



**NONRESIDENT  
TRAINING  
COURSE**



July 1997

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# **Fire Controlman**

## **Volume 6—Digital Communications**

**NAVEDTRA 14103**

**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.**

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# 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:** In completing this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following subjects:

- types of communications systems;
- the decibel system of power measurement;
- synchronous and asynchronous communications as used in data communications systems;
- methods of data modulation and demodulation used in various types of data networks;
- the operation of modems used in data communications;
- methods of multiplexing data in communications networks;
- equipment associated with and the operation of the Link-11 data communications system;
- equipment associated with and the operation of the Link-4A data communications system;
- equipment associated with and the basic operation of 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.

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Published by  
NAVAL EDUCATION AND TRAINING  
PROFESSIONAL DEVELOPMENT  
AND TECHNOLOGY CENTER

**NAVSUP Logistics Tracking Number  
0504-LP-026-7710**

## **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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# 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).

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**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.

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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:

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## **STUDENT FEEDBACK QUESTIONS**

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## Student Comments

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**NAVEDTRA:** 14103 **Date:** \_\_\_\_\_

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## CHAPTER 1

# FUNDAMENTALS OF DATA COMMUNICATIONS

## INTRODUCTION

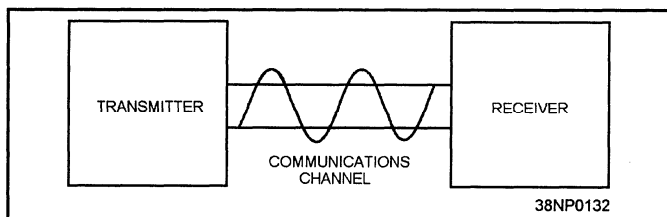
Although you, as a Fire Controlman, may not be directly involved in data communications, you definitely need to be aware of how data communications affects your ship's mission. This training manual introduces and explains the basics of data communications. Computer data frequently must be transmitted from one point to another. The distance involved maybe a few feet, or it may be hundreds of miles. Data transited over long distances often must be converted to a form compatible with either landline or radio wave transmission and reception. This chapter explains how such conversion occurs and techniques used in the conversion and transmission procedures.

**After completing this chapter, you should be able to:**

- **State the types of communications systems.**
- **Describe the decibel system of power measurement.**
- **Explain asynchronous and synchronous communications as used in data communications systems.**
- **Describe the methods of data modulation and demodulation used in various types of data networks.**
- **Describe the operation of modems used in data communications networks.**
- **Describe the methods of multiplexing data in communications networks.**

## COMMUNICATIONS SYSTEMS

The devices used to transfer digital data makeup what is known as a communications system. In its most basic form, a communications system consists of the three components shown in figure 1-1. They are



**Figure 1-1.—Communications system.**

the transmitter, the receiver, and a communications channel that connects the two units.

The transmitting equipment converts the data of the sending system into a form that can be sent over the communications channel, accepted by the receiving equipment, and converted back into usable data by the receiving system. Data sent over a communications system is in one of the following two forms: analog or digital.

An analog signal used in data communications varies continuously between a minimum and a maximum value. As the signal varies, it assumes an infinite number of specific values between the two

limits. The signal can be varied in amplitude (amplitude modulation), frequency (frequency modulation), or phase (phase modulation) to convey the data. We will discuss each type of modulation later in this chapter.

A digital signal has a limited set of values (1 or 0, true or false, etc.). A limited number of discrete pulses can be transmitted in a fixed period. The unique sequence of the bits represents the data.

Digital equipments (computers and peripherals) within a system normally communicate with each other in pure digital pulses (serial and parallel). Transmitting digital information over a distance requires the use of special equipment to convert digital data pulses into a form acceptable to the various types of communications channels. The equipment most often transmits digital data over a distance by varying a continuous analog signal in amplitude, frequency, or phase.

Communications channels that can pass data in two directions (transmit and receive) are known as **duplex channels**. Single-direction channels are **simplex channels**. Duplex channels may operate in one of the following two modes: half-duplex or full-duplex. Half-duplex channels transmit data in one direction, pause, and then receive data coming from the opposite direction. Full-duplex channels, on the other hand, can transmit and receive data simultaneously.

## **TYPES OF COMMUNICATIONS CHANNELS (TRANSMISSION MEDIA)**

In the fleet and at shore activities, you will encounter several forms of communications channels. The most common channels are landlines and radio communications.

### **Landlines**

Landlines are physical lines or cables that connect the digital equipment. Originally, landlines referred to telephone lines and were limited to carrying analog audio frequencies (voice frequencies). For digital information to be carried over these lines, the

characteristics of one or more tones or carriers in the audio-frequency range had to be modified in amplitude, frequency, or phase.

Today, telephone lines are commonly used in many network applications. Bulletin boards, such as BUPERS ACCESS, use existing telephone lines; but many landline-based systems use dedicated lines. Dedicated lines are common in local area networks (LANs). In a LAN system, several computers are joined together to share information with all the users on the system. System connections are made using coaxial, dual-coaxial, fiber-optic, or twisted-pair cable. The type of cable depends on several factors, such as the number of users on the LAN and the maximum distance between workstations.

The device used to convert the digital data into a form usable by the communications channel and back to digital data is known as a **modem**.

Modem is an acronym for MODulator DEModulator. The modulator function converts the data of the transmitting system into discrete modifications of the tone or carrier signals. The demodulator converts the data-carrying tone or carrier signal into digital data for the receiving system.

### **Radio**

Radio waves have been used for teletype and voice communications for many decades. The advantages of radio-based systems are that they are more mobile and can communicate over barriers such as large bodies of water. Tactical information links, like those we will cover in chapter 2, are almost exclusively radio-based.

Radio communications are based on frequency ranges or **radio-frequency bands**. The frequency range of the **carrier frequency** determines the operational characteristics of the system. Table 1-1 illustrates the international frequency bands and their uses. The tactical digital information systems used by the Navy generally use portions of the **hf** and **uhf** bands.

**Table 1-1.—Frequency Bands and Their Applications**

<b>FREQUENCY</b>	<b>DESCRIPTION</b>	<b>APPLICATION</b>
Up to 300 Hz	Extremely low frequency (elf)	Special communications
300 Hz – 3 kHz	Voice frequency	
3 KHz – 30 kHz	Very low frequency (vlf)	Shore-based communications, experimental
30 KHz – 300 kHz	Low frequency (lf)	Shore-based communications, navigation
300 KHz – 3 MHz	Medium frequency (mf)	Commercial broadcast band (550 kHz to 1700 kHz), communications on either side of the broadcast band
3 MHz – 30 MHz	High frequency (hf)	Ship and shore long-range communications
30 MHz – 300 MHz	Very high frequency (vhf)	Communications, navigation
300 MHz – 3 GHz	Ultra high frequency (uhf)	Line-of-sight communications to 400 MHz; above this frequency, radar and special equipments
3 GHz – 30 GHz	Superhigh frequency (shf)	Radar and special equipments
30 GHz – 300 GHz	Extremely high frequency (ehf)	Radar and special equipments

In the radio transmitter, the data signals (discrete or tones) are modulated (impressed) on to the carrier frequency and transmitted into space when the transmitter is keyed. A receiver tuned to the carrier frequency picks up the signal and demodulates the data-carrying signals from the carrier. The data signals can then be converted to digital data by the appropriate devices. For more information on radio operations, refer to Navy Electricity and Electronics Training Series (NEETS), Module 17— *Radio-Frequency Communications Principles*.

**THE DECIBEL MEASUREMENT SYSTEM**

Technicians who deal with communications equipment often speak of the gain of an amplifier or a system in units called decibels (dB). Decibels are used as an indication of equipment performance; therefore, you need a basic understanding of the decibel system of measurement.

As the actual calculation of decibel measurement is seldom required in practical applications, the explanation presented in this text is somewhat simplified. Most modern test equipment is designed to measure and indicate decibels directly. This design

eliminates the need for complicated mathematical calculations. Nevertheless, because many data link system alignment procedures center around dB readings and references, you need to understand the significance of an equipment gain rating as expressed in decibels.

The equipment used in communications systems consists of several components, such as amplifiers, communications lines, antennas, couplers, and switches. Each component in the system will affect the signal by introducing a signal loss or gain. These losses and gains can be described by a ratio of the power input and output by the equipment or cable. The ratio can be calculated by using the following formula:

$$\frac{\text{Output power}}{\text{Input power}} = \text{Power ratio}$$

If a communications system has four components, the gain or loss at each component must be calculated and these ratios multiplied. The following is an example of the gain/loss calculation of a four-component system:

$$\frac{1}{2} \times \frac{1}{10} \times \frac{1}{25} \times \frac{1000}{1} = 2$$

In this system, the output of the signal is twice as strong as the input to the system.

As you can see, this constant multiplication of the ratios can be wearisome, and the products can be extremely small or large. Therefore, the discovery that adding the logarithms of the numbers would yield the same result as this calculation led early scientists to develop the unit of measure called the *bel*.

The bel, named in honor of Alexander Graham Bell, expresses the logarithmic ratio between the input and output of any given component, circuit, or system. The bel maybe expressed in voltage, current, sound levels, or power. The formula is as follows:

$$N = \log_{10} \frac{P1}{P2} \text{ bel}$$

The gain of an amplifier can be expressed in bels (N) by dividing the output (P1) by the input (P2) and taking the base 10 logarithm ( $\log_{10}$ ) of the resulting quotient. Thus, if an amplifier doubles the power, the quotient will be 2. When you consult a logarithm table, you will find that the base 10 logarithm of 2 is 0.3; so the power gain of the amplifier is 0.3 bel.

Experience has shown that the bel is a rather large unit that is difficult to apply. A more practical, easier unit to apply is the decibel (1/10 bel). Any figure expressed in bels can be converted to decibels by multiplying the value by 10. Thus the ratio of 0.3 bel is equal to 3 decibels.

The reason the decibel system is used to express signal strength is shown in table 1-2. For example, saying that a reference signal has increased 50 dB is much easier than saying that the output has increased 100,000 times.

The basis of the decibel measuring system is the amount of increase or decrease from a reference level. Whether the input power is increased from 1 watt to

100 watts or from 1,000 watts to 100,000 watts, the amount of increase, or gain, is still 100 times or 20 dB. Examine table 1-2 again, taking particular note of the power ratios for source levels 3 dB and 6 dB. As the table illustrates, an increase of 3 dB represents a doubling of power. The reverse is also true. If a signal decreases by 3 dB, half of the power is lost. For example, a 1,000-watt signal decreased by 3 dB will equal 500 watts, while a 1,000-watt signal increased by 3 dB will equal 2,000 watts.

**Table 1-2.—Decibel Power Ratios**

Source Level (dB)	Power Ratio
1	= 1.3
3	= 2.0
5	= 3.2
6	= 4.0
7	= 5.0
10	= 10 = 10 <sup>1</sup>
20	= 100 = 10 <sup>2</sup>
30	= 1,000 = 10 <sup>3</sup>
40	= 10,000 = 10 <sup>4</sup>
50	= 100,000 = 10 <sup>5</sup>
60	= 1,000,000 = 10 <sup>6</sup>
70	= 10,000,000 = 10 <sup>7</sup>
100	= 10 <sup>10</sup>
110	= 10 <sup>11</sup>
140	= 10 <sup>14</sup>

When you speak of the dB level of a signal, you are actually speaking of the logarithmic comparison between the input and output signals. The input signal is normally used as the reference signal. In some instances, a standard reference signal must be used in place of the input signal. The most widely used reference level is a 1-milliwatt signal (600-ohm load). When the 1-milliwatt reference is used, the standard decibel abbreviation of dB is changed to **dBm**; dBms are used as an indication of power, while dBs are used to indicate the ratio between the input and output.

A signal level of +3 dBm is 3 dB above 1 milliwatt, and a signal level of -3 dBm is 3 dB below 1 milliwatt. Whether you are using dB or dBm, a plus sign (+) or no sign indicates that the output level is

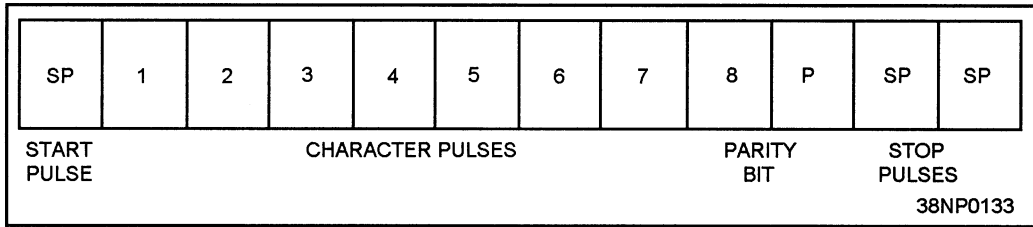


Figure 1-2.—Asynchronous character code.

greater than the reference (power gain), while a minus sign (–) indicates that the power level is less than the reference (power loss). The value 0 dBm indicates that the output power is equal to the 1-milliwatt reference. It is also used to express a definite amount of power (1 milliwatt). The value 0 dBm equates to 1 milliwatt.

### DIGITAL DATA COMMUNICATIONS TECHNIQUES

Data signals transmitted over communications channels need to follow specific protocols to ensure they are synchronized. In normal I/O data exchanges, this process is accomplished by the system of requests and acknowledges. In addition, the data signals have to be properly formatted for the receiving computer to decode them properly.

### ASYNCHRONOUS AND SYNCHRONOUS COMMUNICATIONS

Two major data-formatting methods are used to make sure the transmitting computer and the receiving computer(s) are synchronized: asynchronous (character framed) and synchronous (message framed). Both methods are used to identify intelligence transmitted in the form of serial bit streams.

### Asynchronous Transmission

Asynchronous transmission of data is commonly found in landline communications systems and some forms of teletype communications. Generally, asynchronous, or character-framed, transmission is used to transmit seven- or eight-bit data, usually in ASCII character format. Each character has a specific start and end sequence—usually one start bit and one or two end (stop) bits. Figure 1-2 illustrates the transmission format of an asynchronous data stream. A parity bit (even or odd) maybe included to ensure the accuracy of the transmitted data. Asynchronous characters may be transmitted one at a time or as a string of characters; however, each character transmitted will have start and end bits. When data signals are transmitted in this format, synchronization occurs on a character-by-character basis between the transmitting and receiving devices and provides some allowance for timing inaccuracies. Any inaccuracy in timing is corrected with the arrival of the next character.

### Synchronous Transmission

Most tactical digital information links communicate using synchronous messages. Synchronous transmission is a more sophisticated method of data transmission. It sends data in long uninterrupted streams, with a predefine start and stop sequence. The start sequence is generally referred to

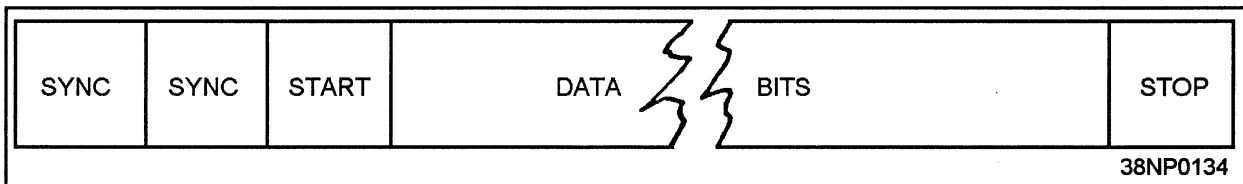


Figure 1-3.—Synchronous message format.

as the preamble. The principal function of the preamble is to alert the receiver of incoming data and provide a reference to synchronize the receiver with the transmitted signal. Following the preamble is a start code that informs the receiving equipment of the beginning of the message data. The basic format of the synchronous data message is shown in figure 1-3. The incoming bit stream is then used to synchronize the receiver or demodulator timing. A stop code follows the message data to indicate the end of transmission.

## MODULATION/DEMODULATION

Modulation modifies a signal so it can carry data over the communications channel. The demodulator removes the data from the carrier. For most data communications applications, the carrier is a continuous sinusoidal waveform (sine wave). The frequency of the carrier varies, depending on the application. Landline transmission generally uses the audio-frequency bandwidth signals (300 to 3,000 Hz). Radio channels use audio-frequency tones as data carriers modulated to a radio-frequency signal, or they modulate the radio-frequency signal itself to convey data.

The three basic modes of modulation are **amplitude modulation**, **frequency modulation**, and **phase modulation**. Each of these modes modifies the carrier signal in some manner to convey data.

### Amplitude Modulation

When amplitude modulation is used for digital transmissions, the amplitude of the carrier signal represents the two discrete data states (1 or 0). The signal represents a logic 1 when the amplitude (peak-to-peak), at the same frequency, is greater at a different time, as shown in figure 1-4. The decrease in signal amplitude, below a predetermined threshold, indicates a change from a logic 1 to a logic 0.

### Frequency Modulation

The frequency of the carrier signal or audio tones modulated to the carrier signal can be modified to indicate the two discrete states. As shown in figure

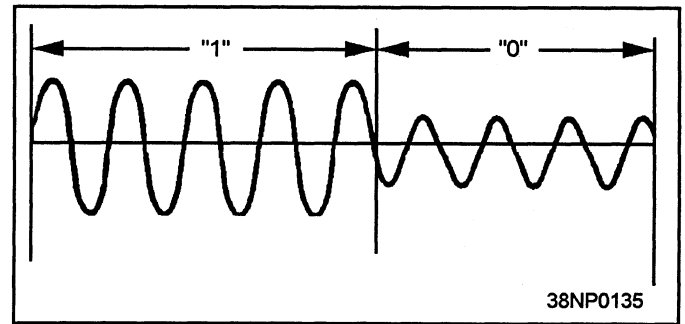


Figure 1-4.—Amplitude modulation.

