4-8.—The message data frames added to the Link-n transmission.

STOP CODE. —The stop code is a two-frame code that follows the data message in a Link-11 transmission and is shown in figure 4-9. There are two types of stop codes: the **control stop code** and the **picket stop code.** The control stop code is used in messages originated by NCS (NCS report) and indicates that a picket address code follows the stop code. The picket stop code indicates to the NCS that the picket unit has completed its message transmission. Both the control stop code and picket stop code cause the receiving DTS to send the **End-of-Receive interrupt** to the CDS computer.

LINK-11 MESSAGE FORMATS

The formats of the messages transmitted by the Link-11 system vary with the mode of operation.

Roll Call Mode Messages

In the roll call mode, the unit designated as the net control station sends out two types of messages. These are the NCS call-up message (interrogation) and the NCS report (message with interrogation). A third message, the picket reply message, is sent by picket unit in response to interrogation messages.
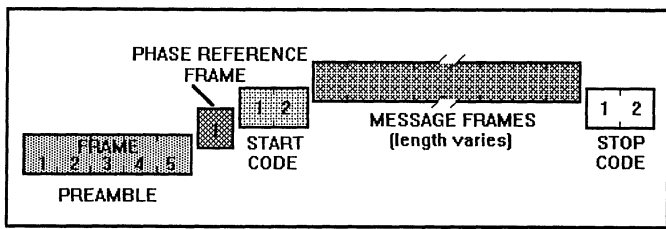
Figure 4-9.—The stop codes added to the Link-11 transmission.

CALL-UP (INTERROGATION) MESSAGE. —This message shown in figure 4-10 consists of the five-frame preamble, the phase reference frame, and the two address frames. The call-up message does not use start and stop codes.
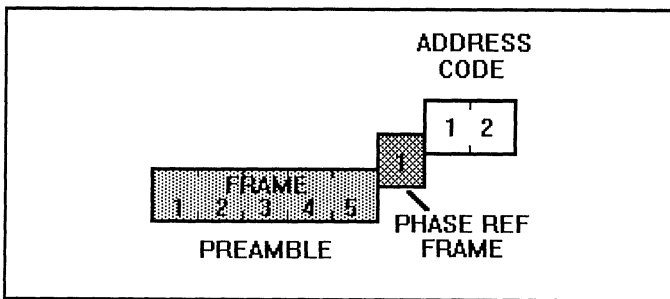
Figure 4-10.—The NCS call-up message.

NCS REPORT AND CALL-UP MESSAGE. —This message shown in figure 4-11 consists of the five-frame preamble, the phase reference frame, the two-frame start code, the data frames containing the NCS report, the two-frame **control** stop code, and two frames containing the address code for the next PU.
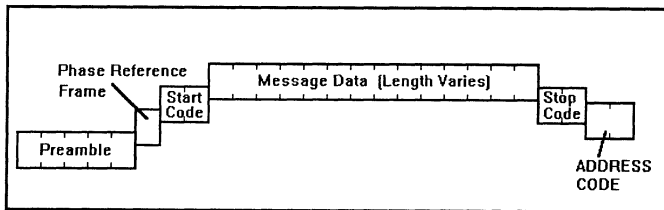
Figure 4-11.—The NCS report and call up message.

PICKET REPLY MESSAGE. —The picket reply message shown in figure 4-12 consists of the five-frame preamble, the phase reference frame, the

two-frame start code, the data frames, and the two-frame **picket** stop code.
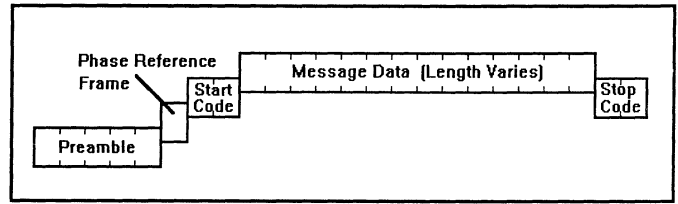
Figure 4-12.—The picket reply message.

Short Broadcast Messages

The Short Broadcast is a single data transmission to all members of a net by a station that maybe acting as either picket or NCS. It is the same format as the picket reply message shown in figure 4-12. The Short Broadcast message is manually initiated by the operator at the DTS.

Broadcast Mode Messages

The Broadcast mode messages consist of a continuous series of short broadcast messages, separated by two frames of dead time, as shown in figure 4-13. The message format is the same as a picket reply message. In the Broadcast mode, only one unit will transmit.

Net Test Mode

The Net Test message consists of the five-frame preamble, the phase reference frame, and the Net Test words generated by the DTS. When all the Net Test words in the library have been transmitted, the sequence starts over until the operator stops the Net Test.

LINK-11 DATA TERMINAL SET (DTS)

As you have seen, the data terminal set is the heart of the Link-11 system. The DTS performs the modulation, demodulation, and control functions required for proper Link-11 operation. It accepts data from the CDS computer in the form of 24-bit data words, adds six bits of error detection and correction (EDAC) data, and converts all 30 bits into an audio tone package that is sent to the transmitter portion of the radio set. The key-line signals necessary to
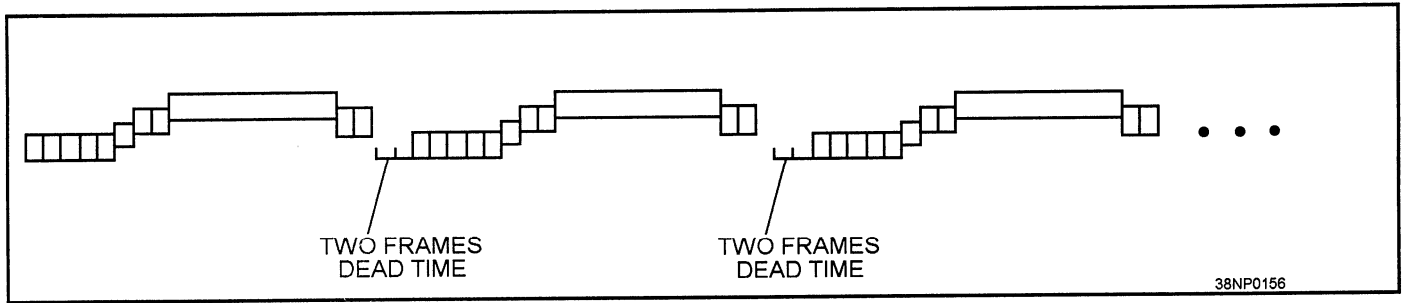
Figure 4-13.—Broadcast mode message format.

control the transmit and receive states of the radio set are also generated by the DTS. Data received from the upper sideband (USB) and lower sideband (LSB) portions of the radio set receiver, in the form of audio tones, is converted into parallel binary data and sent to the CDS computer.

Currently several design generations of Link-11 data terminal sets are used in the fleet. These include the AN/USQ-59 and 59A, the AN/USQ-63, and the AN/USQ-74. Originally introduced in the early 1960s, each successive generation of the Link-11 data terminal set reflects additional knowledge gained from fleet use and advances in technology. Although the technology used in the different models of the Link-11 DTS may be vastly different, all of them perform the same function. Normally, the DTS operates in the **half-duplex** mode, meaning it can

either receive or transmit data, but it cannot do both at the same time. An exception is during system test when the DTS operates in **full-duplex** mode and can simultaneously send and receive data.

DATA TERMINAL SET FUNCTIONS

The DTS also performs the following functions:

- Error detection and correction

- Audio signal generation

- Link-11 protocol and interface control

Error Detection and Correction (EDAC)

The DTS receives data from the CDS computer in the form of 24-bit binary data words. The 24-data bits

Table 4-1.—DTS Parity Bit Status Codes

MODE	ERROR STATUS	BIT POSITION 25	24
Detect and Label	No errors detected	0	0
	Error(s) detected - no correction attempted	1	0
Detect and Correct	No errors detected	0	0
	Parity errors detected	0	1
	Odd error(s) detected - correction attempted	1	1
	Even errors detected - no correction attempted	1	0

are expanded to 30 bits by adding six bits for error detection and correction (EDAC). These six bits are also called **hamming** bits. The value of these bits are based on parity checks of specific combinations of the 24-bit data word.

During the receive cycle, the six EDAC, or hamming bits, are examined for errors. There is enough redundancy in the EDAC to allow for correction of a single bit error. The operator can control the selection of the error correction mode. If the data word is not a control word, the word is examined to determine if it is error-free, contains a correctable error, or contains uncorrectable errors. If the DTS is in the error detection and label mode, a detected error is identified and labeled before the data word is sent to the CDS computer. In the error detection and correct mode, the DTS attempts to correct an error before sending the data word to the CDS computer. In both modes, the six EDAC bits are deleted and replaced with two parity error status bits. These status bits are defined in table 4-1.

Audio Tone Generation and Characteristics

The DTS converts the 24-bit data word, along with the six EDAC bits, into a composite audio signal consisting of 16 tones. This composite 16-tone signal is the **data frame.** The tones range in frequency from 605 Hz to 2,915 Hz and are the odd harmonics of 55 Hz. The specific frequencies of the tones are shown in table 4-2. The 605-Hz tone is used for Doppler correction, and the 2,915-Hz tone is used for data and synchronization. Each of the data subcarrier tones (tones 2 through 16 in table 4-2) represents two binary bits of differential quadrature phase-shift modulated data.

The Doppler tone (605 Hz) is not phase modulated. It is used to correct for Doppler shifts in the received tones caused by the relative motion between the transmitter and the receiver. It is also used to correct for the Doppler shift that may occur because of differences between the transmitter and receiver frequency standards.

The 2,915-Hz tone has two separate uses. During the transmission of the preamble and Net Sync, the 2,915-Hz tone is used to identify frame timing. This tone is phase shifted 180 degrees at the end of each frame. When detected by the receiving DTS, the phase shift indicates the start of a new frame. When the DTS is in corrected timing, this information is used to set the timing for the data frames that follow. When stored timing is used, the frame timing that was set during Net Sync is used.

The Doppler and sync tones vary from each other and the other data-carrying tones in amplitude. The Doppler tone is 6 dB greater than the other tones. During the Net Sync and preamble frames, the Doppler tone is transmitted at 12 dB and the sync tone is transmitted at 6 dB. The Doppler tone is transmitted at 6 dB during the transmission of data frames and the sync tone is used as a data tone. Data tones are transmitted at 0 dB.

The audio tones are divided into data frames to identify the separate parallel groupings of 30 bits. It is the phase angle shift of each of the 15 data tones that conveys the digital information contained in the tone. During each frame, each data tone frequency has a particular phase. At each frame boundary, the phase of each data tone is shifted with respect to the previous frame. The amount of this phase change, or **phase difference,** determines the value of a two-bit number Two data bits yield the following four possible combinations: 00, 01, 10, and 11. Each combination is associated with a phase difference of one of four values: 45 degrees, 135 degrees, 225 degrees, or 315 degrees from the previous position.

Table 4-2.—Tone Library

Tone Number	Frequency (Hz)	Description	Bit Location
1	605	Doppler	*
2	935	Data	0 and 1
3	1045	Data	2 and 3
4	1155	Data	4 and 5
5	1265	Data	6 and 7
6	1375	Data	8 and 9
7	1485	Data	10 and 11
8	1595	Data	12 and 13
9	1705	Data	14 and 15
10	1815	Data	16 and 17
11	1925	Data	18 and 19
12	2035	Data	20 and 21
13	2145	Data	22 and 23
14	2255	Data	24 and 25
15	2365	Data	26 and 27
16	2915	Data/Sync*	29 and 30

* There is no bit location associated with the 605-Hz Doppler tone or the 2,915 Hz tone when used as the Sync tone
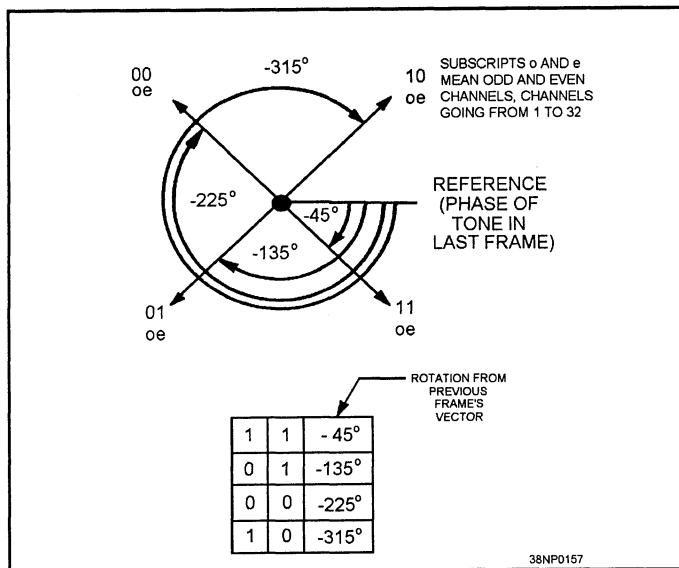
Figure 4-14.—Link-11 data phase shift encoding.

Each of these angles marks the center of a quadrant, as shown in figure 4-14. Each 90-degree quadrant is assigned a two-bit binary value. Any phase difference falling within that quadrant represents that binary value. This system of data encoding can tolerate an error in the prescribed phase shift of up to ±44 degrees before a single bit error will occur. An error in phase shift that is greater than 45 degrees, but less than 135 degrees, will cause the phase angle to fall into an adjacent quadrant. Notice that the values are assigned to each quadrant in such a way that if a phase shift error occurs, that only one bit error will be introduced as long as the quadrant into which it falls is adjacent to the target quadrant.

Link Protocol and Interface Control

In addition to encoding data from the CDS computer, the DTS generates and recognizes protocol data that controls the type and number of link transmissions. These protocol words include codes indicating the start of transmission, the end of transmission, and the address of the next unit to transmit.

The interface with the CDS computer is under the control of the DTS. The DTS signals the CDS computer when it has input data or when it wants output data through the use of external interrupts. These interrupts include the prepare-to-transmit, prepare-to-receive, and end-of-receive interrupts.

DTS CONTROLS AND INDICATORS

Many parameters that affect the operation of the DTS are under the operator's control, whether the station is operating as a picket or as the net control station. Both the operator and the technician must be familiar with the various controls and indicators associated with the DTS. The AN/USQ-59 uses several control panels that are usually mounted next to the operator's display console. These panels enable the operator and the technician to control and monitor the net operation.

The control panels include a **Mode Control** panel, a **TADIL A Control** panel, and an **Address Selection Indicator** panel. Although the AN/USQ-59 control panels are used here to show the controls and indicators of a Link-11 DTS, other data terminal sets have similar controls. The functions controlled by the AN/USQ-59 control panels are software controlled on newer data terminal sets. On these data terminal sets, the entries an made via the computer control console or the display console.

DTS Mode Control Panel

The DTS mode control panel controls and indicators are shown in figure 4-15. The following is a summary of how the controls affect the operation of the link and what the indicators mean.

TRANSMIT MODE INDICATOR —lights when the DTS is in the transmit mode.

RECEIVE MODE INDICATOR —lights when the DTS is in the receive mode.

SUMMARY FAULT INDICATOR —Lights when a fault in the DTS is detected while in the OPERATE mode. There are 27 performance monitor fault-sensing circuits in the data converter (modem) of the DTS. During the OPERATE mode, 14 of these sensors can cause a summary fault. The fault-sensing circuits monitor areas such as various power supplies, signal quality, preamble presence, timing, and audio signal quality. When the DTS is in SELF TEST, the summary fault lamp is lighted when a fault is isolated to a function defined by switch positions on the fault isolation control and built-in tests routines.

LAMP TEST BUTTON —causes all indicators on the mode control panel, the TADIL A control panel, and the address control unit to light.

FAULT MONITOR/RESET SWITCH —In the MONITOR position, this switch allows the fault-sensing function of the DTS to operate normally and provide a fault summary signal to the DTS control. In placed in the RESET position, the fault-sensing circuits of the DTS are reset. The SUMMARY FAULT lamp is turned off when the fault-sensing circuits are reset.

INTERNAL 100-KHZ/EXTERNAL SWITCH —Allows for the selection of the internal or external 100-KHz frequency standard.

DOPPLER CORR ON/CORR OFF SWITCH —Enables the DTS Doppler correction when placed in the CORR ON position.

FULL-DUPLEX/HALF-DUPLEXSWITCH — In the FULL-DUPLEX position, this switch enables full-duplex operation of the data converter and the computer I/O adapter. It also enables loop back processing of the transmit sidetone data for input to the computer. In the HALF-DUPLEX position, the DTS operates in the half-duplex mode and the transmit sidetone is disabled from being processed
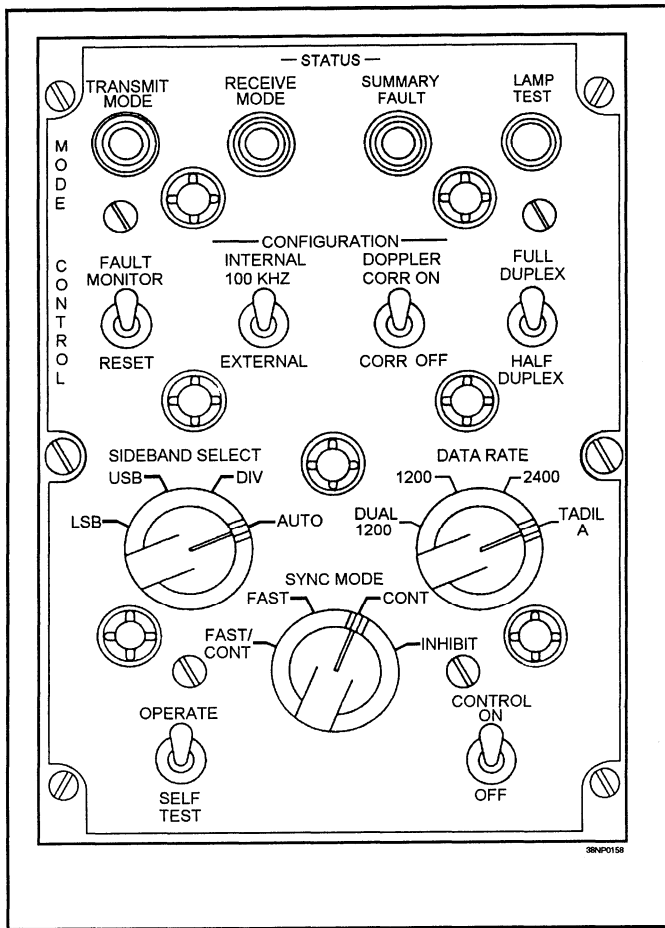
Figure 4-15.—The AN/USQ-59 mode control panel.

and input to the computer. Link-11 uses the half-duplex mode.

SIDEBAND SELECT SWITCH —When the SIDEBAND SELECT switch is placed in the LSB or USB position, the DTS processes only the lower sideband or upper sideband of the received signal. When the switch is in the DIV position, the DTS combines both the upper sideband and the lower sideband signals to create frequency diversity data for input to the computer. When the switch is in the AUTO position, the DTS selects the signal with the best receive quality for processing. The AUTO position is the normal position of this switch.

DATA RATE SWITCH —Selects the data rate that the data converter uses. When the switch is in the DUAL 1200 position, the data converter can transmit and receive two unrelated streams of data at 1200 bps. In the 1200 and 2400 positions, the data converter

transmits and receives a single data stream at 1200 and 2400 bps, respectively. When the switch is in the TADIL A position, the data rate is controlled by the DATA RATE switch on the TADIL A control panel. The TADIL A position is the normal position for Link-11.

SYNC MODE SWITCH —The SYNC MODE switch selects the mode of synchronization used by the DTS receive circuitry and is used in conjunction with the TIMING STORED/CORRECTED switch on the TADIL A control panel. The normal operating position for the SYNC MODE switch is in the FAST/CONT position.

When the switch is in the FAST/CONT position, both the fast and continuous synchronization circuits of the DTS are selected. Synchronization is initially obtained during the five-frame preamble and maintained continuously during the data portion of the transmission. The TIMING switch on the TADIL A control panel must be in the CORRECTED position.

When the FAST position is selected, synchronization is only during the five-frame preamble. If the CONT position of this switch is selected, only the continuous synchronization circuits are selected. Synchronization is obtained only during the data portion of the transmission. The TIMING switch on the TADIL A control panel must be in the CORRECTED position for both of these modes.

The INHIBIT position of this switch disables both the fast and continuous synchronization circuits of the DTS. The DTS will maintain the time base that was stored when the switch was turned to INHIBIT. For synchronization to be held, the unit with its sync mode inhibited must maintain its original geographic relationship to all other units in the net. This position is used when the received signal contains interference that could cause loss of synchronization.

OPERATE/SELF-TEST SWITCH —This switch must be in OPERATE for normal on-line operations. When the switch is placed in the SELF-TEST mode, the DTS is placed in an off-line mode and the fault isolation circuitry is enabled.
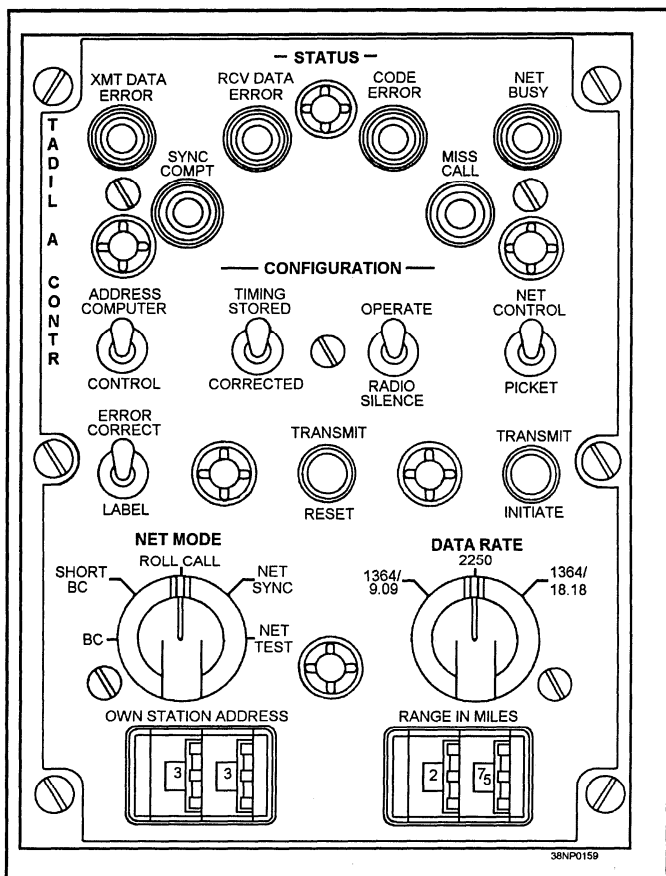
Figure 4-16.—The AN/USQ-59 TADIL A control panel.

CONTROL ON/OFF SWITCH —When the CONTROL switch is placed to the ON position, +28Vdc is applied to the fault isolation control panel, the mode control panel, the TADIL A control panel, and the address control panel.

TADIL A Control Panel

The TADIL A control panel provides the control switches and indicators required to control and monitor Link-11 operations. Figure 4-16 shows the AN/USQ-59 TADIL A control panel.

XMT DATA ERROR INDICATOR. —This indicator is lighted when the DTS detects an error while transmitting data in the TADIL A, or Link-11, mode.

RCV DATA ERROR INDICATOR. —This indicator is lighted when the DTS detects an error in received data being sent to the CDS computer.

CODE ERROR INDICATOR. —The CODE ERROR indicator is lighted when the DTS detects an error in the received or sidetone (transmit) control codes during TADIL A operations.

NET BUSY INDICATOR. —The NET BUSY indicator is lighted when the DTS detects that the communications net is busy. It is activated when a signal called **signal presence** is generated by the DTS .

SYNC COMPT INDICATOR. —The SYNC COMPT indicator is lighted continuously, or flashes, when the DTS has achieved synchronization with the NCS data terminal.

TIMING STORED/CORRECTED SWITCH. —The TIMING STORED/CORRECTED switch determines how the DTS is synchronized. When the switch is in the CORRECTED position, the fast synchronization and/or the continuous synchronization circuitry in the DTS is used. The position of the sync mode switch on the mode control panel determines whether the fast, continuous, or both circuits are used to maintain synchronization. In the STORED position, the DTS uses the time base stored during Net Sync. During normal operations, this switch should be in the CORRECTED position.

OPERATE/RADIO SILENCE SWITCH. —The OPERATE/RADIO SILENCE switch is a two-position toggle switch that allows the DTS to inhibit radio transmissions. In the OPERATE position, the DTS operates normally. When switched to the RADIO SILENCE position, the radio keyline and transmit audio circuits are immediately disabled.

NET CONTROL/PICKET SWITCH. —The NET CONTROL/PICKET switch configures the DTS to operate as the net control station or a picket station in roll call mode.

ERROR CORRECT/LABEL SWITCH. —The ERROR CORRECT/LABEL switch determines how the DTS processes detected errors. In the CORRECTED position, the DTS attempts to correct detected errors. If a single bit error is detected, the location of the erroneous bit is detected and corrected.

If an even number of bit errors occurs, the correction circuitry is inhibited. If an odd number of bit errors occurs, the correction circuitry attempts to correct the data; however, if odd number of multiple bit errors occurs, an erroneous correction is made. When the switch is in the LABEL position, the DTS does not attempt to correct detected errors. Instead, the data word sent to the computer is labeled to indicate that errors were detected in the data word.

TRANSMIT RESET SWITCH. —The TRANSMIT RESET switch is a momentary contact pushbutton switch. When depressed, this switch causes any transmission in progress to be terminated. The DTS stops the transmission by inhibiting the generation of the output data request, causing a stop code to be transmitted. The DTS also resets the address control address sequence logic.

TRANSMIT INITIATE SWITCH. —The TRANSMIT INITIATE switch is a momentary contact pushbutton switch that causes the DTS to initiate data transmission when the DATA RATE switch is in the TADIL A position. The TRANSMIT INITIATE switch must be depressed to initiate all DTS transmissions except when the DTS is configured as a picket and is in the roll call mode. When the net is in the roll call mode, only the net control station is required to initiate transmission by depressing the TRANSMIT INITIATE switch.

MISS CALL INDICATOR. —The MISS CALL indicator is lighted when the net control station has detected no response from a picket station after two successive interrogations. Once lit, it will remain lit until a picket responds or the TRANSMIT RESET switch is depressed.

ADDRESS COMPUTER/CONTROL SWITCH. —The ADDRESS COMPUTER/CONTROL switch determines the source of the address used by the DTS. When the switch is in the CONTROL position, addresses are obtained from the address control unit. In the COMPUTER position, addresses are obtained from the CDS computer, provided the computer is configured for external function operations. The normal position for this switch is dependent on the

configuration of the system on your ship.

NET MODE SWITCH. —The NET MODE switch determines the mode of operation of the DTS. The modes are BC or broadcast, SHORT BC, ROLL CALL, NET SYNC, and NET TEST.

DATA RATE SWITCH. —The DATA RATE switch determines the speed and frame timing operation of the DTS. When the switch is in the 1364/9.09 position, the DTS transmits and receives data at 1364 bps. The data frame phase identification interval is approximately 9.09 milliseconds. When the switch is in the 2250 position, the DTS transmits and receives data at a rate of 2250 bps and a frame interval of 9.09 milliseconds. When the switch is in the 1364/1 8.18 position, the data rate is 1364 bps, but the frame phase shift interval is increased to 18.18 milliseconds.

OWN STATION ADDRESS SWITCH. —The OWN STATION ADDRESS switch consists of two thumb wheel switches in which an address is entered to identify the address the DTS will respond to as its own. In the roll call mode and with the DTS configured as a picket station, the DTS will transmit its tactical data when the interrogation message address matches the address entered into the OWN STATION ADDRESS switches.

RANGE IN MILES SWITCH. —The RANGE IN MILES switch also consists of two thumb wheel switches. These switches are used to select the approximate distance between the net control station and the picket station. The range entered into these switches causes the DTS to alter the frame timing to compensate for the signal propagation delay between the picket station and NCS. The range in miles setting for the NCS is always zero miles.

Address Control Indicator

The address control indicator is used to set the address of the picket stations to be interrogated when a unit is configured to operate as the NCS. The address control indicator is shown in figure 4-17. The address control indicator consists of 20 identical address selection modules, which are used to address

up to 20 stations. More than one address control indicator may be installed in a system to provide the ability to interrogate more than 20 stations.

Each address selector module has two thumb wheel switches in which one of 64 octal addresses may be entered (address 00 and 77 octal are invalid). Also, each address selector module has a power on/off switch, a power on indicator lamp, and a call indicator, as shown in figure 4-18.

When a unit is configured as the NCS, the operator enters all the assigned addresses of the net participating units into the address selector modules, and turns on each module with a valid address. Once the roll call mode is initiated, the DTS will check each module sequentially. If the power of the module is on and a valid address is entered, the address is sent to the DTS for use in an interrogation message. If the power switch is in the OFF position, that module is skipped, even if it contains a valid address. When enabled by the DTS, the address selector module sends the address entered in the thumb wheels to the DTS and the call indicator light. The call indicator will remain lit until the DTS sequences to the next address module.

CDS INPUT/OUTPUT CONTROL

The data terminal set controls the exchange of data with the CDS computer. As described earlier, input/output communications protocol is accomplished through the use of external interrupts. The prepare-to-transmit data interrupt, the prepare-to-receive data interrupt, and the end-of-receive data interrupt are used to control most of the DTS to the computer interface.

CDS Computer Input (Receive) Data Cycle

The input data cycle is initiated by the DTS. When the DTS recognizes the second frame of the start code, it sets the prepare to receive data interrupt on the input data lines and sets the external interrupt line. The computer acknowledges the receipt of the interrupt by sending an input data acknowledge (IDA) to the DTS.
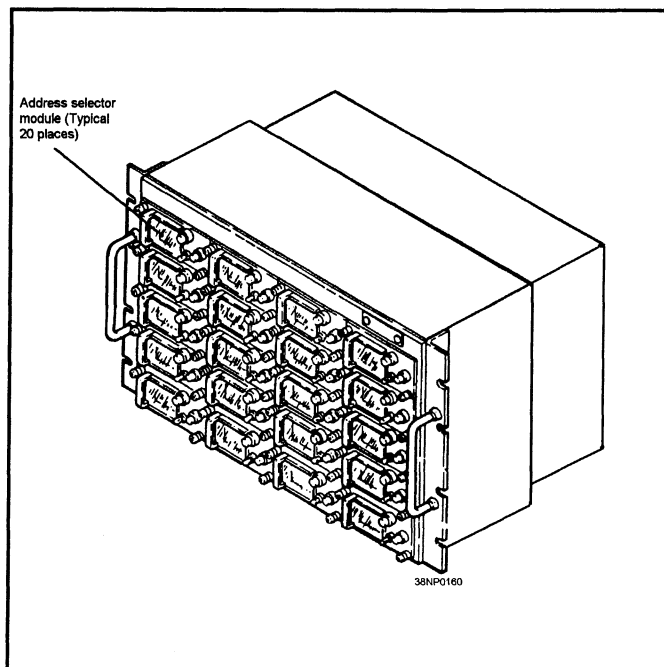
Figure 4-17.—The Address Control Indicator C9062/U.

Upon receipt of the first message frame, the DTS demodulates the 24-bit word and places it on the input data lines, along with the two error detection and correction bits. Once the data is placed on the input data lines, the DTS sets the input data request (IDR) line. The computer will sample the data and send an IDA. This process repeats for all frames of the message. The first frame of the stop code is also treated as a message frame and sent to the CDS computer. When the DTS recognizes the second frame of the stop code, it will place the end of receive
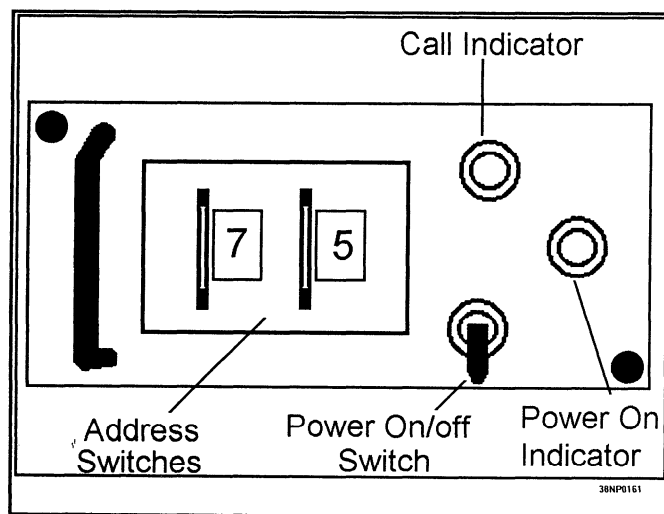
Figure 4-18.—An address selector module.

interrupt on the input data lines and set the interrupt line. The interrupt is then processed by the CDS computer and the input buffer is closed.

If the received stop code is a picket stop code, the DTS simply resets itself. If the stop code is a control station stop code, the DTS will compare the next two frames received with its own station address code.

CDS Computer Output (Transmit) Data Cycle

The output data cycle is initiated when the DTS detects its own station address, either in an interrogation message or at the end of an NCS report and interrogation message. When the DTS recognizes its own station address, it starts to transmit the preamble. During the first frame of the preamble, the DTS sets the prepare to transmit interrupt on the input data lines. The computer samples the interrupt and sends an IDA to acknowledge receipt of the interrupt.

The DTS finishes sending the preamble and phase reference frames During the second frame of the start code, the DTS sets the output data request (ODR) active, requesting the first word of the tactical data. The CDS computer responds by placing 24 bits of data on the lines and then setting the output data acknowledge (ODA). The DTS samples the data and clears the ODR. The first frame of data is processed for transmission and the ODR line is then set to request the next data word.

This procedure is repeated until all the data words have been transmitted. Once the CDS computer has completed sending all the data words, it will not acknowledge the ODR from the DTS. If the CDS computer has not acknowledged an ODR from the DTS in a preset amount of time, the DTS will clear the ODR line and generate a stop code. Upon transmission of the two-frame stop code, the DTS will return to the receive mode.

Net Control Station (NCS) I/O Operations

The station acting as NCS follows the same protocols when communicating with the CDS computer. Some differences exist in the generation of the control codes. The net control station is responsible for interrogating each station. Upon receipt of a picket stop code, the DTS checks the next station address and sends an interrogation message. After the interrogation message is transmitted, the DTS waits to receive a start code from the interrogated station. If a start code is not recognized after 15 frame intervals, the station will be reinterrogated. If a start code is not received after another 15 frame intervals, the address control unit will advance to the next active picket address and the interrogation process is repeated.

The other major difference is when the net control station has completed its own tactical data transmission, a control stop code, followed by the next station address, is transmitted. Again, if a start code is not received within 15 frame intervals, a second interrogation is sent. This second interrogation is a normal interrogation message consisting of the preamble, phase reference frame, and address code.

Modulator/Demodulator

The modulator/demodulator function of the DTS provides the digital to analog and analog to digital conversion. During data transmission, the 24-bit binary data word is expanded to 30 bits by adding the six bits for error detection and correction. The 30 bits are then examined in pairs to determine the required phase angle shift for each of the 15 data-carrying tones in the audio package.