1-5, a selected frequency can be used to indicate the 1 state of a bit, and another selected frequency can be used to indicate the 0 state. The change in frequency, or frequency shift, indicates the same relationship as the change in amplitude did in amplitude modulation.

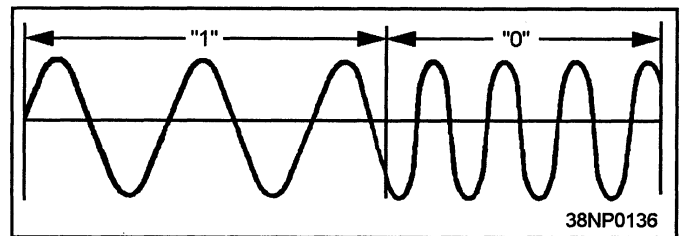


Figure 1-5.—Frequency modulation.

Shifting the frequency of the carrier signal is called **frequency-shift keying (FSK)** or **binary frequency-shift keying (BFSK)**. FSK usually involves shifts to frequencies above or below a selected center frequency. Transmission of the frequency above the center frequency indicates a binary 1; the frequency below the center frequency indicates a binary 0. The center frequency is not transmitted. FSK is used in systems such as link 4A.

Another method of using frequency shifts involves audio-frequency tones. Two discrete audio tones may be modulated to a constant frequency carrier signal. One of the tones is used to indicate a mark, or binary 1, the other a space, or binary 0. This method of frequency modulation is called **audio-frequency tone shift (AFTS)**.

### Phase Modulation

Phase modulation is a more complex mode of modulation. It is based on the relationship of the



360-degree carrier sine wave to the baseline of the sine wave. The carrier signal starts on the baseline, as illustrated in figure 1-6, and continues to form a curve called the sine wave. When the sine wave reaches its maximum positive amplitude, it is at the 90-degree point. When it returns to the baseline, it is at 180 degrees. When it reaches its maximum negative amplitude, it is at 270 degrees; and when it returns to the baseline, it is at 360 degrees or the 0-degree point for the start of the next cycle. This process occurs over a period, with the number of full cycles per second (Hz) being the frequency of the signal. A full cycle is the transition from the 0-degree point to the 360-degree point.

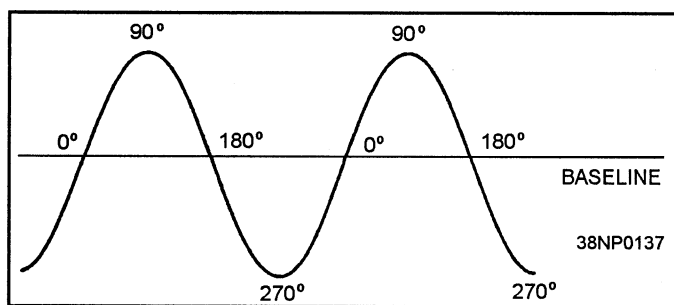


Figure 1-6.—Carrier sine wave,

For a particular frequency this process continues without interruption. Phase modulation involves interrupting the cycle at one or more degree points and instantaneously changing the direction or amplitude of the sine wave. Figure 1-7 shows how a 180-degree phase shift is used to indicate two discrete states. The third cycle of the carrier is interrupted at the 180-degree point. Instead of continuing in the negative direction, the sine starts at the 0-degree point again. The resultant signal has the same frequency and amplitude as the original signal but is 180 degrees out of phase. This phase shift can be directly related to a digital input at a modulator in which one

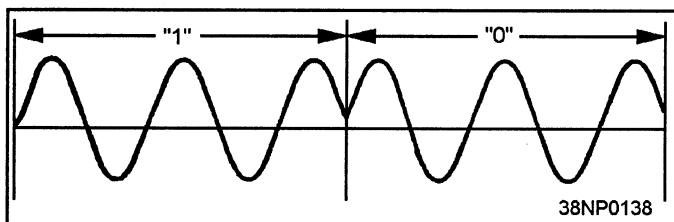


Figure 1-7.—Phase modulation.

particular phase represents the 0 bit and the other phase represents the 1 bit.

### Multibit Modulation

While the 180-degree phase shift can be used to indicate two discrete states, many points on the sine wave can be defined to represent different bit configurations. Individual phase changes of 0 degrees, 90 degrees, 180 degrees, and 270 degrees from a reference phase can each represent two separate data bits. For example, a 0-degree phase shift or no phase shift could indicate a binary 00; a 90-degree phase shift, a binary 01; a 180-degree phase shift, a binary 10; and a 270-degree phase shift, a binary 11. This type of modulation is known as a multibit, or quadrature (four-state) phase-shift modulation, as shown in figure 1-8. Keep in mind that only one continuous frequency and amplitude signal is being phase-modulated to transmit two bits of data for each phase shift.

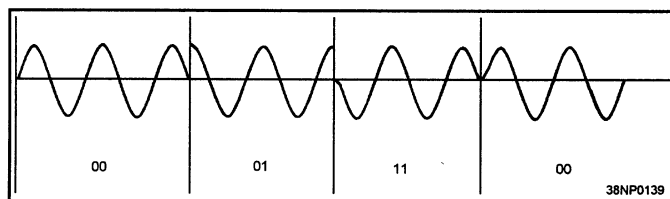


Figure 1-8.—Multibit phase modulation.

A modification of the quadrature phase-shift modulation, called differential quadrature phase-shift keying, uses the difference between a phase-shifted signal and its preceding sine wave to represent data. When a phase shift is detected, the current signal is compared with the previously transmitted phase signal. The difference between the two signals is computed to determine the amount of phase shift. The previously transmitted signal is used as the reference phase for demodulating the data bits. Two binary digits are represented by phase changes of -45, -135, -225, and -315 degrees. The -45 degree shift indicates a binary 11; the -135 degree shift, a binary 01; the -225 degree shift, a binary 00; and the -316 degree shift, a binary 10.

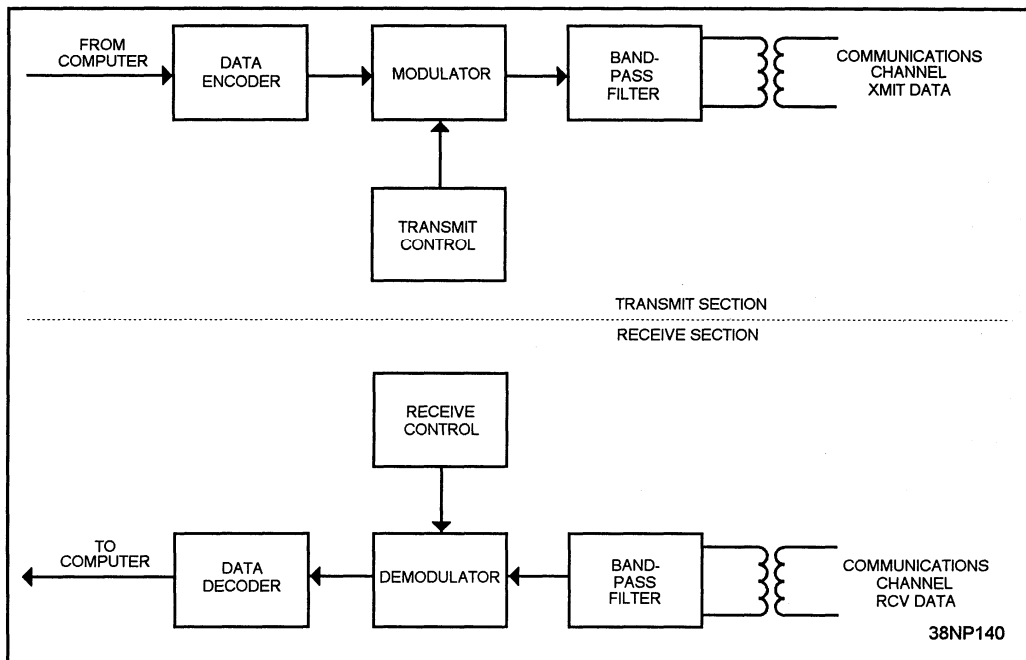


Figure 1-9.—Full-duplex modem.

## MODEMS

Modems come in a variety of configurations. Their design depends on a number of factors, including the following:

- Asynchronous or synchronous data transmissions
- Simplex, half-duplex, or full-duplex communications
- Type of communications channel
- Type of modulation/demodulation used

Modems may be stand-alone devices with their own power supplies and indicators. They may also be integrated into the design of larger equipments in which the modulations or demodulations are only one of the functions performed by the device.

A functional block diagram of a modem is shown in figure 1-9. A full-duplex modem consists of two sections: the **transmitter** and the **receiver sections**. These two sections are functionally separate from each other.

### Transmitter Section

The transmitter section consists of a data encoder, the modulator, the band-pass filter, and the transmit control logic. The data encoder takes the digital data signal to be transmitted, and when necessary, converts it into the bit pattern acceptable to the modulator circuit. The modulator converts the data into the carrier signal. The most popular forms of modulation are frequency-shift keying (FSK), phase-shift keying (PSK), and quadrature phase-shift keying. After the data signals are modulated, they are fed to the band-pass filter circuitry. The band-pass filter then allows only the desired frequency to pass through the communications channel. The transmit control logic provides the timing signals necessary for the transmission of data to take place.

### Receiver Section

The receiver section consists of a band-pass filter, a demodulator, a data decoder, and the receiver control circuit. The band-pass filter allows only the desired carrier signal to be received from the communications channel. The demodulator removes the data from the carrier signal and feeds the data to

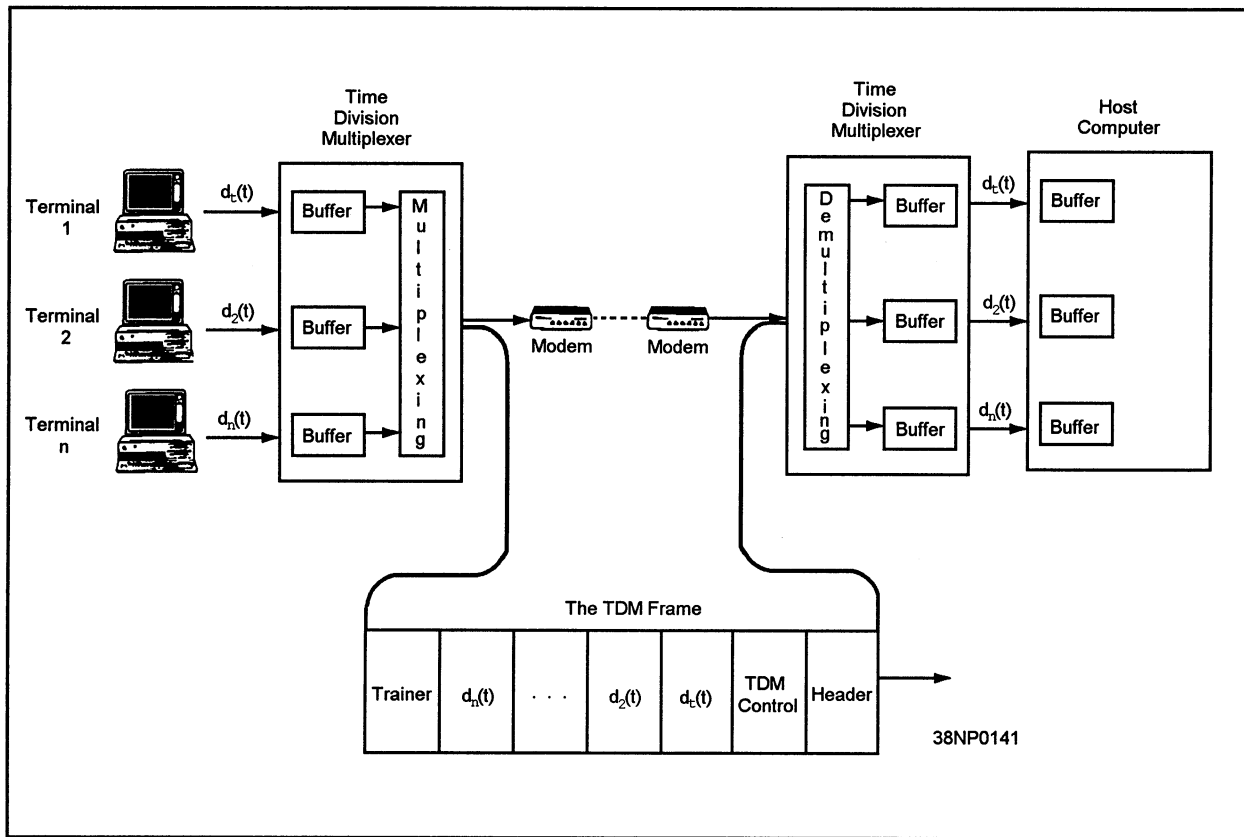


Figure 1-10.—A time-division multiplexer (TDM) system.

the decoder. The decoder reassembles the data into a form compatible with the receiving system. In the receiver section, the incoming signal is often fed to the receiver timing logic to control the receiver timing circuitry.

## MULTIPLEXING

One requirement of a data communications system is for it to transmit as many intelligent signals as possible in a fixed period using a single-communications channel. The rate of data transmission is measured in the number of bits per second (bps) transmitted. The bps rate is often confused with the baud rate. Baud refers to the rate at which a modulated signal between two devices changes in 1 second. For example, if the signal between two modems changes frequency or phase at a rate of 2,400 times per second, the baud is 2,400. If you are using a modulation method in which a single modulation change carries one bit, the 2,400 baud is also 2,400 bits per second. Using more sophisticated modulation methods, several bits of information can

be designated in a single modulation change. If two bits of data are transmitted with each modulation change, the data transfer rate is 4,800 bits per second at 2,400 baud.

The data signals being transmitted are normally multiplexed to increase the transmission rate of data over the communications channel or to increase the efficiency of the channel by allowing multiple users of the same channel. The two methods commonly used to multiplex communications channels are **time-division multiplexing** and **frequency-division multiplexing**.

### Time-Division Multiplexing

Time-division multiplexing (TDM) grants each user full channel capacity, but assigns time slots to each user. Each user is connected to a time-division multiplexer. Data signals from the user are fed to the time-division multiplexer buffer, and the time slots are rotated among the users and scanned for data. Figure 1-10 illustrates the typical construction of a

time-division multiplexer system. The data from each user can be in the form of bits, bytes, or blocks. The data signals from all users are compiled into frames for transmission on a single, high-speed communications channel.

Transmit and receive frames are used for half-duplex communications. Transmit frames are sent and a receive time slot is enabled for return information. In this manner, a single carrier frequency and modem may be used to transmit and receive information at a fairly high rate of speed.

Since time slots are preset and assigned, if a user has no data to transmit, the time slot is wasted. Advantages of a TDM system include the following: its ability to handle devices with varying speeds, its effectiveness when used with devices that transmit data almost continuously, and its simple implementation.

### **Frequency-Division Multiplexing**

Frequency-division multiplexing (FDM) divides a band of frequencies into several distinct channels or tones. Each tone carries a portion of the data being transmitted. FDM devices can be complex because a separate modulator/demodulator circuit is required for each tone used. The composite tones are then modulated to a single carrier frequency for radio transmission.

FDM allows for the parallel transmission of data over a single communications channel. For example, the Link-11 communications system uses 15 audio tones to transmit 30 bits of parallel data. Each tone transmits two bits of differential quadrature phase-shift keyed data.

### **SUMMARY—FUNDAMENTALS OF DATA COMMUNICATIONS**

This chapter introduced you to the building blocks of a data communications system. The following information summarizes the important points you should have learned.

**COMMUNICATIONS SYSTEMS**— Digital data devices that exchange data over distances are known as communications systems. A basic communications system consists of the following three components: a transmitter, a receiver, and a communications channel. The transmitter converts digital data into a form (digital or analog) useable by the communications channel. The receiver accepts data from the communications channel and converts the data back to its pure digital form. Communications systems that can transmit and receive data are known as duplex systems, while communications systems that are limited to transmit only or receive only are simplex systems. Duplex systems that transmit data, pause, and then receive data are half-duplex systems. Full-duplex systems can transmit and receive data simultaneously.

**COMMUNICATION CHANNELS**— Several types of communications channels are in use today. The most common are landlines and radio communications. Landlines are physical cables that connect computers; they are common in local area networks. Radio communications use the radio-frequency bands to exchange information. The most common bands used in the Navy are the HF and UHF bands.

**DECIBEL MEASUREMENT SYSTEM**— The decibel measurement system is used to measure the gain or loss of amplifiers, antennas, communications lines, and other types of communications equipment. A gain of +3 decibels (dB) indicates that the output power of the circuit, compared to the input power, has doubled. Each +3 dB gain indicates a doubling of power. For example, a signal that has a gain of 6 dB is twice as strong as a signal that has a gain of 3 dB.

**ASYNCHRONOUS TRANSMISSION**— Asynchronous transmission refers to data sent without the use of timing pulses. Data signals are sent a byte at a time, with start, stop, and parity bits added to each byte.

**SYNCHRONOUS TRANSMISSION**— Synchronous transmission refers to the sending of long, uninterrupted streams of data with a predefined start and stop sequence.

**MODULATION/DEMODULATION**— Modulation is the modifying of a signal to carry intelligent data over the communications channel. Several types of modulation are available, depending on the system requirement and equipment. The most frequently used types of modulation are amplitude modulation, frequency modulation, and phase modulation. Demodulation is the act of returning modulated data signals to their original form.