At the frame boundary, the phase of each data tone is shifted with respect to the previous frame. Figure 4-19 shows the four possible phase shifts. A sixteenth tone, the 605-Hz Doppler correction tone, is added to the tone package. The Doppler tone is not phase modulated and is used to correct for Doppler shifts caused by the relative motion between the transmitting station and the receiving station. The 16 tones are combined into a composite audio signal and sent to the radio set. The radio set transmits the composite tone package on the carrier frequency in independent sideband form.
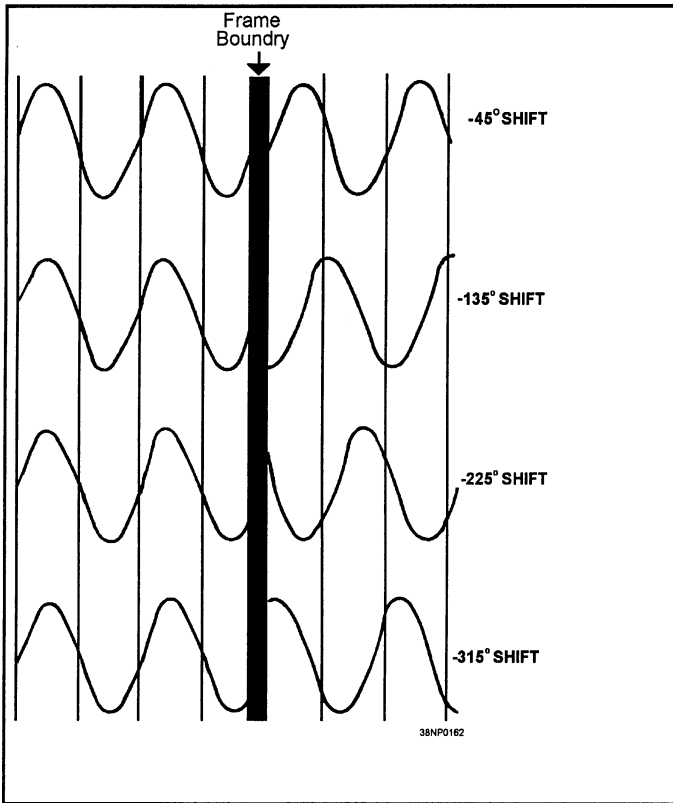
Figure 4-19.—Link-11 frame boundary phase shifts.

During receive operations, the tone package is received from the radio set. The 30 bits of data are extracted from the tone package by determining the phase shift of each data tone with respect to the previous frame. The 30 bits, which contain 24-data bits and six-EDAC bits, are examined for errors. The six-EDAC bits allow for the detection of errors and provide enough redundancy to allow for correcting a single bit error.

The operator can select whether or not the DTS attempts to correct detected errors, as explained earlier in this chapter. In the error detect (label) mode, a detected error is identified and labeled before it is sent to the CDS computer. In the error correction (correct) mode, the DTS attempts to correct a detected

error, labels the error, and sends the data word to the CDS computer.

The DTS is capable of receiving and processing both the upper sideband and the lower sideband when using a HF radio, depending on the position of the sideband select switch. When you are using a UHF radio, only the upper sideband is received and processed.

If the sideband select switch is in the USB or the LBS position, only the designated sideband is processed. In the diversity (DIV) mode, the 30-bit word is generated by adding the relative phase angles of the USB and the LSB.

Because of propagation anomalies, noise, and interference, the AUTO mode can be used to select the sideband (USB, LSB or DIV) that yields the most correct data automatically. In the AUTO mode the DTS processes a word from each sideband and the diversity combination. The decoded words are examined for errors in the following order or priority: DIV, USB, and LSB. A search of the three words is made to find a data word with no error. If one is found, it is selected for input to the CDS computer. If none is found, the RCV DATA ERR indicator is lit and the diversity combination data word is sent to the CDS computer.

Radio Set Interface

The DTS generates the following outputs to the radio set: upper sideband composite audio, lower sideband composite audio, and key line. It receives upper sideband composite audio and/or lower sideband composite audio. UHF radio sets use only the upper sideband signal and the key-line signal.

The key-line signal controls the transmit and receive state of the radio set. The key line is set to transmit Link-11 data. When the key-line is cleared, the radio set returns to the receive mode.

CHAPTER 5

LINK-11 FAULT ISOLATION

INTRODUCTION

A communications network, such as the Link-11 system, can be very complex when the goal is to maintain high-quality communications with all units in the net. Distance, atmospheric anomalies, corrosion, and even the time of day can affect the quality of Link-11 communications. The Link-11 technician has many tools to enable him to pinpoint problems. However, oftentimes the technician may misunderstand such tools, forget them, or not have the knowledge to use them effectively.

Problems occurring with Link-11 communications are best approached by means of the team concept. A typical link team is usually composed of a team leader, an ET, a FC, an OS, and an RM. The team leader is usually a senior ET and could be the electronics material officer (EMO) or combat systems maintenance officer.

After completing this chapter, you should be able to:

● **Describe the procedures required for running single station Programmed Operational and Functional Appraisal (POFA) on the DTS.**

● **State the circuits verified by the successful completion of single station POFA.**

● **Describe the procedures for running multi-station Link-n POFA.**

● **Describe the components of the LMS-11.**

● **Describe the information presented in each of the LMS-11 display modes.**

● **Recognize common Link-n problems as displayed on the LMS-11.**

LINK-11 MYTHS AND FACTS

When a Link-11 problem occurs, usually the link troubleshooting team is called to the combat direction center. Here they can meet with the operator, talk to other ships in the link, and analyze the displays on the LMS-11. Through these initial steps, the team can determine several things, such as whether the problem is local or if the entire net is experiencing problems. Because of the complexity of link equipment, a variety of methods were used over the years to solve link problems. If a particular action worked once, it was often assumed that it would work in all instances. Over the years, this led to a type of folklore or mythology on how technicians were to troubleshoot the link. Senior link techs would pass these myths

on to junior link techs and the mythology developed a life of its own. In the following paragraphs, we examine some of these myths and seek to clarify the real problems that led to the evolution of them.

Myth: Changing the NCS Will Always Solve Net Problems!

Changing the NCS may solve net problems, but only if the current NCS is causing the problem. What is the problem? If data is not being received from a unit because the current NCS has entered the PU number incorrectly, shifting NCS functions to a station with the PU data entered correctly will solve the problem. However, it would be easier if the current NCS were simply to enter the correct PU numbers.

When the current NCS is using a radio set with poor receiver sensitivity and is polling on top of picket responses effectively jamming the entire net, changing the NCS is imperative. Also, if several units are not recognizing their interrogations because NCS is out of range or in an RF propagation shadow, changing to a unit in a better location should improve net communications.

Myth: Changing Frequency Always Solves Net Problems!

Here again is a myth that has some basis of fact. Changing frequency is a time-consuming process. When all the procedures are not carefully followed, then changing the frequency induces additional problems into the net. This myth developed because improperly set switch positions and patch panel configurations were often set to the proper position during the frequency changing process. When the problem is connectivity on the current frequency, the proper action is to find a better frequency.

Myth: More Power Improves Link Performance!

This is a myth. On the transmit side, the idea behind the myth is that keeping the link HF transmitter tuned to maximum output power will result in maximum area coverage. In fact, constantly outputting maximum power can lead to serious RFI/EMI problems (on the ship doing so) and will not significantly increase the signal propagation range.

The idea behind the myth on the receive side is that by keeping the HF receiver audio output control maximized, receive quality improves. In fact, maximizing the audio output saturates most data terminal sets. Saturation generally occurs in the DTS at around 3 dBm. Signal inputs above this level actually increase receive data errors.

Myth: Dummy PUs Improve Link Quality!

A dummy PU is an address insert into the polling sequence by the NCS for which there is no live unit. Dummy PUs cause the net cycle time to increase and net efficiency to decrease. The idea that the NCS must use dummy PUs for the link to

operate properly is not generally true. It may be true only in infrequent, isolated cases. Studies have shown that in the old NTDS system (CP-642 computer and the AN/USQ-36 DTS), a dummy PU entered between a live PU and own address was required for NCS data to be output at each NCS report opportunity. Since the CP-642 computer and the AN/USQ-36 DTS have virtually disappeared, dummy PUs should not be used.

Myth: Radio Silence Reduces Net Cycle Time!

The effect Radio Silence has on net cycle time depends on a number of factors. As you saw in the last chapter, if a PU does not respond to a call up in 15 frames, the PU is interrogated again. After another 15 frames, if the PU still does not respond, then NCS polls the next PU. If the PU that goes to Radio Silence was sending reports that exceeded 38 frames, then net cycle time would be reduced by the PU going to Radio Silence. Effective net management would be to eliminate the PU number of the unit that has to go into Radio Silence until that unit is able to reenter the net.

As you can see, there are several misconceptions on the proper way to manage and troubleshoot the Link-11 system. In this chapter, we concentrate on the tools available to the technician to aid in the isolation of link problems.

LINK-11 PROGRAMMED OPERATIONAL AND FUNCTIONAL APPRAISAL (POFA)

Two types of POFAs are used in the Link-11 system. These are the single station POFA, used to check components of the Link-11 on board a single station, and the multi-station POFA, used to check the connectivity of several units.

SINGLE STATION POFA

The single station POFA is an end-around test that transfers canned data from the computer through the crypto device and the data terminal. The single station POFA can also be run through the radio set to check out part of the audio communications path further.

POFA Setup

The POFA is a special program that is loaded into the computer. It is very important that you follow the instruction manual when attempting to run the POFA. The POFA is designed to run in full-duplex mode. Normal link operations use the half-duplex mode. "Full duplex" means the system is configured to

transmit and receive data at the same time. In the DTS, this is accomplished by the transmit audio being fed directly into the receive input. Also, if the DTS is operating in full-duplex mode, the rest of the system, especially the crypto device, must be in full duplex. On the KG-40, full duplex is accomplished when the front panel switch is turned to the POFA TEST position.

Analyzing Single Station POFA

When a single station POFA is completed, a printout of the results is produced. To analyze this printout properly, the technician must understand
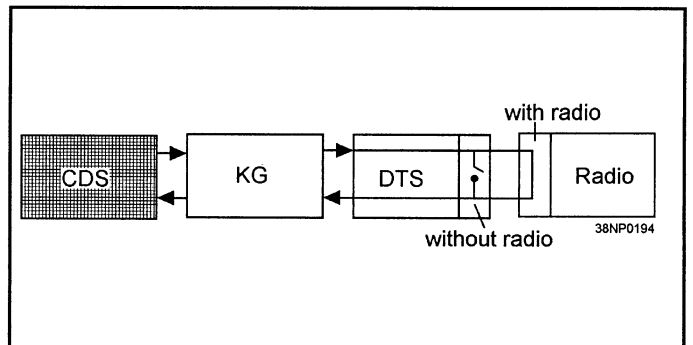
Figure 5-1.—Single station POFA configurations.

what equipment is being tested. The configuration in which the POFA was run determines some of the equipment being tested. The POFA can be run in two configurations, as shown in figure 5-1.

In the full configuration, the single station POFA will test the following areas:

- CDS computer I/O channel interrupt recognition and acceptance

- Security device I/O path

- Data terminal transmit and receive registers, multiplex and demultiplex, and transmit and receive sequence operations

- Switchboard integrity

- DTS-to-radio and radio-to-DTS audio path

- Capability of the HF radio set to develop and accept sidebands (both transmit and receive).

By studying the above list, you can see that most normal link operations are tested during a single station POFA. Certain functions, however, are not checked by running a single station POFA. The DTS uses the transmit timing as the reference for the entire test; therefore, the receive timing circuitry is not checked. Also, certain other functions, such as Doppler correction, are not checked.

The printout generated at the end of a single station POFA lists interrupt status, illegal interrupts, parity, and bit-by-bit word errors. A single station POFA should always produce a totally error-free printout. However, when a printout with errors is received, the technician needs to be able to analyze the error package effectively.

The interrupts, for example, must occur in the following sequence:

- Prepare to transmit

- Prepare to receive

- End of receive

If you receive interrupts in any other order, such as two consecutive prepare to transmit interrupts or an end of receive before the prepare to receive, an error condition exists.

The parity should always equal zero. As you learned in the previous chapter, the parity, or error detection status bits, indicates an error has been detected in the received data. When errors are detected, they are listed in the bit-by-bit section of the printout.

Even if the printout indicates a few random bit errors, this condition should not be ignored. Random bit errors can be caused by several areas in the system, including the CDS computer, the data switchboard, or the DTS. You can narrow down to the exact area causing the problem by running the POFA in several configurations. Changing computers and crypto devices can aid you in determining the malfunction.

Because of the unique function of the crypto device, a single broken line in the switchboard could cause all the bits to be randomly picked up or randomly dropped. When the broken wire is on the encrypted side of the switchboard, the crypto device reads the state of that line during the decryption cycle and the entire decryption cycle is changed.

MULTI-STATION POFA

The multi-station POFA is a test of the Link-11 system that involves more than one platform. Because this POFA most closely represents normal link operations, more equipment is tested. The multi-station POFA is run in the Roll Call mode using a set of known data words. Figure 5-2 shows the data flow for a multi-station POFA. A designated unit transmits a block of 230 data words that are received by the other platforms involved in the multi-station POFA. The receiving computer(s) compare(s) the data against the known pattern, count(s) the words in error, and send(s) this count back to the original ship. This transmission is known as the error status report. Ideally, the multi-station POFA should run error-free.
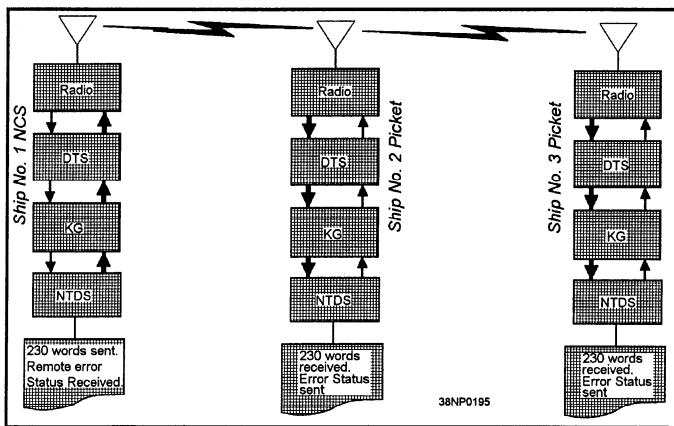
Figure 5-2.—Link-11 multi-station POFA data flow.

Multi-Station POFA Procedures

The procedures for running a multi-station POFA require coordination of all participating units. For this to be a good test, all units must be positioned within 25 miles of each other. This is usually coordinated by the Link-11 manager in conjunction with the battle group commander.

Just before the time the multi-station POFA is to be conducted, NCS should end the operational link and direct all stations to run a single station POFA. The picket station reports back to NCS when the single station POFA has been completed. The picket station will also report the status of the single station error printout. Any errors noted during single station POFA should be corrected before the multi-station POFA, or the station experiencing errors should not be included in the multi-station POFA.

The multi-station POFA should be run using the same frequency as the current operational frequency. After running the single station POFA, NCS should direct all participants to go to Radio Silence. During this time, all stations should monitor the assigned frequency for noise. The frequency can be monitored through the headphones or by using a frequency analyzer. A noisy frequency can cause errors in the multi-station POFA. If the frequency is too noisy, consider using an alternate frequency.

Once the frequency has been checked, NCS will tell all participants to prepare to receive POFA. After all stations report that they are ready, NCS initiates the POFA. All stations monitor the POFA, and check the control panel of the DTS for errors. After a minimum of 5 minutes, NCS terminates the POFA.

When the POFA is terminated, a printout is generated. The final step in running a multi-station POFA is the analysis of the printout.

Analyzing Multi-Station POFA Results

Running a multi-station POFA closely approximates actual link operating conditions. To analyze the printout fully, the technician needs to be aware of some of the factors that can affect link operations.

When the printout is completed, the analysis is easier to complete if the technician records the following information on the printout:

- Which station is NCS

- Distance and relative bearing of all participating units

- Frequency used

- Frequency quality

- Equipment used (radio, trunk line, computer, crypto, etc.)

- Start and stop time of the POFA

The printout will contain a summary of the activity that includes the time, in minutes and seconds, that the station was on the air, the total number of words transmitted, the total number of words received, and the total number of words with errors. This information can be used to calculate the **link quality factor.** To calculate the link quality factor, divide the number of words received by the number of words transmitted. When the quotient is greater than 95 percent but less than 100 percent, consider the POFA successful.

Next, compute the receive error factor. Ideally, the POFA should run with zero errors. Since the multi-station POFA is transmitted, atmospheric

interference, ship's position, antenna location, and EMI are just a few of the things that can induce errors in a radio signal. Determine the receive error factor by dividing the number of words with errors by the number of words received. When the receive error factor is less than 1 percent, consider the POFA successful.

When the printout indicates that data was received from an unrecognized station (UNREC STA), the technician should check the number of words received. The multi-station POFA transmit buffer consists of 230 words. One buffer of 230 words from an unrecognized station is acceptable and generally does not indicate a problem. More than one buffer may indicate a problem, but multiple buffers from an UNREC STA can also be caused by interference on the frequency.

The printout will also indicate the parity status of the words received in error. During the POFA, since the computer knows the contents of the received data block, it performs a parity check on all received words. These parity checks are compared with the parity status received from the DTS. The printout indicates these parity checks. The heading PARITY STATUS OF ERROR WORDS lists the number of error words detected by the DTS and the parity (1, 2, or 3). The heading PARITY STATUS OF CORRECT WORDS indicates the computer parity check of words received as correct from the DTS. When an error is detected, the number of words in error for each of the three parity status conditions are listed here. The final part of the printout indicates the remote station reports. These reports are sent by other stations as part of the data transferred during the POFA.

Since a multi-station POFA is subject to various types of interference, both natural and man-made, several attempts may be required for you to achieve acceptable results. Shifting NCS and repositioning the ships are just two of the actions that could contribute to achieving a successful multi-station POFA.

THE LINK-11 MONITORING SYSTEM (LMS-11)

"The link is down" is a statement that can strike fear into even the most seasoned technician. As we have seen, the operation and maintenance of a high-quality link can be affected by many factors. For years, operators and technicians commonly blamed each other for poor link operations. Some typical Link-11 problems are as follows:

- Participating units (PUs) not responding to call-ups

- Garbled data

- The link goes completely dead, normal operation ceases

- Inability to establish a net

- Excessive net cycle time

When such a problem occurred, the Link-11 technician would run a single station POFA and declare that the DTS was sound and it must be the other ship, a poor frequency, or an operator error. The operator would blame the frequency or NCS. Other units would say the problem was another platform jamming the entire net. Typical strategies used to solve link problems usually began with a recommendation to change frequency. When this strategy failed to solve the problem, the next step was to change NCS. If the problem still existed, then NCS would eliminate PUs from the net, one at a time until the problem unit was identified. All of these actions took time and were hit-and-miss techniques. This tendency of trial-and-error troubleshooting and pointing fingers defined the need for a reliable visual system of monitoring the Link-11 network.

This need was filled with the development of the Link Monitoring System, AN/TSQ-162(V)1, commonly called the LMS-11. The LMS-11 provides an operator or a technician with a real-time visual display of the Link-11 network while it is operating.

The LMS-11 is capable of measuring and displaying link signal data for the network as a whole,

as well as for individual units. It can be used for periodic equipment checks or for continuous monitoring to determine the condition of all members of the net.

LMS-11 SYSTEM CONFIGURATION

The LMS-11 consists of three groups equipment: a data processing group (DPG), a control/display group (CDG), and an accessory group (AG). The LMS-11 is shown in figure 5-3.

The LMS-11 is designed to be portable, and the equipment is installed in three carrying cases. The equipment cases that house the electronic units of the DPG and CDG provide isolation from shock and vibration. The CDG is designed to be mounted on the DPG cases. Four latches fasten the two units together and provide a desk height, self-contained workstation. The system printer, which is part of the accessory group, is mounted on the top of the CDG equipment case. When the LMS-11 is installed, the accessory group case provides storage for the DPG and CDG equipment case covers. The LMS-11 is normally located near the data terminal set, but it may be installed anywhere near a 600-ohm Link-11 audio signal.

Data Processing Group

The equipment required for the LMS-11 to receive, sample, and process Link-11 audio signals is contained in the data processing group. The DPG also provides power control and distribution to the CDG and accessories. The DPG consists of the following equipment:

- The control processing unit

- The audio interface unit

- The dual 3.5-inch floppy disk drive unit

- The power control unit

CONTROL PROCESSING UNIT. —The control processing unit consists of the HP9920U
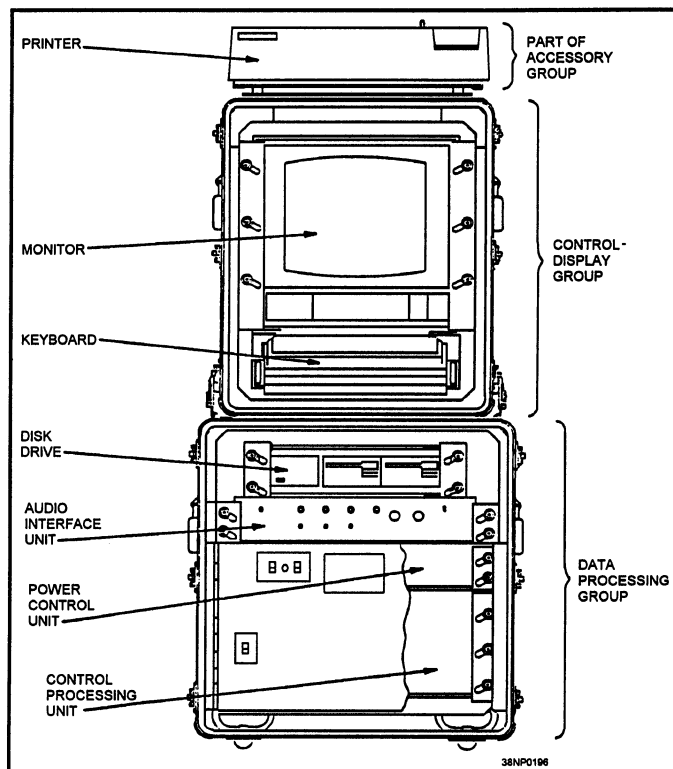
Figure 5-3.—The LMS-11.

computer with an additional 2 MB of ram and associated circuit card assemblies (CCA). These circuit cards include the following:

- Color output CCA

- Composite Video CCA

- Data communications interface

- HP interface bus (HP-IB)

- Analog-to-digital converter assembly

- Fast Fourier Transform (FFT) processor

The color output CCA and the composite video CCA provide the necessary signals to drive the color monitor. The data communications interface provides an RS-232C asynchronous serial interface for the color printer. The HPIB is used to interface the system keyboard and the dual disk drives to the computer.
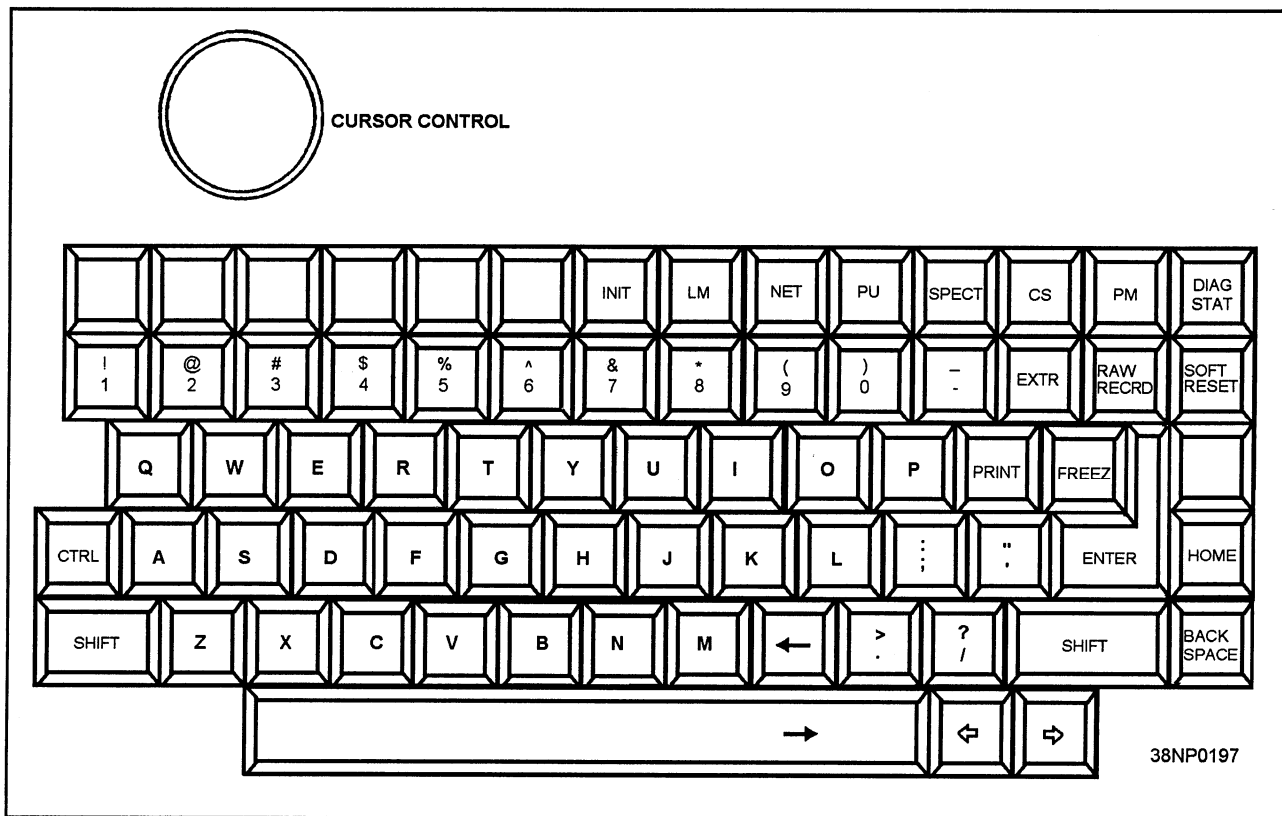
Figure 5-4.—The LMS-11 keyboard.

The analog-to-digital converter converts the Link-11 audio signal into a digital signal for use by the LMS-11. This digital signal is then transferred to the computer where the FFT converts it to a frequency domain. The Fast Fourier Transform consists of a complex mathematical formula used to determine the phase shift of a signal.

AUDIO INTERFACE UNIT. —The audio interface unit connects the upper sideband (USB) and lower sideband (LSB) audio signals from an HF radio or the USB from a UHF radio to the LMS-11. The audio signals are input to the analog-to-digital converter of the control processing unit. The audio interface unit does not add a load to the audio signal.

DUAL 3.5-INCH FLOPPY DISK DRIVE UNIT. —The dual 3.5-inch floppy drive unit is used to load the LMS-11 programs and to record Link-11 data. The disk drives use 788 Kbyte, double-sided, double-density disks.

POWER CONTROL UNIT. —The power control unit provides the control, distribution, and conditioning of the 115 VAC input power.

Control/Display Group (CDG)

The CDG consists of a color graphics monitor and a keyboard. The monitor displays operator-entered data and system operation. The keyboard provides the operator interface with the LMS-11.

COLOR DISPLAY MONITOR. —The color display monitor is capable of displaying both composite and RGB video. The computer generates composite video during the start-up and testing of the LMS-11. The RGB input with an external sync is used for displaying graphics during normal LMS-11 operations. The monitor is also equipped with a speaker and audio input to provide the operator with the capability of monitoring the Link-11 audio signal.

KEYBOARD. —The keyboard is mounted on a tray under the monitor. Under the tray, there is a

storage slot for the LMS-11 technical manual. The functional keys on the keyboard are color-coded to facilitate operator selections and entries. The LMS-11 keyboard is shown in figure 5-4.

Many of the keys on the LMS-11 keyboard are not used and the software does not recognize these keys. The actual functions of the keys are covered later in this chapter.

Accessory Group (AG)

The accessory group contains a color graphics printer and spare parts and supplies for the LMS-11. The shipping container is also used to store the DPG and CDG container covers when the printer is removed and mounted on the LMS-11. The color graphics printer is used to provide hard-copy printouts of the display screen on plain paper or clear transparency material.

LMS-11 OPERATION AND DISPLAYS

The LMS-11 provides real-time monitoring of Link-11 operations. Problems with the net can be easily detected in real time and you can determine the cause of the problems by evaluating the different displays. When the cause is determined, the operator or technician can take corrective action.

System Initialization

When the LMS-11 is turned on following the correct power-up sequence, the computer runs a group of self-tests and it then boots the disk in drive 0. When the booting is complete, the LMS-11 monitor displays the following message: **"BOOTING COMPLETE, SWITCH TO RGB."** At this time, the operator should depress the **RGB** button on the monitor. The Initialization display is the first screen displayed after the software is loaded. The operator can also recall the Initialization display by pressing the INIT button of the keyboard. The Initialization display screen is shown in figure 5-5.

During the initialization process, the operator is required to enter the following Link-11 operating parameters:

- DATE and TIME.

- PRINTER. Selects which printer, if any, is being used with the LMS-11.

- NET-MODE. Selects the Link-11 mode: Net Sync, Net Test, Roll Call, Broadcast, or Short Broadcast. The default is Roll Call.

- DATA RATE. Selects whether the link is operating in the fast or slow data rate.

- FREQ-CORR. Enables or disables Doppler correction.

- CALL-TIMEOUT. Allows the operator to specify the number of frames for the missed call timeout. Normal link operations is 15 frames but is increased to 127 frames for satellite link operations.

When all the required data is entered, the operator should select the desired mode of operation for the LMS-11. The five on-line modes are as follows: LINK MONITOR, NET, PU, SPECTRUM, and CARRIER SUPPRESSION.

Each mode has a unique display screen. All display screens consist of the following three parts: the header, the link signal or information area, and the status display. The header is at the top of the screen and indicates the mode being displayed. information area is the middle section of the display, and the status display is at the bottom of the screen. The status display is the same for all on-line modes.

Link Monitor Mode

The link monitor mode display reflects link activity in real time. This display allows the operator or technician to monitor link operations and detect problems as they occur. To select the link monitor mode, the operator presses the function key labeled LM. The link monitor mode display is shown in figure 5-6.

```
                              INITIALIZATION

        DATE:  01/15/96                              TIME:  0:  1:19




                                PRINTER
                   ┌─────────────────────────────┐
                   │ NONE PAINTJET PRINTRONIX     │
                   └─────────────────────────────┘


          NET-MODE          DATA-RATE        FREQ-CORR       CALL-TIMEOUT
        NSYNC NTST RC       FAST SLOW         ON OFF              15
           BC SBC


     XMT-ADDRS
   ┌───────────────────────────────────────────────────────────────────┐
   │ LMS:    LNS PRE PHA CC1 CC2 EOT NOIS DATA REC:  %DATA: - -   NCT: - - │
   │  ▭                                              ▭                    │
   │                                                                     │
   │                                                                     │
   └───────────────────────────────────────────────────────────────────┘

                                                             38NP0198
```
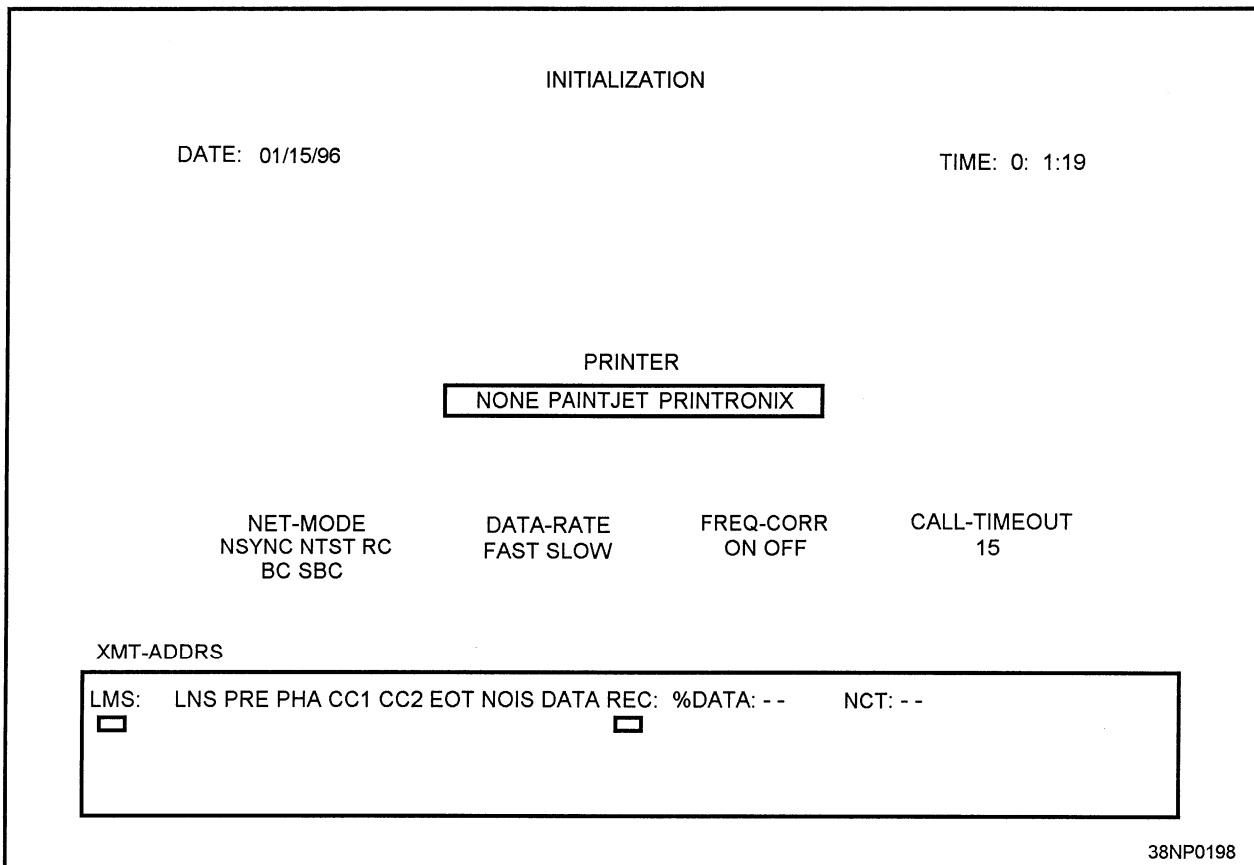
Figure 5-5.—The LMS-11 Initialization display screen.

The top lines of the link monitor display screen contain the header information. The LMS-11 mode is in the top center. The link mode is centered just under the LMS-11 mode. In figure 5-6, this is RC FAST. This means the link is in Roll Call mode, fast data rate. The right side of the header displays the date and time. The left side of the header information allows the operator to enter the NCS address and the sideband to monitor. The LMS-11 uses the address 77 as a default for NCS. However, recall from chapter 2, that 77 is an illegal address and would not be used in an active link. Since NCS never sends an interrogation to itself, the LMS-11 uses this address to designate NCS.