**AMPLITUDE MODULATION**— Amplitude modulation refers to modifying the amplitude of a sine wave to store data.

**FREQUENCY MODULATION**— Frequency modulation refers to changing the frequency of a signal to indicate a logic 1 or a logic 0. One frequency indicates a logic 1, and the other frequency indicates a logic 0.

**PHASE MODULATION**— Phase modulation is more complex than amplitude modulation or frequency modulation. Phase modulation uses a signal frequency sine wave and performs phase shifts

of the sine wave to store data. A modification of phase modulation involves the use of several discrete phase shifts to indicate the state of two or more data bits.

**MODEMS**— A modem is a device that MODulates and Demodulates data in a digital communications system. Modems are available in a variety of types, with various speeds and capabilities. A modem consists of two functionally separate areas—the transmitter section and the receiver section. The transmitter section prepares, or modulates, the data for transmission. The receiver section demodulates, or returns, incoming data to its original form.

**MULTIPLEXING**— Multiplexing refers to processes used in digital communications systems to make the most efficient use of system time. Multiplexing can involve time-sharing of the communications channel by several users or assigning several frequencies for the parallel transmission of data.



# CHAPTER 2

## 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 NATO's 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 2-1.

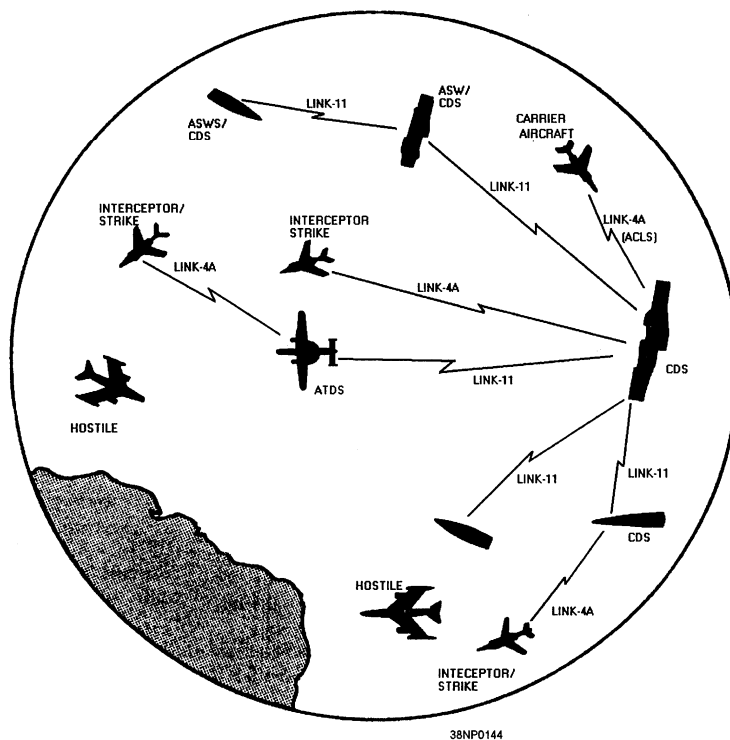


Figure 2-1.—Tactical digital information links.

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. Keep in mind that although the specific equipment used on board your ship may differ from the examples used in this chapter, the purpose of your Link-11 setup is still the same, that is, to pass tactical data to other units.

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 2-2) 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.

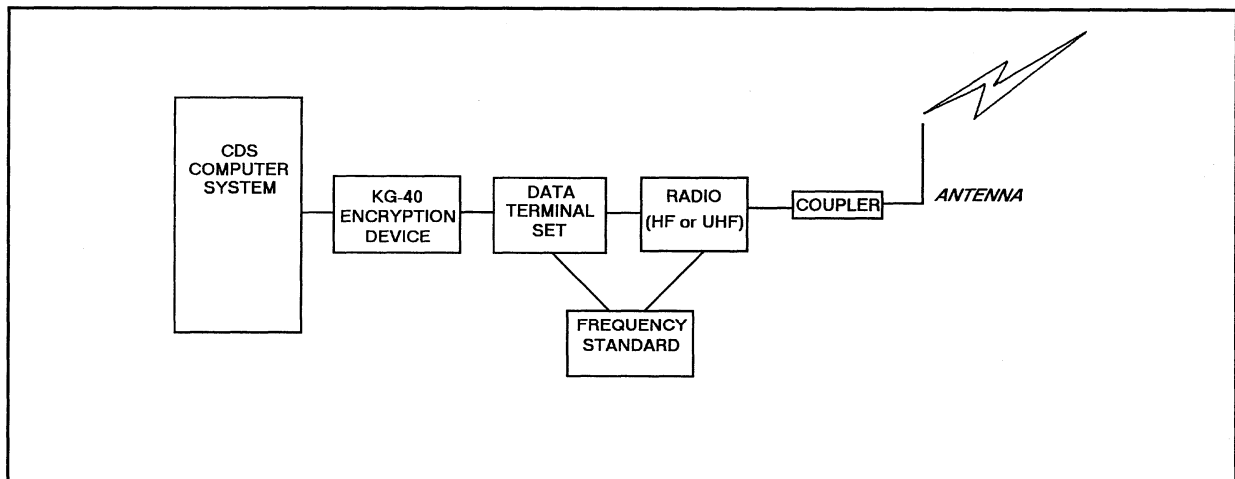


Figure 2-2.—The Link-11 communications system.



## 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 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 2-3.

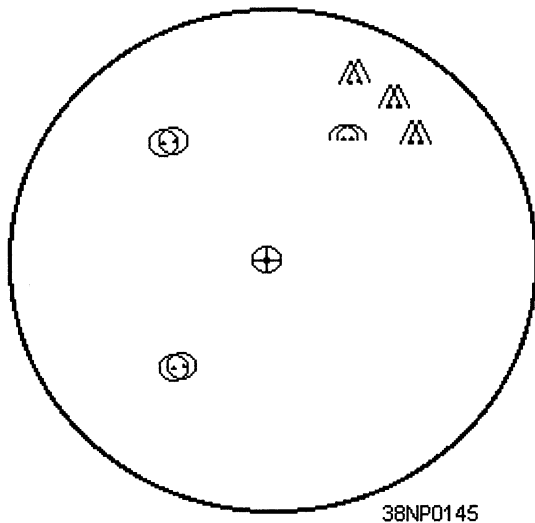


Figure 2-3.—Tracks out of gridlock.

Failure to maintain gridlock maybe 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, the TSEC/KG-40 receives encrypted data from the DTS, decrypts, and sends 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 connection 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 system flexibility and casualty recovery capabilities by allowing manual switching of the data terminal set and individual HF and UHF radios. 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 multi-couplers 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. Since this is too long 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 2-4. 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,

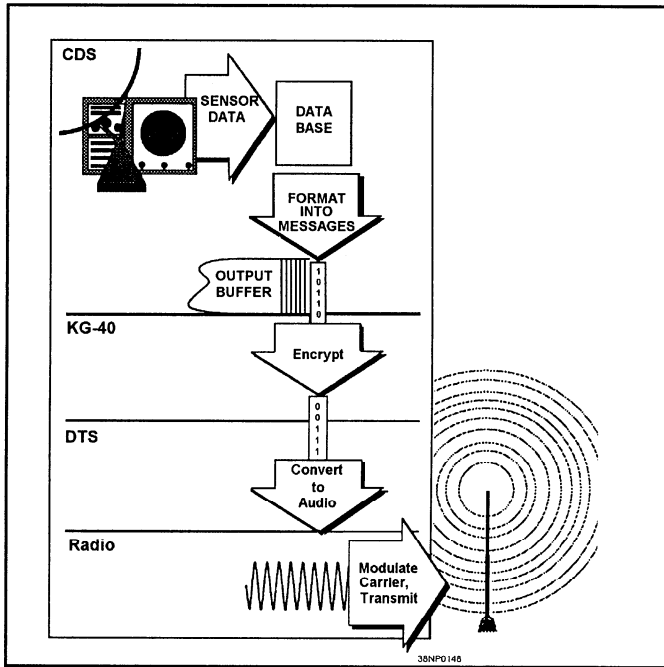


Figure 2-4.—Link-11 data flow for the transmit cycle.

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 the transmit mode. When the signal is stopped, the radio reverts to the receive mode.

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 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 towards 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, an initial gridlock reference unit (GRU) designation, PU identification and addresses, an initial data link reference point (DLRP), and required operating procedures. Voice communications are 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 Test is 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 2-5. A more detailed explanation of the preamble tone is provided later in this chapter.

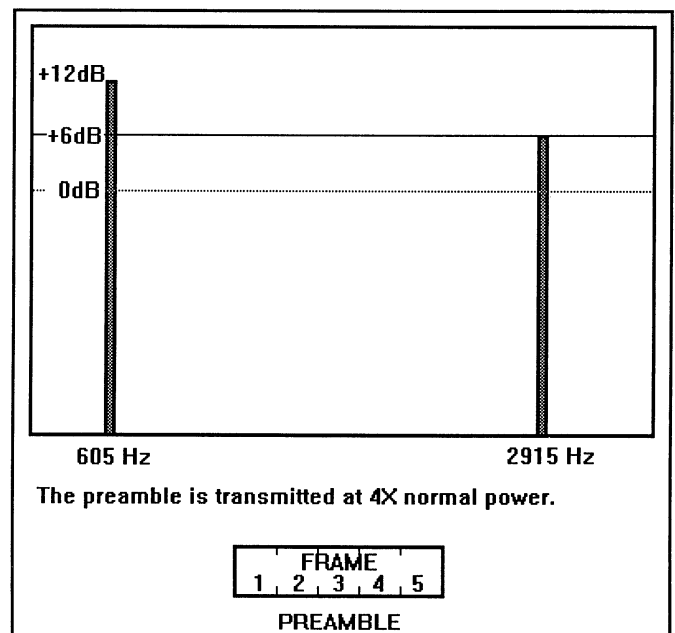


Figure 2-5.—The Link-11 preamble power levels and frame count.

### Phase Reference Frame

The phase reference frame follows the preamble and is shown in figure 2-6. 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. The phase reference frame

provides the reference for the first frame of data. Each succeeding frame becomes the phase reference for the following frame.

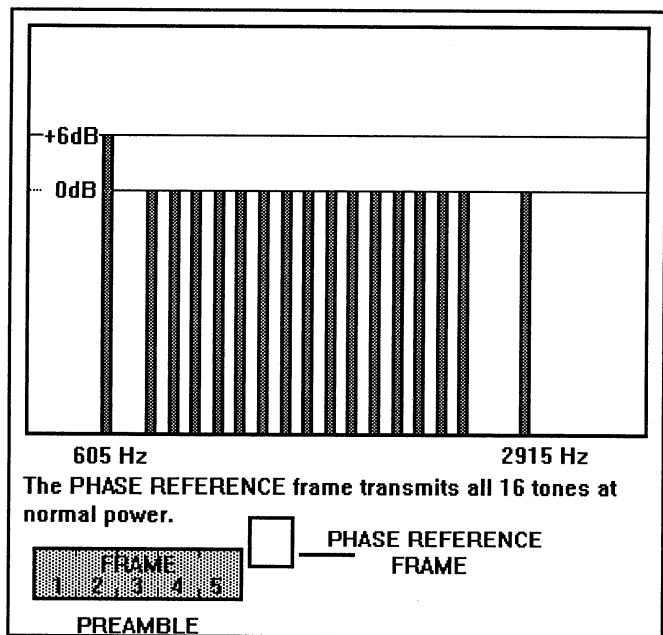


Figure 2-6.—The phase reference frame added to the preamble with normal data tone levels.

### 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.

**START CODE.**— The start code is a two-frame code that follows the phase reference frame, as shown

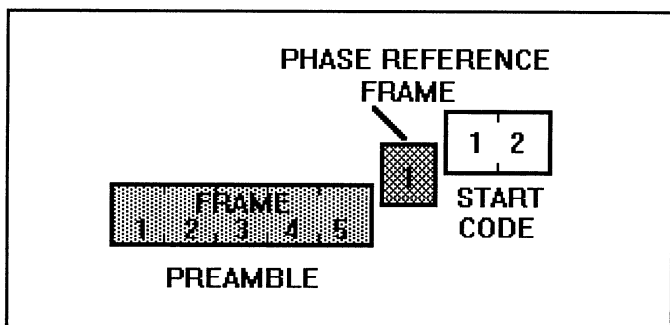


Figure 2-7.—The start code added to the Link-11 transmission.

in figure 2-7. When sensed by the DTS, the start code causes the DTS to send a **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 2-8. 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.

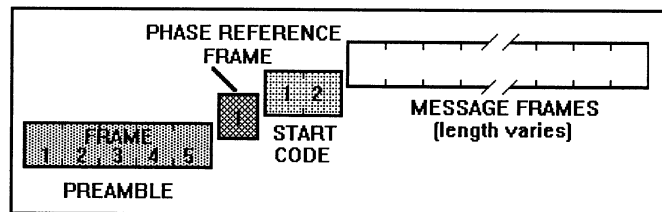


Figure 2-8.—The message data frames added to the Link-11 transmission.

**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 2-9. 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.

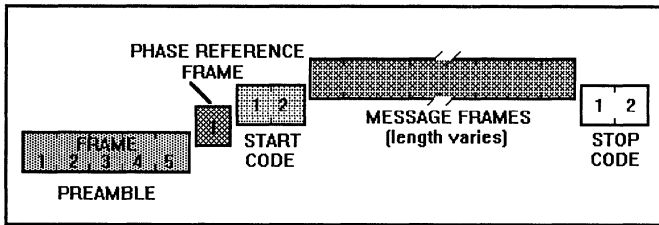


Figure 2-9.—The stop codes added to the Link-11 transmission.

two-frame start code, the data frames, and the two-frame **picket** stop code.

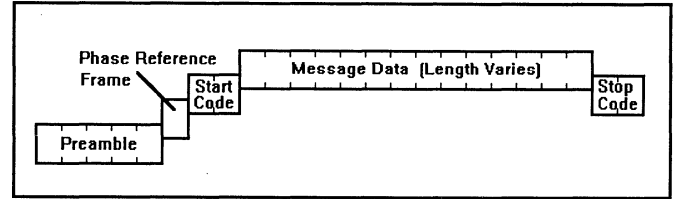


Figure 2-12.—The picket reply message.

**CALL-UP (INTERROGATION) MESSAGE.**— This message shown in figure 2-10 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.

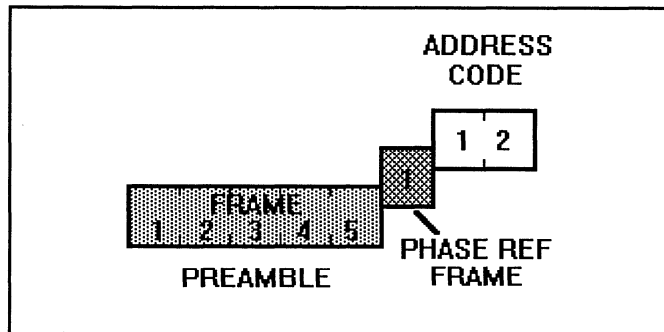


Figure 2-10.—The NCS call-up message.

### Short Broadcast Messages

The Short Broadcast is a single data transmission to all members of a net by a station that may be acting as either picket or NCS. It is the same format as the picket reply message shown in figure 2-12. 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 2-13. The message format is the same as a picket reply message. In the Broadcast mode, only one unit will transmit.

**NCS REPORT AND CALL-UP MESSAGE.**— This message shown in figure 2-11 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.

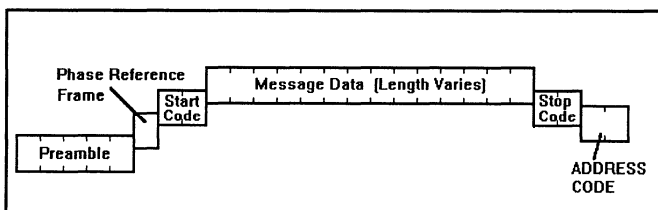


Figure 2-11.—The NCS report message.

### 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

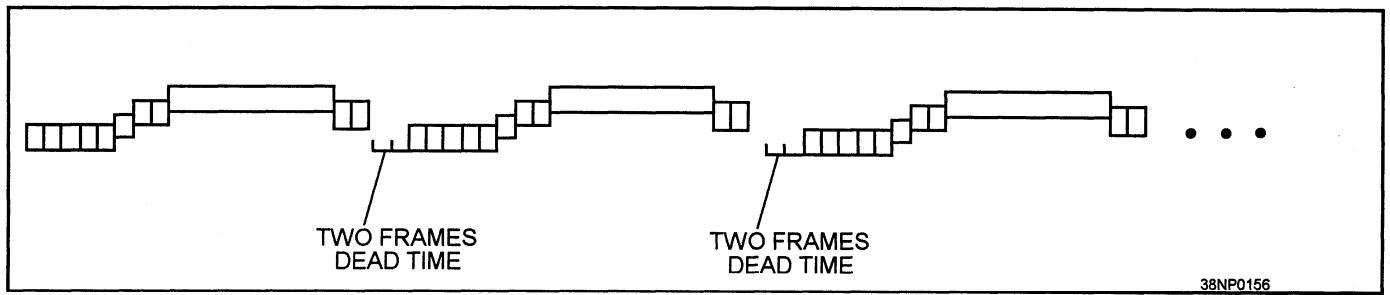


Figure 2-13.—Broadcast mode message format.

the radio set. The key-line signals necessary to 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 2-1.—DTS Parity Bit Status Codes

MODE	ERROR STATUS	BIT POSITION	
		25	24
<b>Detect and Label</b>	No errors detected	0	0
	Error(s) detected - no correction attempted	1	0
<b>Detect and Correct</b>	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 is 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 2-1.

### 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 2-2. 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 2-2) 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.

Each of these angles marks the center of a quadrant, as shown in figure 2-14. 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  $\pm 44$  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, only one bit error will be introduced as long as the quadrant into which it falls is adjacent to the target quadrant.

Table 2-2.—Tone Library

Tone Number	Frequency (Hz)	Description	Bit Location
1	605	Doppler	*
2	935	Data	0 and 1
3	1,045	Data	2 and 3
4	1,155	Data	4 and 5
5	1,265	Data	6 and 7
6	1,375	Data	8 and 9
7	1,485	Data	10 and 11
8	1,595	Data	12 and 13
9	1,705	Data	14 and 15
10	1,815	Data	16 and 17
11	1,925	Data	18 and 19
12	2,035	Data	20 and 21
13	2,145	Data	22 and 23
14	2,255	Data	24 and 25
15	2,365	Data	26 and 27
16	2,915	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

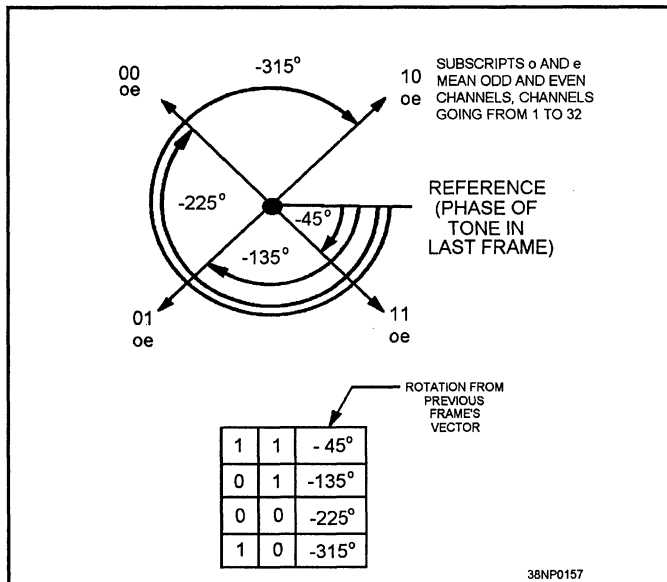


Figure 2-14.—Link-11 data phase shift encoding.

### 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.

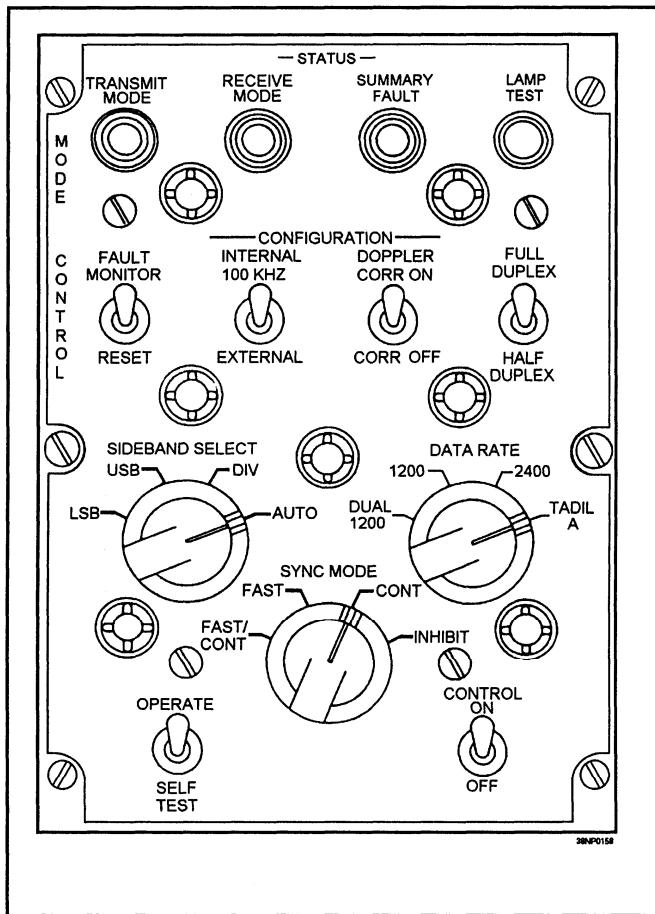


Figure 2-15.—The AN/USQ-59 Mode Control panel.

## 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.

## DTS Mode Control Panel

The DTS mode control panel controls and indicators are shown in figure 2-15. 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 the DTS is 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. When the switch is 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-DUPLEX SWITCH**— 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 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. When the switch is in either the 1200 or 2400 position, the data converter transmits and receives a single data stream at 1200 or 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.

**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 2-16 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. When the switch is 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. When the switch is in the OPERATE position, the DTS operates normally. When the switch is 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. When the switch is 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 an 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.

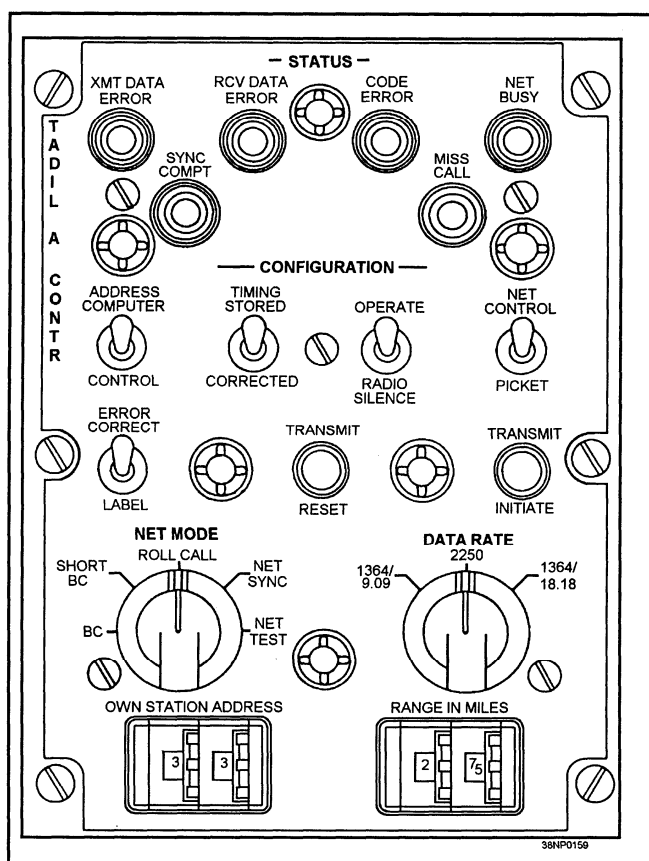


Figure 2-16.—The AN/USQ-59 TADIL A control panel.

**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.

**NET BUSY INDICATOR**— The NET BUSY indicator is lighted when the DTS detects that the communications net is busy.

**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. When the switch is 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 depends 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 1364/18.18 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 the 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 2-17. 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 2-18.

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 describe 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 interrupts control 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.

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 interrupt on the input data lines and set the interrupt

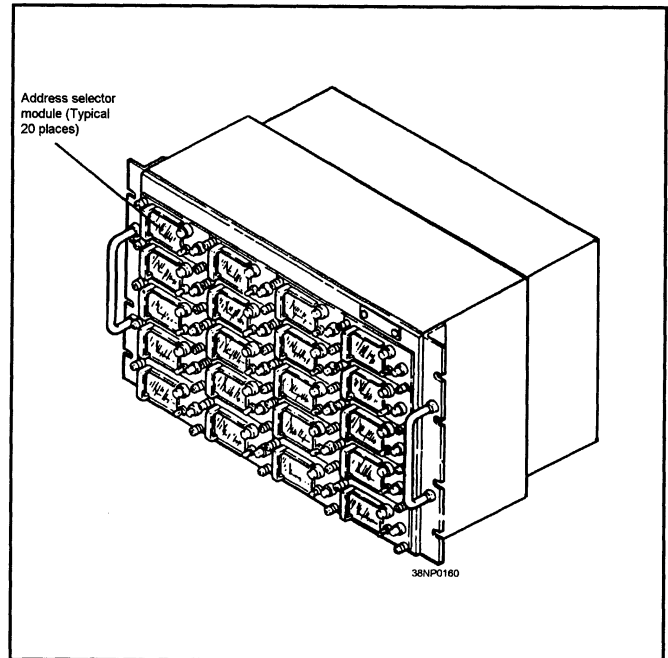


Figure 2-17.—The Address Control Indicator C9062/U.

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

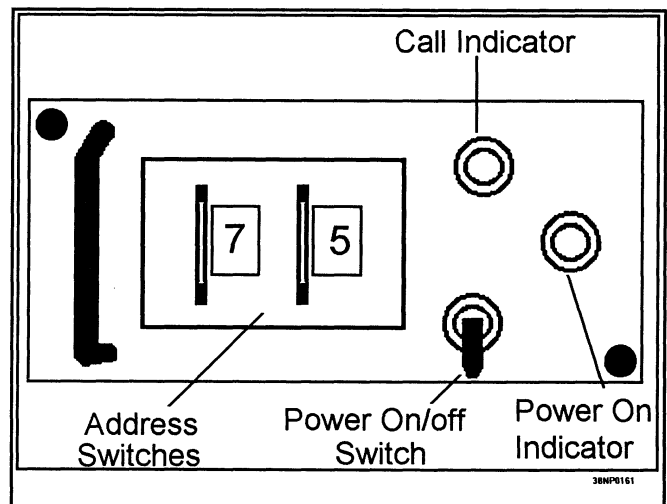


Figure 2-18.—An address selector module.

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 repeat the interrogation process.

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.

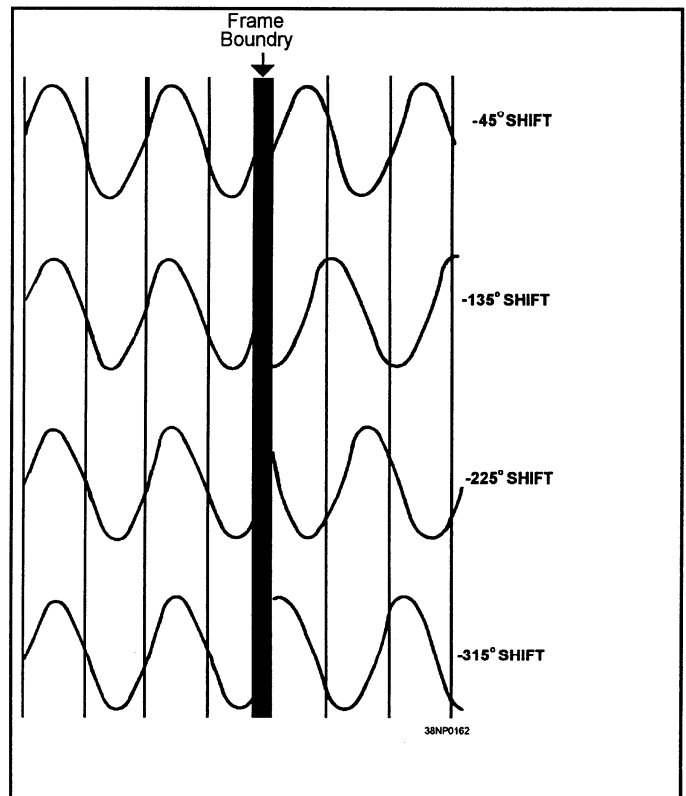


Figure 2-19.—Link-11 frame boundary phase shifts.

At the frame boundary, the phase of each data tone is shifted with respect to the previous frame.



Figure 2-19 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.

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 LSB 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.

## **SUMMARY—THE LINK-11 SYSTEM**

This chapter has introduced you to the Link-11, or TADIL A, system. The following information summarizes important points you should have learned.

**LINK-11 SYSTEM—** Link-11 is used to transmit REAL-TIME tactical information between CDS-equipped ships and similarly equipped ships, aircraft, and shore stations. The typical shipboard configuration of Link-11 hardware consists of the following:

- CDS computer
- Shipboard Gridlock System
- Cryptographic security device
- Data terminal set
- Communications switchboard
- HF or UHF radio set

Antenna coupler and antenna

**LINK-11 NET OPERATING MODES**— The six modes of Link-11 operation are as follows:

Net Synchronization

Net Test

Roll Call

Broadcast

Short Broadcast

Radio Silence

The Net Synchronization mode establishes the initial time base between the NCS and all participating units. The Net Test mode tests the connectivity of all units in the net and the operation of the DTS. The Roll Call mode is the normal mode of Link-11 operations. The Broadcast mode allows a single unit to transmit tactical data to all other units repeatedly. The Short Broadcast mode allows a unit to broadcast its tactical data once every time the operator depresses the transmit start switch. Radio Silence allows a unit to receive Link-11 data, but that unit will not transmit data.

**BUILDING A LINK-11 MESSAGE**— A Link-11 message consists of the preamble, the phase reference frame, and the information segment. The preamble is five frames long and contains the 605-Hz Doppler tone and the 2,915-Hz sync tone. The phase reference frame is one frame and provides a starting reference for the information segment. The information segment of the Link-11 message contains control codes and tactical data. Control codes are the start codes, the stop codes, and the address codes.

**LINK-11 MESSAGE FORMATS**— The format of a Link-11 message is depends on the mode of operation. The Roll Call mode consists of the following three different messages: the call-up (interrogation) message, the NCS report and call-up message, and the picket reply message. The call-up message consists of the preamble, the phase reference

frame, and the address code of the unit being interrogated. The NCS report is made up of the preamble, the phase reference frame, the start code, the tactical information, the control stop code, and the address of the next unit. The picket reply message is comprised of the preamble, the phase reference frame, the start code, the tactical data, and the picket stop code.

The Broadcast and Short Broadcast messages are the same format as a picket reply message. In the Broadcast mode, one unit repeatedly broadcasts its tactical data and all other units in the net monitor this data. In the Short Broadcast mode, the operator must initiate each transmission of data.

In the Net Synchronization mode, the message is a continuously broadcast preamble. The Net Test mode message consists of the preamble, the phase reference frame, and a preset series of data words that are repeated until the test is stopped by the operator.

**LINK-11 DATA TERMINAL SET (DTS)**— The Link-11 data terminal set is the heart of the Link-11 system. The data terminal set performs the modulation, demodulation, and control functions required for Link-11 operations.

**DTS ERROR DETECTION AND CORRECTION (EDAC)**— The DTS is capable of detecting and correcting single bit errors in received data. It accomplishes this correction by decoding the six hamming bits that are added to the 24-bit data word by the transmitting DTS. When a correction is made, if there are multiple errors or the DTS is in the error detect and label mode, the error is designated by two parity bits added to the 24-bit data word before the data is sent to the CDS computer.

**DTS AUDIO TONE GENERATION AND CHARACTERISTICS**— The DTS generates a 16-tone composite audio signal. It converts (modulates) the 24 data bits into 12 audio tones. Each tone contains two data bits. Added to these 12 tones are the three tones containing the six EDAC hamming bits. A sixteenth tone is used for Doppler correction. The audio tones are the odd harmonics of 55 Hz. The

data and hamming tones are quadrature phase shifted with respect to the previous frame.

**LINK-11 PROTOCOL AND INTERFACE CONTROL**— The DTS controls the proper protocols and interface with the CDS computer. The protocols are controlled by the generation of the control codes. Interface with the CDS computer is controlled by the DTS through the use of external interrupts.

**DTS CONTROLS AND INDICATORS**— The DTS control panels provide the operator the means for controlling the operation of the DTS. The physical design of the control panels of the various data terminal sets varies, but the panels all perform the same functions. Important controls include the sideband select switch, the data rate switch, the sync mode switch, and the net control/picket switch.

Indicators are provided to indicate several types of errors.

**ADDRESS CONTROL INDICATOR**— The address control indicator is used to set the addresses of the participating units in the net. The address control indicator is only used when the DTS is in the net control station mode.

**RADIO SET INTERFACE**— The radio set interface of the DTS provides for the transfer to and reception from the radio set of the composite audio tone package. The DTS receives the composite audio on the upper and lower sidebands when using HF frequencies and the upper sideband only when using UHF frequencies. The DTS provides a key-line signal to put the radio set in the transmit mode during the transmission cycle.



## CHAPTER 3

# 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 the single station Programmed Operational and Functional Analysis (POFA) on the DTS.**
- **State the circuits verified by the successful completion of single station POFA.**
- **Describe the procedures for running multi-station Link-11 POFA.**
- **Describe the components of the LMS-11.**
- **Describe the information presented in each of the LMS-11 display modes.**
- **Recognize common Link-11 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 was 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 the myths.

**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 NCS is imperative. Also, if several units are not recognizing their interrogations because the 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, 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, it is interrogated again. After another 15 frames, if the PU still does not respond, the NCS polls the next PU. If the PU that goes to Radio Silence was sending reports that exceeded 38 frames, net cycle time will 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 FUNCTIONAL AND OPERATIONAL ANALYSIS (POFAs)**

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.

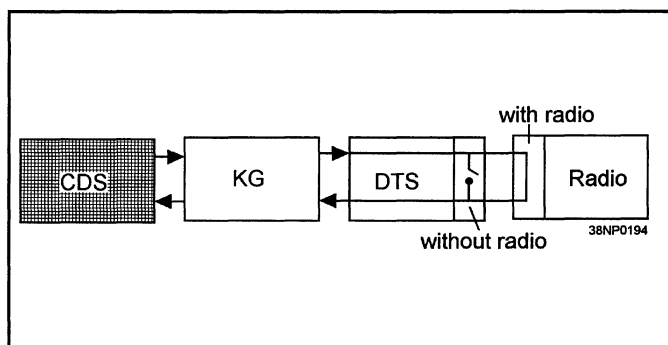
#### **POFA Setup**

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 3-1.—Single station POFA configurations.**

what equipment is being tested. The configuration in which the POFA is run determines some of the equipment being tested. The POFA can be run in two configurations, as shown in figure 3-1.