The display sweeps from left to right and from top to bottom. The display is color-coded and uses a stair-step pattern that is easy to understand. The display of a single NCS report and the meaning of the colors and levels is shown in figure 5-7. Figure 5-8 shows how the different messages appear on the LMS-11 link monitor screen. Note that the NCS

report ends with the interrogation of the next PU in the polling sequence.
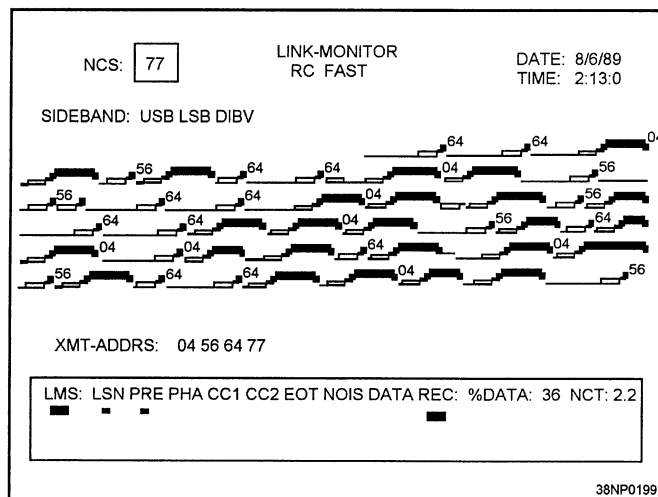
Figure 5-6.—The link monitor display screen.

5-10

Study figure 5-6 again and follow the polling sequence of the four units in the net. The last report on the top line is an NCS report and call to PU 04. This is followed by PU 04's response on the left side of line two. Next, PU 56 is called and responds with a picket reply. Upon completion of PU 56's reply, PU 64 is called. After 15 frame times without a response, PU 64 is called again. PU 64 appears to have responded to the second call, but the LMS-11 only recognized the five preamble frames.

By using the link monitor display, the operator or technician can make sure the connectivity has been established and that all the correct PUs are being polled and are responding.

Figure 5-6 also shows several problems that commonly occur during Link-11 operations. Notice that PU 64 sometimes responds to the first call-up, sometimes to the second call-up, and sometimes PU 64 does not respond at all. PU 56 responds all the time except for the call-up at the end of line two and beginning of line three. On line six there is a double response, or echo, from PU 04. If you were to examine this particular sequence using the frame-by-frame analysis, you would find the PU 04 was called again. This indicates the NCS did not receive the report from PU 04 and repeated the call-up during the middle of the response.

Status Display

As shown in figure 5-9, the status display is at the bottom of each of the LMS-11 display screens. The

Figure 5-8.—Link-11 messages as displayed by the LMS-11 link monitor mode.

status display consists of the status box and two lines of information just above the status box. The top line, with the heading "XMT-ADDRS:" displays the addresses of all PUs in the order they are being polled. The operator can monitor the polling in real time. The displayed addresses change colors to indicate their status. If the address is yellow, it is currently being interrogated. The yellow address turns green when the start code is received. The yellow address turns red when the PU has been interrogated twice and no response is received.

The line under the "XMT-ADDRS:" is used to display system messages and LMS-11 alerts. Alerts are displayed on the left side of this line. System messages are displayed on the right side of the line.

The status box provides the operator with information about signal processing, link activity, and , raw recording of link data. Just below each of the frame types, a small green box, or light, appears to indicate the type of frame being processed. These signal processing status indicators are not displayed in real time. They are updated approximately every 50 milliseconds. The signal processing indicators are as follows:

Figure 5-7.—The link monitor display pattern.

```
XMT-ADDRS:                    20  02  24  06  41  22  31  43  12  24  32  36  36  16  10  04  30  23  15  21  77
OPERATOR ALERTS APPEAR HERE                                                               ERROR MESSAGES APPEAR HERE

        LMS:   LSN    PRE   PHA    CC1  CC2  EOT  NOIS  DATA  REC:  %DATA: 12        NCT: 6.9
         ■                  ■           ■    ■    ■           ■     ■
```
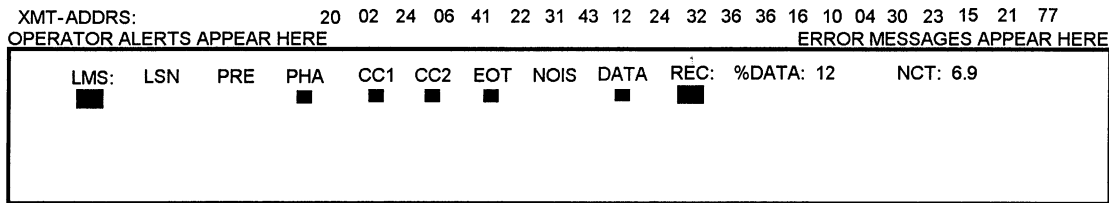
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Figure 5-9.—The LMS-11 Status display.

- **LMS** —Should always be green.

- **LSN** —Indicates that the LMS-11 is listening for the link audio.

- **PRE** —Indicates that a preamble has been detected.

- **PHA** —Indicates that a phase reference frame has been detected.

- **CC1** —Indicates the first frame of a control code.

- **CC2** —Indicates the second frame of a control code.

- **EOT** —Indicates that the LMS-11 has detected the end of transmission.

- **NOIS** —Indicates that the received data frame did not pass the data quality test.

- **DATA** —Indicates that the LMS-11 has detected a data frame that has passed the quality test. Note that the control codes and phase reference frames are also data frames.

- **REC** —Shows the status of the raw record function of the LMS-11. The indicator will be green when the recording is turned on and red when the recording is stopped.

The last two fields of the status box indicate the performance of the net. The "%DATA:" field will be followed by a number representing the percentage of net cycle time message data is transmitted with no errors. The "NCT:" displays the net cycle time in seconds. Net cycle time is the time required for one completed polling of the net. It can be measured from control stop to control stop from NCS, or the operator can specify a PU as the reference for net cycle time. The operator can also specify the number of cycles to use to determine net cycle time. The operator makes these entries using the summarize parameter in the NET DISPLAY mode.

Net Display

The Net Display mode is activated when the operator presses the **NET** key on the keyboard. The Net Display mode presents the following two separate types of information: a Net Summary (summarize mode) or a PU History (history mode). In the Net Summary mode, the Net Display presents a summary of quantitative information about the performance of up to 21 PUs. In the PU History mode, the LMS-11 displays data for a selected PU. The most recent 21 transmissions of the specified PU will be displayed while in the PU History mode.

The Net Display mode is only available when the link is in the Roll Call mode. Figure 5-10 shows a screen for the Net Display in the Summarize mode and figure 5-11 shows the screen for a PU History mode.

After the operator enters the Net Display mode, there are four operator entries that can affect the information and how it is displayed. These are NCS, PU, SIDEBAND, and SUMMARIZE. All of the entries are displayed as part of the header of the Net Display screen. The NCS, PU, and SIDEBAND fields are on the left side of the screen, and the SUMMARIZE field is on the right side of the screen just below the date and time fields.

PU	SIG PWR	SWR	FRAME CNT	% THRU	CF	BER	REL 605	VAR DATA	PHASE ERR M	SD	RFE/DS	NCT
77	0	>34	75	100	15	0	6	1	0	3	0	7.0
2	0	>31	13	100	0	0	6	1	1	2	0	7.0
4	0	>34	5?	0	0	0	6	1	1	2	0	7.1
6	0	>31	11	33	0	20	6	1	0	2	0	7.0
10	-51	0	0	0	100	0	0	0	0	0	0	0.0
12	0	14	5?	0	0	8	5	4	8	18	-2	7.0
14	0	22	11	100	0	0	6	2	5	7	-1	7.0
15	0	>23	15	20	0	23	6	1	2	3	0	7.0
16	0	>31	11	33	0	20	6	1	-1	2	0	7.0
20	-51	0	0	0	100	0	0	0	0	0	0	0.0
21	0	23	5?	0	0	0	6	2	0	6	75	7.0
22	0	23	9	0	0	25	6	1	-1	4	15	7.0
23	0	24	6?	100	0	0	6	1	-3	5	-5	7.0
24	0	22	13	100	0	0	6	1	-3	5	-26	7.0
30	-51	0	0	0	100	0	0	0	0	0	0	0.0
31	0	>31	13	100	0	0	6	1	-1	2	0	7.0
32	0	>34	11	100	0	0	6	1	2	3	0	7.0
36	-51	0	0	0	100	0	0	0	0	0	0	0.0
41	0	>30	13	100	0	0	7	2	1	2	0	7.0
43	0	>33	11	100	0	0	7	3	1	2	0	7.1

NCS: 77   PU: 0   SIDEBAND: USB LSB DIV   NET DISPLAY RC FAST   DATE: 9/29/89   TIME: 0:12:33   SUMMARIZE: [1] CYCLES

XMT-ADDRS: 20 02 24 06 41 22 31 43 12 24 32 36 36 16 10 04 30 23 15 21 77

LMS: ■ LSN PRE PHA ■ CC1 ■ CC2 ■ EOT ■ NOIS DATA ■ REC ■ %DATA: 12 NCT: 7.0

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Figure 5-10.—The LMS-11 Net Display in Summarize Mode.

NCS. —The NCS field allows the operator to designate the PU number of the NCS. When a number is not entered in this field, the default address of 77 is used. It will also be used as the PU number in the polling display of the status area and in the PU field of the Net Display.

PU. —The PU field is used by the operator to designate the PU whose recurring transmission is used to define a cycle. The PU field works with the SUMMARIZE field.

SIDEBAND. —The SIDEBAND field allows the operator to designate which sideband (USB, LSB, or DIV) is used for the information displayed.

SUMMARIZE. —The SUMMARIZE field enables the operator to designate the number of cycles over which the summary is computed. A "cycle" is defined as the recurring transmission from the designated PU. The data is tabulated after the specified number of transmissions are received from the designated PU or after 200 transmissions are received by any station, whichever occurs first. The SUMMARIZE field is also used to enable the PU History mode. The PU History mode is entered when the operator enters a zero in the summary field. When the PU History mode is enabled by the operator, the word **HISTORY** is added to the Net Display title. The PU History mode display updates one line of data immediately after the specified PU has completed its transmission.

The information displayed by the Net Display mode is described in the following paragraphs.

PU. —The PU number. The first number listed is the NCS, which has a default number of 77, or the address entered in the NCS field. The rest of the PUs are listed in numerical order.
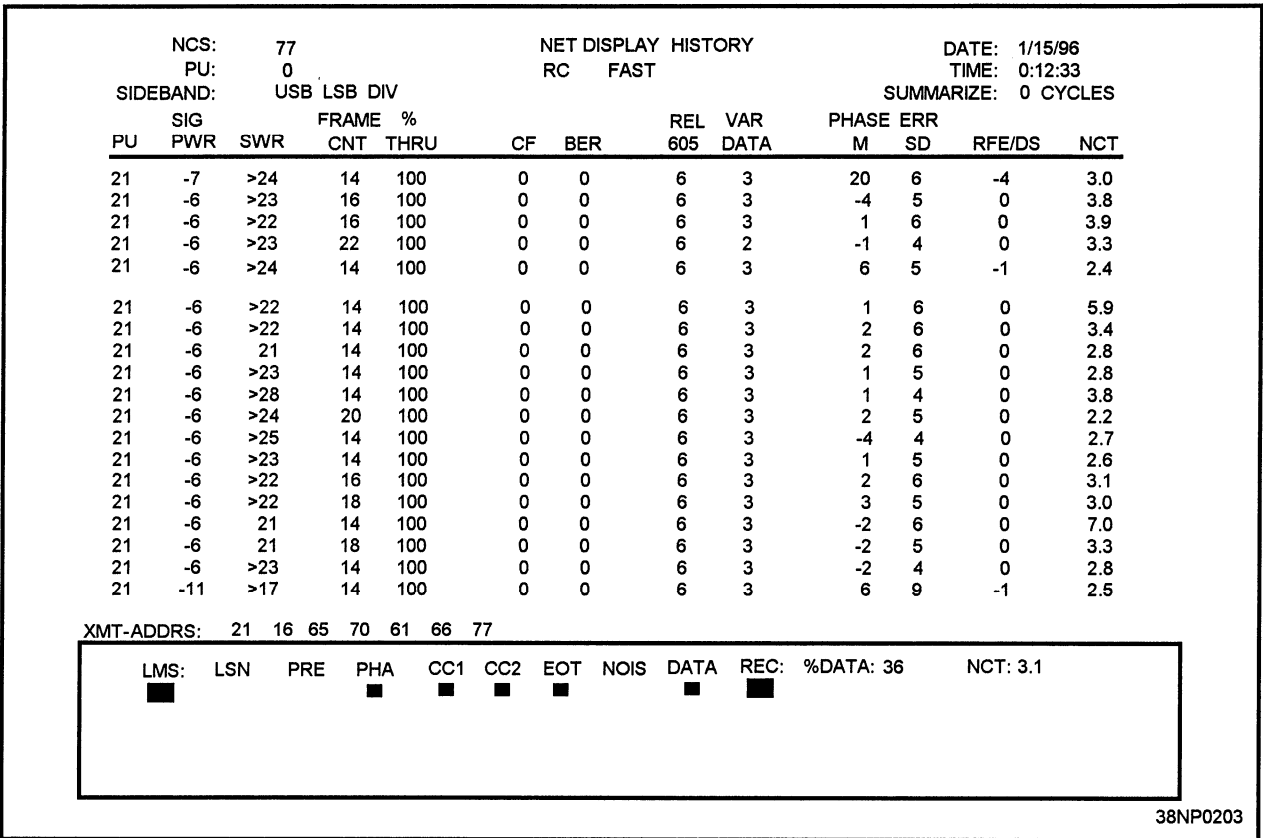
```
        NCS:      77                    NET DISPLAY HISTORY              DATE:   1/15/96
         PU:       0                     RC      FAST                     TIME:   0:12:33
   SIDEBAND:     USB LSB DIV                                          SUMMARIZE:   0 CYCLES
          SIG          FRAME  %                      REL  VAR    PHASE ERR
    PU   PWR   SWR    CNT  THRU      CF   BER        605  DATA     M    SD    RFE/DS    NCT
    21    -7   >24    14   100       0    0           6    3       20    6      -4       3.0
    21    -6   >23    16   100       0    0           6    3       -4    5       0       3.8
    21    -6   >22    16   100       0    0           6    3        1    6       0       3.9
    21    -6   >23    22   100       0    0           6    2       -1    4       0       3.3
    21    -6   >24    14   100       0    0           6    3        6    5      -1       2.4

    21    -6   >22    14   100       0    0           6    3        1    6       0       5.9
    21    -6   >22    14   100       0    0           6    3        2    6       0       3.4
    21    -6    21    14   100       0    0           6    3        2    6       0       2.8
    21    -6   >23    14   100       0    0           6    3        1    5       0       2.8
    21    -6   >28    14   100       0    0           6    3        1    4       0       3.8
    21    -6   >24    20   100       0    0           6    3        2    5       0       2.2
    21    -6   >25    14   100       0    0           6    3       -4    4       0       2.7
    21    -6   >23    14   100       0    0           6    3        1    5       0       2.6
    21    -6   >22    16   100       0    0           6    3        2    6       0       3.1
    21    -6   >22    18   100       0    0           6    3        3    5       0       3.0
    21    -6    21    14   100       0    0           6    3       -2    6       0       7.0
    21    -6    21    18   100       0    0           6    3       -2    5       0       3.3
    21    -6   >23    14   100       0    0           6    3       -2    4       0       2.8
    21   -11   >17    14   100       0    0           6    3        6    9      -1       2.5

  XMT-ADDRS:    21  16  65  70  61  66  77

     LMS:    LSN    PRE    PHA    CC1  CC2  EOT  NOIS  DATA  REC:   %DATA: 36      NCT: 3.1
      ■                    ■      ■    ■    ■          ■    ■


                                                                              38NP0203
```

Figure 5-11.—The LMS-11 Net Display in PU History Mode.

SIG PWR. —The total signal strength of the 16 tones, measured in dBm. A value of -51 indicates that no signal was received.

SNR. —The signal-to-noise ratio, as measured in dB. The SNR is calculated as the average power in the data tones divided by the average power in the noise tones. The LMS-11 can measure a SNR of near 34 dB. A number preface by the greater than symbol ">" indicates that the average power in the noise tones was below the measurable threshold. In this case, the number represents the data tone signal strength only. An SNR value of 30 or higher is considered excellent. An SNR value of less than 10 is unusable.

FRAME CNT. —A count of all data frames received over the specified number of cycles. Data frames include the phase reference frame and control code frames in each message. A value that is followed by a "?" and color-coded yellow is displayed if the frame count of a picket station average is less than or equal to six frames. The two start code

frames, the phase reference frame, the crypto frame, and the two stop code frames would account for the six frames. Therefore, if a picket unit transmits six or less frames, no actual message data is being received and may indicate a problem with the computer or DTS of the unit. A yellow color-coded value followed by the "?" is added for an NCS when the number of frames is equal to or less than eight. The two additional frames account for the next station address at the end of an NCS report.

PERCENTAGE THROUGH. —The %THRU column is a number that indicates the percentage of message data that is received error-free. the percentage is found by comparing the number of error-free message data frames with the total number of message data frames received.

CF. —This is a percentage of control code failures. A PU with strong signals that never misses a call will have a 0 % code failure. A PU that never answers, such as a dummy PU, will have a 100 % code failure.
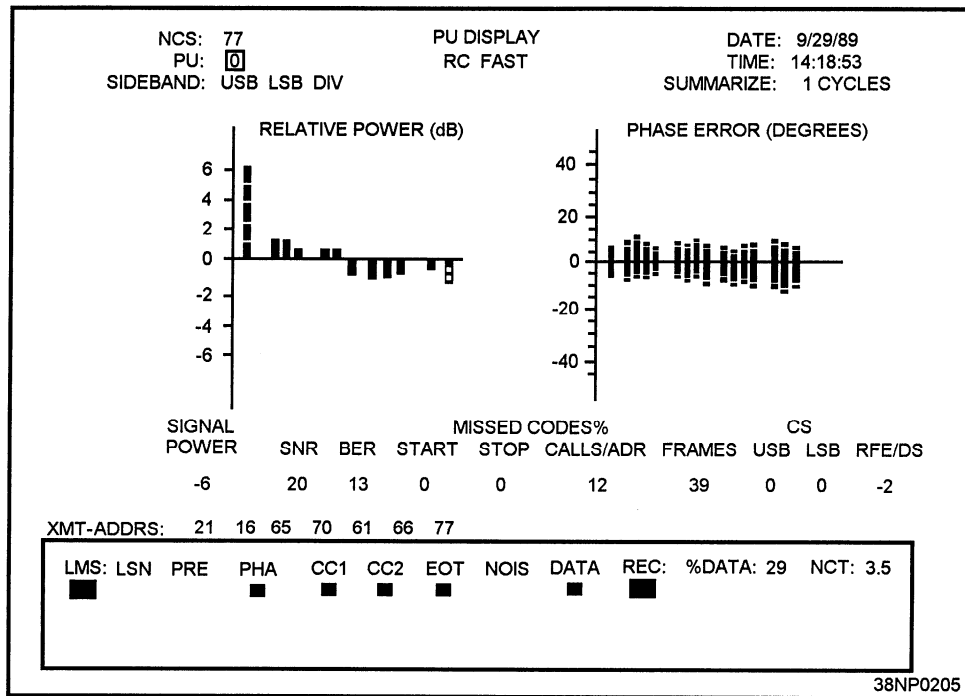
5-14

Figure 5-12.—The LMS-11 PU Display mode.

Values between 1 and 100 could be due to noise or weak equipment or an equipment malfunction.

BER. —This is the bit error rate measured as the number of bit errors per 1,000. Bit errors increase as the signal-to-noise ratio decreases. A bit error rate that exceeds a theoretical value for a given SNR is indicated by displaying both the BER and SNR in yellow.

REL 605. —This column indicates the relative power of the 605-Hz tone with respect to the average power of the 15 data tones, measured in dB. It should be +6 dB.

VAR DATA. —This is the variation of power in the data tones in dB. The relative power of each of the data tones, with respect to the average power of the data tones, is determined. The variation is the difference between the maximum and the minimum. Under ideal conditions, the variation is zero. The TADIL A specification for maximum variation is 1.5 dB.

PHASE ERR M. —This is the mean, or average, phase error of the data tones. The intelligence is stored in the data tones by use of the phase differences that are odd multiples of 45 degrees. If the phase difference of a data frame is 50 degrees when the expected difference is 45 degrees, the error would be 5 degrees. The phase errors for each tone are added up, and after the specified number of cycles, the sum for each tone is divided by the number of frames to obtain the mean phase error for each tone. The mean phase error for all 15 tones is then summed and divided by 15 to obtain the value displayed.

PHASE ERROR SD. —This is the standard deviation of the phase error in all 15 tones.

RFE/DS. —This is the radio frequency error, or Doppler shift, measured in Hertz. If the Doppler correction was enabled during the LMS-11 initialization, the value is color-coded green. If the Doppler correction is turned off, this value is color-coded cyan.

NCT. —This is the net cycle time, as measured from phase reference frame to-phase reference frame,

5-15

of the reporting unit. Note that this measure of net cycle time is different from that used in other NCT calculations.

PU Display

The PU display shows detailed information about the signal received from the specified PU. The PU display can operate in broadcast, short broadcast, and Roll Call modes. In Broadcast and Short Broadcast, the display is updated after every transmission. In Roll Call mode, the display is updated after the specified number of net cycles or 200 transmissions, whichever occurs first. When the net cycles are set to zero, the display updates immediately after the designated PU has transmitted. The PU display is shown in figure 5-12.

The PU display is activated when the operator presses the PU function key on the keyboard. The information in the PU display is presented in two bar graphs with additional amplifying information just under the bar graphs. In the PU display header, the operator enters the address of NCS (or 77), the address of the unit to be evaluated, the sideband to be evaluated (USB, LSB, or DIV), and the number of cycles to summarize for the display. The following paragraphs describe the information presented in the PU display.

RELATIVE POWER (dB). —This bar graph displays the relative power in each of the Link-11 tones. The relative power is calculated with respect to the average of the data tones. The expected values should be +6 dB for the 605-Hz tone (tone 5) and 0 dB for the data tones. The TADIL A specifications allow for a difference of 1.5 dB between the maximum and minimum power levels of the data tones. A noisy signal may cause the power levels of the data tones to deviate considerably from the standard. The bar graph for relative power is also color coded. When the relative power of a data tone is ±1 dB, the bar is green. If the power level is in the range of +1 to +2 dB or –1 to –2 dB, the bar will be yellow. The bar is red if the power level is greater than +2 dB or less than -2 dB. The length of the bars plotted on the graph is rounded off to the nearest 1/2 dB.

PHASE ERROR (DEGREES). —The phase error (degrees) bar graph shows the mean and the standard deviation of the Link-11 tones. The standard deviation of a tone is plotted by a color bar on the graph. The size of the color bars is plotted to the nearest whole degree of deviation. The mean deviation of the tone is indicated by a small white line, usually in the center of the standard deviation color bar. The mean phase error should fall between +45 degrees and -45 degrees. If the data is bad, the mean phase error is set to -45 degrees and the standard deviation is set to 90 degrees. This causes the bar to be drawn across both quadrants of the graph.

The standard deviation is represented by a color-coded bar for each tone. A green bar is displayed if the standard deviation is within 10 degrees. Deviations between 10 degrees and 20 degrees are represented by a yellow bar, and deviations greater than 20 degrees are red. The standard deviation must be a positive value that is less than 45 degrees. If the standard deviation is out of range for a given tone, the data is bad. This condition is indicated by the LMS-11 by setting the mean deviation to 45 degrees and the standard deviation to 90 degrees. As with the mean deviation phase error, this causes the bar to be painted in both quadrants of the graph.

Some causes of phase errors are noise, simultaneous transmissions, poor framing, and errors in Doppler correction due to noise on the preamble. For example, a picket unit transmitting Net Sync during Roll Call will cause an error condition. The expected value of the mean deviation is 0 degrees with a standard deviation of ±5 degrees. If only one tone has a mean value that is greatly different from the other tones, it may be an indication of a frequency error on that tone.

SIGNAL POWER. —The signal power is part of the amplifying information under the two bar graphs. The signal power is the total signal strength in the 16 tones. It is measured in dBm. If no signal is received, the default value of -51 dBm is listed.

SNR. —This is the signal-to-noise ratio. It is measured in dB and calculated as the ratio of the

average power in the data tones to the average power in the noise tones. If the SNR value is preceded by the symbol ">," it indicates that the average power in the noise tones is below the measurable threshold and the actual SNR is greater than the value indicated. The maximum value that the LMS-11 can measure is about 34 dB. An SNR that is greater than 30 dB is excellent. If the SNR is less than 10 dB, the data is unusable.

BER. —This is the bit error rate per thousand. The incidence of bit errors increases as the signal-to-noise ratio decreases.

MISSED CODES PERCENTAGE. —This is a percentage of each type of code that is missed. The number of codes (start, stop, and address call-ups) missed and received is tabulated and the percentage of each type missed is calculated.

FRAMES. —This is the total number of data frames received, including the phase reference and control code frames.

CS. —This field displays the carrier suppression value of the upper and lower sidebands as a ratio of the power in the 605-Hz to the power of the carrier frequency. The value display is measured in dB.

RFE/DS. —The radio frequency error or Doppler shift of the received signal in Hertz. The display is color-coded cyan if frequency correction was disabled during LMS-11 initialization.

Spectrum Display

The spectrum display graphically shows the power levels of all the Link-11 tones and the noise tones that are the odd harmonics of 55 Hertz. The spectrum display screen is shown in figure 5-13. The x-axis of the bar graph is numbered from 1 to 30 to represent 30 tones. Tone 05 is the 605-Hz Doppler tone. Tones 8 through 21 and tone 26 are the data tones. The remaining tones are not used by the Link-11 system but are sampled and displayed to give the operator an indication of the noise level.

The y-axis of the bar graph displays the relative power of each tone in dB. The highest value of the scale is 0 dB and decreases to -40 dB. The tone with the greatest amount of power is set to 0 dB on the scale. This should be the 605-Hz tone. The remaining tones are measured relative to the tone with the greatest power. A single blue line is drawn horizontally across the screen at the -6 dB level. Ideally, all data tones should extend up to this line.

The 605-Hz tone and the data tones are displayed by solid green vertical lines. If the power of a data tone is greater than -6 dB with respect to the 605-Hz tone, the area above the -6 dB line is indicated by an open yellow bar on top of the green bar. If the power level of a data tone is below the -6 dB threshold, an open yellow bar is used to fill in the remaining distance. This allows the operator to view the effects of the noise. The power of the noise tones is also indicated by open yellow bars.

To enter the spectrum display, depress the SPECT key on the keyboard. Several options are available to the operator by entering data into the header fields of the spectrum display. The operator may designate the address of the NCS. The default address is 77. The operator can also select a particular sideband (USB, LSB, or DIV) for display. By using the RESTRICT field, the operator can restrict the display to only data frames or only preamble frames, or choose no restrictions. The PU field allows the operator to designate a particular PU for display. If 00 is entered into the PU field, then the data display is continuously updated with samples from the entire net.

Carrier Suppression Display

The carrier suppression display measures how successfully the carrier frequency is suppressed. The carrier suppression measurements can only be made during Net Sync. To measure the carrier suppression, the radio must be off-tuned by -500 Hz for the upper sideband and +500 Hz for the lower sideband. This off-tuning allows the program to measure and compare the relative power of the carrier frequency and the 605-Hz tone of the preamble.
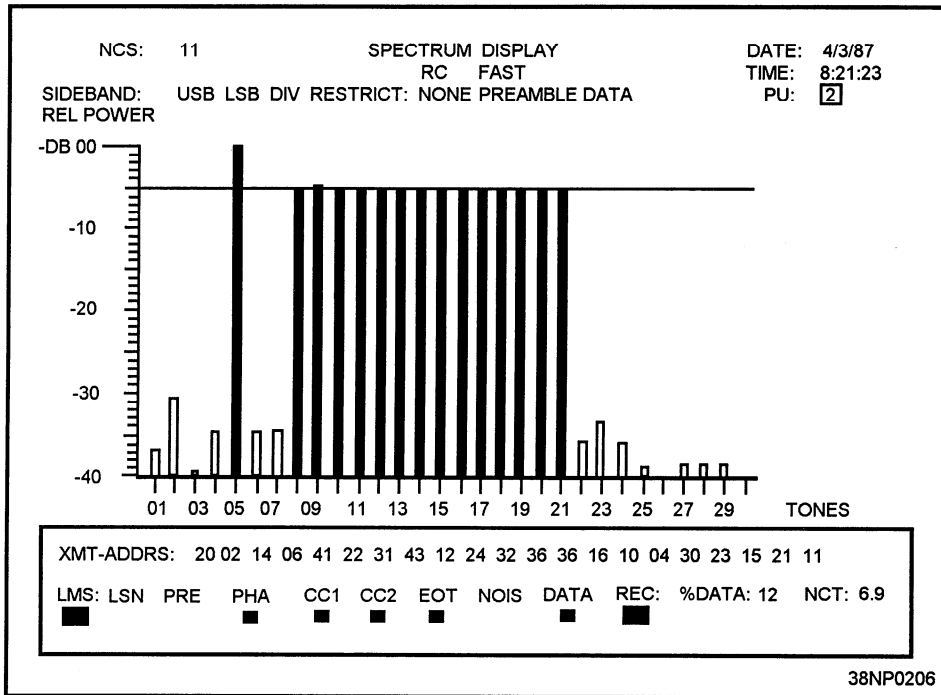
Figure 5-13.—The Spectrum Display screen of the LMS-11.

RECOGNIZING LINK-11 NET PROBLEMS

The LMS-11 is very useful in evaluating Link-11 net quality. As you have seen, the various on-line modes can help you determine various problems. These include a station that is consistently missing call-ups, poor signal-to-noise ratio, and low power from a unit. Some common Link-11 problems and the LMS-11 display are covered in the next few paragraphs.

Figure 5-14 shows an example of how a PU not responding to call-ups would appear on the LMS-11 operating in the Link Monitor mode. When a PU does not respond to a call-up, the reason may be that the incorrect PU number was entered at the NCS or at the DTS of the unit. It can also be caused by a poor receiver at the PU, causing the PU to not receive its call-up. A third problem could be a weak transmitter at the PU, causing the NCS to not receive the response and therefore, repelling the PU.
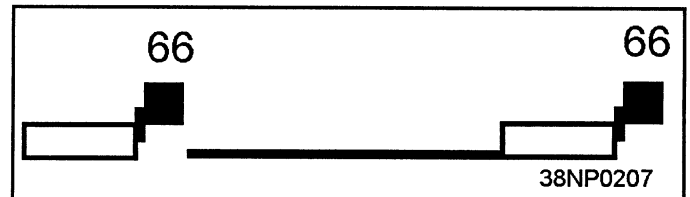
Figure 5-14.—A PU not responding to NCS call-up.

Figure 5-15 shows the display that appears when a PU is responding to NCS call-ups, but the report contains no data. Causes of this problem could be the KG-40 has an alarm, the CDS program is down, or the problem is in the CDS computer to DTS patching.
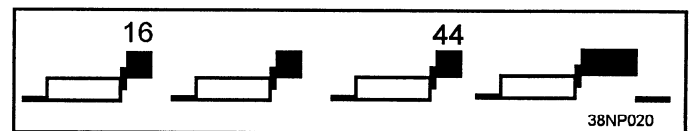

Figure 5-15.—A PU responding with no data.

When NCS fails to receive a stop code from a PU, it causes a stoppage of the net, as shown in figure 5-16. If this condition occurs repeatedly and can be traced to a single PU, the NCS should delete the PU until the stop code problem in the DTS is corrected.
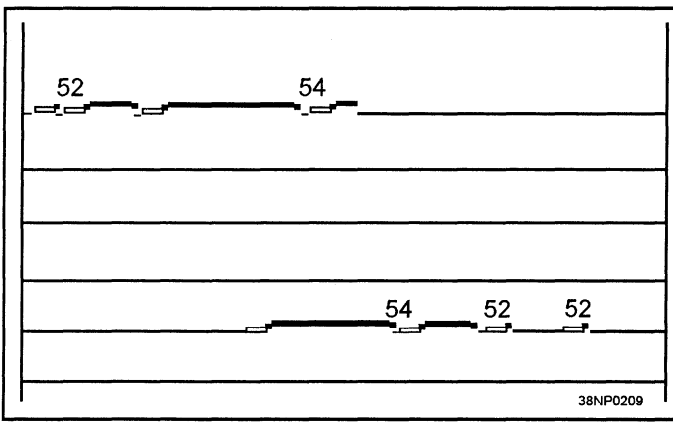
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Figure 5-16.—A net stoppage caused by NCS not receiving a stop code.

Figure 5-17.—Several PUs not responding to NCS call-ups.

Figure 5-17 shows several PUs not responding to call-ups. Some of the causes for this condition could be the following: NCS having an incorrect PU address entered in the DTS, low transmitter power out from NCS, an excessively noisy frequency, or weak PU receivers.
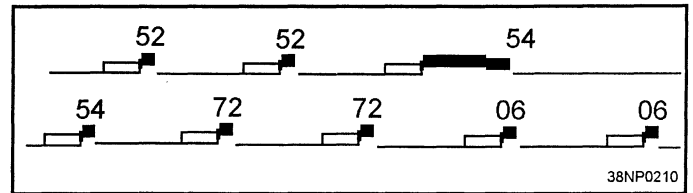
The LMS-11 also has several off-line modes that allow you to save data onto a disk and analyze the data in detail. The off-line modes include a frame-by-frame display to analyze each frame of a transmission. This allows you to analyze the data of a particular PU and shows the status of each bit position. Remember that when you are doing a frame-by-frame analysis, the data has not been decrypted.

More information on all modes of the LMS-11 can be found the *System Operation and Maintenance Instructions, Organization Level, Link Monitor System AN/TSQ-162(V)1,* EE-190-AB-OMI-010/TSQ-162(V)1.

CHAPTER 6

LINK-4A

INTRODUCTION

The Link-4A system is a fully automatic, high-speed data transmission system used for aircraft control. The system provides controlling information to the aircraft, using radio transmission between the controlling ship and the controlled aircraft. The Carrier Aircraft Inertial Navigation System (CAINS) is also a part of the Link-4A system. The CAINS system is used to load alignment and way-point data into the aircraft on the flight deck or the hangar deck.

After completing this chapter, you should be able to:

- **Describe the functions of the Link-4A system.**

- **Describe the operating modes of the Link-4A data terminal set.**

- **Describe the types of messages used by the Link-4A system.**

- **Describe the functional operation of the Link-4A data terminal**

- **Describe the test messages used in the Link-4A system.**

LINK-4A SYSTEM OVERVIEW

The two major components of the Link-4A system are the Link-4A CDS system and the CAINS system. Both systems use serial time-division multiplexing to transmit control and reply messages over a frequency-shift keyed (FSK) UHF radio communications channel. The CAINS system can also transmit data via hard-wired stations on the flight deck or hangar deck.

LINK-4A CDS SYSTEM

The Link-4A CDS system is used to provide one-way or two-way communications between the controlling station and up to 100 controlled aircraft. The controlling station transmits to the aircraft control messages containing vectoring information, commands, and data pertaining to the target or destination of the aircraft. The aircraft transmits reply messages containing information concerning its heading, altitude, airspeed, and tactical readiness. The aircraft control messages are developed by the CDS

computer using radar-derived target data, reply data from the aircraft, and other tactical data.

A typical shipboard Link-4A system configuration is shown in figure 6-1. It consists of the CDS computer, a data terminal set, a communications switchboard, and a UHF radio transceiver.