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 picked up randomly or 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 3-2 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.



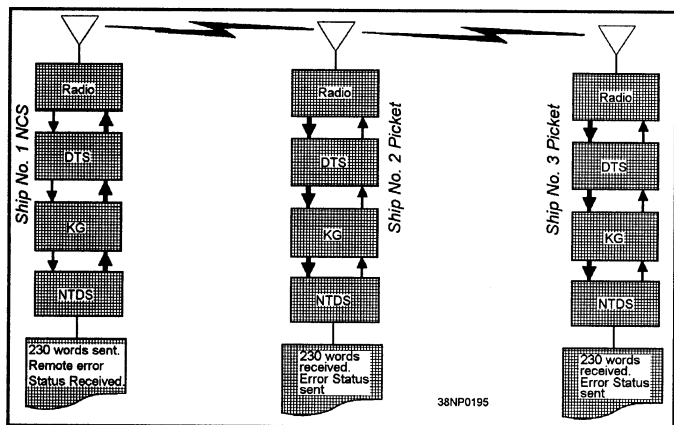


Figure 3-2.—Link-11 multi-station POFA data flow.

### 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

## THE LINK-11 MONITORING SYSTEM (LMS-11)

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 the 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 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 areas 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 the 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 the NCS. If the problem still existed, the 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 of equipment: a data processing group (DPG), a control/display group (CDG), and an accessory group (AG). The LMS-11 is shown in figure 3-3.

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 top of 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

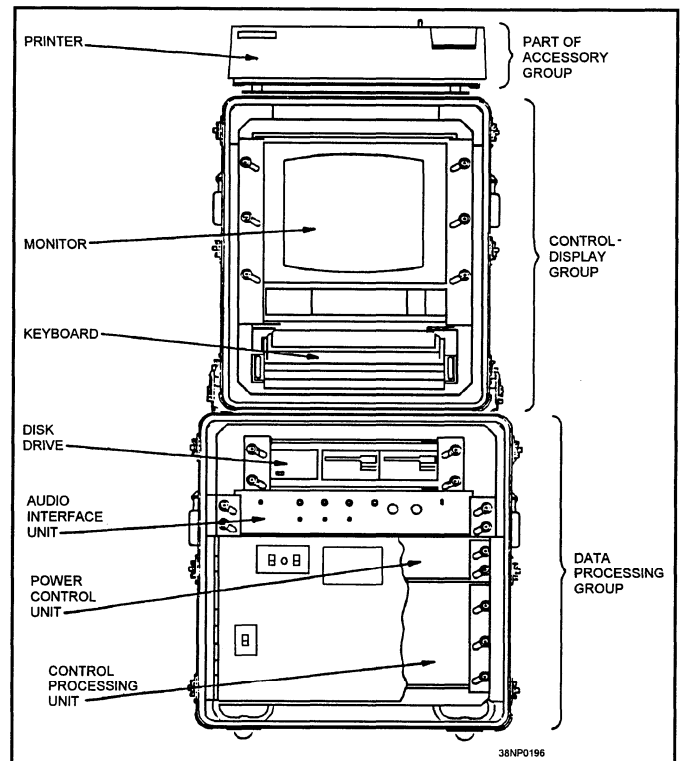


Figure 3-3.—The LMS-11.

**CONTROL PROCESSING UNIT.**— The control processing unit consists of the HP9920U 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.

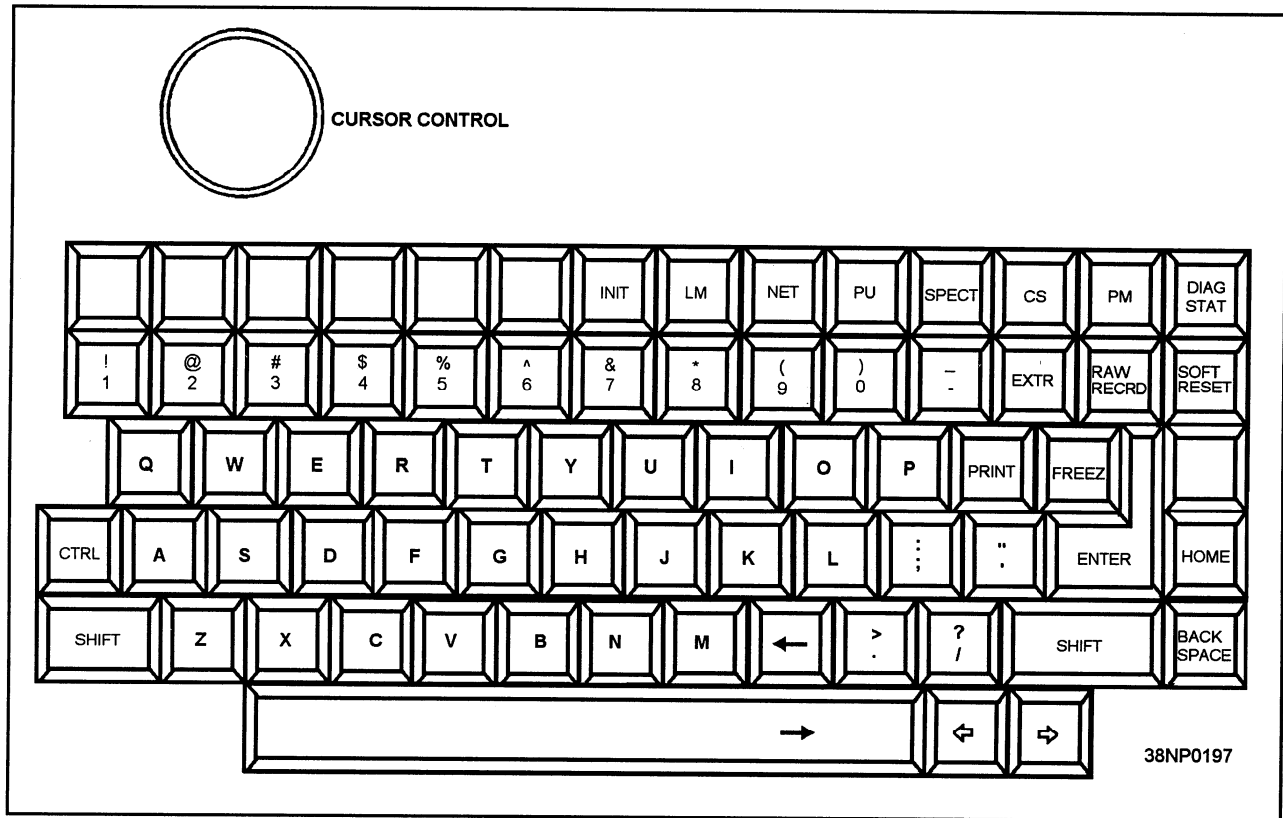


Figure 3-4.—The LMS-11 keyboard.

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 3-4.

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 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 3-5.

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. The 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 3-6.

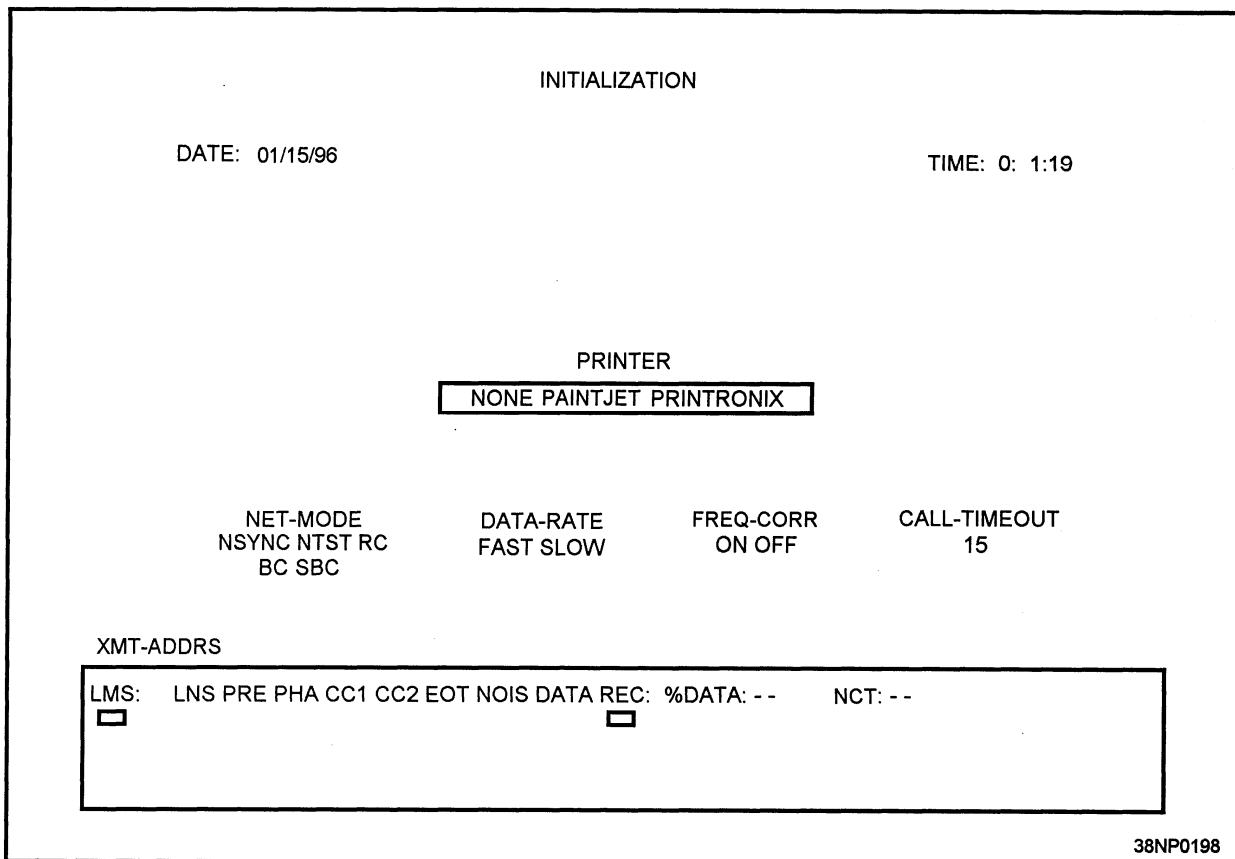


Figure 3-5.—The LMS-11 Initialization display screen.

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 3-6, this is RC FAST. This means the link is in the 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 the NCS. However, recall from chapter 2, that 77 is an illegal address and would not be used in an active link. Since the NCS never sends an interrogation to itself, the LMS-11 uses this address to designate the 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 3-7. Figure 3-8 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.

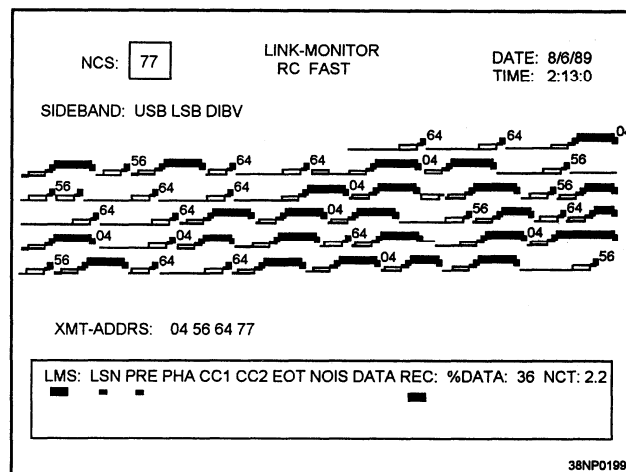


Figure 3-6.—The link monitor display screen.

Study figure 3-6 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 3-6 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 3-9, the status display is at the

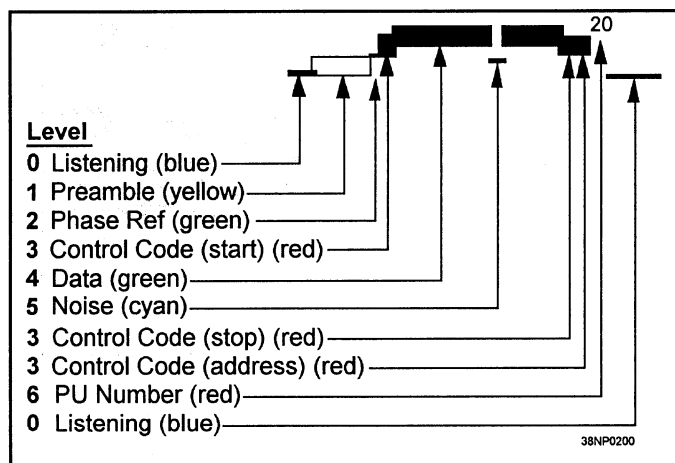


Figure 3-7.—The link monitor display pattern.

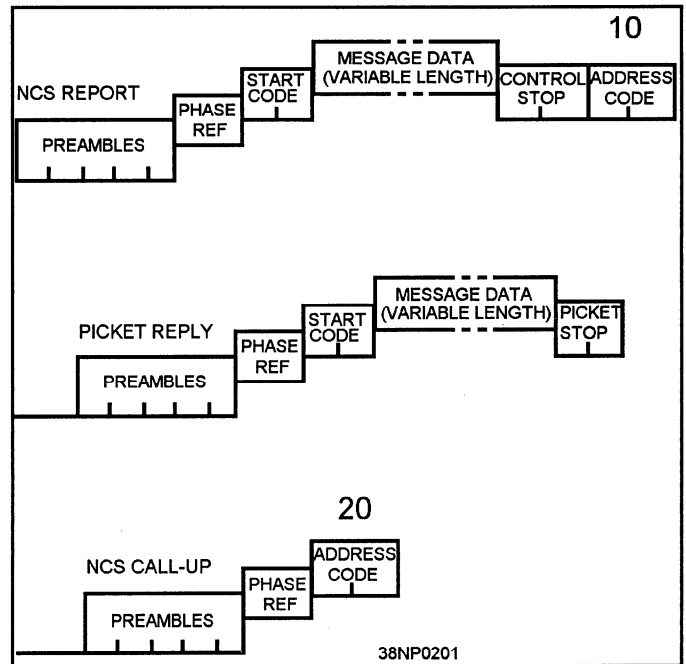


Figure 3-8.—Link-11 messages as displayed by the LMS-11 link monitor mode.

bottom of each of the LMS-11 display screens. The 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 with no response.

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:

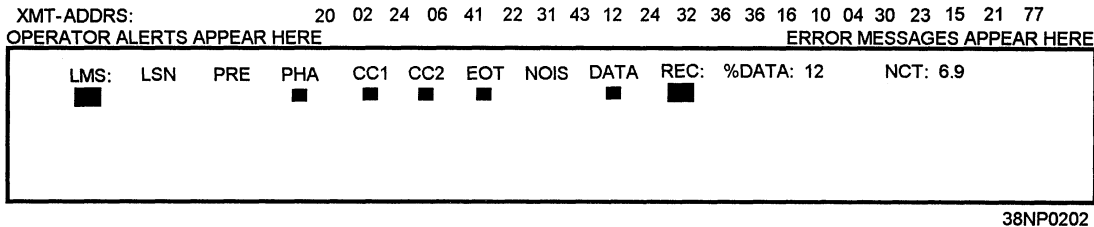


Figure 3-9.—The LMS-11 Status display.

- **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 that 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

complete polling of the net. It can be measured from control stop to control stop from the NCS, or the operator can specify a PU to be 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 the most recent 21 transmissions for a selected PU.

The Net Display mode is only available when the link is in the Roll Call mode. Figure 3-10 shows a screen for the Net Display in the Summarize mode and figure 3-11 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 entries 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.



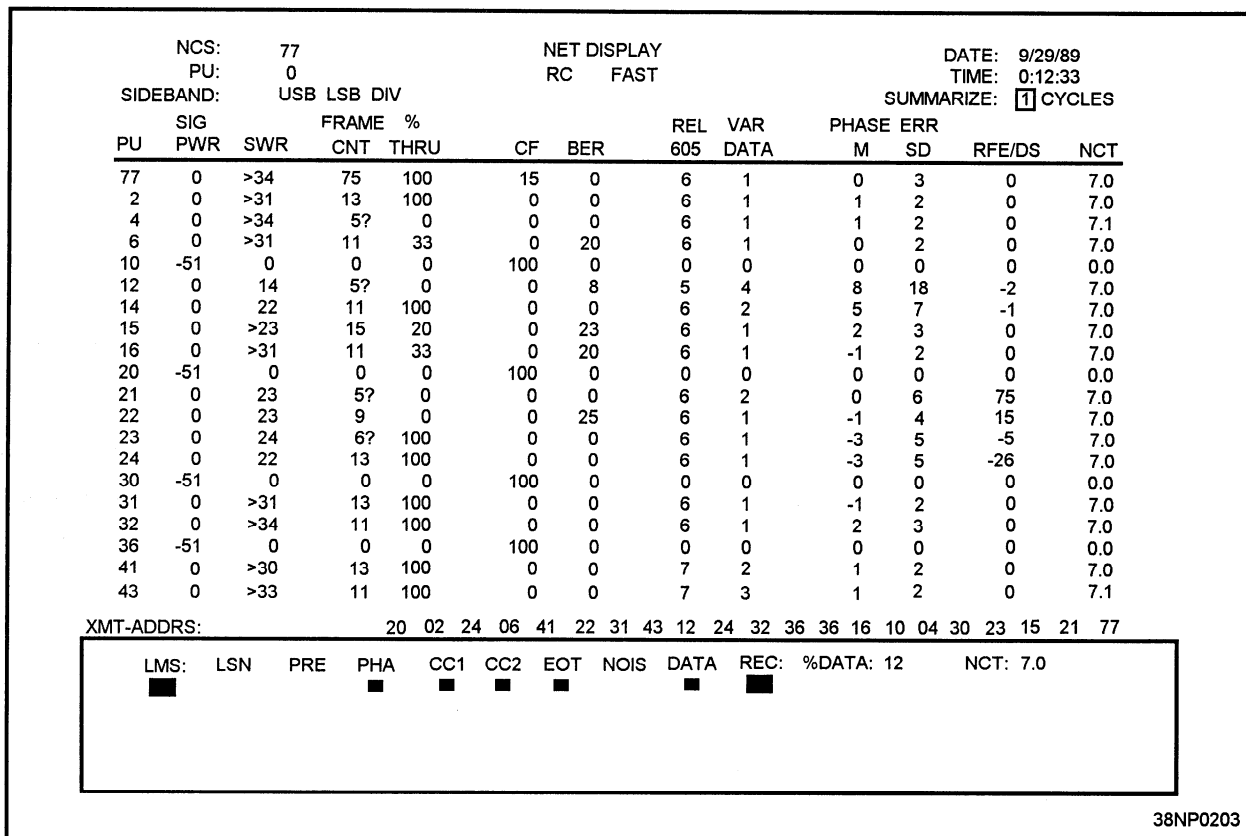


Figure 3-10.—The LMS-11 Net Display in Summarize Mode.

**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.

**SIDE BAND.**— The SIDE BAND field allows the operator to designate which sideband (USB, LSB, or DIV) is used for the information displayed.

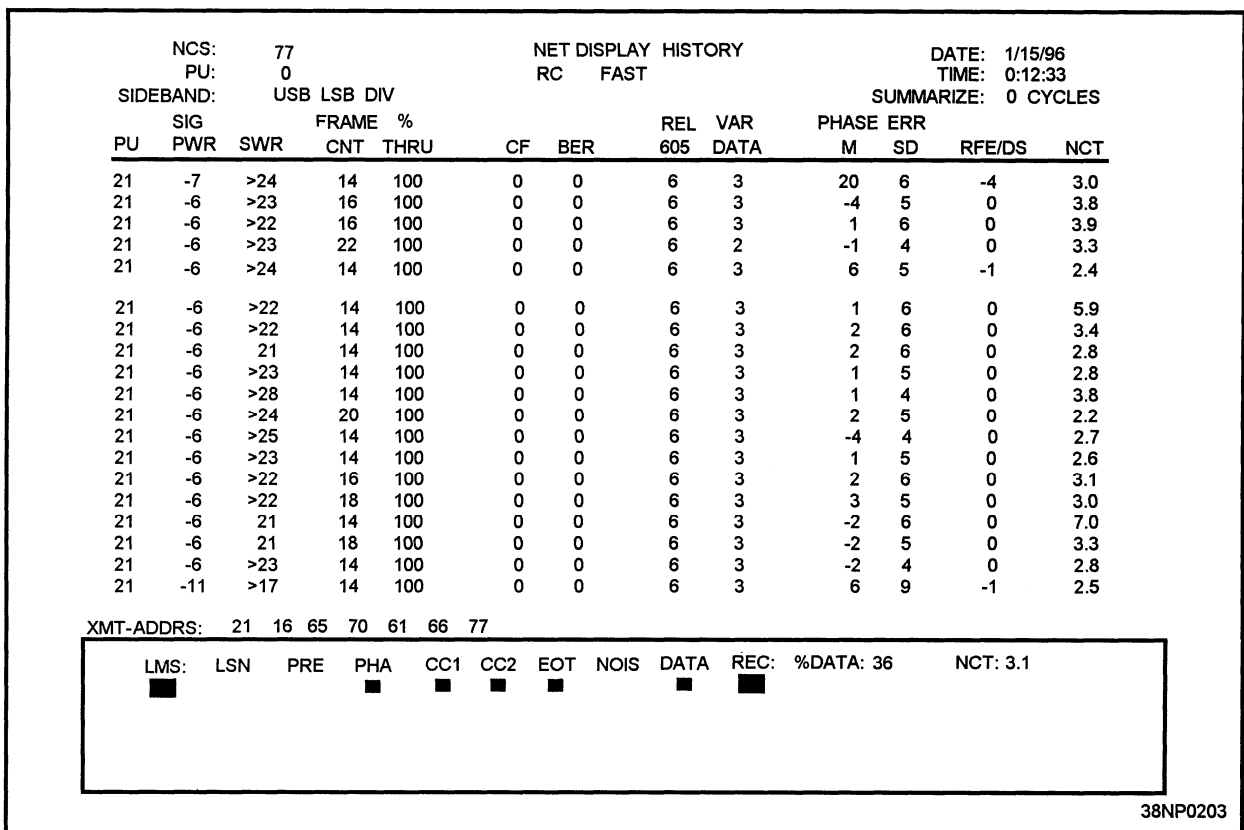
**SUMMARIZE.**— The SUMMARIZE field enables the operator to designate the number of cycles over which the summary is computed. A “cycle” is defined as the recurring transmission from the designated PU. The data is tabulated after the specified number of transmissions are received from the designated 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.

**SIG PWR.**— The total signal strength of the 16 tones, measured in dBm. A value of -51 indicates that no signal was received.



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Figure 3-11.—The LMS-11 Net Display in PU History Mode.

**SNR.**— The signal-to-noise ratio, 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 account for the six frames. Therefore, if a picket unit transmits six or less frames, no actual message data is being received. This may indicate a problem with either the computer or the 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.

**%THRU.**— This number is 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. 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.

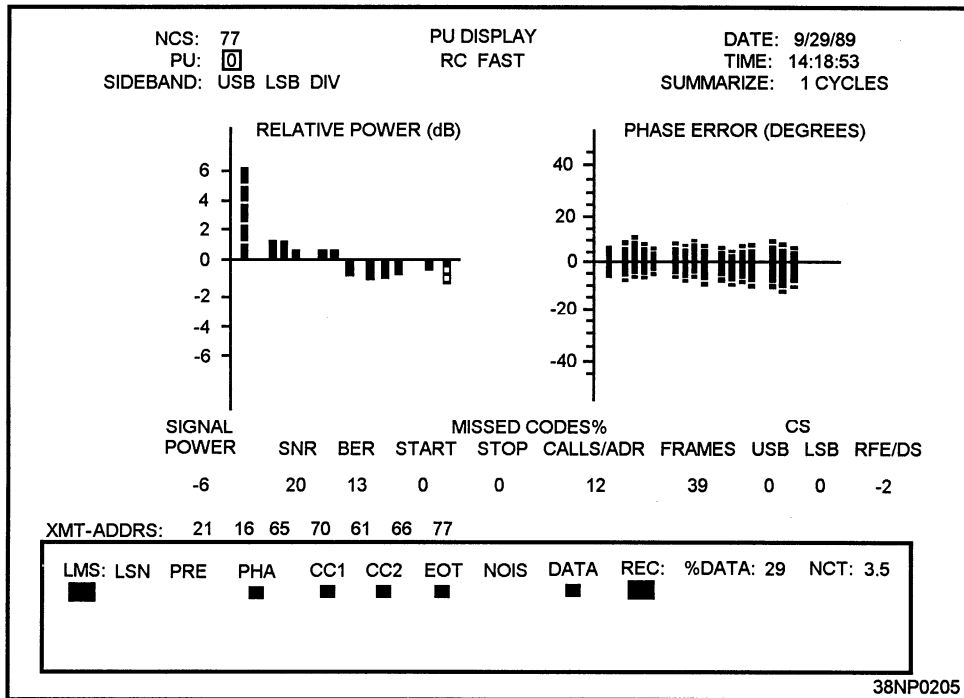


Figure 3-12.—The LMS-11 PU Display mode.

**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 is 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, 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 the 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 3-12.

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  $\pm 1$  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  $\pm 5$  degrees. If only one tone has a mean value that is greatly different from the other tones, it maybe 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.

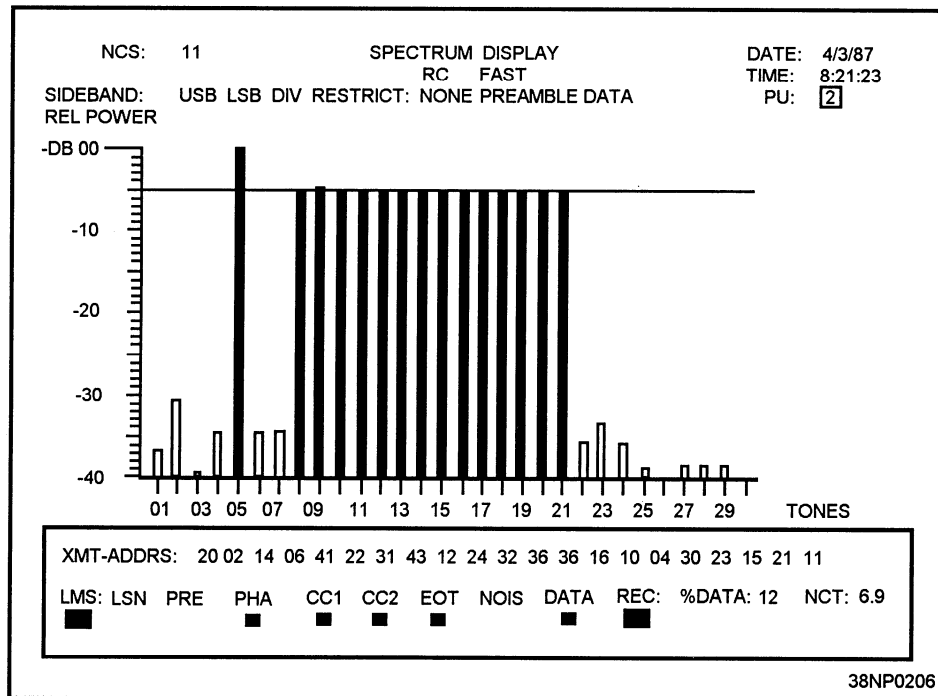


Figure 3-13.—The Spectrum Display screen of the LMS-11.

**MISSED CODES %.**— 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 tone 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 3-13. 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, 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.

### 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 3-14 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 maybe 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.

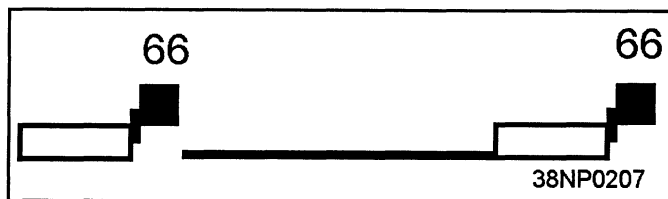


Figure 3-14.—A PU not responding to NCS call-up.

Figure 3-15 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 that the KG-40 has an alarm, the CDS program is down, or the problem is in the CDS computer to DTS patching.

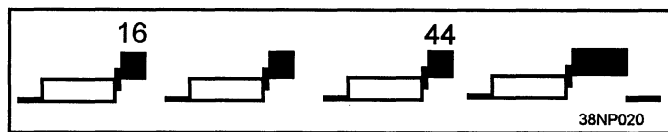


Figure 3-15.—A PU responding with no data.

When the NCS fails to receive a stop code from a PU, a stoppage of the net occurs, as shown in figure 3-16. 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.

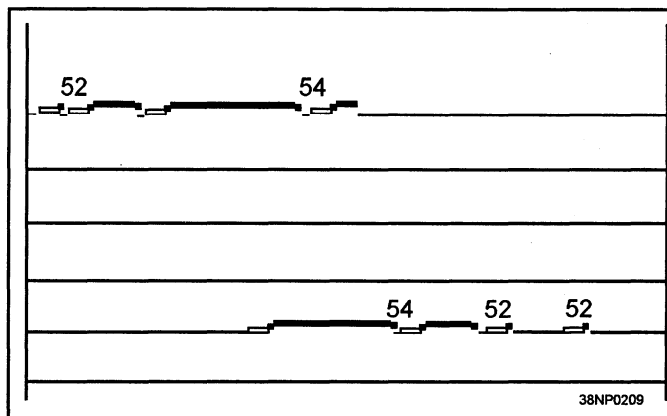


Figure 3-16.—A net stoppage caused by NCS not receiving a stop code.

Figure 3-17 shows several PUs not responding to call-ups. Some of the causes for this condition could

be the following: the NCS having an incorrect PU address entered in the DTS, low transmitter power out from the NCS, an excessively noisy frequency, or weak PU receivers.

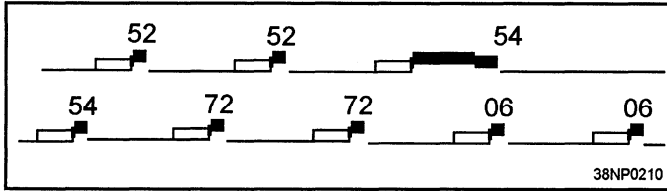


Figure 3-17.—Several PUs not responding to NCS call-ups.

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 in 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*.

### SUMMARY—LINK-11 FAULT ISOLATION

This chapter introduced you to some of the tools available to ensure the Link-11 system is operating at maximum efficiency. The following information summarizes some of the important points you should have learned.

**LINK-11 MYTHS AND FACTS—** Through time, several myths about troubleshooting Link-11 have evolved. We explored some of the myths and tried to determine the facts. Some of the myths are as follows:

- Changing NCS solves net problems. This is only true if the NCS is causing the net problems.
- Changing frequency solves net problems. Again, this is true only if the frequency is

noisy or is being jammed by another frequency.

- More power improves Link-11 performance. This is a myth. In fact, too much power can actually degrade the Link-11 net.
- Dummy PUs improve link quality. Again, this is a myth. This myth evolved from the time of the CP-642 family of computers and the AN/USQ-36 DTS. Back then, a dummy PU would help improve link quality, perhaps by providing a time delay for the computer to process all received data.
- Radio Silence reduces net cycle time. This could be true if the unit that goes radio silent is transmitting less than 38 frames of data. As a rule, if a unit goes radio silent, its PU should be deleted from the polling sequence until the unit is ready to rejoin the net.

**LINK-11 POFAS—** The two POFAs used in the Link-11 system are the single-station POFA and the multi-station POFA.

**SINGLE-STATION POFA—** The single-station POFA is an end-around test that will test most of the DTS, the computer input and output circuits, and the audio path if the radio is not removed from the test path. A single-station POFA does not check the receive timing circuits. When a single station POFA is completed, a printout is produced that lists the errors detected during the test. To be considered successful, a single station POFA should always run with zero errors.

**MULTI-STATION POFA—** A multi-station POFA is a test between two or more units. The multi-station POFA closely represents normal link operations. A multi-station POFA requires coordination among all units participating. All units should be within 25 miles of each other when attempting a multi-station POFA. Since the multi-station POFA actually transmits data over the air, it is subject to many types of interference, and several attempts may be required before acceptable results are obtained.

**THE LINK-11 MONITORING SYSTEM (LMS-11)**— The LMS-11 provides the operator and technician with a means of monitoring the integrity of the Link-11 net. With the LMS-11, the technician has a real-time visual display of the link while it is operating. The LMS-11 consists of the following three groups of equipment: the data processing group, the control/display group, and an accessory group. The data processing group contains the central processor and the interfaces required to process the link audio. It also contains a dual 3.5-inch floppy disk drive and the power control unit. The control/display group consists of a color graphics monitor and a keyboard. The keyboard provides the operator interface with the LM-11. The functional keys on the keyboard are color-coded for ease of operation. The accessory group consists of the color graphics printer and the spare parts and supplies for the LMS-11.

**LMS-11 OPERATION AND DISPLAYS**— The LMS-11 has five on-line modes of operation. Each mode has a unique display screen and allows the technician to evaluate various parts of the link audio signal and the link digital data. The five modes are as follows: LINK MONITOR, NET DISPLAY, PU, SPECTRUM, and CARRIER SUPPRESSION.

**LINK MONITOR MODE**— The link monitor mode provides the technician with a real-time display of link activity. This allows the technician to monitor and detect link problems as they occur.

**NET DISPLAY**— The net display contains the following two distinct modes of operation: the NET SUMMARY and a PU HISTORY. The Net Summary

mode presents a summary of quantitative information about the performance of up to a maximum of 21 PUs in the net. The PU History mode displays the same quantitative data for a single PU. This data is updated each time the selected PU transmits. The most recent 21 transmissions of the specified PU are displayed in the PU History mode.

**PU DISPLAY**— The PU display presents detailed information about the audio signal received from a specified PU. The information is presented in two bar graphs and shows the relative power and the phase error of the received signal.

**SPECTRUM DISPLAY**— The spectrum display shows the relative power level of the Link-11 tones and the noise tones that are the odd harmonics of 55 Hertz. The 605-Hz tone is used as a reference and is set to 0 dB. The relative power of the data and noise tones is displayed with respect to this level. In this mode, the effects of noise can be easily viewed.

**CARRIER SUPPRESSION**— The carrier suppression can only be measured while in Net Sync. The LMS-11 measures the power of the carrier frequency and compares it to the power of the 605-Hz tone. The carrier suppression can be measured accurately when the radio is off-tuned by – 500 Hz for the USB and +500 Hz for the LSB.