The CDS computer outputs parallel digital data to the Link-4A data terminal set. Currently, the data terminal set most shipboard installations use is a type of the AN/SSW-1 (U). It will be designated as the AN/SSW-lA/B/C/D/E(U). The data terminal set converts the computer data into a serial time-division multiplexed pulse train that is transferred to the radio transceiver through the communications switchboard. The communications switchboard connects the selected UHF transceiver to the data terminal set. The radio transceiver converts the pulse train into FSK variations in the carrier signal frequency.

After the aircraft receives the transmitted data, it may respond by transmitting data to the controlling
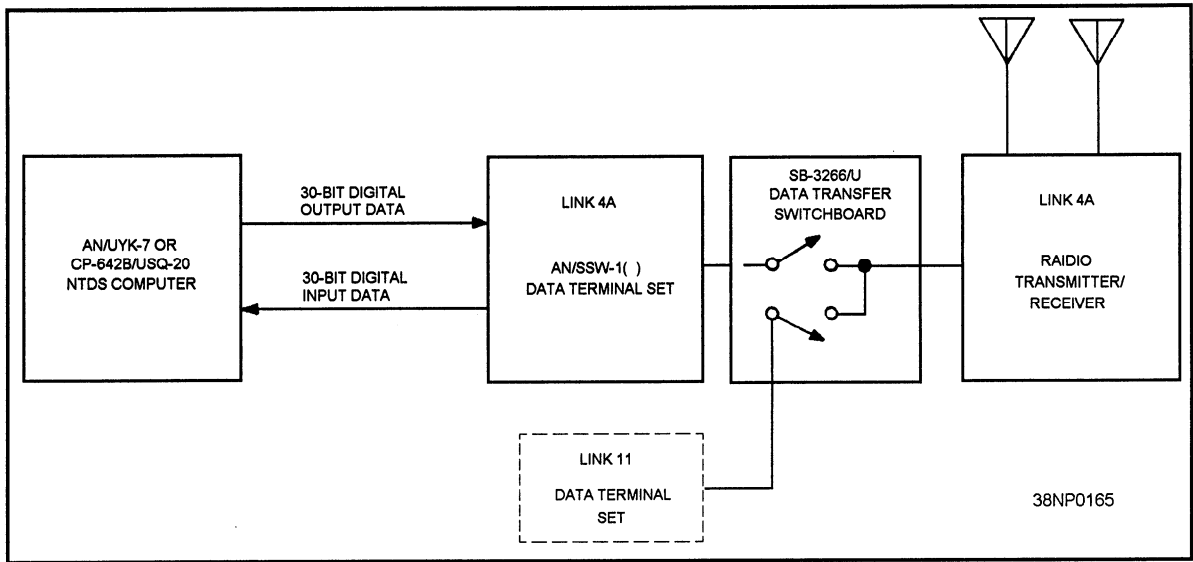
Figure 6-1.—The shipboard Link-4A CDS system.

station. This is the reception cycle. The receiver removes the carrier frequency and forms the serial data pulse train. The pulse train is sent to the data terminal set via the switchboard. The data terminal set converts the serial pulse trains into parallel data and sends the data to the CDS computer.

In a typical aircraft carrier system, the four distinct modes of operation in the Link-4A system are intercept vectoring, air traffic control, automatic carrier landing system, and precision course direction.

Intercept Vectoring

Intercept vectoring enables the controlling ship to guide an aircraft to an intercept point. The two types of data sent to the aircraft during intercept vectoring are command data and situation data. Command data provides direct steering and control information, whereas situation data provides the aircraft with an overall picture of the tactical situation with respect to its target.

This data is used to guide the aircraft within striking range of its target at optimum position and altitude for an attack. The messages also contain instructions to the pilot, such as target identity, break engagement, and return to base.

Air Traffic Control

In the air traffic control mode, Link-4A is used to control the aircraft in the carrier's traffic pattern. The control station transmits data to the aircraft to maintain safe flight patterns and assigns priority for landing approach. As each aircraft enters the landing pattern, it is transferred to the automatic carrier landing system for final approach and landing.

Automatic Carrier Landing System

The automatic carrier landing system selects aircraft in the order of priority from the pattern and enters them into the final approach. During the final approach, a precision radar tracks the aircraft. Correct information pertaining to the approach is transmitted to the aircraft's autopilot. When conditions are unfavorable for a landing, the wave-off control is initiated and the aircraft is guided through a short pattern and the landing approach is repeated.

Precision Course Direction

The precision course direction mode is used in the remote guidance of bomber and reconnaissance aircraft, and drones. The guidance messages contain pitch, bank, heading, altitude, and airspeed commands to permit very precise control of the aircraft's flight path.

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CARRIER AIRCRAFT INERTIAL NAVIGATIONAL SYSTEM (CAINS)

The CAINS system is used to load alignment and way-point data into aircraft on the flight deck or the hanger deck. Aircraft alignment data consists of longitude, latitude, and ship's velocity data from the ship's inertial navigation system. Way-point data is a set of predetermined geographical points loaded into the aircraft's navigation computer. Way points provide the aircraft with destination or target information.

When the CAINS system is used, data can be loaded into the aircraft by either a hard-wired system or RF radio transmission. The hard-wired insertion of data is accomplished when the aircraft is connected to a deck edge outlet box (DEOB). The pulse amplifiers of the AN/SSW-1D/E can provide outputs for up to 40 of these DEOBs. After the initial data is loaded, the aircraft is disconnected from the DEOB, but it continues to receive alignment data until the launch. Then the aircraft system reverts to its original tactical condition.

LINK-4A MESSAGE FORMATS

The following are the three types of messages used in the Link-4A system: **control messages, reply messages,** and **test messages.** These messages use two basic formats. Control messages are transmitted from the controlling ship to the aircraft. Reply messages are transmitted from the aircraft to the control station.

The timing for Link-4A communications is determined from the duration of the transmit and receive cycles. The standard CDS control messages are 14 msec in duration, while the receive cycle for reply messages is 18 msec in duration. The CAINS system does not use reply messages; therefore, a 2 msec receive cycle is substituted to allow time for the Link-4A data terminal set to initialize the next message. Thus we have the following two timing cycles: 14/18 (control message 14 msec/receive cycle 18 msec) and 14/2 (control message 14 msec/receive cycle 2 msec).

CONTROL MESSAGE FORMAT

Control messages are assembled and transmitted during the 14-msec **transmit frame.** Figure 6-2 shows the standard structure of a Link-4A control message. During the transmit frame, the transmit key signal and the control message pulse train are sent to the radio set transmitter. The transmit frame is divided into seventy 200 μsec time slots that contain the **sync preamble,** the **data bits,** and the **transmitter un-key** signal.
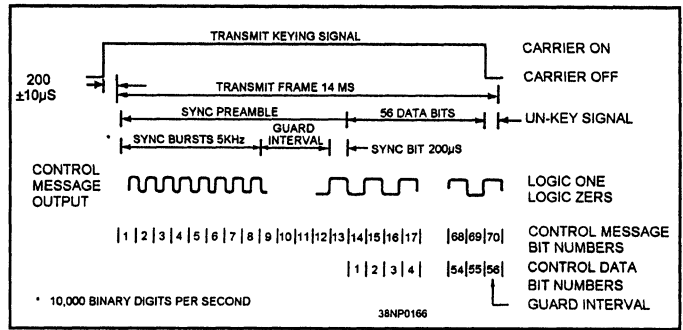

Figure 6-2.—The Link-4A control message format.

Sync Preamble

The sync preamble is made up of the first 13 time slots of the control message. The first eight time slots each contain one cycle of a square wave, consisting of 100 μsec in the "0" state and 100 μsec in the "1" state. These eight time slots are known as the sync burst. Following the sync burst are four time slots in the "0" state, called the guard interval. The guard interval indicates the changeover to the 200-μsec data signals. Time slot 13 is the start bit and is always a "1."

Data Bits

The Link-4A message data is contained in the 56 time slots (slots 14 through 69) that follow the sync preamble. Each time slot contains one data bit. The first 13 bits of this data is a binary number that indicates the address of the particular aircraft. Only the aircraft with this preassigned address will recognize the message and act on the message data. Following the address is a five-digit label that designates the type of data contained in the message. The labels correspond to the modes of operation. The

last digit designates whether the message is an A or B type. In most modes, both an A and a B type of message are required to transmit all the necessary data to the aircraft. The remaining data bit time slots contain the various control commands.

Transmitter Un-key Signal

The last time slot (slot 70) is a 200-μsec period allotted for transmitter turn-off time and does not contain any data.

REPLY MESSAGE FORMAT

Reply messages are received during the 18-msec receive cycle. The reply message contains a total of 56 time slots and occupies a period of 11.2 msec. This 11.2-msec reply must be received during the 18-msec receive cycle. This allows for a maximum of 4.8 msec for transmission delay.

The reply message consists of a sync preamble, 42-data bit time slots, and a guard interval, as shown in figure 6-3. The sync preamble is identical to the control message sync preamble. The information in the 42-data time slots is divided into groups of digits that identify the source and type of message, and the message data. The last time slot is the guard interval and it allows for transmitter turn-off time.
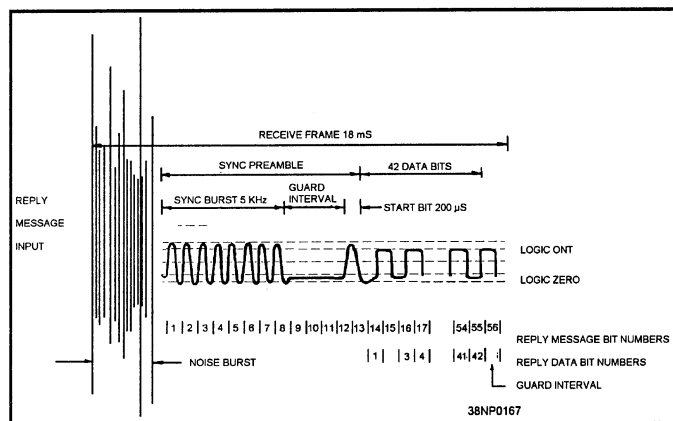

Figure 6-3.—The Link-4A reply message format.

TEST MESSAGES

During Link-4A operations the controlling station sends test messages at periodic intervals to the data terminal set for testing the message processing and display circuitry of the aircraft being controlled. The test messages also check the data terminal set and its interfaces. The two types of test messages are **universal test message** (UTM) and **monitor control and reply messages** (MCM/MRM).

Universal Test Messages

Universal test messages (UTMs) are Link-4A control messages that are always addressed to a particular universal address and contain fixed, specific information in each data field. The UTMs provide the controlled aircraft with a means to verify proper operation of the link.

Monitor Control and Reply Messages

Monitor control messages (MCMs) are Link-4A control messages that are sent to the data terminal set from the CDS computer to initiate internal testing of the data terminal set. After the data terminal set completes its self-check, the MCM is transmitted with the universal address. Depending on the equipment configuration of the aircraft, the MCM will either be rejected or processed as a UTM.

The monitor reply message (MRM) is sent to the CDS computer upon the successful processing of the MCM. The MRM is effectively a return of the MCM data content which indicates that the internal and interface tests were successful.

THE LINK-4A SYSTEM COMPONENTS

The Link-4A system consists of the CDS computer, a data terminal set, a communications switchboard, and a UHF radio set.
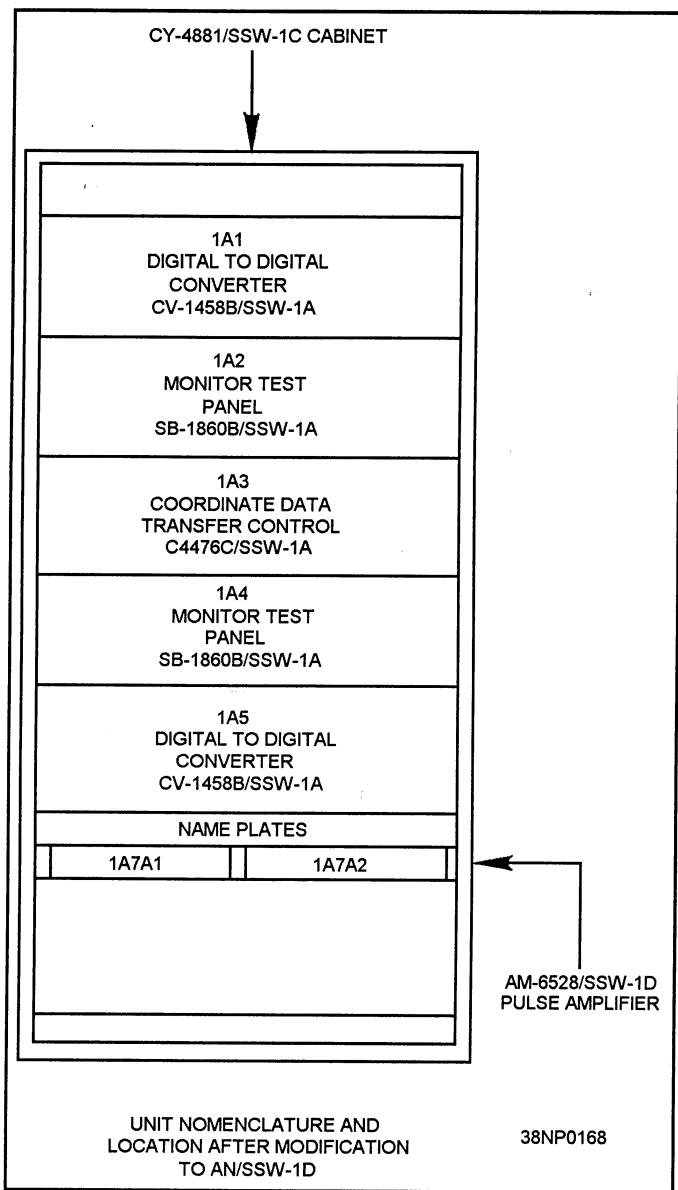
Figure 6-4.—The AN/SSW-1D/E data terminal set.

DATA TERMINAL SET AN/SSW-1D/E

The Link-4A data terminal set is the AN/SSW-lD/E. The data terminal set performs the following functions:

- Provides overall Link-4A system timing

- Converts parallel data from the CDS computer into serial data for transmission to controlled aircraft

- Converts serial data received from controlled aircraft into parallel data for input to the CDS computer.

The current five versions of the AN/SSW-1 used in shipboard Link-4A systems are the AN/SSW-1A, 1B, 1C, 1D, and 1E. The AN/SSW-1A, 1B, and 1C are operationally and functionally identical, as are the AN/SSW-1D and 1E. The major difference between the two groupings of versions is the single-channel capability of the AN/SSW-1A/B/C and the dual-channel capability of the AN/SSW-1D/E. Each of the dual channels is capable of the link operations of the single channel AN/SSW-1. The dual-channel AN/SSW-1D/E is also capable of transmitting CAINS data. For purposes of this lesson, we use the AN/SSW-1D/E.

The AN/SSW-1D/E shown in figure 6-4, consists of the following eight major subassemblies: one **coordinate data transfer control,** two **digital-to-digital converters,** two **monitor test panels,** two
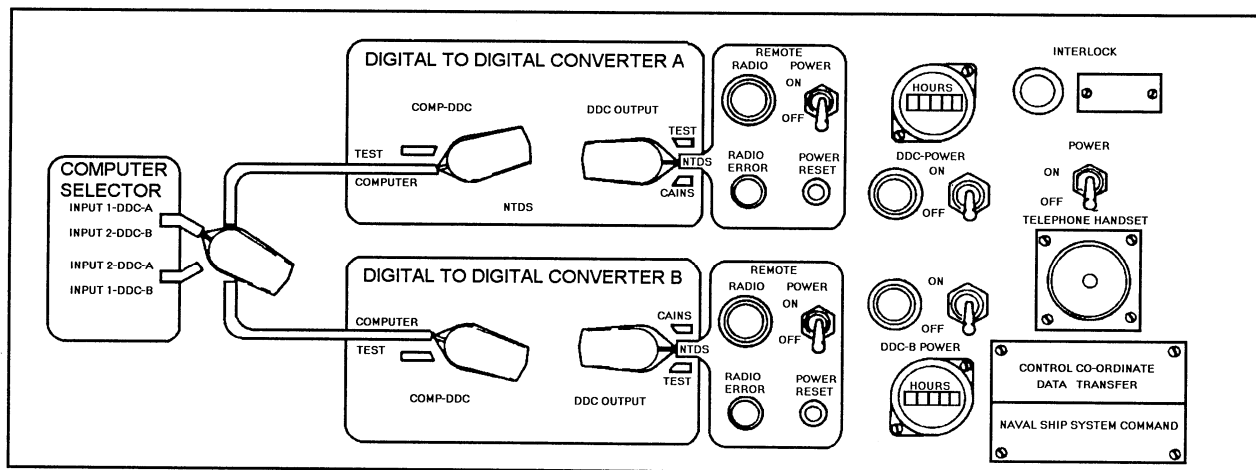
Figure 6-5.—The coordinate data transfer control assembly (AN/SSW-1D/E).

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pulse amplifier assemblies, and a power supply assembly. There are two independent equipment groups in the AN/SSW-1D/E. Each group is capable of simultaneous operations with separate and dedicated computer input-output channels and dedicated UHF radio sets.

Coordinate Data Transfer Control

The coordinate data transfer control assembly enables the connection of each of the digital-to-digital converters (DDC) to one of two different computers. The control panel for the coordinate data transfer control assembly is shown in figure 6-5. The COMPUTER SELECT provides switching, such that DDC A is connected to computer 1 and DDC B is connected to computer 2 or vice versa. Either of the two DDCs maybe connected to its monitor test panel for off-line testing. The DDC output options are the CDS (old NTDS) radio set, the CAINS system, or the test mode.

Digital-to-Digital Converter

The digital-to-digital converter assembly provides system timing, converts parallel data from the CDS computer into serial data for transmission by the UHF radio set, and converts serial data received from the radio set into parallel data for input to the CDS computer. The DDC is the heart of the data terminal set.

Monitor Test Panel

The monitor test panel provides the technician with a means to monitor Link-4A operations and off-line testing capabilities. There is one monitor test panel for each DDC.

Pulse Amplifier

The pulse amplifiers provide level and signal conversion functions to allow the AN/SSW-1D/E data terminal set to drive the serial output for the UHF radio set and the deck edge outlet boxes for CAINS.

COMMUNICATIONS SWITCHBOARD

The communications switchboard interconnects the AN/SSW-1 to the UHF radio sets. The communications switchboard is similar to the Link-11 switchboard described in chapter 4 of this manual.

LINK MONITOR SYSTEM (LMS-4)

The LMS-4 provides stand-alone Link-4A monitor and readiness check capabilities, and its operation is similar to the LMS-11 covered in the previous chapter. The monitor function listens passively to the Link-4A communications between the control station and the controlled aircraft. Signal analysis and test message validity are performed on the data. The readiness check function tests the readiness of the control station to conduct live two-way Link-4A operations. Control messages transmitted by the control station are monitored and the LMS-4 generates the reply messages required to maintain two-way communications.

CHAPTER 7

NEW TECHNOLOGY IN DATA COMMUNICATIONS

INTRODUCTION

The current Link-11 and Link-4A systems are being updated with new equipments. The Data Terminal Set AN/USQ-125 is currently replacing the older Link-11 data terminals. In addition, new communications systems, such as the **Command and Control Processor (C2P)** and the **Joint Tactical Information Distribution System (JTIDS),** are quickly becoming commonplace on various platforms in the Navy. This chapter will introduce you to some of the changes taking place and the basic features of some of the new systems.

After completing this chapter, you should be able to:

● **Describe the various components of the AN/USQ-125 Data Terminal Set.**

● **Describe the operation of the AN/USQ-125 in a typical Link-11 system.**

● **State the purpose of the Joint Tactical Information Data System (Link-16).**

● **Describe the components of the Link-16 system.**

● **State the function of the Command and Control Processor (C2P) system.**

● **Describe the components of the C2P system.**

THE AN/USQ-125 DATA TERMINAL SET

The AN/USQ-125 data terminal set is the newest Link-11 data terminal set in the Navy. It is quickly replacing older DTSs, such as the AN/USQ-36 and the AN/USQ-59. There are several configurations of the AN/USQ- 125. The CP-2205(P)(V)/USQ-125 data terminal with the MX-512P/RC Remote Control Unit configuration. The other configuration is CP-2205(P)(V)2/USQ-125 data terminal with a personal computer (386 or better) running the MXPCR software. The personal computer serves the same function as the remote control indicator in this configuration. The standard interface configuration of the AN/USQ-125 is shown in figure 7-1. In this chapter, we examine the data terminal and the functions of the control indicators, either the MX-512P/RC or a personal computer.
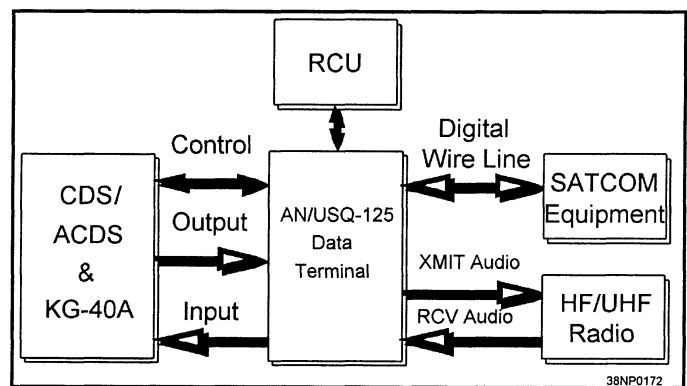

Figure 7-1.—The AN/USQ-125 data terminal set standard interface block diagram.

THE CP-2205(P)(V)/USQ-125 DATA TERMINAL

The CP-2205(P)(V)/USQ-125 data terminal is a compact, state-of-the-art data terminal that is mounted in a standard 19-inch equipment rack. The data
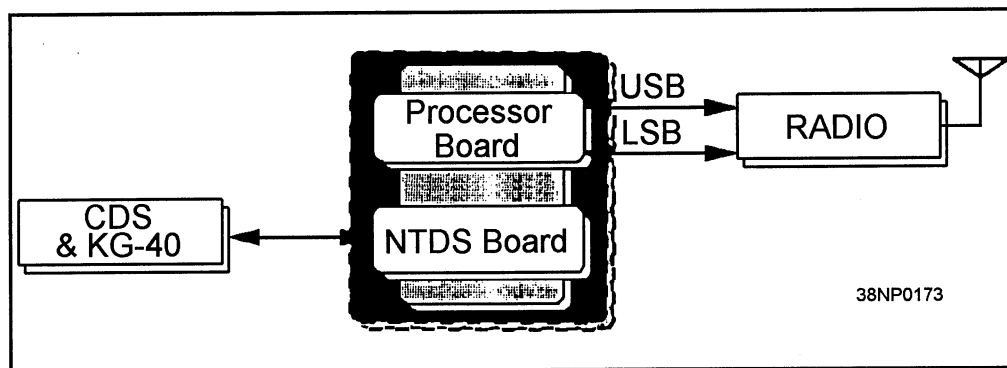
Figure 7-2.—The CP-2205(P)(V)/USQ-125 data terminal block diagram.

terminal has the following three major components: a processor board, a CDS interface board, and the power supply. Figure 7-2 is a block diagram of the CP-2205(P)(V)/USQ-125 data terminal. The processor board performs modulation/demodulation and error detection and correction, and provides the interface with the radio set. The CDS interface board provides the interface with the CDS computer. The CP-2205(P)(V)/USQ-125 data terminal performs many of the same functions as previous Link-11 data terminal sets. These functions include the following:

- Data conversion

- Data error detection and correction

- Control code generation and detection

- Synchronization

- Encryption device data transfer

- Computer and radio control signals for two-way Link-11 data transfers

In addition, the CP-2205(P)(V)/USQ-125 data terminal provides the following new features:

- Both multi-tone and single-tone waveform operations

- Enhanced Link Quality Analysis (ELQA)

- Maximum useable frequency (MUF) option

- Multi-Frequency Link

- On-line and Off-line System Test Options

Multi-Tone Waveform Link

Multi-tone link operations are basically the same as in the previous Link-11 data terminal sets and are called conventional Link-11 waveforms. The data terminal generates the 605-Hz Doppler tone and 15 data tones. The frequencies of the data tones are the same as described in chapter 4. Message formats and modes are also the same.

Single-Tone Waveform Link

Single-tone waveform link updates the 1960's technology used in data communications. The single-ton waveform is a 1,800-Hz phase-modulated waveform containing the Link-11 data in a serial bit stream. The single-tone waveform is most commonly used with the wire-line option of the USQ-125 data terminal. The CP-2205(P)(V)/USQ-125 data terminal wire-line option provides an interface port that can be used with a standard wire-line or a satellite modem. Using this option expands the means in which Link-11 data can be exchanged, overcoming the limitations of the traditional UHF and HF radio links.

Enhanced Link Quality Analysis (ELQA)

The Enhanced Link Quality Analysis option of the data terminal incorporates almost all of the functions of the LMS-11. This allows the operator to monitor and evaluate the performance of the link net. Information that can be displayed includes the

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following: sideband power, error rate, and percentage of interrogations answered.

Maximum Useable Frequency (MUF) Option

The maximum useable frequency option is a routine that calculates the optimum frequency for Link-11 operations. This routine calculates a frequency for each hour of the day based on geographic location, the range of other participants in the net, and sunspot activity.

Multi-Frequency Link

The multi-frequency link option improves current link operations. by simultaneously using four frequencies. The normal configuration for multi-frequency link operations uses three HF and one UHF frequency. To implement this option, three additional processor boards are installed in the data terminal. Each data terminal board is connected to a separate radio, as shown in figure 7-3.
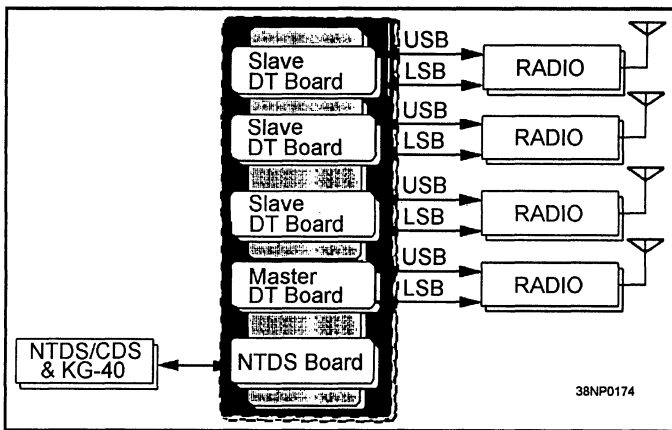

Figure 7-3.—Block diagram of the AN/USQ-125 data terminal configured for multi-frequency link operations.

During the Link-11 receive cycle, each data terminal board demodulates the link signal and sends the data to the master processor board. The master processor compares the received data and selects the signals with the fewest errors to send to the CDS computer. Although this mode is normally used with three HF frequencies and one UHF frequency, there is no set limitation of the radio configuration.

On-line and Off-1ine System Test Options

The data terminal provides several options for both on-line and off-line testing. These include the following: radio echo test, loopback tests 1, 2, 3, and 4, and DTS fault isolation tests. The radio echo test, loopback test 1, and loopback test 4 are on-line tests, while loopback test 2, loopback test 3, and the DTS fault isolation tests are off-line tests.

RADIO ECHO TEST. —When this option is selected, the data terminal is placed in full-duplex mode. This option is selected when a single station POFA is run with the radio and checks the operation of the computer interface, the crypto device, the data terminal, and the radio.

LOOPBACK TEST 1. —Loopback test 1 is selected when running a single station POFA without the radio. When you select this test option, the audio lines are internally disconnected from the radio and the audio outputs are connected to the audio inputs. Full-duplex operation is also enabled. This test checks the operation of the computer interface, the crypto device, and the data terminal.

LOOPBACK TEST 2. —Loopback test 2 configures the data terminal for an off-line self-test. The audio lines are disconnected from the radio and the audio output lines are internally jumpered to the audio input lines. A test message is internally generated and sent through the audio circuits. The receiver output is monitored for data errors, parity errors, control code errors, and preamble recognition. Any errors detected will cause the LOOPBACK FAIL indicator to be displayed.

LOOPBACK TEST 3. —Loopback test 3 is a data terminal to radio test. Normal audio connections are maintained, while the computer interface is disabled. A test message is internally generated and repeatedly sent through the radio. As with loopback test 2, the receiver output is monitored for data errors, parity errors. control code errors, and preamble recognition. Any errors detected will cause the LOOPBACK FAIL indicator to be displayed.

LOOPBACK TEST 4. —Loopback test 4 is used to check the operation of the computer interface, the crypto device, and the data terminal interface circuitry. When this test is selected, the audio circuits are disabled and the data from the computer is sent to the memory in the data terminal. Upon receipt of the end of transmit signal, the data in memory is sent back to the computer for evaluation.

DTS FAULT ISOLATION TESTS. —The DTS fault isolation tests are built-in tests (BIT) designed to test and isolate a fault to a particular circuit board.

REMOTE CONTROL UNIT

The C-12428/USQ-125 remote control unit (CU) enables the operator to control the data terminal from a remote location. The control unit, used with the data terminal, forms the data terminal set (DTS). The control unit is used by the operator to enter operating parameters, start and stop link operations, and change link modes. One model, shown in figure 7-4, consists of a 486DX2/66 MHz AT compatible personal computer in a rugged chassis for shipboard operation. The keyboard/trackball unit is in a special detachable enclosure that also serves as a front cover for the CU. A 386 or better personal computer maybe substituted for the control unit when loaded with the proper software and connected to the data terminal.
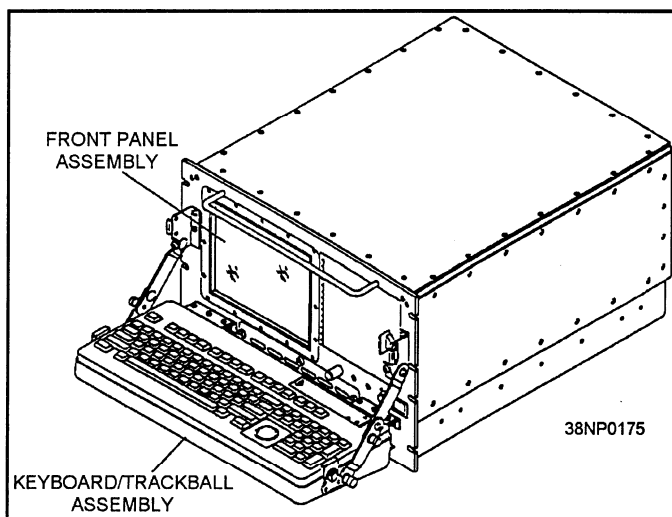

FRONT PANEL ASSEMBLY

KEYBOARD/TRACKBALL ASSEMBLY

38NP0175

Figure 7-4.—The C-12428/USQ-125 Control Unit.

THE JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM (LINK-16)

The Joint Tactical Information Distribution System (Link-16) is a new tactical data link that was introduced to the fleet in 1994. Link-16 has been referred to by several names and acronyms. The Tactical Digital Information Link (TADIL) is a term used by the U. S. Joint Services. The TADIL designation for Link-16 is TADIL J. The Joint Tactical Information Distribution System (JTIDS) refers to the communications component of Link-16. The communications component includes the terminal software, hardware, RF equipments, and the waveforms they generate. The NATO terms for JTIDS is the Multifunctional Information Distribution System (MIDS). For our purposes, we will use the term Link-16 when referring to this system.

FEATURES OF LINK-16

Link-16 allows for the exchange of real-time tactical information between units of the Navy, the Joint Services, and the members of NATO. Although some of the functions are identical to the functions of Link-11 and Link-4A, Link-16 also provides data exchange elements that the other link systems lack. These include the following:

● Nodelessness

● Jam resistance

● Flexibility of communication operations

● Separate transmission and data security features

● Increased numbers of participants

● Increased data capacity

● Network navigation features

● Secure voice capabilities

Transmission Protocols

Since Link-16 exchanges much of the same data that is used in both Link-11 and Link-4A, a brief comparison of the architectures, the capacities, and the data rates of the three systems is useful.

During normal operation, Link-11 operates using the protocols of the Roll Call mode. In this mode, each participating unit is polled by the NCS to transmit data. On completion of data transmission, the unit returns to the receive mode and the next unit is polled until all units have been polled. This cycle is continuously repeated. Link-11 messages are called **M series** messages.

Link-4A uses the time-division multiplexing principle with a command-and-response protocol to enable the operator to control multiple aircraft independently on the same frequency. Link-4A messages sent to the controlled aircraft are referred to as **V series** messages and messages received from the controlled aircraft are called **R series** messages.

Link- 16 uses the **Time-Division Multiple Access (TDMA)** principle of data communications. Using this architecture with time interlacing provides the system with multiple and apparently simultaneous communications nets. Instead of assigning each unit a PU number, Link-16 assigns each unit a **JTIDS Unit** number, or **JU.** The JU identifies the units and determines a preassigned set of time slots that designate when the unit transmits and receives data. Each time slot is 1/128 of a second, or 7.8125 milliseconds, in duration.

When a JU transmits data, the frequency that the data is transmitted on is changed every 13 microseconds (μsec), according to a predetermined pseudo-random pattern. Link-16 uses 51 different frequencies for data exchange. This **frequency hopping** adds to the security and integrity of the system by making it nearly impossible to jam.

Link-16 Nets

Link-16 has the capability to handle multiple nets. A Link-16 net is a group of participants sharing mutually beneficial tactical information. For example, using the Link-11 system, a net is formed by a group of participants. These participants operate on the same frequency. A separate net is formed when another group of participants operates on a different frequency. The second net would be used by participants involved in a fleet exercise that wouldn't want the exercise data to interfere with the normal tactical net. The controlling station and aircraft using Link-4A is also a net.

Link-16 has the ability to form multiple nets. The Link-16 system has 128 numbers used to designate particular nets (00-127). Net number 127 is reserved to indicate a stacked net. A **stacked net** is formed by setting up the time slots so that they have the same set, initial slot number, and recurrence rate. When the system is initialized, the use of net number 127 indicates a stacked net is to be used and the operator can then specify locally which net to use for operations. Figure 7-5 illustrates the concept of a stacked net used for air control. Net 1 is a group of aircraft controlled by the ship, while Net 3 is a group of aircraft controlled by an E-2. If the E-2 requires additional aircraft, the ship can direct the aircraft under its control to the E-2. As the aircraft approaches the E-2, the pilot can switch to Net 3 and immediately become an active participant in the new net. Even though the operator has several nets available to monitor or use, a single terminal can transmit or receive on only one of them for each time slot. Stacked nets are possible because the frequency-hopping pattern is different for each net. Examples of stacked nets are voice nets and control nets.
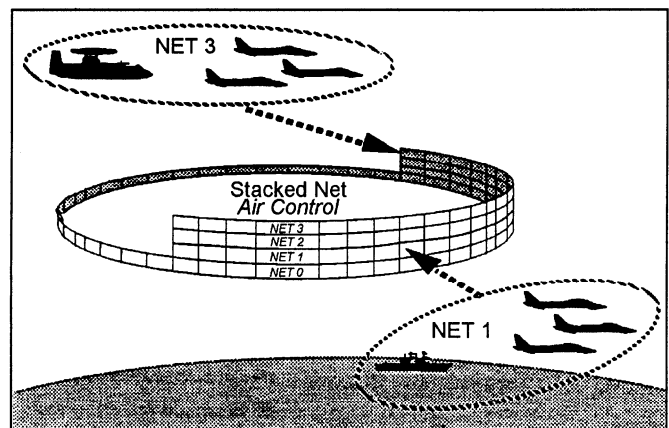
38NP0176

Figure 7-5.—Stacked nets using Link-16.

Link-16 Data Exchange

Link-16 transmits data serially using 70 bit data words. During the transmit time slot, either three, six, or 12 data words can be transmitted. The number of words transmitted depends on whether the standard, packed-2, or packed-4 data packing structure is used. The number of words that composes a Link-16 message is variable but is normally 1, 2, or 3 words. There are three types of messages: fixed format, free text, and variable format. The fixed format messages are called J-series messages and are used to exchange tactical information. Free text messages are used for voice communications, while the variable format messages are user defined in length and content. Variable format messages are not used by the Navy.

JTIDS Architecture

There are several features of the JTIDS architecture that have resulted in improved communications of the Link-16 system. These features include the following:

- Nodelessness

- Security

- Network participation groups

NODELESSNESS. —A **node** is a unit required to maintain communications of a data link. In Link-11, the NCS is a node. If the NCS goes down, the entire net is inoperative. Link-16 does not need a dedicated station. When the Link-16 net is established, a single JU transmits a **Network Time Reference (NTR).** The time established by this unit is the network system time. All other units in the net use the NTR message to synchronize with the network. Once the NTR and the network have been established, the network can continue to operate regardless of the participation of any particular unit.

SECURITY. —The security of the Link-16 system is vastly improved over that of the Link-11 system. In Link-16, both the data and the transmissions are encrypted. Data is encrypted by a

cryptovariable for message security. The security of the data transmission is provided by the use of a second cryptovariable that controls the transmitted waveform. Frequency hopping to prevent jamming is one of the features of the security system. The transmission security also provides for the introduction of jitter and a pseudo-random noise to be added to the waveform. The addition of jitter and noise, along with the frequency hopping, makes the transmitted signal extremely difficult to detect and jam.

NETWORK PARTICIPATION GROUPS. —The time slots of a Link-16 network can be broken down into separate **Network Participation Groups (NPGs).** An NPG is defined by its function and determines the types of messages that are transmitted on it. Some of the NPGs used by the Navy are as follows:

- Surveillance

- Electronic Warfare

- Mission Management

- Weapons Coordination

- Air Control

- Fighter-to-Fighter

- Secure Voice

- Precise Participant Location and Identification (PPLI) and Status

By dividing the net into NPGs, each JU can participate on only the groups that support the mission of the unit. Most Navy Command and Control (C^2) units, both ships and aircraft, operate on all the defined NPGs except the Fighter-to-Fighter NPG.

Link-16 New Capabilities

The increased size of the Link-16 enables the reporting of up to three times as much tactical information as was available under the Link-11

system. Areas that have been improved under the Link-16 system include the following:

- Number of Participants

- Track Numbers

- Track Quality

- Track Identification

- Friendly Status

- Granularity of Measurement

- Relative Navigation

- Electronic Warfare

- Land Points and Tracks

NUMBER OF PARTICIPANTS. —The number of units that can participate in a Link-16 net has been increased dramatically over that of Link-11. The JTIDS Unit number, or JU, is a five-digit octal number from 00001 to 77777. This allows for a maximum of 32,766 possible JUs. Addresses 00001 to 00177 are normally assigned to units that have the need and capability to participate in both Link-16 and Link-11. When a unit participates in both Link-11 and Link-16, it must use the same address on both links. For example, Link-16 JU 00043 is the same as Link-11 PU 043.

TRACK NUMBERS. —Link-l6 replaces the old four-digit (octal) Link-11 track numbers with a five-character alphanumeric track number. The track number can be within the range 00001 to 77777 (octal) or 0A000 through ZZ777. This allows for a maximum of 524,284 track numbers, compared with the 4,092 available with Link-11. One reason for the need for the additional track number is that Link-16 cannot operate in the track number pool mode, in which a common pool of track numbers is shared by several PUs. Every JU must be assigned a unique block of track numbers.

To maintain interoperability with Link-11, Link-16 track numbers 00200 through 07777 designate the same track as Link-11 track numbers 0200 through 7777.

TRACK QUALITY. —The Track Quality (TQ) value used by Link-16 relates to the accuracy of the reported position of the track. The TQ has a range of 0 to 15. To achieve the highest track quality, the track must be within 50 feet of the reported position. Link-11 uses the update rate to determine track quality. Using Link-11, a track that is reported by a PU at every interrogation is usually assigned a TQ of 7. Therefore, a Link-11 air track with a TQ of 7 can be more than 3 nautical miles from its reported position.

TRACK IDENTIFICATION. —The Link-16 system greatly expands the information that is reported with Track Identification (ID). The new ID reports include fields for platform, activity, specific type, and nationality of the track. Additional provisions have also been added to identify a track as "Neutral," and the Unknown Assumed Enemy ID is changed to "Suspect."

FRIENDLY STATUS. —The Link-16 system also provides for more detailed status reports from friendly aircraft. The following fields are added to Link-16 friendly status reports: equipment status, ordnance inventory, radar and missile channels, fuel available for transfer, gun capability, and station ETA and ETD.

INCREASED GRANULARITY. —Granularity refers to how precisely an item is reported in the link message. Link-16 has made major improvements in the granularity of reports concerning track position, air track speed, altitude, and lines of bearing.

LINES AND AREAS. —The Link-16 system allows the reporting of multi-segment lines and areas of all sizes and descriptions. Link-11, for comparison, only allows reports of areas that are limited in size and are circles, ellipses, squares, or rectangles. Link-11 does not have the capability to report lines.

GEODETIC POSITIONING. —The Link-16 messages use the geodetic coordinate system to report positions. This system uses latitude, longitude, and altitude to report positions anywhere in the world. Link-11 uses the Cartesian coordinate system, which requires the reporting unit to be within a certain range when reporting positions.

RELATIVE NAVIGATION. —The Relative Navigation (RELNAV) function of the Link-16 system is automatically started by every Link-16 participant and is constantly operating. The RELNAV function determines the distance between reporting units by measuring the arrival times of transmissions and correlating them with the reported position of the unit. This information is required by each terminal in the network to maintain synchronization. The RELNAV data can also improve a unit's positional accuracy. Also, if two or more units have accurate geodetic positions, RELNAV can provide all other units with accurate geodetic positions.

ELECTRONIC WARFARE. —The Link-16 system increases the types and amount of electronic warfare information that is exchanged between units.

LAND POINTS AND TRACKS. —The Link-16 system adds Land as a track category, and allows the reporting of land objects, such as buildings or vehicles.

EQUIPMENT CONFIGURATION

Currently, Link-16 will be installed onboard aircraft carriers, cruises, destroyers, and amphibious assault ships. Two phases of shipboard installation, designated Model-4 and Model-5, are planned.

Model-4 is being installed on ACDS and AEGIS platforms in conjunction with the installation of the Command and Control Processor (C2P). Model-4 does not implement any of the expanded data exchange capabilities of Link-16. Instead, it supports existing Link-11 and Link-4A with its jam-resistant, increased capacity waveform. Platforms with the Model-4 Link-16 system will retain their original

Link-11 and Link-4A systems, and can use these systems by placing the C2P in bypass. Model-4 is being installed on very few ships, most of which will be upgraded to Model-5; therefore, our discussion of Link-16 equipment will concern the Model-5 system.

Link-16 Model-5

The major components of the Link-16 system are the Tactical Data System (TDS), the C2P, and the JTIDS terminal, as shown in figure 7-6. The TDS and C2P provide the JTIDS terminal with tactical data to be transmitted. The Link-16 Model-5 fully implements all the capabilities of Link-16. For this implementation to take place, major software changes must be made to the TDS and C2P programs. Also, the OJ-663 console replaces the current display
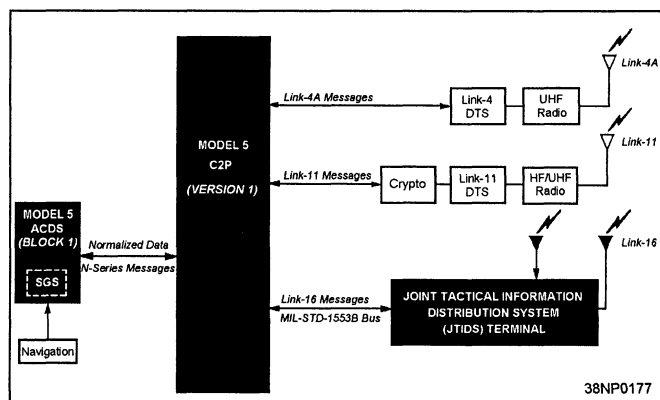

Figure 7-6.—The Link-16 Model-5 ACDS system block diagram.

Data flow to the Link-16 JTIDS terminal is from the ACDS computer, through the C2P computer, to the Link-16 computer. Link data generated by the ACDS computer is now *normalized* to be independent of any one particular link system. The C2P computer reformats the normalized data into the format necessary for transmission over Link-16. The C2P computer can also format the normalized data for transmission over Link-11 and Link-4A. If necessary, all three link systems can be in operation at the same time.

The JTIDS Terminal

The JTIDS terminal used in Link-16 is the AN/URC-107(V)7. This is an advanced radio system that provides secure, jam-resistant, digital data and voice communication among a large number of users. This radio system combines the functions performed by the Link-11 crypto device, data terminal set, and radio into one cabinet. Many other capabilities are also incorporated in the radio. These added capabilities include the following:

- Precise participant location and identification

- Relative navigation

- Synchronization

- Secure voice

- Relay

- Built-in test

Shipboard Terminal

The AN/URC-107(V)7 JDIDS terminal is a single five drawer electronics cabinet, as shown in figure
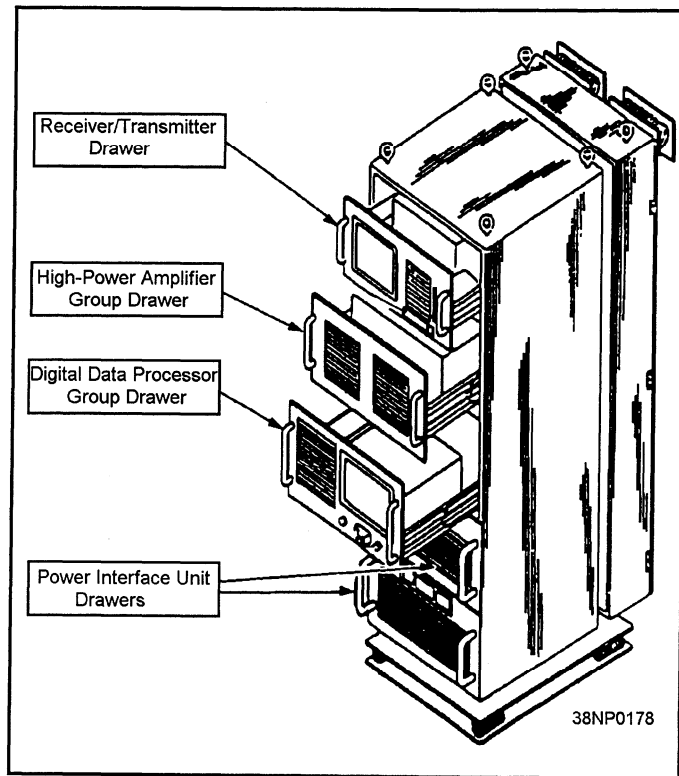
Figure 7-7.—The AN/URC-107(V)7 JTIDS data terminal.

7-7. The components of the JTIDS terminal include the **Digital Data Processor Group** (DDPG), the **Receiver/Transmitter Group** (R/T), the **High-Power Amplifier Group** (HPAG), and the **Power Interface Unit** (PIU). The **Secure Data Unit** (SDU)
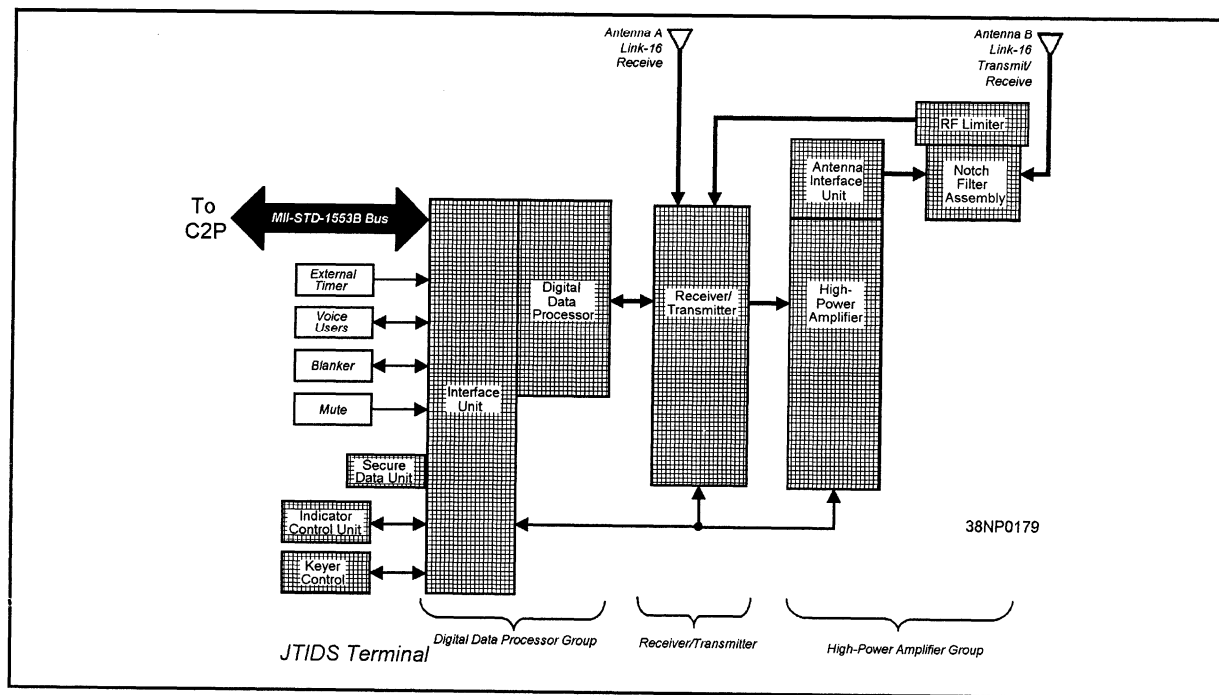

Figure 7-8.—The JTIDS terminal functional block diagram.

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is a separate assembly that is mounted to the Digital Data Processing Group. Figure 7-8 is the functional block diagram of the JTIDS terminal.

DIGITAL DATA PROCESSOR

GROUP. —The third drawer of the terminal houses the digital data processor group. The two major components are the **interface unit** (IU) and the **digital data processor** (DDP). A battery assembly is mounted to the front of the DDPG drawer. This assembly consists of one nickel cadmium (NiCad) battery and two lithium sulphur dioxide cells. The NiCad battery will provide power to critical components during short power failures. The lithium sulphur dioxide cells supply power to the chronometer.

The Interface Unit controls the communications between the JTIDS terminal and the host computer and provides amount for the Secure Data Unit (SDU). On shipboard systems, the C2P is the host computer. The **Subscriber Interface Computer Program** (SICP) is a software program that controls the communications with the host computer and provides the data processing necessary to integrate the terminal and the host computer. The IU and SICP also provide

the following functions: analog-to-digital and digital-to-analog conversion of voice signals, feed through interface between the DDP and the SDU, and primary and backup power interface. The IU also provides the interface for receiving and supplying the TACAN blanking pulses. These blanking pulses prevent the TACAN and the JTIDS terminal from transmitting at the same time.

The Digital Data Processor (DDP) controls the receiver/transmitter and the high-power amplifier groups. The DDP performs the processing required for transmitting and receiving Link-16 messages. This processing includes the following:

- Data encryption and decryption

- Error detection and correction encoding and decoding

- Generation of the frequency-hopping pattern

- Selection of the carrier frequency

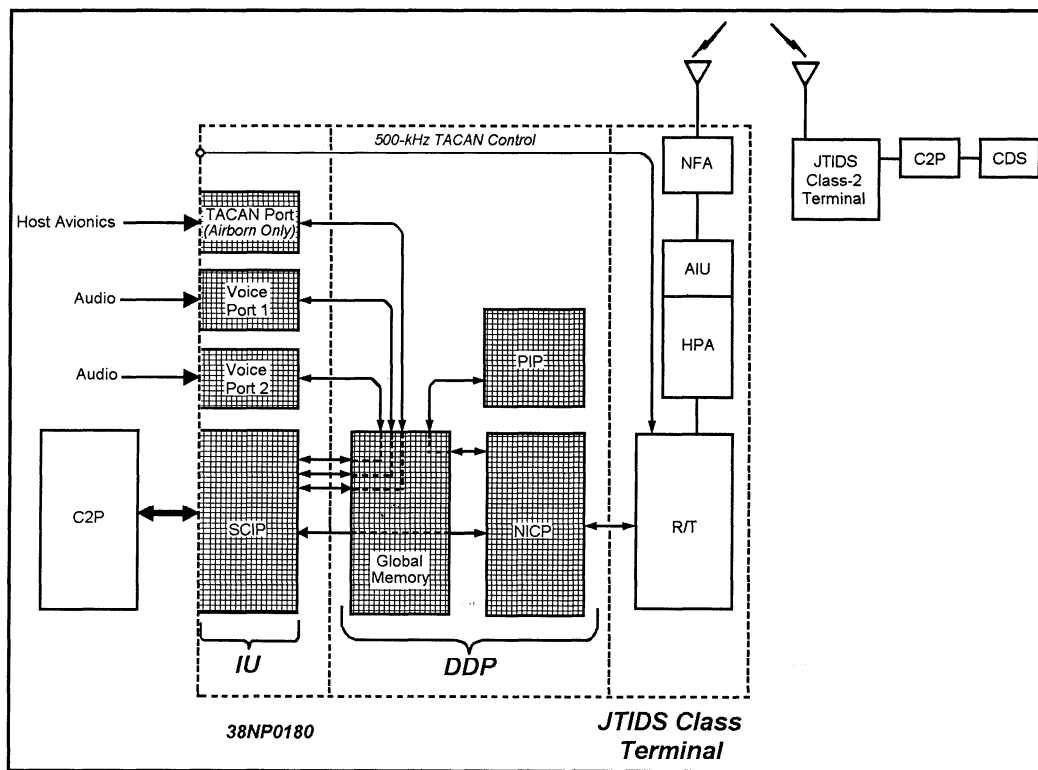- Measurement of time of arrival data for position and synchronization calculations

Figure 7-9.—The Digital Data Processing Group functional block diagram.

- Execution of the Built-in Tests (BIT) for fault isolation

- Generation of alerts

The **Network Interface Computer Program** (NICP) is the software that runs in the DDP and is responsible for the communications with the JTIDS RF network. The NICP controls message transmission and reception processing, coarse and fine terminal synchronization, relative navigation processing, and terminal and network monitoring.

Figure 7-9 is the block diagram for the DDPG. The global memory in the DDP is shared by all the processors in the terminal. Communications between the processors is over an internal bus called the plain text bus. All transactions on the plain text bus are either read or write commands to the global memory or port-to-port transfers. When the SICP, running in the IU, needs to communicate with the NICP, it does so by using the shared global memory in the DDP. A port-to-port transfer is a transfer of data between ports, such as when communicating with the host external timer (see fig. 7-9).

SECURE DATA UNIT. —The SDU is a removable assembly that is mounted to the IU. It stores the cryptovariables that are loaded during initialization. The SDU provides for both message security and transmission security. Message security is provided by the encryption of the data, while transmission security is provided by the pseudo-random frequency-hopping pattern and the introduction of a pseudo-random pattern of noise and jitter on the RF signal.

RECEIVER/TRANSMITTER GROUP. —The R/T is in the top drawer of the equipment cabinet and processes the radio frequency signals. The R/T also generates a 75-MHz intermediate frequency signal used for internal communication between the R/T and DDPG. When a Link-16 message is received, the R/T converts the RF to the intermediate frequency and sends it to the DDPG for processing. When the terminal transmits a Link-16 message, the R/T receives a Continuous Phase-Shift Modulation (CPS)

IF signal from the DDPG. The R/T then converts it to a 200-watt RF signal that is sent to the high-power amplifier group.

HIGH-POWER AMPLIFIER GROUP. —The HPAG is in the second drawer of the equipment cabinet and consists of a high-power amplifier and the antenna interface unit (AIU). The signal from the R/T group is received by the HPAG and amplified from 200 to 1,000 watts. The HPAG can also operate in a low-power mode, in which case the output signal is about 200 watts. The AIU provides the interface between the output of the HPAG and the antenna.

POWER INTERFACE UNIT. —There are two Power Interface Units (PIUs) in the equipment cabinet. The fourth drawer is the HPAG PIU and the bottom drawer is the PIU for the R/T and DDG. The two PIUs are identical. The three-phase, 115-VAC, 60-Hz input power is converted to two outputs: three-phase, 115-VAC, 400-Hz, and one-phase, 115-VAC at 400 Hz.

THE COMMAND AND CONTROL PROCESSOR

The Command and Control Processor (C2P) is a message distribution system designed to control and manage the interfaces between the three tactical data links (Link-4A, Link-11, and Link-16), the operator, and the hardware.

PURPOSE OF THE C2P

The C2P controls and manages the interfaces between the various data links on major surface and aircraft Command and Control (C2) platforms. The surface platforms that will have the initial installations of the C2P system are aircraft carriers (CV, CVN) and AEGIS cruisers (CG), followed by installation on amphibious assault ships (LHA, LHD), and AEGIS destroyers (DDG). There are two configurations of the C2P, one tailored for ships with the Advanced Combat Direction System (ACDS) Block 0 configuration and one for ACDS Block 1 configurations. On AEGIS ships, AEGIS Model 4 is similar to ACDS Block 0, and AEGIS Model 5 is similar to ACDS Block 1. The C2P system installed
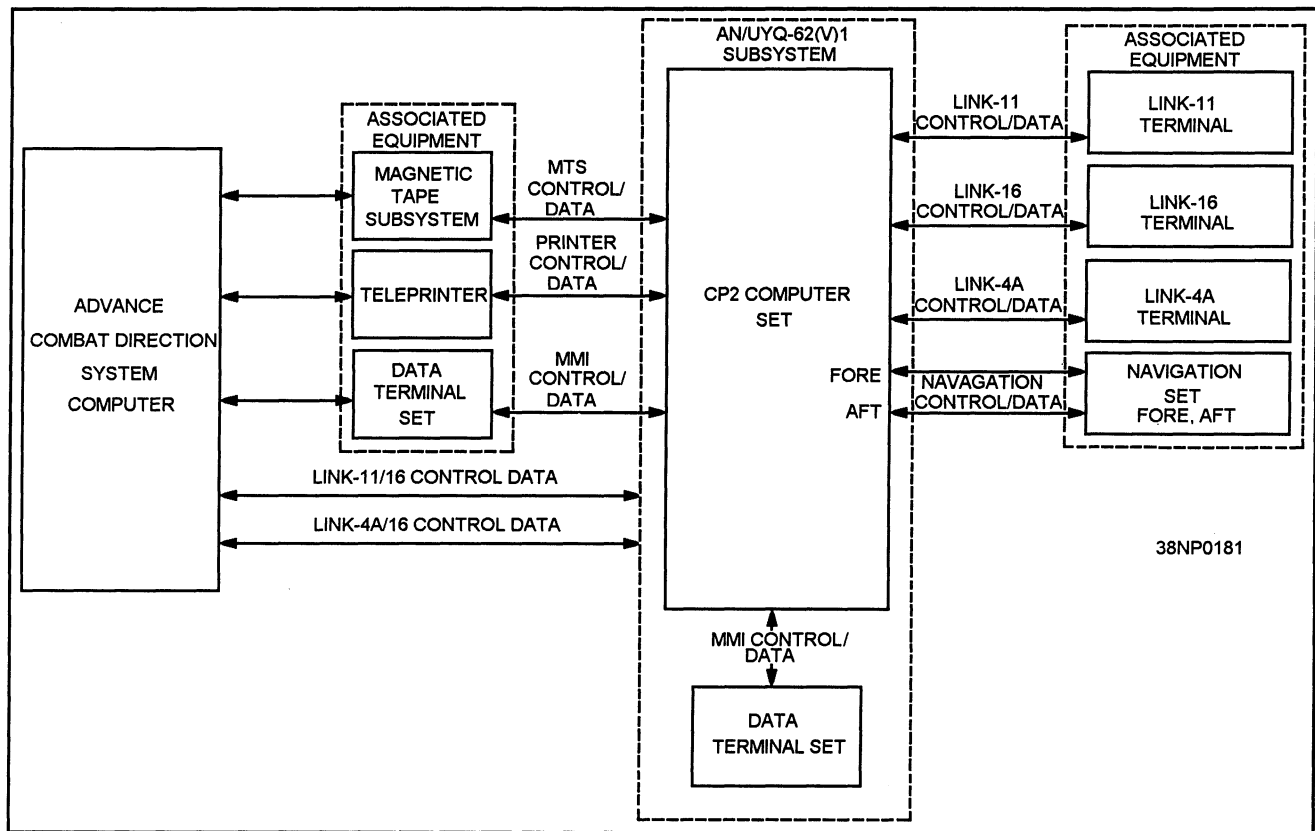
Figure 7-10.—The C2P system block diagram for ACDS Block 0 platforms.

on an ACDS Block 0 platform is very similar to the system that is installed on an AEGIS Model 4 platform. Figure 7-10 illustrates the system block diagram of the C2P for ACDS Block 0 platforms.

Link messages generated in the ACDS computer are sent to the C2P computer where they are formatted for transmission on the proper link (Link-4A, Link-11, or Link-16). Depending on the mode of operation and operator entered parameters, some messages may be sent over two or more data links. For example, it is not uncommon for Link-11 messages to be transmitted over Link-11 and Link-16. The C2P computer stores the data in a central database, called the normalized data base, and then formats the data in the proper message format for the link system(s) being used.

Messages received by the various data links are processed for errors by the C2P computer and sent to the proper destination. Received messages can also be reformatted for retransmission on a different link. A Link-11 or Link-4A message received by a C2P platform can be reformatted into a Link-16 message

and retransmitted on Link-16.

SYSTEM CONFIGURATION

The hardware block diagram of the equipment used in the C2P system is shown in figure 7-11. The AN/UYK-43(V) is a general-purpose, large scale, tactical computer used to store and execute the C2P software. The C2P configuration of the AN/UYK-43 consists of the following major modules:

- Two central processor units

- Two input/output controllers and adapters

- Six expanded time volatile memory units

- One embedded memory subsystem (EMS) with two embedded mass memory storage devices (EMMSD)

A major change in the configuration of the AN/UYK-43A(V) is the EMS and its associated EMMSDs. The EMS consists of two 383 megabyte
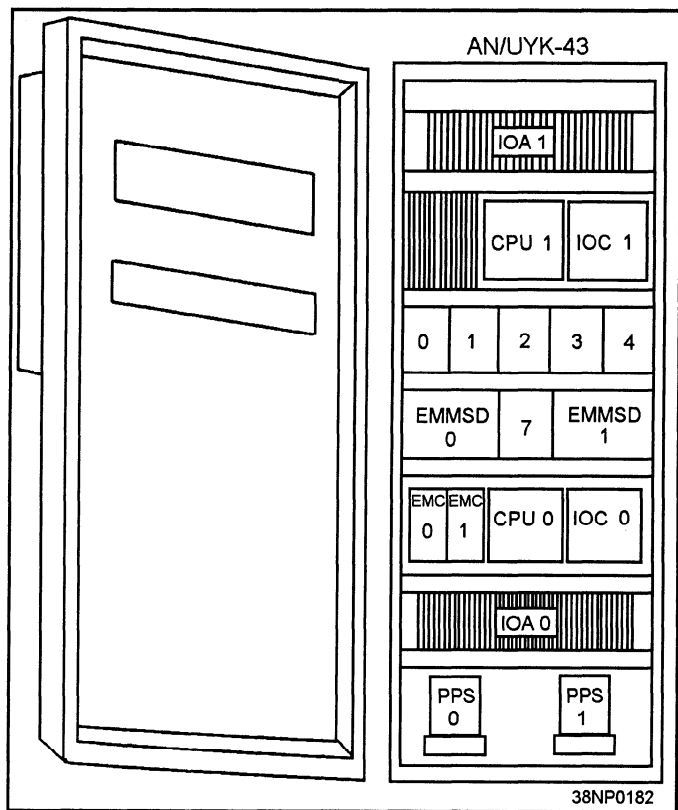
Figure 7-11.—The C2P system hardware configuration.

hard drives installed in the AN/UYK-43(V) cabinet. Even though these disk drives are internally installed in the computer, the software accesses them as if they were external disk drives.

The AN/USQ-69(V) data terminal set is used to provide the man-machine interface (MMI). It is installed next to the Track Supervisor in CIC.

Several equipments are shared between the ACDS system and the C2P system. These include the magnetic tape unit, a teleprinter, and a second AN/USQ-69(V) data terminal set. The magnetic tape unit is used for initial program loading (to EMS), data extraction, and reading and writing JTIDS information to and from tape. It is also a backup load device when the EMS is down. The teleprinter provides hard copy printouts of C2P system status, error codes, and data dumps. The second AN/USQ-69(V) is used as a backup.

Shared equipments are switched to the desired systems through the Combat Systems Switchboard. The switchboard also provides switches to connect Link-4A and Link-11 directly to the CDS computer, bypassing the C2P system.

CHAPTER 8

LOCAL-AREA NETWORKS

INTRODUCTION

A local-area network (LAN) is a communications system designed to transmit and receive digital information between computers. A LAN consists of **nodes** that are interconnected by **links.** Nodes are the hardware connected to the network, such as personal or microcomputers, printers, large capacity hard drives, and so on. Links are the communications media, such as twisted-pair wire, coaxial, or fiber-optic cables that connect the nodes In most applications, the LAN interconnects a relatively small number of personal computers (PCs), data storage devices, printers, and other peripherals. These nodes and links usually cover a relatively small geographical area, such as an office or a department. Through common usage, the term *local-area network* can also refer to much larger systems, such as the SNAP III system on a ship, which could have literally hundreds of terminals and miles of cables. For our purposes, we will be using a small system in our discussion of LANs.

Any device connected to the network can send and receive data on the network. A majority of data exchanged over a network is text and graphics, which is assembled as structured data that can be manipulated by computers. Unstructured data, such as pictures and facsimile messages, can be stored and retrieved efficiently, but cannot be manipulated easily by the computer.

After completing this chapter, you should be able to:

- **Describe the major components of a LAN.**

- **State the types of cable used in a LAN.**

- **State the function of the network interface card.**

- **Describe the function of the various network servers required by a LAN.**

- **Describe the function of the central mass storage area of a LAN.**

- **Describe the Open System Interconnection (OSI) Reference Model used in the design and implementation of a LAN.**

- **Describe the advantages and disadvantages of the different LAN topologies.**

- **Describe the hardware systems used in LANs.**

- **Describe the function of the software operating system of a LAN.**

LOCAL-AREA NETWORK HARDWARE

The basic hardware components of a LAN are cables, network interface cards, network servers, peripherals, and workstations. These components are covered in the material that follows.

CABLES

Several types of cables can be used in LAN applications. The selection of the type of cable depends on several factors, such as maximum length of a single cable run, security requirements, and the capacity and speed of the system.

Twisted-Pair Cable

The twisted-pair cable is easy to install and costs little on a per-foot basis. In some cases, existing telephone cable may be used. Its disadvantages include limitations in capacity and speed. It is also susceptible to electrical interference unless it is shielded.

Shielded Twisted-Pair Cable

The shielded twisted-pair cable is encased in an RFI shield. The stranded wire used as a conductor is manufactured with greater precision and is capable of greater data transmission rates and longer cable runs.

Coaxial Cable

Coaxial cable networks have gained in popularity because of their use in cable television. The quantities of cable and connectors produced for cable television have greatly reduced the prices of these components for network users. Coaxial cable comes in various thicknesses and is designated by a number: RG-11, RG-58, RG-59, RG-62, and so forth. You can use either baseband or broadband transmission methods with coaxial cable.

Baseband coaxial systems transmit digital signals unchanged over a single channel and have several advantages. They are inexpensive, easy to install, and have low maintenance. They also allow very high data transmission rates. One disadvantage is that they are limited to transmitting digital signals only.

In contrast, **broadband coaxial systems** require the digital signal to be converted to an analog signal before transmission and then back to digital by modem at the receiving device. Broadband systems support data, voice, and video signals that may be transmitted simultaneously. Disadvantages of broadband systems are their higher installation costs and complex maintenance.

Fiber-Optic Cable

Fiber-optic cable is the best choice if a secure network is needed. Because the cable transmits light, the transmissions are immune to interference caused by electrical or electronic devices. Also, if your network will run through an area of heavy industrial activity or a work place with strong radio frequency interference, fiber-optic cable is the most appropriate choice. Other advantages of the fiber-optic cable are that it lasts longer than other types of cable and can carry many more channels. Its disadvantages include its high price, poor connectivity, and low flexibility.

NETWORK INTERFACE CARD

To attach personal computers to the LAN, you must connect a network interface card (NIC) to each PC and attach the network cable to the NIC. Each individual workstation must have a network interface card. The NIC is nothing more than a circuit board that normally plugs directly into one of the expansion slots inside a PC. Sometimes, the NIC comes as a separate unit. In this case, you would plug it into the back of the PC. Most NICs have their own built-in microprocessor(s) designed to take care of network communications. This relieves the PC's main processor of this responsibility. The type of cable used on the network is determined by the type of LAN to be installed.

NETWORK SERVERS

Your understanding the concept of a **server** is important to understanding how LANs work. A server is a combination of hardware and software that

is used to manage the shared resources of the network. The hardware may be a PC or a computer designed specifically to act as a server. A **network server** is able to control network traffic as well as the sharing of other resources, such as application programs, disk space, data files, and printers. In either case, the computer normally has a hard disk and the software needed to run the network system. There are several different types of servers, and each has a particular function. In newer systems, some separate server functions are combined into a central file server. The servers we will look at are the disk server, the file server, and the print server.

Disk Server

The disk server was the first of the network operating systems. In the early days of PC networks, very few computers were equipped with a hard disk. When the hard disk became affordable, manufacturers were asked to develop a system to allow several users to share a single hard drive. The earliest disk servers were multiplexers that polled each connected computer for requests to write a file on the hard drive or to retrieve a file from the disk. The multiplexer then responded accordingly. A major problem with this process was that it did not allow for any type of security, data organization, or disk management.

As LAN technology evolved, the development of the disk server software in the early 1980s addressed some of these issues. The disk server is a software routine that was installed on each computer in the network. The disk server software allowed each PC to access the shared hard drive as if it were a local drive. In other words, the computer thought the drive was installed in the computer, but in reality, the drive was remotely located on the network.

The disk server also provided for some information sharing. One purpose of a network is to allow multiple users access to the same information. One problem encountered with early disk servers occurred when two or more users updated the same file at the same time. When the file was saved by both users, the updates of one of the users was lost.