**EVALUATING THE LINK-11 NET**— The LMS-11 can be a very useful tool in evaluating Link-11 net operations. The best way to become proficient on reading the various screens of the LMS-11 is through practice.



## CHAPTER 4

# 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 set.
- 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 4-1. 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-1A/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.

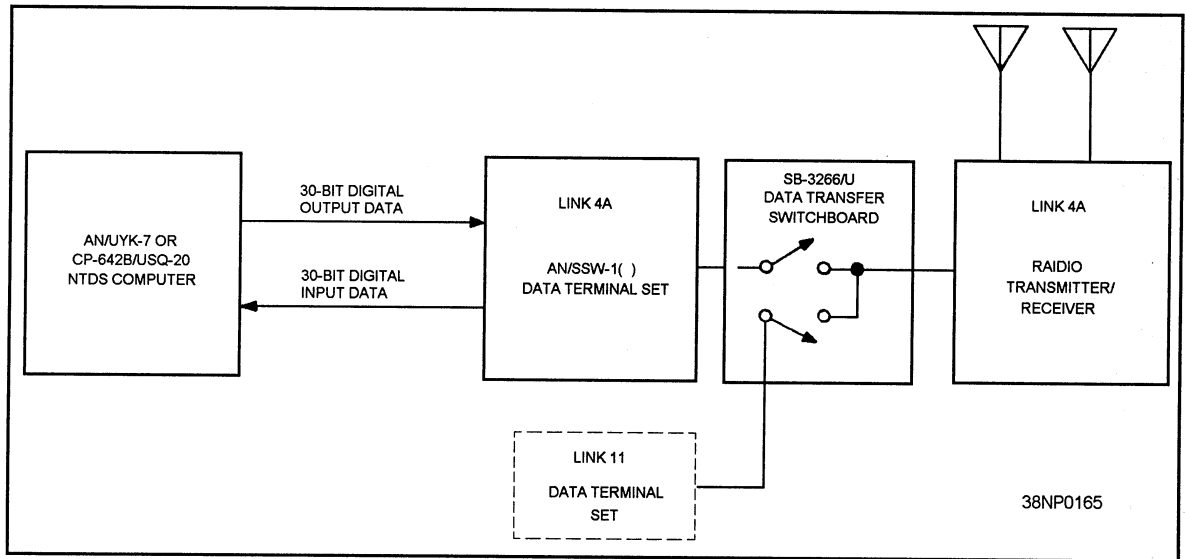


Figure 4-1.—The shipboard Link-4A CDS system.

After the aircraft receives the transmitted data, it may respond by transmitting data to the controlling 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.

## 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 hangar 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 4-2 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- $\mu$ sec time slots that contain the sync preamble, the data bits, and the transmitter un-key signal.

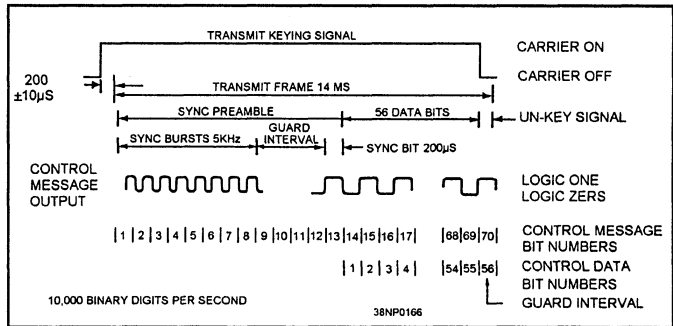


Figure 4-2.—The Link-4A control message format.

### 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  $\mu$ sec in the "0" state and 100  $\mu$ sec 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- $\mu$ sec 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- $\mu$ sec 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 4-3. 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 allows for transmitter turn-off time.

### 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.

### DATA TERMINAL SET AN/SSW-1D/E

The Link-4A data terminal set is the AN/SSW-1D/E. The data terminal set performs the following functions:

- Provides overall Link-4A system timing

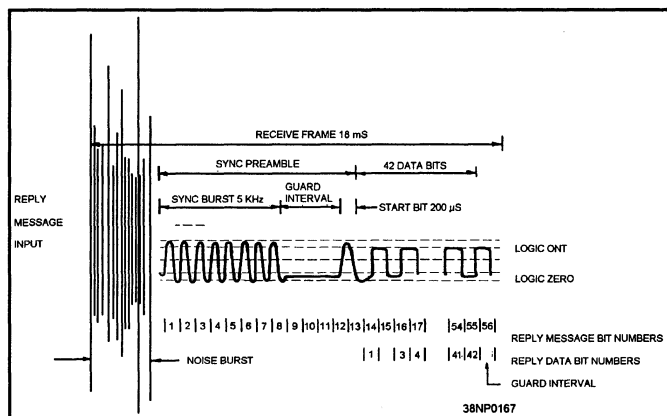
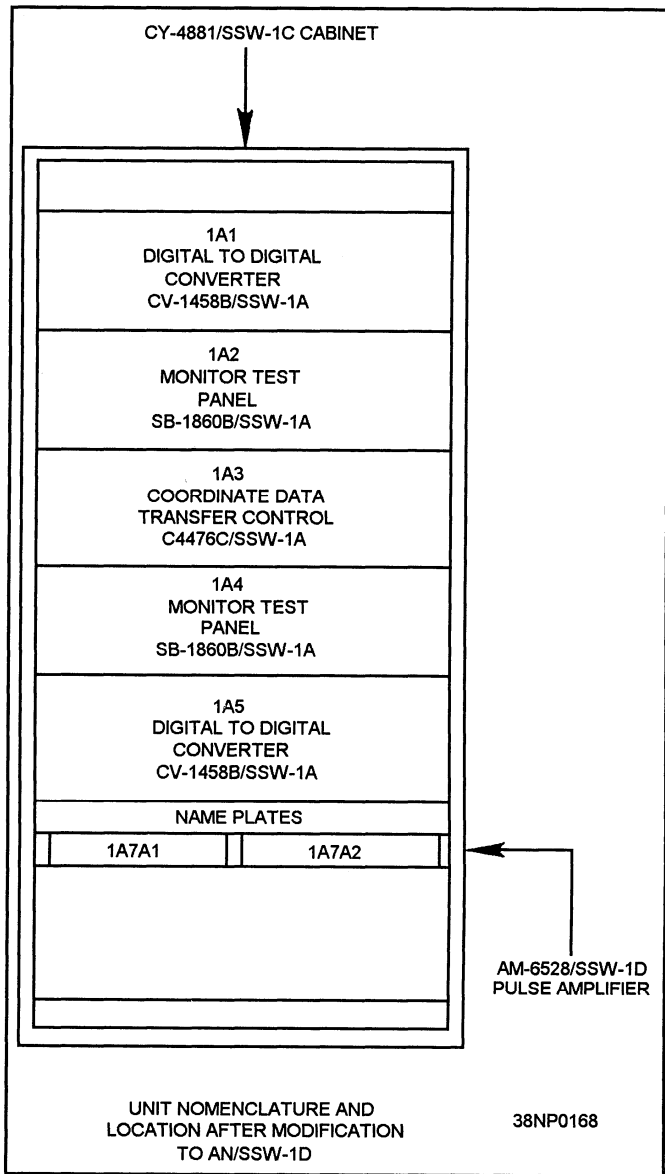


Figure 4-3.—The Link-4A reply message format.

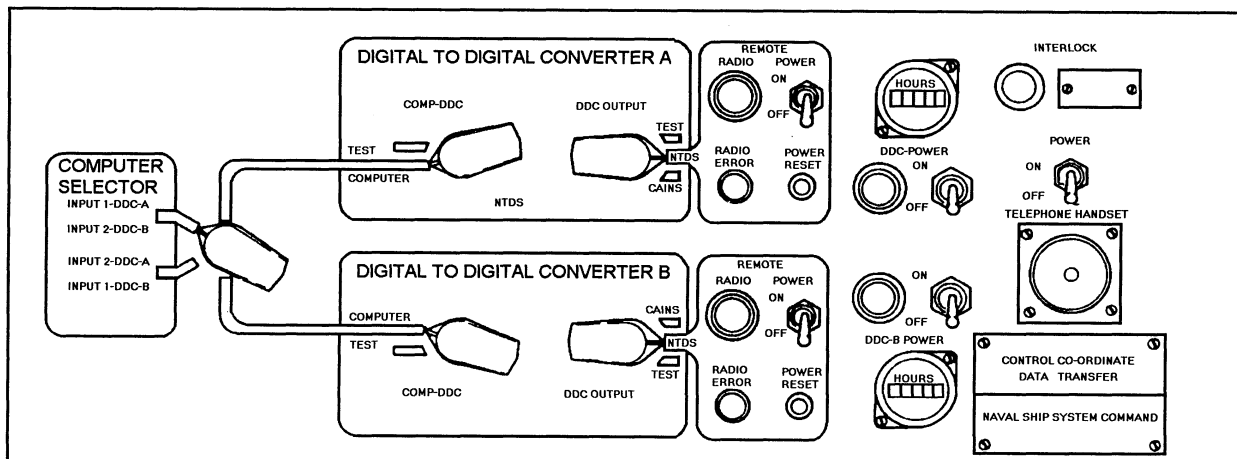


- Converts parallel data from the CDS computer into serial data for transmission to controlled aircraft
- Converts serial data received from controlled aircraft into parallel data for input to the CDS computer.

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 fictionally 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 4-4, consists of the following eight major subassemblies: one coordinate data transfer control, two digital-to-digital converters, two monitor test panels, two 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,

Figure 4-4.—The AN/SSW-1D/E data terminal set.



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Figure 4-5.—The coordinate data transfer control assembly (AN/SSW-1D/E).

## **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 4-5. 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 2 of this manual.

## **LINK MONITOR SYSTEM (LMS-4)**

The LMS-4 provides stand-alone Link-4A monitor and readiness check capabilities. Its operation is similar to that of 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.

### **SUMMARY—LINK-4A**

This chapter introduced you to the Link-4A communications system. The following information highlights some of the important points you should have learned.

**LINK-4A CDS SYSTEM—** The Link-4A CDS system provides one-way or two-way communication between the controlling station and up to 100 aircraft. Link-4A messages contain flight commands and tactical information for the aircraft's pilot. The four modes of operation for the Link-4A CDS system are intercept vectoring, air traffic control, the automatic carrier landing system, and precision course direction.

Intercept vectoring mode is used to guide an aircraft to an assigned target. Air traffic control mode is used to control the aircraft in a carrier's landing traffic pattern. The automatic carrier landing system uses the carrier's precision approach radars to land an aircraft on the flight deck automatically. Precision course direction mode provides very accurate control of an aircraft's flight path and is used for the remote guidance of bombers, reconnaissance aircraft, and drones.

**CARRIER AIRCRAFT INERTIAL NAVIGATIONAL SYSTEMS (CAINS)—** The CAINS system is used to load way-point and alignment data into the navigation computer of an

aircraft. Data is initially entered via a hard-wired deck edge outlet box and updated by UHF radio until the aircraft is launched. At launch, the aircraft's on-board computer reverts to tactical operation.

**LINK-4A MESSAGE FORMATS**— The three types of messages used in the Link-4A system are control messages, reply messages, and test messages.

**CONTROL MESSAGE FORMAT**— Control messages consist of seventy 200- $\mu$ sec time slots that contain a 13-time slot sync preamble, 56 time slots of data bits, and a one time slot transmitter un-key signal. Control messages are sent from the controlling station to the aircraft and are transmitted during the 14-msec transmit frame.

**REPLY MESSAGE FORMAT**— Reply messages consist of 56 time slots that contain the sync preamble, 42 data bits, and the transmitter un-key signal. Reply messages are sent from the aircraft to the controlling station in response to a control message. Reply messages are received by the controlling station during the 18-msec receive frame. The additional time required for reply messages is to compensate for time delays encountered during transmission of the control and reply messages.

**TEST MESSAGES**— The two types of test messages used in the Link-4A system are the universal test message and monitor control/reply test message. Test messages are generated periodically during Link-4A operations to verify proper operation.

Universal test messages are sent to the controlled aircraft, using a universal address and verify proper operation of the controlled aircraft's system.

Monitor control messages are sent from the CDS computer to the data terminal set and cause the data terminal set to initiate a self-test. When the data terminal set successfully completes the self-test, the monitor control message is sent back to the CDS computer as a monitor reply message.

**DATA TERMINAL SET AN/SSW-1D/E**— The most common Link-4A data terminal set is some variation of the AN/SSW-1(). The AN/SSW-1D and AN/SSW-1E provide dual channel operation. The data terminal set provides the overall Link-4A system timing, converts parallel data into serial data for transmission, and converts received serial data into parallel data for input to the CDS computer.

**LINK MONITOR SYSTEM (LMS-4)**— The LMS-4 is a stand-alone system that allows the technician to monitor Link-4A operations and perform readiness checks on the Link-4A system.





## CHAPTER 5

# NEW TECHNOLOGY IN DATA COMMUNICATIONS

### INTRODUCTION

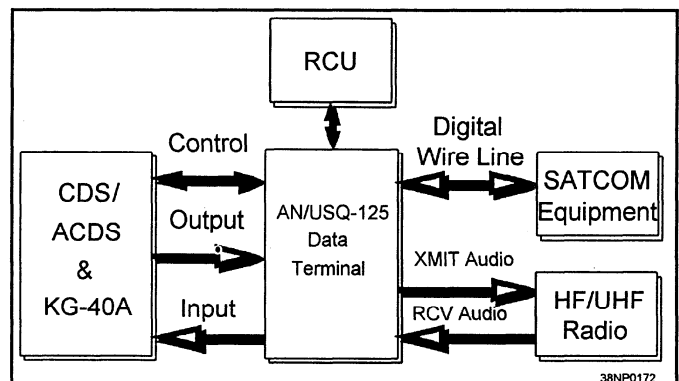
The current Link-11 and Link-4A systems are being updated with new equipments. The Data Terminal Set AN/USQ-125 is currently replacing the older Link-11 data terminals. In addition, new communications systems, such as the **Command and Control Processor (C2P)** and the **Joint Tactical Information Distribution 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.

### 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 is one 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 5-1. 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 5-1.—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

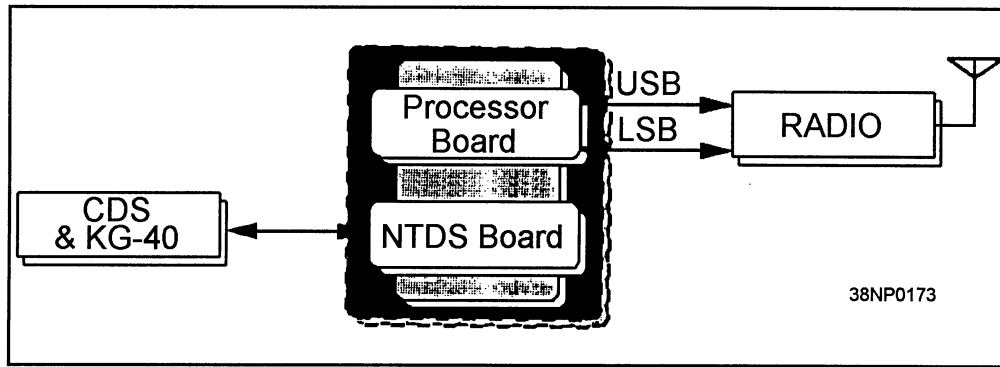


Figure 5-2.—The CP-2205(P)(V)/USQ-125 data terminal block diagram.

terminal has the following three major components: a processor board, a CDS interface board, and the power supply. Figure 5-2 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 2. 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-tone 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

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 frequencies 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 5-3.

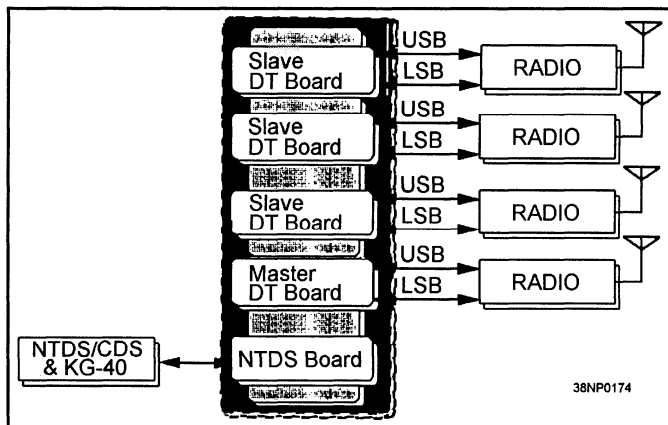


Figure 5-3.—Block diagram of the AN/USQ-125 data terminal configured for multi-frequency link operations.

During the Link-11 receive cycle, each processor 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-line 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, to start and stop link operations, and to change link modes. One model, shown in figure 5-4, 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 may be substituted for the control unit when loaded with the proper software and connected to the data terminal.

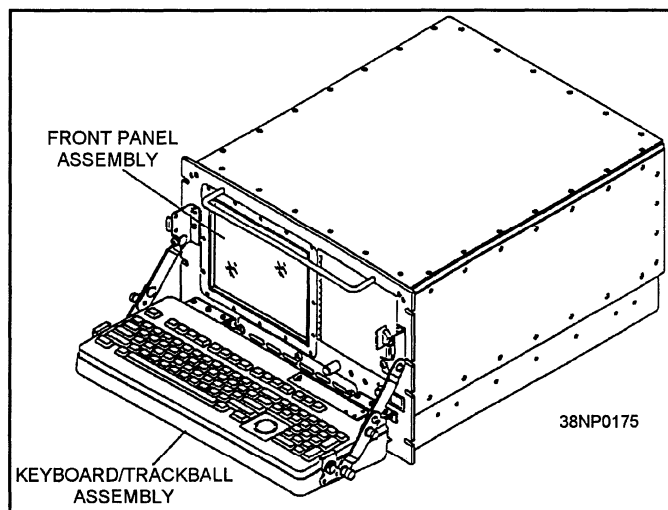


Figure 5-4.—The C-12428/USQ-125 Control Unit.