A method of preventing this information loss is file locking. File locking means that when one user accesses a file, all the other users are prevented from accessing that file until the first user is finished with it. As you can see, this method severely limits the number of users able to access the information.

Another method used to prevent data loss is record locking. In a data-base environment, many users could access the same data file, but when a record was being modified by one user, the other users were locked out of the record being modified. A data file can be updated by several users without threatening the integrity of the data by using this technique.

Although the disk server was used in most LANs developed before 1985, a major problem still existed in maintaining data integrity. The two methods covered in the previous paragraphs provided for data management, but not for reliable disk management. A disk drive stores information on the next available block on the disk. When the disk server was used, it was not uncommon for two users to try to write data to the same block at the same time. When this happened, the second user would overwrite the data just written by the first user, causing a loss of data. The development of the file server in 1983 solved all of the problems encountered with the disk server.

File Server

Currently, all local-area networks require some type of file server. In most cases, the file server is a dedicated PC or minicomputer. The file server performs the processing of the network control software and the central processing and storage point of the application software and data files of the network. The file server has a hard disk with a very large storage capacity.

The file server manages the hard disk and ensures that multiple requests for the same file do not conflict with each other. In the disk server environment, each PC workstation manages its I/O with the disk through low-level sector calls. In the file server environment, each workstation communicates with the central disk through the use of high-level calls to the file server. A high-level call can be a request to open a particular file or to store a file, while a low-level call maybe to

write this file to sector *xyz* on the disk. The file server converts the high-level calls from the users to low-level disk commands, thus providing effective disk management. The file server maintains the list of privileges and authorizations for each user. This protects the data files from unauthorized access and protects the data. An example of this is that one user may be authorized total access to a data-base file to update the file, while another user may be authorized read-only access to the information. Still a third user may be denied access to the file altogether.

A network file server is a special-purpose unit that can reside in either a dedicated computer, or one of the workstations (a PC) that has a hard disk containing the software of the network. When the network server is used solely for serving the network and is **NOT** used as a workstation, it is referred to as a **dedicated server.** If the server can also be used as a workstation, it is referred to as a **nondedicated server.**

Some networks do **NOT** have a single dedicated file server. Instead, they use a **distributed** approach in which **any** of the nondedicated servers may make available files that reside on their hard disks. Under these circumstances, any workstation on the network can use or copy these files. Moving files back and forth on such a network establishes a temporary relationship, you might say, between the two PCs involved. One PC acts as the server, and the other PC acts as the receiving workstation.

Print Server

The print server is a software routine that allows all the workstations on the LAN to use a single printer. When the laser printer was introduced to the market, the extremely high-quality print and multiple fonts made it desirous for all correspondence. Unfortunately, the cost of a laser printer often exceeded that of an individual workstation and made it impractical for each workstation to have a dedicated printer. The print server solved that problem by accepting requests for print jobs from the network users and directing them to the printer. The print server makes sure one job is completed before a new job is started. Print server routines are included in

almost all network operating systems on the market today.

WORKSTATIONS

Workstations is another name for the PCs used on a network. The PCs can be of the same brand, such as Zenith, or they can be a combination of different brands, such as IBM, Zenith, Compaq, along with other PC compatible computers (clones). Each PC can be configured differently. Some might have their own hard disk drives; others might have expanded memory. Still others might **NOT** even have diskette drives or printer ports of their own. Instead, these less expensive workstations use the storage and printing resources available through the network. Even though a PC may be part of a LAN system, you can use it independently as a stand-alone PC at any time or you can use it as part of the LAN.

THE OPEN SYSTEM INTERCONNECTION (OSI) REFERENCE MODEL

Over the past few years, a number of network standards or protocols (rules to live by) have been developed by the International Standards Organization (ISO) to provide some level of uniformity among computer manufacturers and network vendors. ISO is one of several governing organizations in this field that has developed such protocols. ISO has defined a five level, seven-layer architecture. These seven layers of standards, shown in figure 8-1 define a generalized architecture called the **Reference Model of Open Systems Interconnection.** It is also known as the **OSI reference model** or **OSI model.** The primary purpose of the OSI model is to provide a basis for coordinating the development of standards that relate to the flexible interconnection of incompatible systems using data communications facilities.

The OSI model does **NOT** define anyone vendor's particular network software as such, nor does it define detailed standards for any given software. It simply defines the broad categories of functions that each of the seven layers should perform. The OSI model can include different sets of standards at each layer that are appropriate for given situations. For example, in a very simple data communications system, one that
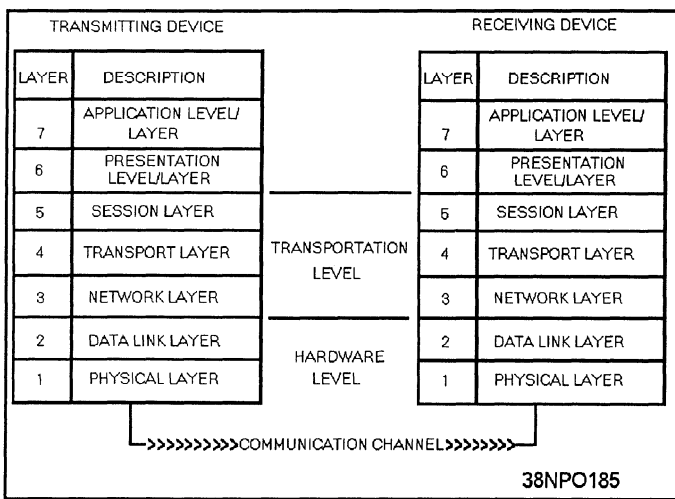
Figure 8-1.—The OSI model showing the seven layers.

uses a simple point-to-point link, the software at the higher level layers (say 5, 6, and 7) might be very simple or possibly nonexistent. However, in a very complex data communications system, all seven software layers may be implemented. Although there is no requirement for any hardware or software vendor to adhere to the principles set forth in the OSI model, there is a **worldwide** trend in the computer industry toward acceptance and conformance to these standards.

Ideally, if the hardware, network software, application software, and cabling were all supplied by the same manufacturer, there would be relatively few problems for users to contend with when designing and implementing a network. Everything would work together rather smoothly. However, a computer manufacturer's architecture can make it difficult to interconnect hardware offered by other competing manufacturers or vendors. The protocols used by communications devices are also highly complex and are often completely different from one manufacturer to another. Then there is the network software. Usually, the network software from one LAN vendor will not work with that of a competitor, neither will the application programs. Even the cabling must be selected for a specific local-area network.

HARDWARE LEVEL

The hardware level contains the first two layers of the OSI reference model. They are the physical layer

and the data-link layer. These are concerned primarily with the actual hardware used in a network.

Physical Layer

The physical layer is concerned with the transmission of the unstructured raw bit stream over a physical medium. It describes the electrical, mechanical, and functional interfaces to the carrier. The physical layer carries the signals for all the higher layers as follows:

- Voltages and pulse encoding of bits

- Media and media interface (cables, connectors, NIC, and so on)

- Line discipline (full- or half-duplex)

- Pin assignments

Data-Link Layer

The data-link layer provides error-free transmission of information over the physical medium. This allows the next higher layer to assume virtually error-free transmission over the link. The data-link layer is responsible forgetting data packaged and onto the network cable. It manages the flow of the data bit stream into and out of each network node as follows:

- Creates and recognizes frame boundaries

- Checks received messages for integrity

- Manages channel access and flow control

- Ensures correct sequence of transmitted data

The data-link layer detects and, when possible, corrects errors that occur in the physical layer without using the functions of the upper layers. It also provides flow-control techniques to ensure link-buffer capacity is not exceeded.

TRANSPORT LEVEL

The next three layers of the OSI reference model make up the transport level, also known as the *subnet.* The transport level defines the software protocols necessary to exchange data on the network. The three layers of the transport level are the network layer, the transport layer, and the session layer.

Network Layer

The network layer decides which physical pathway the data should take based on network conditions, priorities of service, and other factors. Software on the network interface card must build the data packet, so the network layer can recognize and route the data to the correct destination address. It relieves the upper layers of the need to know anything about the data transmission and switching technologies used to connect the systems. It is responsible for establishing, maintaining, and terminating connections across the intervening communications facility as follows:

- Addresses messages

- Sets up the path between communicating nodes on possibly different networks

- Routes messages among networks

- Is concerned with the sequence delivery of data packets

- Controls congestion if too many packets are on the network

- Translates logical addresses or names into physical addresses

- Has accounting functions to count packets or bits sent by users to produce billing information

Transport Layer

The transport layer makes sure data units are delivered error-free, in sequence, without losses or duplications. It relieves higher layer protocols from any concern with the transportation of data between them as follows:

- Message segmentation. Accepts data from the session layer, splits it up into smaller units, and passes the units down to the network layer

- Establishes and deletes host-to-host connections across the network

- Multiplexes several message streams onto one channel and keeps track of which message belongs to which connection

- Provides reliable end-to-end delivery with acknowledgment

- Provides end-to-end flow control and window management

Session Layer

The session layer allows users on different machines to establish sessions between one another. It performs the functions that enable two or more applications to communicate across the network, performing security, name recognition, logging, administration, and other similar functions. Unlike the network layer, this layer is dealing with the programs in each machine to establish conversations between them as follows:

- Allows two applications processes on different machines to establish, use, and terminate a connection (or session)

- Performs synchronization between end-user tasks by placing checkpoints in the data stream so that if the network fails, only the data after the last checkpoint has to be retransmitted

- Provides dialogue control (who speaks, when, how long, and so on)

PRESENTATION LEVEL/LAYER

The presentation level consists of the presentation layer. The presentation layer formats data to be presented to the application layer. It can be viewed as the translator for the network. This layer provides a common representation for data which can be used between the application processes. The presentation layer relieves the applications from being concerned with data representation, providing syntax independence as follows:

- Encodes data in a standard way (integers, floating point, ASCII, and so on)

- Provides data compression to reduce the number of bits that have to be transmitted

- Provides data encryption for privacy and authentication

APPLICATION LEVEL/LAYER

The final level is the application level, which consists of the application layer. The application layer serves as the window for the application process to access the OSI environment. This layer represents the services that directly support users and application tasks. It contains a variety of commonly needed protocols for the following items:

- Network virtual terminals

- File transfers

- Remote file access

- Electronic mail

- Network management

USING THE OSI MODEL

A communications system that does not use a layered architecture can be designed. A specifically designed communications system is faster, more efficient, requires less software code, and eliminates redundant functions and activities. Why, then, is the OSI reference model considered the standard in designing networks and writing software? It is considered the standard primarily because the use of a layered architecture, such as the OSI reference model, provides the network with flexibility and migration.

The greatest advantage of your using layer architecture in a network is hardware independence. As advances in technology continue, it is not necessary to scrap a network completely because one component has been superseded. For example, if you have a network and need to upgrade the cable to a type that can handle increased data at a faster rate, the layered architecture of the OSI model will allow you to make this replacement to the physical layer without changing the other layers.

LAN TOPOLOGIES

The physical arrangement of the components of a LAN is called its configuration or topology. The three major types of configurations, or topologies, of a LAN are the **linear bus,** the **star,** and the **ring.** You can also create hybrid topologies by combining features of these configurations. For example, several bus networks can be joined together to form a ring of buses.

Each topology requires the components of a LAN to be connected in a different arrangement. These components are also referred to as nodes. A node is any point on a network where data can be sent (transmitted) or received—a workstation, a server, and so on.

LINEAR BUS NETWORK

The linear bus topology is like a data highway. That is, all components or nodes are connected to the same cable, and the far ends of this cable never meet, as shown in figure 8-2. Linear bus LANs are best suited to applications involving relatively low usage of the bus coupled with the need to pass relatively short messages from one node to another. In many such networks, the workstations check whether a message is coming down the cable before sending their messages. Since all nodes share the bus, all

messages must pass through the other workstations on the way to their destinations. Each node checks the address attached to the message to see if it matches its own address. Bus topologies allow individual nodes to be out of service or to be moved to new locations without disrupting service to the remaining nodes.

Because of the way linear bus cabling is laid out, this type of network is simple. The bus topology is very reliable, because if any node on the bus network fails, the bus itself is **NOT** affected, and the remaining nodes can continue to operate without interruption. Many of the low cost LANs use a bus topology and twisted-pair wire cabling.
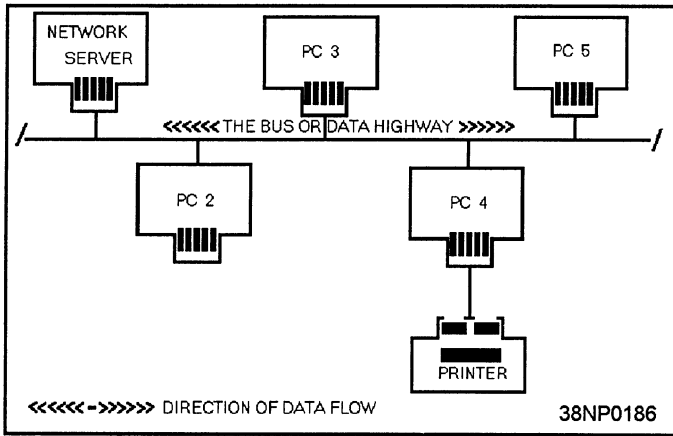
Figure 8-2.—A bus network topology.

A disadvantage of the bus topology is that generally there must be a minimum distance between workstations to avoid signal interference. Another disadvantage is that the nodes must conpete with each other for the use of the bus. Simultaneous transmissions by more than one node are **NOT** permitted. This problem, however, can be solved by using one of several types of systems designed to control access to the bus. They are collision detection, collision avoidance, and token passing, which we will cover shortly. Also, there is no easy way for the network administrator to run diagnostics on the entire network. The bus network can be easily compromised by an unauthorized user, since all messages are sent along a common data bus. For this reason, it is difficult to maintain network security.
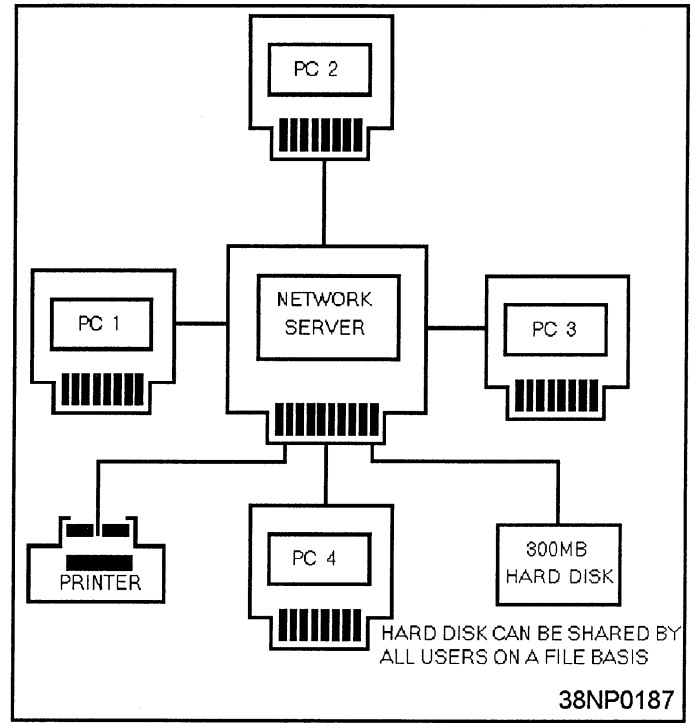

Figure 8-3.—A star network topology.

STAR NETWORK

In a star network, each component is connected directly to the central computer or network server, as shown in figure 8-3. Only one cable is required from the central computer to each PC's network interface card to tie that workstation to the LAN. The star is one of the earliest types of network topologies. It uses the same approach to sending and receiving messages as our phone system. Just as a telephone call from one person to another is handled by a central switching station, all messages must go through the central computer or network server that controls the flow of data. New workstations can be easily added to the network without interrupting other nodes. This is one of the advantages of the star topology.

Another advantage of star topology is that the network administrator can give selected nodes a higher priority status than others. The central computer looks for signals from these higher priority workstations before recognizing other nodes. The star topology also permits centralized diagnostics (troubleshooting) of all functions. It can do this because all messages must first go through the central

computer. This can prove invaluable in making sure that network security has not been breached.

The main disadvantage of the star topology is its reliance on the central computer for performing almost all the functions of the network. When the central computer fails, all nodes also stop functioning, resulting in failure of the entire network.

DISTRIBUTED STAR

The distributed star, or tree, topology is shown in figure 8-4. It provides many of the advantages of both bus and star topologies. It connects workstations to a central point called a hub. This hub can support several workstations or hubs which, in turn, can support other workstations. Distributed star topologies can be easily adapted to the physical arrangement of the facility site. If the site has a high concentration of workstations in a given area, the system can be configured to more closely resemble a star topology. If the workstations are widely dispersed, the system can use inexpensive hubs with long runs of shared cable between hubs, similar to the bus topology.

RING NETWORK

In a ring network, all the components or nodes are connected to the main cable, and the cable forms a ring, as shown in figure 8-5. This topology allows a node to send a message to another node on the ring.
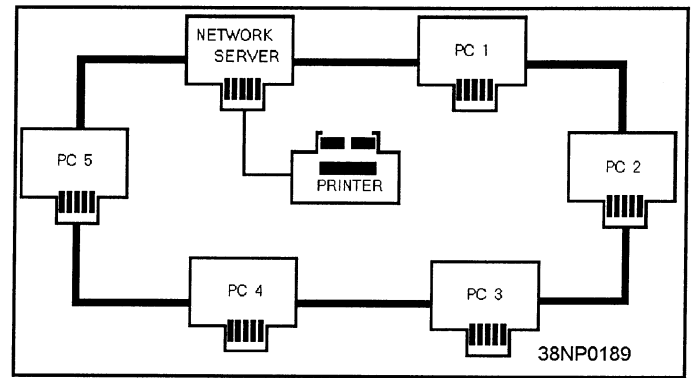

Figure 8-5.—A ring network topology.

However, the message must be transmitted through each node until it reaches its destination. Messages proceed from node to node in one direction only. Should a node fail on the network, data can no longer be passed around the ring unless the failed node is either physically or electronically bypassed. Using bypass software, the network can withstand the failure of a workstation, by bypassing it, and continue to maintain the integrity of the network. One of the major issues in a ring topology is the need for making sure all workstations have equal access to the network.

One of the major disadvantages of ring topologies is the extreme difficulty of adding new workstations while the network is in operation. Normally the entire network has to be brought down while a new node is added and cabling reattached. However, this particular problem can be overcome by the installation
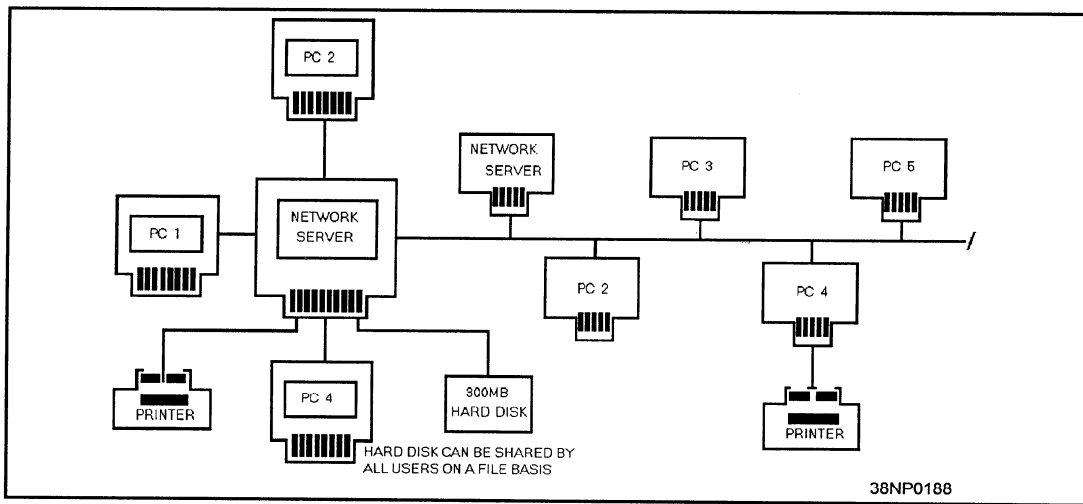

Figure 8-4.—A distributed star (tree) network topology.

of additional connectors when the network is initially set up. These connectors enable you to add or remove nodes while the network remains intact and in operation.
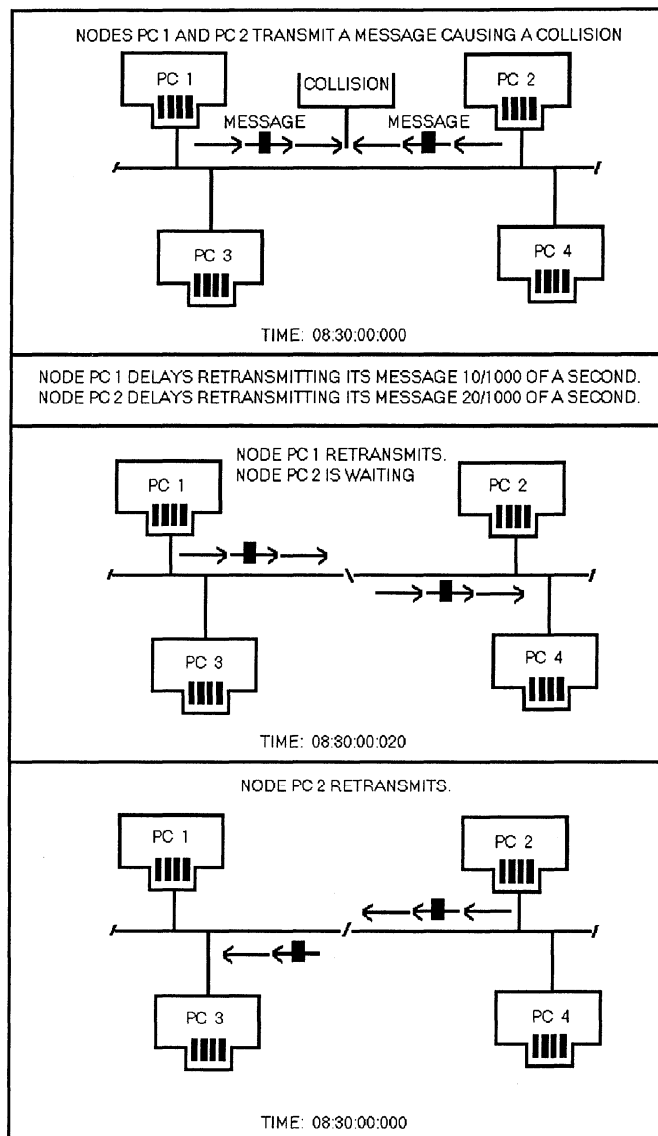
ACCESS METHODS

Another decision the designer makes is that of which access method to use. Access methods are the arrangements used to make sure each workstation has fair and equal access to the network. The access method used is governed primarily by the topology and the protocol of the network. The principal access methods are contention and token passing.

Contention

The contention method features Carrier Sense Multiple Access (CSMA) and Carrier Sense Multiple Access with Collision Detection (CSMA/CD). The CSMA/CD method is shown in figure 8-6. Access for both is on a first-come, first-served basis. The CSMA access scheme is very similar to that of a citizens band (CB) radio. Stations with data to send listen to the channel and wait until it is clear to transmit. With CSMA/CD, when two or more workstations transmit simultaneously, their messages will collide. As soon as a workstation detects a collision, it ceases transmission, monitors the network until it hears no other traffic, and then retransmits. Most contention networks assign a unique retry algorithm to vary the wait-and-retry period. This algorithm reduces the likelihood that after a collision, two workstations will transmit retries simultaneously.

Token Passing

Token passing is an orderly access method and is shown in figure 8-7. Each workstation passes on the opportunity to transmit to its closest neighbor until a station is found with a message to send. This permission to transmit is called a token. When a workstation with data to send is handed a token, part of the token is changed, indicating it is carrying a message, and then data is transmitted with the token. The token is then passed around the network, and every station checks whether the message is intended for it. The receiving station copies the message from

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Figure 8-6.—A bus network using the CSMA/CD access method.

the token, but then passes the unchanged token along the network. When the transmitting station receives the same token, it knows the message has been passed around the network. The transmitting station erases the message and puts the empty token back into circulation on the network. The amount of information that may be transmitted during possession of the token is limited so that all workstations can share the cable equally.

PROTOCOLS

Network protocols are an important component because they define how networks establish

communications between element, exchange information, and terminate communications. Protocols have two major operational functions. They establish the circuit for transmission (handshaking) and for the transmission itself. Transmission is conducted subject to the line discipline. The line discipline is the sequence of operations that actually transmits and receives the data, handles the error-control procedures, handles the sequencing of message blocks, and provides for validation for information received correctly.

Two representative protocols, which control line discipline, are the Binary Synchronous communications Protocol (Bisync) and the Synchronous Data Link Control (SDLC).

Bisync

Bisync is a half-duplex protocol that transmits strings of characters at lower speeds over dial-up circuits. The information movement is in one direction at a time, with each data transfer being answered by an acknowledgement.

SDLC

SDLC is a control procedure that sends multiple blocks of data and returns a single acknowledgement for many blocks, thereby increasing the amount of time spent transmitting data. The bits that are put before and after the message at the transmitting end are removed at the receiving end, so only the message is presented to the user.
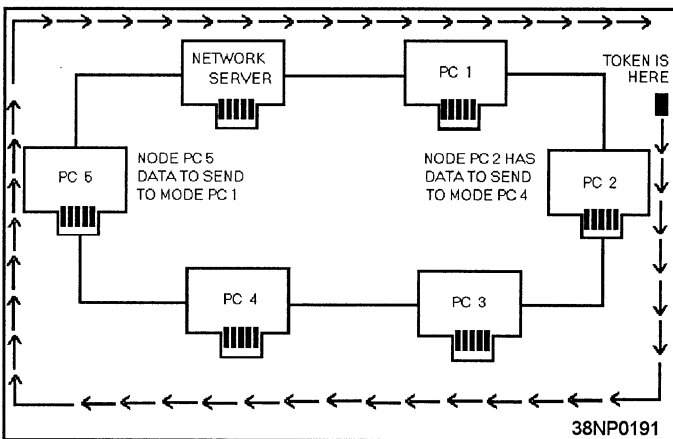

Figure 8-7.—A ring network using the token passing access method.

The hardware chosen for the network plays a part in the choice of network protocol. Most users and many of the vendors who build the clone type of equipment would like to see universal interfaces, while others think that the availability of different specifications will lead to a proprietary set of equipment, even though they favor the overall OSI specifications.

LAN SYSTEMS

When you decide to install a LAN system, the type of topology used in the initial wiring of the system will have a major effect on the type of system that can be used. There are many LAN systems available, each with advantages and disadvantages. In the following paragraphs, we briefly examine some of the available LAN systems.

The Institute of Electrical and Electronics Engineers (IEEE) has developed a set of standards for local-area networks. These standards encourage the use of common approaches for LAN protocols and interfaces. The IEEE LAN standards were developed by a committee of engineers and classified as the 802 standards. The 802 standards are broken down even further to define the protocols and topology used in a LAN. Some of the standards we are concerned with are the following:

- IEEE 802.3—Carrier sense multiple access/collision detection (CSMA/CD)

- IEEE 802.4—Token Bus

- IEEE 802.5—Token ring

ETHERNET

The EtherNet local-area network was developed by Xerox, the Intel Corporation, and the Digital Equipment Corporation. It became the model for the development of the IEEE 802.3 standard. The original standard defined a maximum throughput for EtherNet of 10 Mbit/s, but it has been revised to support throughput of much higher rates. When operating over coaxial cable, EtherNet has a 20-Mb per second throughput speed. For high-demand

environments, such as engineering or graphics, EtherNet is often the choice. It is a bus topology and uses CSMA/CD protocol. It is available in the following three versions: standard EtherNet, ThinNet, and twisted-pair EtherNet.

Standard EtherNet and ThinNet both use coaxial cable. Standard EtherNet is somewhat more expensive and more difficult to install than ThinNet, but it allows networking over greater distances with more users. Twisted-pair EtherNet uses a distributed star topology with wiring concentrator hubs, not the bus topology characterizing standard EtherNet and ThinNet. Connecting more than 100 users on a standard EtherNet trunk or on a series of twisted-pair concentrators is not uncommon, while ThinNet LANs usually support less than 50 users.

All versions of EtherNet create a LAN with high interconnectivity options. A number of products are available for connecting EtherNet LANs to minicomputers and mainframe computers and for bridging to other LANs; examples are STARLAN, ARCnet, and IBM Token Ring Network.

STARLAN

STARLAN uses a star topology with a CSMA/CD protocol. Its throughput speed is 1Mb per second over twisted-pair cable. If buildings are already wired with twisted-pair cable meeting AT&T premise cabling specifications, STARLAN can be installed easily. It is considered to be a low cost-per-user network and its star topology makes it a flexible network.

ARCnet

ARCnet is a distributed star topology that uses a token passing protocol and either twisted-pair or coaxial cabling. Its throughput speed is 2.5Mb per second. Although ARCnet does not conform to an IEEE standard, it closely resembles the 802.4 standard for a token bus system. It can easily handle up to 75 users. If user demand is low, it can handle additional users. It is considered an extremely reliable network and it is easy to install, expand, and modify.

IBM Token Ring Network

The IBM Token Ring Network uses a star ring topology, and is defined by the IEEE 802.5 specification. It has a throughput speed of 4 Mbits per second and 16 Mbit per second. This allows for flexible expansion of very large networks. Because of its speed and token passing protocol, it is a good choice to meet high-volume requirements. It is a sophisticated LAN technology developed by IBM to be used with an IBM cabling system and it is currently the fastest growing installed network base. The star ring topology also makes use of redundant circuits and loopbacks to handle breaks in the ring and results in high-fault tolerance on the network.

NETWORK OPERATING SYSTEMS

Network operating system software is necessary to control the overall operations of the network. Careful consideration must be given to the various packages on the market to ensure the operating software is fully compatible with your system, topology, and needs.

NETWORK OPERATING SYSTEM BASICS

The two basic components of the network operating system are the network operating system server and the workstation. The network server is usually a dedicated computer that runs the operating system software and processes all requests for services. The workstation computer runs the application software needed by the workstation user and establishes communications with the network server.

The network server operating system consists of the following five subsystems: the **control kernel,** the **network interfaces,** the **file systems,** the **system extensions,** and the **system services.**

Control Kernel

The control kernel is the main subsystem of the network operating software. The control kernel coordinates the various processes of the other subsystems. Some of the functions performed by the control kernel are as follows:

- Optimizing access to services by users

- Maintaining status information of many of the processes

- Error reporting

- Service initialization and service termination of workstations

Network Interfaces

The network interfaces provide the low-level subnet protocols and basic translation for bridging hardware drivers with the network operating system. In sophisticated systems, the network interfaces can also provide for bridging a new network into an operating network without having to rebuild the operating system.

File Systems

The file system controls the way the data is organized, stored, and retrieved from the storage systems available to the network. The files may be stored on hard drives, RAM disks, or optical storage devices, such as CD-ROM or write once, read many (WORM) drives.

File systems are generally designed to provide universal applicability. This means that the file system can be compatible with any application program's expectation of file input/output protocol. When adaptable interfaces are used, the file system can appear to emulate a number of different file systems.

System Extensions

The system extensions define the openness of the network operating system and are used by third party developers to produce add-on products. The extensions are usually high-level protocol handlers that perform operations, such as file access protocol translations required by different operating systems. The extensions available also include network management, system tools, and data-base services.

System Services

Network system services contain all services that are not easily defined by any of the other areas of the network. Examples of network services are security, system reliability features, error conditions, and access violations.

NETWORK OPERATING SYSTEMS SOFTWARE

The most important job of a network operating system (NOS) is to provide file service for the attached computers. This allows information retrieval and usage and the storage of data in a shared environment. A NOS manages the other resources shared by the network and provides the following functions:

- Directory structure for shared hard disk storage devices

- File service for sharing and using data

- Interface to the network for application software/programs

- The means by which the network manager manages the network and its users

- Network security and data protection

- Communications with other networks

The types of network operating systems include full-featured, low-cost, and zero-slot operating systems.

Full-Featured Network Operating Systems

Most full-featured network operating systems allow for high performance, flexibility, and excellent security measures. They require a LAN administrator. They require network interface cards. Also, they can be quite costly. Examples of a full-featured NOS are EtherNet, Novell's NetWare, 3Com's 3+Share, IBM Token Ring Network, and Banyan's Vines.

Low-Cost Network Operating Systems

Most low-cost network operating systems differ from full-featured systems only in the maximum number of users accommodated on the network and the number of security levels incorporated into the operating system. In general, they are much lower in cost and are easier to install and use. Examples of low-cost systems are STARLAN, ARCnet, 10Net, and LANtastic.

Zero-Slot Network Operating Systems

Zero-slot network operating systems are appropriate only for networks with very few users and Light usage. They are an inexpensive and simple alternative to the NOSs that require expensive network interface cards. Rather than requiring each workstation computer to have a NIC, the computer's RS-232 serial communications port and twisted-pair cables are used. Because of this, they are very slow and offer limited file transfer abilities. They may not provide disk sharing. An example of a zero-slot system is LANLink.

APPENDIX I

LIST OF ACRONYMS

ACDS —advanced combat direction system.

ACRO (or CRO) —auxiliary cathode readout,

ALT key —alternate key.

A/N —alphanumeric.

APA —all points addressable.

AM —amplitude modulation.

ASCII —American Standard Code for Information Interchange.

ASTAB —automated status board.

ASW —antisubmarine warfare.

BC —broadcast.

BDU —basic display unit.

BER —bit error rate.

BITE —built-in test equipment.

BPS —bits per second.

C2P —Command and Control Processor.

CAG —central automated status board generator.

CCAEP —computer-controlled action entry panel.

CDB —central data buffer.

C-DITEG —common digital television graphics generator.

CDS —combat direction system.

CED —console electronic drawer.

CEG —central equipment group.

CGA —color graphics adapter.

CIGARS —console internally generated and refreshed symbols.

CIU —computer interface unit.

CONICS —circles and ellipses.

CP —clock pulse.

CPS —cycles per second.

CRO —TV monitor.

CRT —cathode-ray tube.

CTRL —control.

dB —decibels.

DCC —display control console.

DCI —direct computer interface.

DDEU —digital data entry unit.

DDI — (1) digital data indicator; (2) digital display indicator.

DITEG —digital television graphics generator.

DIV —diversity.

DLRP —Data Link Reference Point.

DMU —display multiplexer unit.

DRAC —digital radar azimuth converter.

DSC —digital scan converter.

DTS —data terminal set.

EDAC —error detection and correction.

EF word —external function word.

EGA —enhanced graphics adapter.

EMI/RFI —electromagnetic interference/radio frequency interference.

EPROM —erasable, programmable read-only memory.

ESC key —escape key.

FM —frequency modulation.

GUI —graphic user interface.

HF —high frequency.

HVPS —high voltage power supply.

HZ —hertz.

I/O —input/output.

IFF/SIF —identification, friend or foe/selective identification feature.

JTIDS —Joint Tactical Information Distribution System.

J-SERIES MESSAGE —The fixed format messages containing tactical data and commands that are used to exchange information over the JTIDS system.

JU —JTDS Unit.

LCD —liquid crystal display.

LCLV —liquid crystal light valve.

LED indicator —light-emitting diode indicator.

LINK-4A —The tactical digital data link for controller-to-controlled aircraft communications.

LINK-11 —The tactical digital data link for communications among a multiple number of units.

LINK-16 —The tactical digital data link for communications among a multiple number of units. This link is a secure, jam resistant, nodeless, high-capacity link that uses the JTIDS terminal.

LSB —Lower Side Band.

LSD —large screen display.

LVPS —low voltage power supply.

MDA —Monochrome Display Adapter.

M-SERIES MESSAGES —Link-11 messages.

NCS —Net Control Station.

NCT —Net Cycle Time.

NICP —Network Interface Control Program.

N-SERIES MESSAGES —The "normalized" messages exchanged between the C2P computer and the ADCS computer.

NTDS —naval tactical data system.

ODR —output data request.

OJT —on-the-job training.

OSC —operations summary console.

PA/SG —pulse amplifier/symbol generator.

PC —personal computer.

PEFT —peripheral equipment functional test.

PIO —peripheral I/O

PIXEL —picture element.

PMS —planned maintenance system.

POFA —programmed operational functional appraisal.

PPI —plan position indicator.

PPLI —precise participant location and identification.

PPU —projection plotting unit.

PROM —programmable read-only memory.

PU —participating unit.

RAC —radar azimuth converter.

RAM —random access memory.

RC —Roll Call.

RDDS —radar data distribution switchboard.

RELNAV —relative navigation.

RF —radio frequency.

RGB —red, blue, green.

ROM —read-only memory.

ROM BIOS —ready-only memory basic input output system.

R-SERIES MESSAGES —Link-4A messages from the controlled aircraft that are sent in response to a control message.

SAC —sonar azimuth converter.

SCG —sensor converter group.

SDDS —sensor data distribution switchboard.

SG —symbol generator.

SRAC —synchro radar azimuth converter.

SVGA —super video graphics array.

TDM —tactical DITEG module.

TDS —tactical data system.

TFT —thin film transistor.

TMG —test message generator.

TN —track number.

TQ —track quality.

TSLO —third salvo lock out.

TTL —transistor-transistor logic.

TVC —television converter group.

TVSC —television scan converter.

UHF —ultra-high frequency.

USB —upper side band.

V/C word —velocity/category word.

VDT —video display terminal.

VFK panel —variable function key panel.

VGA —video graphics array.

V-SERIES MESSAGES —Link-4A control messages sent from the controlling station to the controlled aircraft.

VSS —video signals simulator.

XGA —extended graphics array.

APPENDIX II

REFERENCES USED TO DEVELOP
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INDEX

Assignment Questions

ASSIGNMENT 1

1-1. What type of equipment is used to coordinate the activities of fleet units by linking them with each other and shore stations?

1. Radio
2. Weather
3. Radar
4. Navigation

1-2. Radio is the transmission and reception of electronic impulses or signals through space by means of what type of waves?

1. Pulsed
2. Phased
3. Electromagnetic
4. Electrostatic

1-3. Who is ultimately responsible for safety?

1. CO
2. CMC
3. LCPO
4. Everyone

1-4. What are the basic requirements of a communications system?

1. Transmitter and receiver
2. Teletype and converter
3. Transmitter and handset
4. Receiver and handset

1-5. AN/UCC-1, AN/URA-17, and CV-2460 are examples of what type of shipboard equipment?

1. Ancillary
2. Auxillary
3. Special
4. Terminal

1-6. For efficient transmission, which of the following frequency bands require(s) high power and long antennas?

1. ELF only
2. VLF only
3. LF only
4. ELF, VLF, and LF

1-7. Which of the following frequency bands has limited naval use?

1. HF
2. MF
3. UHF
4. VHF

1-8. What does the abbreviation "los" commonly mean?

1. Loss-of-signal
2. Line-of-sight
3. Loss-of-sight
4. Line-of-signal

1-9. The super-high-frequency band is used extensively in what of communications?

1. Teletype
2. Repeater
3. Microwave
4. Computer

1-10. The emission class of an rf transmitter is based on what characteristic?

1. Modulation
2. Power
3. Sensitivity
4. Frequency

1-11. An FM signal should remain constant in (a) what characteristic and change only in (b) what characteristic?

1. (a) Frequency (b) amplitude
2. (a) Frequency (b) modulation
3. (a) Amplitude (b) frequency
4. (a) Amplitude (b) modulation

1-12. What type of modulation is especially suited for use in time-division multiplexing?

1. Amplitude
2. Frequency
3. Phase
4. Pulse

1-13. For modern communication needs, CW is not a preferred method. Why is this true?

1. CW is slow
2. CW is complicated
3. CW is expensive
4. CW is noisy

1-14. In an FM transmitter, the audio signal shifts the carrier frequency in what network?

1. Audio-shift
2. Phase-shift
3. carrier-shift
4. Band-shift

1-15. In a ssb transmitter the carrier is removed to concentrate the power in the sideband(s).

1. True
2. False

1-16. Which of the four receiver functions involves extraction of the modulation from the rf signal?

1. Detection
2. Reception
3. Reproduction
4. Selection

1-17. Which of the four receiver characteristics require compromise because of bandpass requirements?

1. Selectivity and noise
2. Selectivity and fidelity
3. Noise and fidelity
4. Noise and sensitivity

1-18. What term is used to describe receiver amplification?

1. Fidelity
2. Noise
3. Gain
4. Power

1-19. The term "dBm" is based on what standard reference level?

1. 1 watt
2. 1 volt
3. 1 milliwatt
4. 1 millivolt

1-20. Normal power out is 100 watts. During PMS, you discover that power out has dropped by 3dB. What is the new power out?

1. 97 watts
2. 70 watts
3. 50 watts
4. 3 watts

1-21. How many radio set controls can be paralleled to one transmitter/ receiver group?

1. One
2. Two
3. Three
4. Four

1-22. To transfer control of switched circuits to another transmitter or receiver switchboard, you should use what switch position?

1. Off
2. X
3. Five
4. Six

1-23. Which of the following terms is used for a machine that operates as a single-phase transformer?

1. Servo
2. Synchro
3. Gyro
4. Compass

1-24. When you use subdivisions to assign reference designators to equipment, what is the designator of the (a) largest subdivision and (b) smallest subdivision?

1. (a) System (b) set
2. (a) Set   (b) unit
3. (a) System (b) part
4. (a) Unit   (b) assembly

1-25. Extremely-low-frequency transmission is primarily directed at which of the following users?

1. Aircraft
2. Shore installations
3. Submarines
4. Surface ships

1-26. The very-low-frequency receive system is designed to receive what types of signals?

1. AM and FM
2. FSK and CW
3. FSK and ICW
4. SSB and FSK

1-27. The AN/FRT-72 (if) transmitter is used to provide (a) how many channels of frequency-division multiplex rtty traffic over (b) what type of fleet broadcast system at (c) what type of power?

1. (a) Eight (b) multichannel (c) high
2. (a) Eight (b) singlechannel (c) high
3. (a) Four (b) multichannel (c) low
4. (a) Four (b) multichannel (c) high

1-28. HF communications from shore-based transmitters to ships at sea using frequency and space diversity is an example of which of the following types of systems?

1. Fleet broadcast
2. Point-to-point
3. Ground-to-air
4. ship-to-shore

1-29. Which one of the following equipment would you use to match a transmitter's output impedance to an antenna's input impedance?

1. CV-2460
2. SB-988/SRT
3. AN/UCC-1
4. AN/URA-38

1-30. The AN/VRC-80 is not just a vhf transmitter or receiver. What is the name given to a piece of equipment that performs both functions?

1. Transducer
2. Multiplexer
3. Retransmitted
4. Transceiver

1-31. During UHF secure voice transmission, the operator uses a secure voice remote phone unit. What is the common term for this unit?

1. RPS
2. RPU
3. SVP
4. SPU

1-32. which of the following combinations of radio-relay systems provides (a) one-way communications and (b) two-way communications?

1. (a) Simplex (b) multiplex
2. (a) Duplex (b) multiplex
3. (a) Simplex (b) duplex
4. (a) Duplex (b) simplex

1-33. What term is normally used for microwave transmitter input signal?

1. Baseband signal
2. Emphasis signal
3. Insertion signal
4. Linear signal

1-34. In a microwave transmitter, the linearize couples a portion of the output power back to the klystron. This allows for modulation densities as high as 1200 channels and compensates for what klystron deficiency?

1. Nonlinearity
2. Oscillations
3. Overheating
4. Selectivity

1-35. In a typical microwave receiver, what is the standard intermediate frequency?

1. 40 MHz
2. 50 MHz
3. 60 MHz
4. 70 MHz

1-36. Which of the following methods are usually used for microwave communications?

1. Los and troposcatter
2. Los and satcom
3. Troposcatter and satcom
4. Troposcatter and shortwave

1-37. By which of the following methods can you increase the maximum number of intelligible signals transmitted on a single path?

1. Modulation
2. Single audio mixing
3. Multiplexing
4. Single signal splitting

1-38. Which of the following communications methods involves subdividing a channel into smaller segments of equal size and placing a signal in each subchannel?

1. FDM
2. TDM
3. DFM
4. DTM

1-39. Which of the following requirements does SAS satisfy?

1. Nonsecure voice communications
2. Secure voice communications
3. Voice signal switching
4. All of the above

1-40. How many crypto and plain subsystems are used within SAS?

1. Five
2. Two
3. Three
4. Four

1-41. One mode of teletypewriter operation is the synchronous mode. What other mode is used for basic teletypewriter operation?

1. Asynchronous
2. Bisynchronous
3. Nonsynchronous
4. Trisynchronous

1-42. What is the name of the five-unit code that includes mark and space signals and is used in teletypewriter operation?

1. Baud
2. Baudot
3. ASCII
4. Morse

1-43. Which of the following problems is reduced by not using start and stop signals in the synchronous teletypewriter mode?

1. Converted signal
2. Delayed signal
3. Distorted signal
4. Lost signal

1-44. Which of the following terms accually pertains only to modulation rate?

1. Baud
2. Words per minute
3. Bites per second
4. Words per second

1-45. In neutral tty operation, current flow and no current flow represent the mark and space conditions. In polar tty operation what is the condition of the line current?

1. It is always absent
2. It is always positive
3. It is always negative
4. It is always present

1-46. What device is used to change tty dc pulses into mark and space signals to modulate the transmitter carrier wave?

1. Detector
2. Keyer
3. Modulator
4. Transformer

1-47. After the tty signal is received, what device(s) must be used to change the signal back to dc pulses?

1. Convertor
2. Receiver
3. Both 1 and 2 above
4. Keyer

1-48. The Navy's two basic RATT systems are AFTS and RFCS. What is the RFCS system commonly called?

1. ASK
2. FSK
3. PSK
4. RSK

1-49. What device provides looping current for the tty?

1. A solid state power supply
2. A generator
3. An alternator
4. The tty battery

1-50. What is/are used to interconnect all the tty equipment in any configuration needed?

1. Multiple cabling
2. Wire runs
3. TTY panel
4. Switching resistors

1-51. Which of the following methods is/are used to reduce fading and interference in long-range communications?

1. Frequency diversity
2. Space diversity
3. Both 1 and 2 above
4. Ionospheric inversion

1-52. What type of frequency diversity is used for multichannel broadcasts?

1. Signal
2. Space
3. Triple
4. Tone

1-53. During unpatching, pulling which plug from its tty panel jack first will produce a dangerous dc voltage on the exposed plug?

1. Looping
2. Set

1-54. How many rotary switch positions will you find on a remote transmitter control unit?

1. One
2. Two
3. Three
4. Four

1-55. In AFTS, to what does the term "half-duplex" refer?

1. "Send only"
2. "Receive only"
3. "Send or receive"
4. All of the above

ASSIGNMENT 2

Textbook Assignment: "Systems Equipment Configurations," chapter 2, pages 2-27 through 2-33; "Satellite Communications," chapter 3, pages 3-1 through 3-35.

2-1. Which of the following methods should you use to transmit printed text?

1. Facsimile
2. Single tone
3. Multiplexing
4. Sequencing

2-2. In which of the following publications can you find information on TEMPEST requirements?

1. MIL-STD-1650
2. MIL-STD-1660
3. MIL-STD-1670
4. MIL-STD-1680

2-3. What is the designator of any conductor intended to carry classified plain language terminating in RED equipment or the RED side of crypto equipment?

1. Coded red
2. Primary red
3. Secondary red
4. Terminal red

2-4. Of the following radios, which is popularly known as the "Gibson girl"?

1. AN/CRT-3A
2. AN/PRC-77
3. AN/PRC-96
4. AN/PRC-117

2-5. Which of the following radios provides homing and two-way voice communications between liferafts and searching ships?

1. AN/CRT-3A
2. AN/PRC-77
3. AN/PRC-96
4. AN/PRC-104

2-6. Which of the following radios is particularly useful during tactical black-out operations?

1. AN/PRC-96
2. AN/PRC-104
3. AN/PRC-117
4. AN/PSC-3

2-7. Which of the following radios has frequency hopping capability?

1. AN/PRC-96
2. AN/PRC-104
3. AN/PRC-117
4. AN/PSC-3

2-8. The use of frequency hopping has certain advantages. One advantage is that the signal is difficult to detect. How is this accomplished?

1. No single carrier is used
2. No modulation is used
3. No signal amplification is used
4. No multiplexing is used

2-9. One important feature of the AN/PSC-3 uhf radio is that it can interface directly with vhf radios. What is the purpose of this interface?

1. To provide a satellite link for vhf radios
2. To make everyone use uhf instead of vhf
3. To provide a keyer for the vhf radios
4. To provide dual channel capability for the vhf radios

2-10. DMDG messages are sent at 300 or 1200 baud in the satellite mode and 266.6 baud when connected to AN/PRC-70/74. When these messages are received, they are read on a display screen. Which of the following is the device used to type and read these messages?

1. KY-823/P
2. KY-798/P
3. KY-283/P
4. KY-879/P

2-11. What system was specifically designed to provide solutions to equipment planning by automatically determining the best system that each participant in a communications link should use?

1. CLEPS
2. CLIPS
3. CLSPS
4. CLWPS

2-12. Of the two terms listed below, which one refers to reflection of radio signals back to earth by a satellite?

1. Active
2. Passive

2-13. Which term refers to reception and retransmission?

1. Active
2. Passive

2-14. Which of the following terms refers to transmissions received from a satellite?

1. Uplink
2. Downlink
3. Modelink
4. Backlink

2-15. SATCOM links are only slightly affected by what phenomena associated with hf propagation difficulties?

1. Atmospheric
2. Cosmic
3. Siezemic
4. Vortic

2-16. Trained crews can set up what type of satellite earth terminals within hours to establish communications in remote areas?

1. Crisis
2. Defensive
3. Mobile
4. Partial

2-17. Of the following factors, which, if any, limit the use of a satellite communications system?

1. Orbital parameters and technical characteristics
2. Transmitter power and receiver sensitivity
3. Both 1 and 2
4. None of the above

2-18. What purpose does CUDIXS/NAVMACS serve?

1. Provides an extension to terrestrial teletypewriter networks
2. Provides status reporting and management of system assets
3. Provides a communications link between submarines and shore terminals
4. Provides a communications network for transmitting general-service message traffic between ships and shore installations

2-19. How many NCTAMS have primary responsibility for communications via satellite?

1. One
2. Two
3. Three
4. Four

2-20. Subsystems consist of two parts. What are they?

1. Baseband equipment; rf terminal
2. Multiplexing equipment; satellite
3. Satellite; rf terminal
4. Transmitters; receivers

2-21. In modes 1 through 6, what are the uplink and downlink frequency bands used in Fleet Satellite Broadcast?

1. Hf; shf
2. Uhf; hf
3. Uhf; shf
4. Shf; uhf

2-22. What system do subscribers use to receive Fleet Satellite Broadcast?

1. AN/BRA-1
2. AN/FRT-1
3. AN/SSR-1
4. AN/VRC-1

2-23. What is the minimum number of broadcast channels that NAVMACS guards automatically?

1. One
2. Two
3. Three
4. Four

2-24. What is the bandwidth (in kHz) of the satellite channels allocated to CUDIXS/NAVMACS?

1. 10
2. 15
3. 20
4. 25

2-25. What term is associated with a submarine commander's ability to receive messages via satellite at scheduled intervals?

1. Group broadcasts
2. Interval broadcasts
3. Network broadcasts
4. Timed broadcasts

2-26. Secure voice uses digitized voice with a 3-kHz voice channel. What type of voice modulation does this describe?

1. Multiband
2. Narrowband
3. Singleband
4. Wideband

2-27. When using Secure Voice, a ship must contact what authority before initiating communications with a shore command?

1. Fleet controller
2. Group controller
3. Net controller
4. Voice controller

2-28. Which of the following is a subsystem specifically designed for special intelligence communications?

1. OTCIXS
2. TADIXS
3. TACINTEL
4. FLTSATCOM

2-29. TADIXS-equipped surface ships and submarines operate in what mode(s)?

1. Receive only
2. Transmit only
3. Transmit and receive

2-30. What subsystem is used in conjunction with TADIXS to transmit OTH-T data from the fleet to other ships and shore commands?

1. OTCIXS
2. SSIXS
3. TACINTEL
4. FLTSATCOM

2-31. Because the reception of TADIXS information by a ship does not require an acknowledgement, the ship can l operate in what type of environment and still receive message traffic?

1. Emission control
2. Emission quiet
3. Transmit control
4. Transmit quiet

2-32. What system was developed to multiplex several users on one 25-kHz satellite channel?

1. MSAS
2. DAMA
3. VINSON
4. NCTAMS

2-33. What term is used to describe how the Demand Assigned Multiple Access data stream is formatted?

1. Frame
2. Picture
3 Segment
4. Window

2-34. In the DAMA multiplexed data stream, which slot is used to test for communications error?

1. Data
2. Link
3. Ranging
4. Return channel

2-35. What are all DAMA multiplexer transmit times referenced to?

1. The controller
2. The satellite
3. The transmitter
4. The Vocoder

2-36. Which of the following equipments is used as the DAMA multiplexer?

1. DM-1217B/U
2. TD-1271B/U
3. DM-1271B/U
4. TD-1217B/U

2-37. Who performs day-to-day control and operation of naval satellite communications assets?

1. Chief of Naval Operations
2. Satellite Operations Command
3. Naval Space Command
4. Naval Computer and Telecommunications Command

2-38. Of the 23 uhf communications channels each FLTSATCOM satellite has, how many one dedicated to Navy use?

1. 1
2. 5
3. 10
4. 15

2-39. How many FLTSATCOM satellites have ehf packages installed?

1. One
2. Two
3. Three
4. Four

2-40. LEASAT satellites have fewer 25-kHz channels than FLTSATs. What ground-based system do they use to maintain communications efficiency?

1. DAMA
2. MSAS
3. PSAS
4. VINSON

2-41. What is the replacement satellite for GAPFILLER, FLTSATCOM, and LEASAT?

1. UHF F/O
2. UFO F/O
3. SHF F/O
4. SRP F/O

2-42. The AN/FSC-79 satellite communications terminal transmits on what band?

1. Ehf
2. Hf
3. Shf
4. Uhf

2-43. Which of the following is another term used to describe the shf communications band?

1. A-band
2. S-band
3. U-band
4. X-band

2-44. The AN/WSC-5(V) uhf transceiver is capable of using differentially encoded phase-shift-keying and what other type of modulation?

1. AM
2. CW
3. FM

2-45. Which of the following radios
is the primary shipboard los
and satellite transceiver?

1. AN/WSC-3
2. AN/WCS-3
3. AN/WSC-5
4. AN/WCS-5

2-46. The AN/WSC-3 transceiver has
two rf output levels. One of
these is 30 watts. What is the
other rf output level?

1. 50 watts
2. 100 watts
3. 150 watts
4. 200 watts

2-47. What shipboard system is used
to receive Fleet Satellite
Broadcast?

1. AJS/BRC-1
2. AN/SRR-1
3. AN/SSR-1
4. AN/BRR-1

2-48. Which of the following is a
spread spectrum type modem and
is used with the AN/FSC-79
satellite communications
terminal?

1. OM-33A/USC
2. OM-43A/USC
3. OM-51A/FR
4. OM-61A/FR

2-49. Of the two processors listed
below, which one is used in the
TADIXS subsystem?

1. AN/UYK-20(V)
2. AN/UYK-44(V)

2-50. The AN/USQ-69(V) data terminal
set is currently used with what
two subsystems?

1. SSIXS/OTCIXS
2. TACINTEL/NAVMACS
3. NAVMACS/TADIXS
4. OTCIXS/TADIXS

2-51. Audio digital converter
CV-3333/U is used primarily as
an analog-to-digital converter
for what type of communica-
tions?

1. Analog voice
2. Crypto voice
3. Secure voice
4. Unsecured voice

2-52. Where are the system interface
connectors installed on the
Electrical Equipment Rack
CY-7597/WSC-3?

1. On the back panel
2. On the front panel
3. On the side panel
4. On the top panel

2-53. DAMA-equipped shore
installations use the OK-
481(V)2/FSC Control Monitor
Group to interface TD-1271B/Us,
AN/WSC-5(V)s, and baseband
equipment. It can accommodate
up to how many TD-1271B/Us?

1. 11
2. 12
3. 13
4. 14

Textbook Assignment: "The Link-11 System," chapter 4, pages 4-1 through 4-18.

3-1. Link-11 is designated as which of the following types of tactical data information link?

1. TADIL A
2. TADIL C
3. TADIL J
4. Teletype

3-2. Link-11 communications can operate with which of the following radios?

1. HF only
2. UHF only
3. Either HF or UHF
4. VHF only

3-3. When Link-11 is operated with UHF radio, it is capable of over-the-horizon communications.

1. True
2. False

A. CDS Digital Computer
B. SGS Computer
C. Cryptographic Device
D. Data Terminal Set
E. Communications Switchboard
F. Radio Set

Figure 3A.

IN ANSWERING QUESTIONS 3-4 THROUGH 3-11, SELECT FROM FIGURE 3A THE EQUIPMENT THAT PERFORMS THE FUNCTION DESCRIBED IN THE QUESTION. ITEMS IN THE LIST MAY BE USED MORE THAN ONCE.

3-4. Selects the HF or the UHF transceiver.

1. B
2. C
3. D
4. E

3-5. Encrypts parallel data from the CDS computer and passes the encrypted data to the data terminal set.

1. A
2. B
3. C
4. D

3-6. Correlates reported positions of local and remote tracks.

1. A
2. B
3. C
4. D

3-7. Outputs 24-bit data words to the security equipment via the SGS computer.

1. A
2. B
3. C
4. D

3-8. Multiplexes and modulates parallel data into audio tones.

1. A
2. B
3. C
4. D

3-9. Receives the audio tone package from the data terminal set and transmits the tones.

1. C
2. D
3. E
4. F

3-10. Demodulates the audio tones and checks the six hamming bits for transmission errors.

1. A
2. B
3. C
4. D

3-11. Decrypts the 24-bit data word and sends it to the CDS computer.

1. A
2. B
3. C
4. D

3-12. Which of the following functions is performed by an antenna coupler?

1. Amplification of the HF radio signal
2. Impedance matching of the antenna and the radio set
3. Conversion of atmospheric electromagnetic energy to RF current
4. Coupling of the data terminal set to the radio

3-13. The size of an antenna is determined by which of the following factors?

1. The operating power
2. The operating frequency
3. The range of the receiver
4. The type of data being transmitted

3-14. The frequency range of an antenna can be extended by adding which of the following factors?

1. A resistive load only
2. A capacitive load only
3. An inductive load only
4. Either a capacitive or an inductive load

3-15. Which of the following functions is NOT performed by the data terminal set?

1. Generating the radio key-line signal
2. Converting digital data to audio tones
3. Encrypting CDS computer data
4. Converting audio tones to digital data

3-16. The data terminal set communicates with the radio set via which of the following devices?

1. The communications switchboard
2. An antenna coupler
3. The cryptographic device
4. The SGS computer

3-17. Which of the following radio frequency modulation methods is used to minimize propagation-caused signal loss during HF Link-11 operations?

1. Quadrature phase-shift modulation
2. Frequency modulation
3. Phase modulation
4. Amplitude modulation independent sideband

3-18. Which of the following individuals is responsible for assigning primary and secondary Link-11 frequencies before the deployment of a task force?

1. The aircraft carrier commanding officer
2. The net control station track supervisor
3. The task force commander
4. The fleet CinC

3-19. When a Link-11 net is established, which of the following sequences of operations should be followed to determine readiness of all units to enter the net?

1. Net Test, Net Sync, roll call
2. Net Sync, Net Test, roll call
3. Net Sync, Net Test, Broadcast
4. Roll call, Net Test, Net Sync

A. Net Synchronization
B. Net Test
C. Roll Call
D. Broadcast
E. Short Broadcast
F. Radio Silence

Figure 3B.

IN ANSWERING QUESTIONS 3-20 THROUGH
3-25, SELECT FROM FIGURE 3B THE
OPERATING MODE DESCRIBED IN THE
QUESTION.

3-20. What Link-11 operating mode
establishes a uniform time base
from which all net
communications are normally
initiated?

1. A
2. B
3. C
4. D

3-21. In what Link-11 operating mode
is each picket unit
interrogated, in turn, by NCS?

1. A
2. B
3. C
4. D

3-22. What Link-11 operating mode
provides an overall evaluation
of net and equipment
performance?

1. B
2. C
3. D
4. E

3-23. In what Link-11 operating mode
will one participating unit
transmit data continuously to
all other net members?

1. C
2. D
3. E
4. F

3-24. In what Link-11 operating mode
are the radio set key line and
data terminal audio output
inhibited?

1. C
2. D
3. E
4. F

3-25. In what Link-11 operating mode
is a single data transmission
sent only when the operator
depresses the TRANSMIT START
button?

1. B
2. C
3. D
4. E

3-26. Net Sync continuously
broadcasts which of the
following signals?

1. Phase reference frames
2. Start codes
3. Stop code
4. Preamble frames

3-27. When the stored sync mode is
operating, the picket station
uses which of the following
signals to establish a time
base?

1. An external frequency
standard
2. The internal frequency
standard in the DTS
3. The sync signal received
from NCS
4. The sync signal received
from another picket

3-28. Which of the following
functions is NOT tested when
Net Test is running?

1. DTS to radio interface
2. CDS computer to DTS
interface
3. Radio to antenna interface
4. Radio receiver function

3-29. The preamble of a Link-11
message consists of a total of
how many frames?

1. Five
2. Six
3. Seven
4. Eight

3-30. During transmission of the
preamble, the 605-Hz tone is
transmitted at which of the
following power levels?

1. -6 dB
2. +6 dB
3. -12 dB
4. +12 dB

3-31. To enable the DTS to detect frame transitions during the preamble, the 2915-HZ sync tone is phase shifted how many degrees at each frame?

1.   90
2. 180
3. 270
4. 360

3-32. The phase reference frame of a Link-11 header performs which of the following functions?

1. Provides synchronization between the DTS and the CDS computer
2. Provides a time reference for the DTS
3. Provides a time reference for the radio
4. Provides the reference to extract the data in the next frame

3-33. During a receive cycle, the start code causes which of the following actions?

1. The CDS computer to send the prepare to receive data interrupt
2. The DTS to send the prepare to receive data interrupt
3. The CDS computer to send the prepare to transmit data external function
4. The DTS to send the prepare to transmit data interrupt

3-34. Exactly how many data bits are contained in each Link-11 information frame?

1. 18
2. 24
3. 30
4. 32

3-35. The control stop code is generated by which of the following units?

1. NCS only
2. Picket station only
3. Either NCS or a picket station, indicating the end of a control message

3-36. During a receive cycle, the stop code (control or picket) causes which of the following actions?

1. The CDS computer to send the end of data interrupt
2. The DTS to send the end of data external function
3. The CDS computer to send the end of receive interrupt
4. The DTS to send the end of receive interrupt

3-37. A call-up, or interrogation message, consists of a total of how many frames?

1. Five
2. Six
3. Seven
4. Eight

3-38. The two frames following a control stop code indicate which of the following?

1. The address of the NCS
2. The next picket address in the roll call
3. The end of the NCS message
4. The last address interrogated

3-39. A picket reply message is sent in which of the following sequences?

1. Preamble, phase reference, data, stop code
2. Preamble, phase reference, start code, data, control stop code
3. Preamble, phase reference, start code, data, picket stop code
4. Phase reference, preamble, start code, data, stop code

3-40. The DTS operates in full duplex when it performs which of the following operations?

1. System testing
2. Net Test
3. Normal operations
4. Short Broadcast

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3-41. The DTS performs which of the following functions?

1. Data encryption
2. Error detection and correction
3. Track gridlock
4. Transmitting data tones on a carrier frequency

3-42. The six hamming bits added to the data word enables the DTS to correct what maximum number of data bits?

1. One
2. Two
3. Three
4. Four

3-43. The DTS is operating in the detect and correct mode. A data word is received by the CDS computer with bit 24=0, and bit 25=1. Which of the following conditions is indicated by this bit combination?

1. No errors detected
2. Parity error(s) detected
3. Odd bit error(s) detected, correction attempted
4. Even errors detected, no correction attempted

3-44. The DTS develops a composite signal consisting of what total number of frequency division multiplexed audio-frequency tones?

1. 2
2. 11
3. 16
4. 30

3-45. Bits 4 and 5 of a 30-bit data word are carried by which of the following audio tone frequencies?

1. 935 Hz
2. 1155 Hz
3. 1265 Hz
4. 1705 Hz

3-46. What is the basic unit of the Link-11 transmission?

1. Bit
2. Tone
3. Frame
4. Doppler

3-47. In a single frame, the DTS can tolerate what maximum phase shift error without generating an error code?

1. + 44 degrees only
2. - 44 degrees only
3. ± 44 degrees
4. ±135 degrees

3-48. A phase-shift error of +105 degrees in any one of the data tones will cause a single bit to be erroneous.

1. True
2. False

3-49. Which of the following Link-11 signals allows the receiving unit to correct errors caused by the relative motion between the sending and receiving units?

1. Sync tone
2. Doppler tone
3. Data carrying tones
4. Motion correct tone

3-50. During the preamble, the 2915-Hz tone sets which of the following references?

1. Frame timing when the DTS is in corrected timing
2. Signal power levels when the DTS is in corrected timing
3. Frame timing when the DTS is in stored timing
4. Signal power levels when the DTS is in stored timing

3-51. During the reception of the data segment of a Link-11 message, the 605-Hz Doppler tone should be at which of the following power levels?

1. +12 dB
2. + 6 d B
3. - 6 d B
4. 0 dB

3-52. When the DTS is in the OPERATE mode, exactly how many fault-sensing sensors can cause the SUMMARY FAULT lamp to light?

1. 11
2. 14
3. 23
4. 27

3-53. The LAMP TEST switch on the Mode Control Panel will cause all of which of the following lamps to light?

1. Those on the mode control panel only
2. Those on the TADIL A control panel only
3. Those on the address control unit only
4. Those on the mode control panel, the TADIL A control panel, and the address control unit

3-54. When the FULL-DUPLEX/HALF-DUPLEX switch is in the FULL-DUPLEX POSITION, the transmit sidetone is processed for input to the computer.

1. True
2. False

3-55. When the SIDEBAND SELECT switch is in the DIV position, which sideband signal is processed for input to the computer?

1. USB only
2. LSB only
3. The combination of the USB and LSB signals
4. Either the USB or the LSB, depending on the signal quality of each sideband

3-56. During normal Link-11 operations, the DATA RATE switch on the mode control panel should be in which of the following positions?

1. 1,200 bps
2. 2,400 bps
3. DUAL 1,200 bps
4. TADIL A

3-57. The SYNC MODE switch on the mode control panel is used in conjunction with which of the following switches on the TADIL A control panel?

1. OPERATE/RADIO SILENCE switch
2. NET CONTROL/PICKET switch
3. TIMING STORED/CORRECTED switch
4. ERROR CORRECT/LABEL switch

3-58. When the SYNC MODE switch is placed in the FAST position, synchronization is obtained by which of the following methods?

1. Use of the frame timing reference stored during Net Sync
2. Use of the frame timing reference obtained from the preamble of, the current message only
3. Use of the frame timing reference obtained at each data frame of the current message only
4. Use of both the frame timing reference obtained during the preamble and the frame timing of each frame of the current message

3-59. The NET BUSY indicator of the TADIL A control panel is activated by which of the following signals?

1. Signal presence
2. Receive mode
3. Transmit mode
4. Start code detected

3-60. The SYNC COMPT indicator is lighted after the DTS has achieved which of the following conditions?

1. It is in sync with the radio
2. It is using stored synchronization signals
3. It is in sync with NCS
4. It is testing the internal sync circuits

3-61. The TIMING/STORED/CORRECTED switch is set to the STORED position. Which of the following signals will the DTS use for frame timing synchronization?

1. The frame timing reference stored during Net Sync
2. The frame timing reference obtained from the preamble of the current message only
3. The frame timing reference obtained at each data frame of the current message only
4. Both the frame timing reference obtained during the preamble and the frame timing of each frame of the current message

3-62. When the ERROR CORRECT/LABEL switch is in the CORRECT position, the DTS is capable of performing which of the following operations?

1. Detecting and correcting an even number of bit errors in the received data word
2. Detecting and correcting an odd number of multiple bit errors in the received data word
3. Detecting and correcting a single bit error in each received data word
4. Detecting and correcting a single bit error in the received data message

3-63. When you depress the TRANSMIT RESET switch on the TADIL A control panel, it causes the DTS to perform which of the following operations?

1. To immediately stop all transmissions
2. To inhibit the generation of output data requests, generating a stop code and ending the current transmission
3. To place the radio in radio silence
4. To inhibit the generation of input data requests, generating a stop code and ending the current reception

3-64. The DTS is configured as a picket station in roll call mode. When you depress the TRANSMIT INITIATE switch on the TADIL A control panel, it will cause the DTS to perform which of the following operations, if any?

1. To immediately transmit the data
2. To allow the unit to enter the net
3. To assume control of the net as NCS
4. None

3-65. On the NCS platform, the MISS CALL indicator on the TADIL A panel will light when a picket fails to respond to two successive interrogations.

1. True
2. False

3-66. The address entered into the OWN STATION ADDRESS switches perform which of the following DTS functions?

1. Transmits the entered address to all other members of the net
2. Transmits the entered address to NCS only
3. Receives messages that match the entered address
4. Transmits tactical data when the interrogation message address matches the entered address

3-67. On the NCS platform operating in a Link-11 net where the units are approximately 100 miles apart, which of the following values should be entered into the RANGE IN MILES switches?

1. 0 miles
2. 25 miles
3. 50 miles
4. 100 miles

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3-68. With a single address control indicator, an NCS platform can control what maximum number of participating units?

1. 5
2. 10
3. 15
4. 20

3-69. Data exchange between the Link-11 DTS and the CDS computer is controlled by the DTS using which of the following control signal protocols?

1. External interrupts
2. External functions
3. Input data requests
4. Output data requests

3-70. During a receive data cycle, the DTS performs which of the following actions when frame two of the stop code is detected?

1. The frame is processed as a data frame and sent to the computer
2. The DTS processes the stop code and resets itself only
3. The DTS sends the end of receive external interrupt to the computer
4. The computer processes the stop code and closes the input data buffer

3-71. Which of the following actions is performed by the DTS when a control station stop code is received?

1. The DTS compares the next two frames received with the own station address
2. The DTS resets all I/O timing circuits
3. The DTS sends the next two frames received to the CDS computer
4. The DTS sends the prepare to transmit data interrupt to the computer

3-72. When the DTS recognizes own station address, it transmits which of the following signals first?

1. Prepare to transmit interrupt
2. The first frame of the preamble
3. The phase reference frame
4. Input data request

3-73. At the start of a transmit cycle, the output data request is first set active during which of the following frames?

1. The first frame of the preamble
2. The first frame of the start code
3. The phase-reference frame
4. The second frame of the start code

3-74. Which of the following events takes place when the CDS computer does not answer an ODR from the DTS within the specified time limit?

1. The DTS generates the stop code
2. The DTS hangs-up
3. The computer generates an external function to clear the DTS
4. The computer sends a stop code to the DTS

3-75. Which of the following events occur if an interrogated picket station does not answer an initial interrogations from the NCS within 15 frame intervals?

1. NCS interrogates the next station
2. NCS waits another 15 frame intervals
3. Link-11 network hangs up
4. NCS retransmits the interrogation to the unit that did not reply

ASSIGNMENT 4

4-1. A total of how many data tones
are in the composite tone
package developed by the DTS?

1. 13
2. 14
3. 15
4. 16

4-2. The intelligence (data bits) in
a data tone is stored by which
of the following methods?

1. Phase shifting the tone by a
predetermined amount with
respect to the following
frame
2. Phase shifting the tone by a
predetermined amount with
respect to zero degrees
3. Phase shifting the tone by a
predetermined amount with
respect to the preceding
frame
4. Increasing or decreasing the
amplitude of the data tone
with respect to the
preceding frame

4-3. During receive operations,
exactly how many EDAC bits are
extracted from the received
data tones?

1. One
2. Two
3. Five
4. Six

4-4. The EDAC bits enable the DTS to
correct a total of how many
received bit errors?

1. One
2. Two
3. Three
4. Four

4-5. When operating the Link-11 with
a UHF radio set, you should
place the SIDEBAND SELECT
switch in what position only?

1. LSB
2. USB
3. DIV
4. AUTO

4-6. With Link-11 transmitting on
the HF range and the sideband
select switch set to the AUTO
position, which of the
following priorities are used
by the DTS to find the data
word with no errors to send to
the computer?

1. LSB, USB, DIV
2. LSB, DIV, USB
3. DIV, LSB, USB
4. DIV, USB, LSB

4-7. The Link-11 radio set is in the
transmit mode when the key line
is clear.

1. True
2. False

4-8. Which of the following
conditions would NOT be a valid
reason for changing the unit
functioning as NCS in a Link-11
net to improve net
communications?

1. The current NCS has one PU
address entered wrong
2. The current NCS has poor
receiver sensitivity and is
polling on top of PU
responses
3. Several PUs are in a
propagation shadow
4. Several PUs are out of range
of the current NCS unit

4-9. Changing frequencies will
always solve Link-11 problems.

1. True
2. False

4-10. When you keep the radio set tuned to output maximum power, it causes which of the following problems?

1. Increases RFI/EMI on transmitting unit only
2. Increases receive data errors on receiving units by saturating the data terminal sets only
3. Increases RFI/EMI on the transmitting unit and increases receive data errors by DTS saturation
4. Decreases RFI/EMI on the receiving units

4-11. When the NCS enters dummy PUs, which of the following net conditions will exist, if any?

1. Net efficiency increases
2. Net cycle time decreases
3. Net cycle time increases
4. None, dummy PUs have no effect on the net

4-12. What following NCS action is the most effective net management technique when a PU is having trouble maintaining Link-11 communications?

1. Continuing normal Link-11 operations the trouble PU
2. Directing the PU to go to radio silence so that the PU does not respond to interrogations
3. Directing all units to change from a HF frequency to an UHF frequency
4. Removing the troubled PU from the polling sequence until the problem is corrected and the troubled PU is ready to reenter the net

4-13. When you set up the DTS to run a single-station POFA, the DTS must be configured to operate in which of the following modes?

1. Simplex
2. Half duplex
3. Full duplex
4. POFA TEST mode

4-14. When you run a single-station POFA with the radio set, which of the following equipments is/are NOT checked?

1. Security device 1/0 path
2. Antenna coupler
3. DTS-to-radio audio lines
4. Radio-to-DTS audio lines

4-15. Running a single-station POFA can assist the technician in isolating a problem in which of the following sections of the DTS?

1. Receive timing
2. Doppler correction
3. DTS to antenna interface
4. Transmit timing

4-16. A single-station POFA should print the interrupts in what sequence?

1. End of receive, prepare to transmit, prepare to receive
2. Prepare to receive, prepare to transmit, end of receive
3. Prepare to transmit, end of receive, prepare to receive
4. Prepare to transmit, prepare to receive, end of receive

4-17. A single-station POFA error printout that lists bit errors that are less than 10 percent of the total words transmitted is considered a successful POFA.

1. True
2. False

4-18. A single broken line in the switchboard between the DTS and the crypto device could cause which of the following problems?

1. One bit always set to a logic "1"
2. One bit always set to a logic "0"
3. All bits randomly set to a logic "1"
4. All bits randomly set to a logic "1" or a logic "0"

4-19. The multi-station POFA is run in which of the following modes ?

1. Net test
2. Roll call
3. Broadcast
4. Short broadcast

4-20. When a multi-station POFA is run, what total number of data words are in each block of data transmitted?

1. 115
2. 230
3. 345
4. 460

4-21. When a multi-station POFA is run, all units participating in the test should be positioned within how many miles of each other?

1. 25
2. 50
3. 75
4. 100

4-22. A multi-station POFA should be run using which of the following frequencies?

1. Any HF frequency
2 Any UHF frequency
3. The current operational frequency only
4. The current secondary frequency only

4-23. The multi-station POFA should be run for what minimum amount of time?

1. 5 minutes
2. 7 minutes
3. 10 minutes
4. 15 minutes

4-24. At the completion of the multi-station POFA, the technician should record which of the following information on the error printout?

1. Distance and bearing of all PUs
2. Frequency used
3. Start and stop time of the POFA
4. All of the above

4-25. A multi-station POFA should be considered successful when the link quality factor is which of the following values?

1. Greater than 90 percent
2. Greater than 100 percent
3. Greater than 95 percent but less than 100 percent
4. It must equal 100 percent

4-26. A multi-station POFA is considered successful when the computed receive error factor is less than what percentage?

1. 1
2. 5
3. 10
4. 15

4-27. Which of the following buffers is acceptable to be received from an unrecognized station (UNREC STA) when a multi-station POFA is running?

1. One buffer of 200 words
2. One buffer of 230 words
3. Two buffers of 200 words
4. Two buffers of 230 words

4-28. The heading PARITY STATUS OF CORRECT WORDS lists which of the following error conditions?

1. Words determined to be correct by the DTS parity check and found in error by the computer parity check
2. Words determined to have an error and corrected by the DTS
3. Words determined to be correct by both the DTS and the computer parity checks
4. Words determined to be in error by the DTS parity check and found correct by the computer parity check

4-29. The LMS-11 is designed to perform which of the following functions?

1. Isolate problems to the component level in the Link-11 system
2. Provide a history of Link-11 net performance
3. Provide a real-time visual display of the Link-11 net operations
4. Provide the technician with a visual display of the Link-11 operation of one unit

4-30. The LMS-11 is a complex system designed to be permanently installed.

1. True
2. False

4-31. The DPG and CDG equipment cases of the LMS-11 provide isolation from which of the following environmental forces?

1. Shock only
2. Vibration only
3. Shock and vibration
4. Power surges

4-32. The LMS-11 system printer is part of which of the following equipment groups?

1. Accessory
2. Control/display
3. Data processing
4. Support

4-33. Which of the following components is NOT part of the LMS-11 data processing group?

1. Control processing unit
2. Dual 5.25-inch disk drive unit
3. Audio interface unit
4. Power control unit

4-34. The HP9920U computer of the LMS-11 contains what amount of random access memory (RAM)?

1. 2 MB
2. 4 MB
3. 8 MB
4. 12 MB

4-35. The data communications interface of the LMS-11 provides which of the following functions?

1. Parallel synchronous interface with the Link-11 data terminal
2. Parallel asynchronous interface with the printer
3. Serial synchronous interface with the Link-11 data terminal
4. Serial asynchronous interface with the printer

4-36. The audio interface unit of the LMS-11 connects which of the following signals?

1. USB from HF radios only
2. LSB from HF radios only
3. USB from UHF radios only
4. USB and LSB from HF radios and USB from UHF radios

4-37. To determine the phase shift of the Link-11 audio tones, the LMS-11 uses which of the following methods?

1. Fast Fourier Transform formula
2. Comparison of the raw analog signal with the preceding frame
3. Phase shift signal from the DTS
4. Digital data from the crypto device

4-38. The control/display group consists of which of the following units?

1. Composite video and color output circuit card assemblies
2. Data communications interface and HP interface bus
3. Color monitor and keyboard
4. Color printer and interconnecting cables

4-39. The color display monitor of the LMS-11 uses composite video when it performs which of the following operations?

1. Normal LMS-11 operations
2. Start-up operations only
3. Testing operations only
4. Both start-up and testing operations

4-40. The functional keys on the LMS-11 keyboard are color-coded to facilitate operator selections and entries.

1. True
2. False

4-41. During initialization of the LMS-11, which of the following operator entries is NOT a required entry?

1. Date and time
2. Own-ship PU number
3. Net mode
4. Data rate

4-42. When initializing the LMS-11, the operator enters 127 frames as the CALL-TIMEOUT value. What type of Link-11 operation is indicated by this entry?

1. NET TEST
2. Normal roll call mode
3. Satellite link operation
4. NET SYNC

4-43. The link monitor mode of the LMS-11 displays what information?

1. Quantitative information concerning the operation of a maximum of 21 PUs
2. Detailed characteristics of the received signal from a specified PU
3. Real-time link activity
4. A graphic representation of the power levels of the received Link-11 tones from a single PU

4-44. Which of the following function keys on the LMS-11 keyboard would the operator depress to select the link monitor mode?

1. LM
2. NET
3. SPECT
4. PU

4-45. A PU address of 77 is used by the LMS-11 to indicate which of the following units, if any?

1. PU 77
2. NCS
3. Task force flagship
4. None, 77 is illegal address

IN ANSWERING QUESTIONS 4-46 THROUGH 4-75, REFER TO FIGURE 5-7 IN THE TEXT.

4-46. which of the following colors indicates the preamble on the link monitor screen of the LMS-11?

1. Yellow
2. Red
3. Cyan
4. Green

4-47. A small cyan line in the middle of the data field indicates the LMS-11 has detected which of the following signals?

1. Start code
2. Stop code
3. Phase-reference frame
4. Noise

4-48. Which of the following displays is used to indicate the LMS-11 is listening?

1. A thick blue line
2. A thin blue line
3. A thick red line
4. A thin red line

4-49. The phase-reference frame is displayed on the link monitor display in what manner?

1. As a small green line between the start code and the data
2. As a small red line between the start code and the data
3. As a small green line between the preamble and the start code
4. As a small red line between the preamble and the start code

4-50. Data frames are represented on the link monitor display by which of the following colors?

1. Yellow
2. Red
3. Cyan
4. Green

4-51. An NCS report can be easily identified on the link monitor display by which of the following features?

1. A two digit address at the end of a report only
2. No call-up message between the end of the preceding report and the NCS report only
3. Both a two digit address at the end of the report and no call up message between the preceding report and the NCS report
4. A call message to the NCS address

4-52. An address shown in red on the XMT-ADDRS line of the status display indicates which of the following conditions?

1. The addressed unit is being interrogated
2. The addressed unit failed to answer two interrogations
3. The addressed unit has replied to an interrogation
4. The unit indicated is the next address in the polling sequence

4-53. When the LMS-11 is operating in the link monitor mode and a phase reference frame is detected, which of the following status indicators is active?

1. CC1
2. PHA
3. PRE
4. EOT

4-54. When the LMS-11 is operating in the link monitor mode and the first frame of a picket stop code is detected, which of the following status indicators is active?

1. CC1
2. PHA
3. PRE
4. EOT

4-55. In the status box, the number in the %DATA indicates which of the following quantities?

1. The total percentage of data in the last message received
2. The percentage of data that is error free in the last message received
3. The total percentage of data received during the most recent net cycle
4. The percentage of data that is error free received during the most recent net cycle

4-56. The net cycle time that is displayed in the LMS-11 status box indicates which of the following time cycles?

1. Start code to start code of NCS only
2. Control stop to control stop of NCS only
3. Control stop to control stop of an operator selected PU only
4. Control stop to control stop from either NCS (default) or an operator selected PU

4-57. The Net Display mode of the LMS-11 is capable of displaying two separate types of information.

1. True
2. False

4-58. In the summarize mode of the net display, a summary of quantitative information is displayed for a maximum of how many PUs?

1. 10
2. 11
3. 20
4. 21

4-59. The net display mode can only be displayed when Link-11 is operating in which of the following modes?

1. Net test
2. Net sync
3. Roll call
4. Short broadcast

4-60. The PU field in the header of the Net Display screen of the LMS-11 is used to define which of the following units, if any, while in the summarize mode?

1. NCS
2. Own station PU number
3. The PU whose recurring transmission is used to define a cycle
4. None, the PU field is only used during the History mode

4-61. To change the Net Display screen from the summarize mode to the PU history mode, the operator would take which of the following actions?

1. Depress the history mode key on the keyboard
2. Enter a zero into the SUMMARIZE field of the Net Display header
3. Enter the PU number of the unit to be monitored in the PU field
4. Both 2 and 3 above

4-62. On the Net Display screen, which of the following values indicates an unacceptable SNR?

1. 5 dB
2. 15 dB
3. 25 dB
4. 34 dB

4-63. When the LMS-11 is in the Net Display (summarize) mode, which of the following conditions will cause the FRAME CNT value of a picket to be displayed in yellow and followed by a "?"?

1. The average number of frames per transmission exceeds seven
2. The average number of frames per transmission is six or less
3. The average signal to noise level per transmission exceeds 20 dB
4. The average signal to noise level per transmission is less than 20 dB

4-64. The %THRU column of the Net Display screen displays which of the following values?

1. The percentage of data received by the listed PU that is error-free
2. The percentage of message data frames received by the LMS-11 that contains errors
3. The percentage of message data frames received by the LMS-11 that are error-free
4. The percentage of control code frames received

4-65. Which of the following power levels listed in the REL 605 column of the Net Display screen indicates normal operation of the link?

1. -3 dB
2. -6 dB
3. +3 dB
4. +6 dB

4-66. Using TADIL A specifications, what is the maximum allowable variation of power in the Link-11 data tones?

1. 1.0 dB
2. 1.5 dB
3. 3.0 dB
4. 4.0 dB

4-67. The PU display of the LMS-11 presents a graphic representation of the relative power and phase error of the Link-11 signal received from a specified unit.

1. True
2. False

4-68. What information is displayed on the relative power bar graph of the PU display?

1. The power of the 605-Hz tone only
2. The relative power of the data tones with respect to the 605-Hz tone
3. The relative power of each data tone with respect to the average power of all the data tones
4. The relative power of each data tone with respect to an internal standard

4-69. When the relative power bar graph is read, a data tone that is +2 dB greater than the average will be displayed in which of the following colors?

1. Cyan
2. Green
3. Yellow
4. Red

4-70. The phase error bar graph of the LMS-11 display what information about the Link-11 signal?

1. Relative power
2. Mean deviation of the phase error only
3. Standard deviation of the phase error only
4. Both the mean and standard deviations of the phase error

4-71. A standard phase deviation of 15 degrees for a data tone will be represented on the bar graph in which of the following colors?

1. Cyan
2. Green
3. Yellow
4. Red

4-72. The LMS-11 will indicate that the data received is bad if the standard deviation falls in which of the following ranges?

1. A positive value less than 45 degrees
2. A positive value greater than 45 degrees
3. A negative value less than 45 degrees
4. Both 2 and 3 above

4-73. The incidence of bit errors will increase as the signal-to-noise ratio increases.

1. True
2. False

4-74. Which of the following tones are graphically displayed by the LMS-11 Spectrum Display?

1. 30 tones that are the odd harmonics of 55 Hz
2. 30 tones that are the even harmonics of 55 Hz
3. The 605 Hz tone and the noise tone only
4. The 15 data tones only

4-75. Under ideal conditions, at what level should the data tones be displayed on the bar graph of the spectrum display?

1. 0 dB
2. +6 dB
3. -6 dB
4. +4 dB

Textbook Assignment: "Link-11 Fault Isolation," chapter 5, pages 5-17 through 5-19 (continued); "Link-4A," chapter 6, pages 6-1 through 6-6; and "New Technology in Data Communications," chapter 7, pages 7-1 through 7-6.

5-1. When the operator enters PU 00 into the PU address field of the spectrum display, what effect, if any, will it have on the operation of the LMS-11?

1. 00 is an illegal address; therefore, no data will be displayed
2. The LMS-11 will continuously update the display for each unit in the net
3. The LMS-11 will update the display for NCS only
4. No effect; the LMS-11 will continue to update the last legal address entered

5-2. Carrier suppression can only be tested when the Link-11 system is operating in which of the following modes?

1. Net Test
2. Net Sync
3. Roll call
4. Broadcast

5-3. When reading the LMS-11 spectrum display, the technician notices that only the 605-Hz tone and the 2195-Hz tones are displayed. Which of the following setup entries would cause this display?

1. The RESTRICT field set to preamble only
2. The RESTRICT field set to data only
3. The PU field is set to a unit not in the net
4. The SIDEBAND SELECT is set to USB only

5-4. The CDS computer outputs serial digital data to the Link-14A DTS.

1. True
2. False

5-5. Link-4A is used to transmit which of the following types of information?

1. High-speed computer-to-computer tactical information
2. Tactical information from a CDS ship to a non-CDS ship
3. Aircraft control and target information
4. All of the above

5-6. Link-4A data is transmitted by using which of the following methods?

1. Frequency-shift keying
2. Phase-shift keying
3. Audio frequency tone shift
4. Quadrature differential phase-shift keying

5-7. What is the maximum number of aircraft that can be controlled by a single Link-4A controlling station?

1. 25
2. 50
3. 75
4. 100

5-8. Aircraft control messages from the Link-4A controlling station are developed by the CDS computer using which of the following types of information?

1. Radar-derived target data
2. Reply data from aircraft
3. Other sources of tactical information
4. All of the above

5-9. Link-4A uses which of the following frequency bands for data exchange?

1. HF only
2. UHF only
3. VHF only
4. Both UHF and VHF

5-10. In which of the following Link-4A modes of operation is an aircraft directed to a specific location to be at an optimum position for an attack?

1. Precision course direction
2. Automatic carrier landing system
3. Air traffic control
4. Intercept vectoring

5-11. In which of the following Link-4A modes of operation is used to maintain safe flight patterns and assigns priority for landing approach?

1. Precision course direction
2. Automatic carrier landing system
3. Air traffic control
4. Intercept vectoring

5-12. Which of the following Link-4A modes of operation is used for the remote guidance of bombers, reconnaissance aircraft, and drones?

1. Precision course direction
2. Automatic carrier landing system
3. Air traffic control
4. Intercept vectoring

5-13. In which of the following Link-4A modes of operation is used to land an aircraft on the flight deck of a carrier?

1. Precision course direction
2. Automatic carrier landing system
3. Air traffic control
4. Intercept vectoring

5-14. The CAINS aircraft alignment data loaded into the navigation computer of the aircraft consists of which of the following types of data?

1. The latitude and longitude of the ship only
2. The ship's velocity only
3. The latitude, longitude, and ship's velocity
4. The waypoint data

5-15. The CAINS alignment and waypoint data is initially loaded into the aircraft using which of the following methods?

1. Hard-wired deck edge outlet boxes only
2. UHF RF transmission only
3. Either hard-wired deck edge outlet boxes or UHF RF transmission
4. HF transmission only

5-16. The standard CDS control message is ___(a)___ (2), (14) milliseconds in duration, while the reply message is ___(b)___ (14), (18) milliseconds in duration.

1. (a) 2   (b) 14
2. (a) 2   (b) 18
3. (a) 14   (b) 14
4. (a) 14   (b) 18

5-17. The CAINS receive cycle duration is equal to what total number of milliseconds?

1. 2
2. 4
3. 14
4. 18

5-18. The transmit frame is divided into what total number of 200 µsec time slots?

1. 13
2. 56
3. 70
4. 200

5-19. What total number of time slots make up the sync preamble of each transmit frame?

1. 13
2. 42
3. 56
4. 70

5-20. What total number of transmit frame time slots contain message data bits?

1. 8
2. 13
3. 56
4. 70

28

5-21. Which of the following transit frame signals causes the transmitter to turn off and starts the receive cycle?

1. Stop pulse
2. Sync burst
3. Guard interval
4. Transmitter un-key

5-22. The reply message contains what total number of data time slots?

1. 13
2. 42
3. 56
4. 70

5-23. Which of the following Link-4A test messages is used to provide aircraft with the means to verify proper operation of Link-4A?

1. The monitor reply message
2. The monitor control message
3. The universal test message
4. All of the above

5-24. Which of the following Link-4A test messages causes internal testing of the data terminal set?

1. The monitor reply message
2. The monitor control message
3. The universal message
4. All of the above

5-25. Which of the following AN/SSW-1() subassemblies provides system timing for Link-4A operations?

1. Digital-to-digital converter
2. Monitor test panel
3. Coordinate data transfer control
4. Pulse amplifiers

5-26. Which of the following pieces of equipment is replacing older Link-11 data terminal sets?

1. AN/USQ-36 Data Terminal Set
2. C2P
3. AN/USQ-125 Data Terminal Set
4. Link-16

5-27. The CP-2205 (P) (V)/USQ-125 processor board performs which of the following functions?

1. Modulation/demodulation
2. Error detection and correction
3. Radio set interface
4. All of the above

5-28. Which of the following CP-2205 (P) (V)/USQ-125 components provides for communications with the CDS computer?

1. Processor board
2. Interface board
3. Power supply
4. Modulator

5-29. The CP-2205 (P) (V)/USQ-125 is capable of data encrytion.

1. True
2. False

5-30. The single-tone waveform link capability of the CP-2205 (P) (V)/USQ-125 provides which of the following functions?

1. Interface with a satellite modem
2. Increases UHF transmission range
3. Increases HF transmission range
4. Reduces HF propagation anomalies

5-31. Which of the following options of the CP-2205 (P) (V)/USQ-125 incorporates a routine to calculate the optimum frequency?

1. Enhanced link quality analysis
2. Maximum useable frequency
3. Single-tone waveform link
4. Multi-frequency link

5-32. Which of the following options of the CP-2205 (P) (V)/USQ-125 transmits Link-11 data through a standard wire-line modem?

1. Enhanced link quality analysis
2. Maximum useable frequency
3. Single-tone waveform link
4. Multi-frequency link

5-33. Which of the following options
of the CP-2205 (P) (V)/USQ-125
incorporates most of the
functions of the LMS-11?

1. Enhanced link quality
analysis
2. Maximum useable frequency
3. Single-tone waveform link
4. Multi-frequency link

5-34. Which of the following options
of the CP-2205 (P) (V)/USQ-125
improves Link-11 operations by
using four frequencies
simultaneously?

1. Enhanced link quality
analysis
2. Maximum useable frequency
3. Single-tone waveform link
4. Multi-frequency link

5-35. The normal configuration of the
multi-frequency link options
uses _____(a)_____
      (2)   (3)
HF frequencies and ___(b)___
                    (1),   (2)
UHF frequencies.

1. (a) 2   (b) 1
2. (a) 3   (b) 1
3. (a) 2   (b) 2
4. (a) 3   (b) 2

```
A.   Radio echo test
B.   Loopback test 1
C.   Loopback test 2
D.   Loopback test 3
E.   Loopback test 4
F.   DTS fault isolation test
```

FIGURE 4A.

5-36. This option is selected when a
single station POFA is running
without the radio.

1. A
2. B
3. C
4. D

5-37. When this test is run, the
computer interface is disabled
and a test message is
repeatedly sent to the radio
set.

1. A
2. B
3. C
4. D

5-38. This test is used to verify the
operation of the computer
interface, crypto device, and
the data terminal interface
circuits.

1. C
2. D
3. E
4. F

5-39. This test places the DTS in
full-duplex mode to run a
single station POFA with the
radio.

1. A
2. B
3. C
4. D

5-40. This option performs an
internal self-test of the DTS
audio circuits.

1. A
2. B
3. C
4. D

5-41. The data terminal can be controlled from a remote location by use of which of the following pieces of equipment?

1. A 286 personal computer only
2. A 386 or better personal computer only
3. The C-12428/USQ-125 Control Unit only
4. Either a 386 or better personal computer, or the C-12428/USQ-125 Control Unit

5-42. Link-16 uses which of the following communications protocols?

1. Netted or roll call
2. Time division, command and response
3. Time division multiple access
4. Frequency-division multiplexing

5-43. Each unit participating in a Link-16 net is identified by assigning each unit what type of designator?

1. A PU number
2. A JU number
3. A link identifier
4. A hull number

5-44. What is the duration of each time slot in a Link-16 message?

1. 7.8125 msec
2. 7.8125 μsec
3. 7.8125 seconds
4. It varies, according to the amount of data transmitted

5-45. During the transmission of data, exactly how often does Link-16 change frequency?

1. Every 13 μsec
2. Every 13 msec
3. Daily
4. When the frequency is excessively noisy

5-46. Link-16 is configured for a stacked net. At-any one time, what number of nets can a single terminal transmit and receive data?

1. One
2. Two
3. Three
4. Four

5-47. A Link-16 data word is comprised of what number of data bits?

1. 50
2. 60
3. 70
4. 80

5-48. A Link-16 fixed format message is which of the following message types?

1. V-series
2. R-series
3. M-series
4. J-series

5-49. Which of the following message types are used for Link-16 voice communications?

1. Fixed format
2. Free text
3. Variable format
4. Unformatted

5-50. Which of the following message types are used to exchange tactical data?

1. Fixed format
2. Free text
3. Variable format
4. Unformatted

Textbook Assignment: "New Technology in Data Communications," chapter 7, pages 7-6 through 7-11 (continued); "Local-Area Networks," chapter 8, pages 8-1 through 8-14.

6-1. Compared to Link-11, Link-16 is nodeless for which of the following reasons?

1. Once the net is established, all units must participate
2. Only one unit controls the net
3. Once the net is established, operations can continue regardless of the participation of any particular unit
4. A computer is not required to participate in the net

6-2. Which of the following JTIDS security features is designed to prevent jamming?

1. Data encryption
2. Waveform encryption
3. Introduction of jitter and noise
4. Frequency hopping

6-3. Which of the following network participation groups is normally excluded from Navy command and control units?

1. Weapons coordination
2 Air control
3 Fight-to-fighter
4 Secure voice

6-4. JU numbers 00001 through 00177 are normally assigned to which of the following units?

1. Link-4A and Link-16 capable units
2. Command and Control units
3. Link-16 capable aircraft
4. Link-11 and Link-16 capable units

6-5. Which of the following Link-16 track numbers would designate the same Link-11 track?

1. 00000 through 07777
2. 01000 through 77777
3. 00200 through 07777
4. 00500 through 77777

6-6. A Link-16 track that has a reported track quality of 15 indicates the track is within exactly how many feet of the reported position?

1. 10
2. 25
3. 50
4. 75

6-7. Which of the following track identifications has been added for use with the Link-16 system?

1. Neutral
2. Hostile
3. Assumed hostile
4. Unknown

6-8. The identifier "Unknown assumed enemy has been changed in the Link-16 system to what identifier?

1. Neutral
2. Suspect
3. Unknown assumed hostile
4. Hostile

6-9. Link-16 has added which of the following data fields to friendly aircraft status reports?

1. Ordnance inventory
2. Equipment Status
3. Fuel available for transfer
4. All of the above

6-10. The Relative Navigation function of the Link-16 system is required for which of the following functions?

1. Maintain synchronization
2. Maintain position
3. Detect course errors
4. Correct the navigation plot

6-11. Which of the following
equipment configurations fully
implements the capabilities of
the Link-16 system?

1. Model-3
2. Model-4
3. Model-5
4. Model-6

6-12. Using the Link-16 Model-5
system, link data generated by
the ACDS computer is normalized
to be independent of any
particular system.

1. True
2. False

6-13. Using the Link-16 Model-5
system, which of the following
components formats link data
for transmission over any one
of the three data links?

1. ACDS
2. C2P
3. Link-16 data terminal
4. TDS computer

```
A. Digital data processor group
B. Receiver/transmitter group
C. High power amplifier group
D. Power interface unit
E. Secure data unit
```

Figure 6A.

IN ANSWERING QUESTIONS 6-14 THROUGH
6-17, SELECT FROM FIGURE 6A THE
EQUIPMENT COMPONENT GROUP OF THE JTIDS
TERMINAL THAT PERFORMS THE FUNCTION OR
OPERATION DESCRIBED IN THE QUESTION.
NOT ALL ITEMS IN THE LIST ARE USED.

6-14. A removable assembly that
stores cryptovariables.

1. B
2. C
3. D
4. E

6-15. Generates a 75-MHz intermediate
frequency for internal
communications.

1. A
2. B
3. C
4. D

6-16. Provides the interface with the
antenna.

1. A
2. B
3. C
4. D

6-17. Performs digital-to-analog and
analog-to-digital conversion of
voice signals.

1. A
2. B
3. C
4. D

6-18. The Command and Control (C2P)
system controls and manages the
interface of which of the
following data links?

1. Link-4A only
2. Link-11 only
3. Link-16 only
4. All tactical data links

6-19. Messages received by the C2P
over the Link-11 net cannot be
retransmitted over the Link-16
net.

1. True
2. False

6-20. A local area network (LAN)
performs which of the following
functions?

1. Enables users to share data
2. Enables users to share
peripheral devices
3. Allows users to send and
receive messages via
computer
4. All of the above

6-21. Which of the following items is
a node in a LAN system?

1. Twisted pair cable
2. Communications media
3. Fiber-optic cable
4. Large capacity hard drive

6-22. Twisted pair cable used in a LAN has which of the following advantages?

1. High data transmission speeds
2. Low costs and easy to install
3. Shielded from electrical interference
4. Secure data transmission

6-23. In designing a LAN system that requires the transmission of digital data, audio, and video simultaneously, which of the following cables would be best suited to the system?

1. Twisted pair
2. Shielded twisted pair
3. Broadband coaxial
4. Baseband coaxial

6-24. Which of the following types of cable is immune to interference from electrical and electronic devices?

1. Fiber optic
2. Baseband coaxial
3. Shielded twisted pair
4. Telephone cable

6-25. Which of the following devices provides the interface between the LAN and a personal computer?

1. Network server
2. NIC
3. Disk server
4. Cables

6-26. Which of the following devices is used to manage the shared resources of the LAN?

1. Network server
2. NIC
3. Disk server
4. Network monitor

6-27. Early disk servers suffered from which of the following problems?

1. Lack of security
2. No data organization
3. No disk management
4. All of the above

6-28. Ensuring data integrity by preventing multiple users access to the same record at the same time is known as what process?

1. File locking
2. Field locking
3. Record locking
4. Disk lockout

6-29. Which of the following servers was developed to provide reliable disk management in a LAN?

1. Disk server
2. Print server
3. File server
4. Network server

6-30. Which of the following functions is NOT performed by the file server?

1. Routing files to a central printer for printing
2. Processing of the network control software
3. Converting high-level disks calls from a workstation to low-level disk commands
4. Maintaining the list of user privileges and authorizations

6-31. When designing and building a LAN system, all workstations must be from the same manufacturer.

1. True
2. False

6-32. The OSI reference model is used to define which of the following communications standards?

1. Interconnection of communications facilities
2. Software
3. Hardware
4. Protocol

6-33. What layer of the OSI reference model describes the electrical, the mechanical, and the functional interface of the communications channel?

1. Physical layer
2. Data link layer
3. Network layer
4. Transport layer

6-34. What layer of the OSI reference model establishes and deletes host-to-host connections across the network?

1. Data link layer
2. Network layer
3. Transport layer
4. Session layer

6-35. As a translator for the network, what layer of the OSI reference model provides a common representation for data which can be used between the application processes?

1. Network layer
2. Transport layer
3. Session layer
4. Presentation level/layer

6-36. Which of the following layers of the OSI reference model provides error-free transmission of information over the physical medium?

1. Physical
2. Data link
3. Network
4. Transport

6-37. Communications between users on two different machines are established by what layer of the OSI reference model?

1. Data link
2. Network
3. Transport
4. Session

6-38. Based on network conditions and priority of service, what layer of the OSI reference model decides which physical pathway the data should take?

1. Physical
2. Data link
3. Network
4. Transport

6-39. The application level/layer of the OSI reference model provides the protocols for which of the following user items?

1. Media interface
2. Electronic mail
3. Routing of messages between networks
4. Data compression

6-40. Which of the following is NOT a LAN topology?

1. Linear
2. Ring
3. Star
4. EtherNet

6-41. Which of the following features of a linear bus topology should be considered an advantage?

1. Signal interference when nodes are too close to each other
2. System remains operable even when one or more nodes fail
3. Very secure system
4. Very easy to run system diagnostics from the LAN administrator

6-42. In which of the following network topologies, if any, is each node individually connected to the network server?

1. Linear bus
2. Star
3. Ring
4. None of the above

6-43. Which of the following network access methods requires each node to wait for permission to transmit data?

1. CSMA
2. CSMA/CD
3. Token passing
4. Contention

6-44. On a network that uses the CSMA/CD access method, which of the following actions, if any, will be taken when a data collision is detected?

1. The workstation will cease transmission and wait until the line is clear
2. The workstation will continue to transmit data
3. The network server will assign the next open time to the workstation that suffered the collision
4. No action is taken; the data is lost

6-45. In a LAN using a token ring topology, the interface and protocols are defined by which of the following IEEE standards?

1. IEEE 802
2. IEEE 802.3
3. IEEE 802.4
4. IEEE 802.5

6-46. Which of the following LAN systems uses a token ring topology and has a data throughput of 4 Mbits and 16 Mbits per second?

1. EtherNet
2. STARLAN
3. ARCnet
4. IBM Token Ring

A. Control kernel
B. Network interfaces
C. File systems
D. File extensions

Figure 6B.

IN ANSWERING QUESTIONS 6-46 THROUGH 6-49, SELECT FROM FIGURE 6B THE NETWORK OPERATING SYSTEM COMPONENT THAT PERFORMS THE FUNCTION DESCRIBED IN THE QUESTION. NOT ALL ITEMS IN THE LIST ARE USED.

6-47. Provides low-level subnet protocols and translation for bridging hardware drivers with the network operating system.

1. A
2. B
3. C
4. D

6-48. Controls data organization, storage, and retrieval on the various storage systems available to the network.

1. A
2. B
3. C
4. D

6-49. The main subsystem of the network operating software.

1. A
2. B
3. C
4. D

6-50. Which of the following network operating systems, if any, is designed for very few users and light usage?

1. Full featured
2. Low cost
3. Zero slot
4. None of the above

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