## 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. 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 term 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.

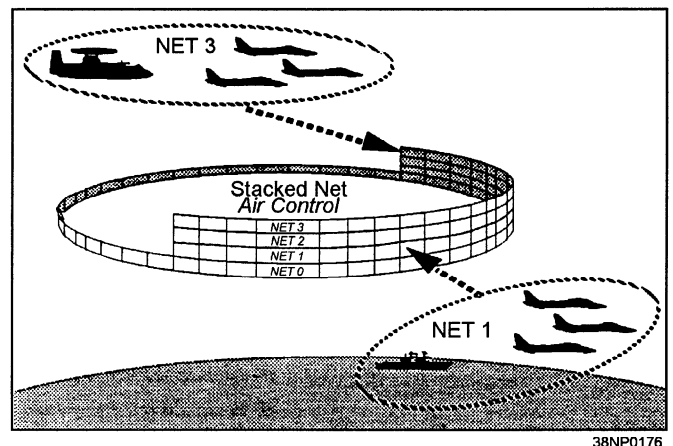
When a JU transmits data, the frequency that the data is transmitted on is changed every 13 microseconds ( $\mu\text{sec}$ ), according to a predetermined pseudo-random pattern. Link-16 uses 51 different frequencies for data exchange. This **frequency hopping** adds to the security and integrity of the 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 5-5 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.



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Figure 5-5.—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 compose 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 device similar to Link-11, using a specified

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<sup>2</sup>) 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-16 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 tracks 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.

**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.

**GEODETTIC 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 5-6. 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 console.

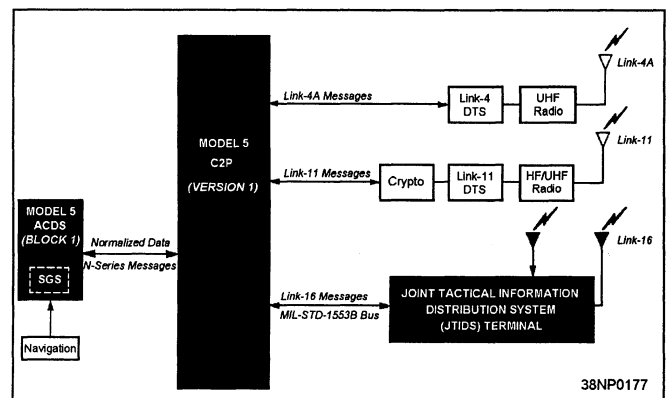


Figure 5-6.—The Link-16 Model-5 ACDS system block diagram.

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 JTIDS terminal is a single

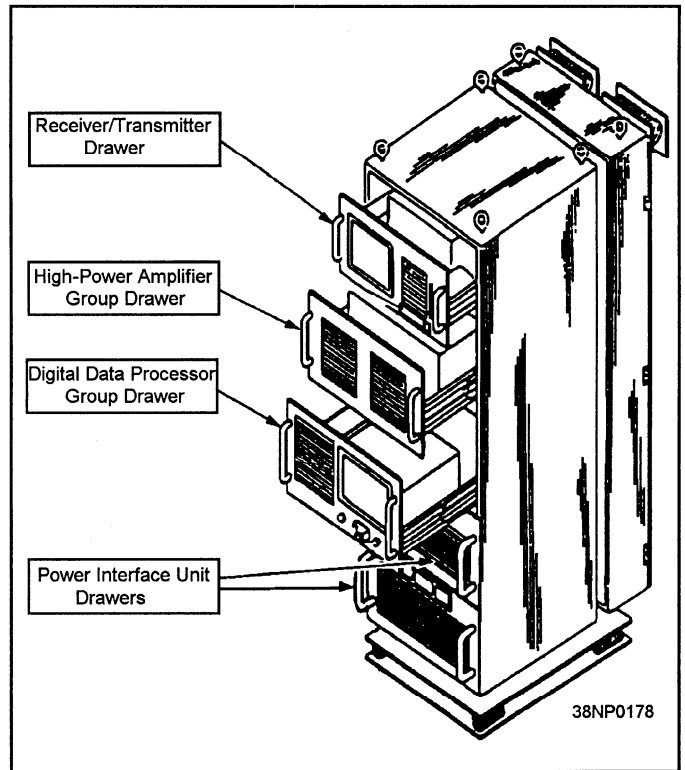


Figure 5-7.—The AN/URC-107(V)7 JTIDS data terminal.

five drawer electronics cabinet, as shown in figure 5-7. The components of the JTIDS terminal include the Digital Data Processor Group (DDPG), the Receiver/Transmitter Group (R/T), the High-

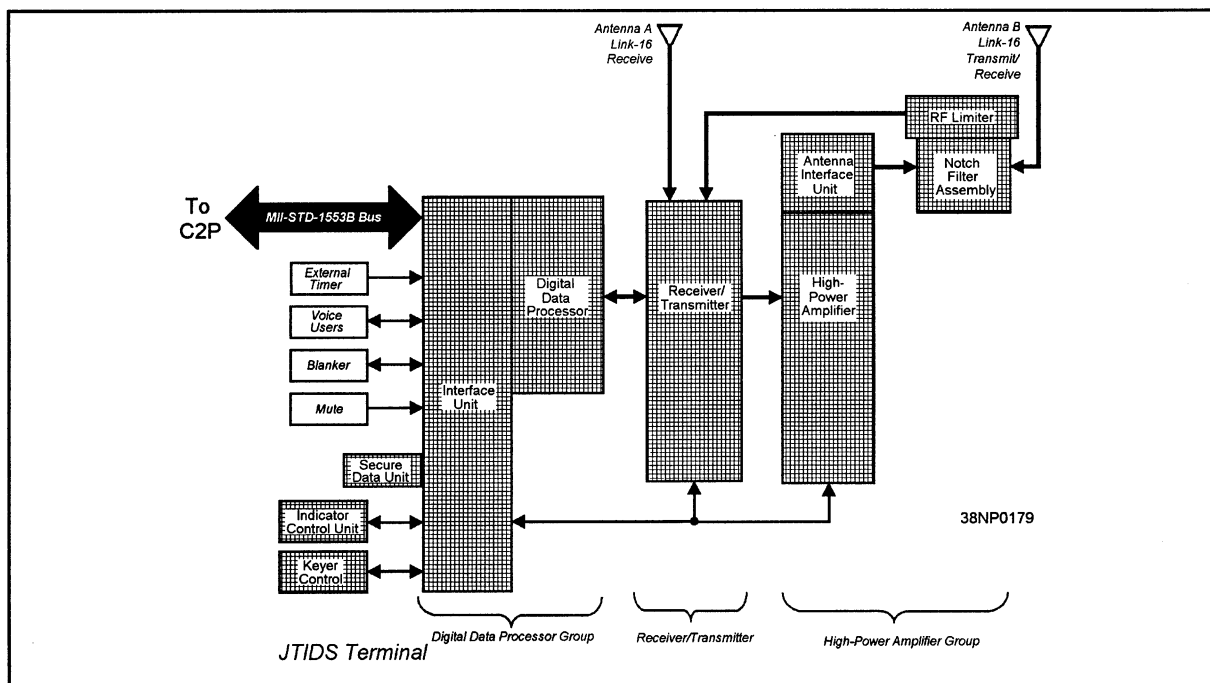


Figure 5-8.—The JTIDS terminal functional block diagram.

**Power Amplifier Group (HPAG), and the Power Interface Unit (PIU). The Secure Data Unit (SDU)** is a separate assembly that is mounted to the Digital Data Processing Group. Figure 5-8 is the fictional 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

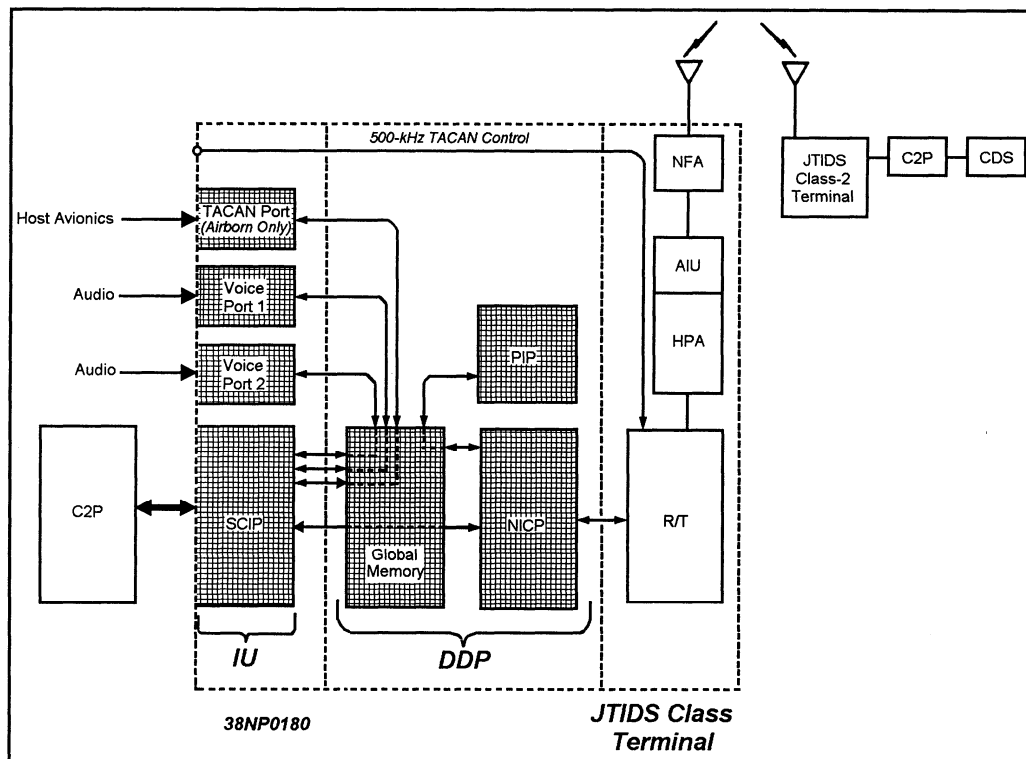


Figure 5-9.—The Digital Data Processing Group functional block diagram.

- Selection of the carrier frequency
- Measurement of time of arrival data for position and synchronization calculations
- 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 5-9 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. 5-9).

**SECURE DATA UNIT.**— The SDU is a removable assembly that is mounted to the IU. It stores the cryptovariabes 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.

## 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

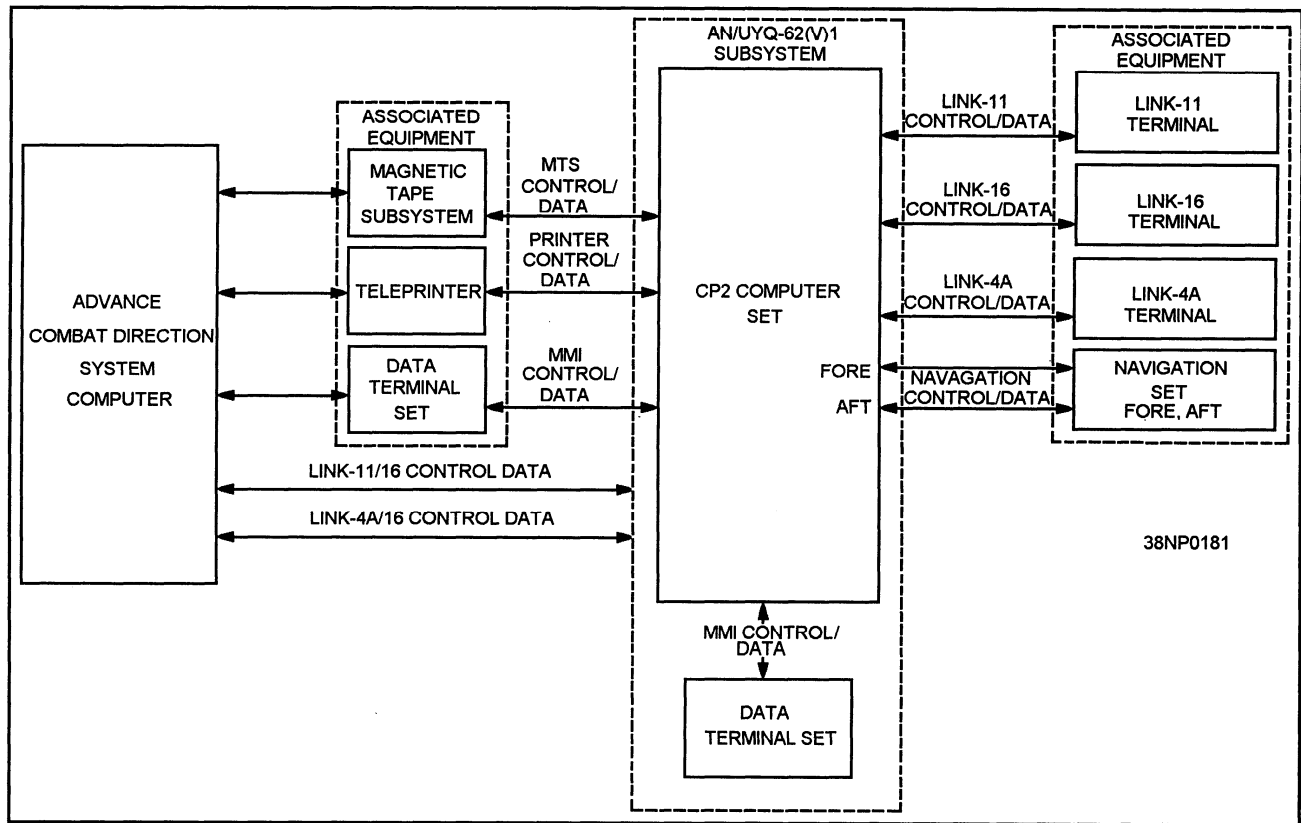


Figure 5-10.—The C2P system block diagram for ACDS Block 0 platforms.

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 on an ACDS Block 0 platform is very similar to the system that is installed on an AEGIS Model 4 platform. Figure 5-10 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 data base, 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 5-11. 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

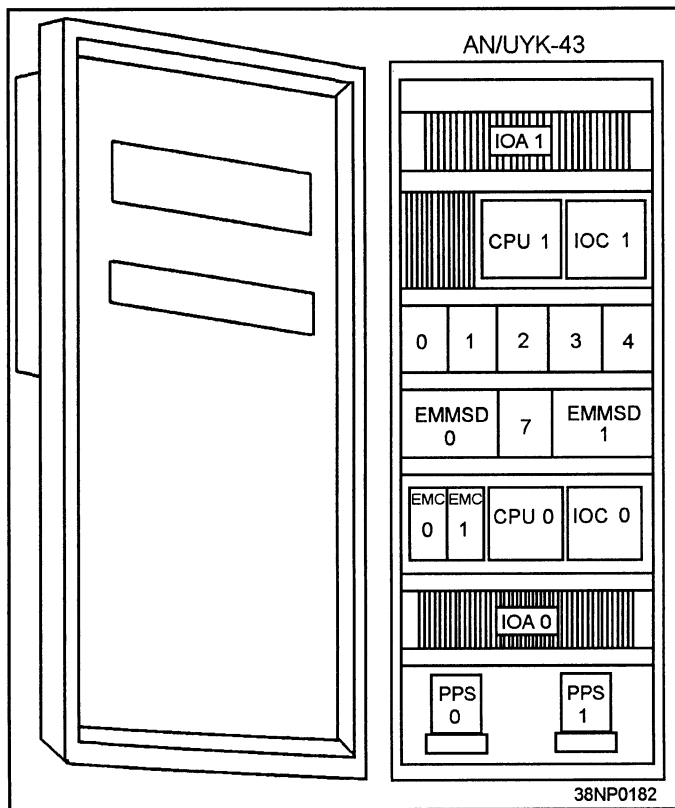


Figure 5-11.—The C2P system hardware configuration

- 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 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.

## SUMMARY—NEW TECHNOLOGY IN DATA COMMUNICATIONS

This chapter introduced you to some of the new changes and systems concerning data communications in the Navy. The following information summarizes the important points you should have learned.

**THE AN/USQ-125 DATA TERMINAL SET**— The AN/USQ-125 data terminal set replaces many of the older Link-11 data terminal sets in the Navy. It consists of the CP-2205(P)(V)/USQ-125 data terminal and a remote control unit.

**THE CP-2205(P)(V)/USQ-125 DATA TERMINAL**— The CP-2205(P)(V)/USQ-125 data terminal performs the modulation/demodulation, error detection and correction, CDS computer and radio interface, signal analysis and built-in test functions. In addition to performing all of the standard multi-tone Link-11 operations, the data terminal has several new capabilities. These capabilities include the following:

- **Single-Tone Waveform Link**— This option of the Link-16 system is used to transmit data over a standard telephone modem or a satellite modem. It uses an 1,800-Hz phase-modulated waveform that has the Link-11 data embedded in it as a serial bit stream.
- **Enhanced Link Quality Analysis**— ELQA allows the operator to monitor and evaluate the performance of the Link-11 net by providing most of the functions of the LMS-11.

- **Maximum Useable Frequency**— This option calculates the best frequency for use based on geographic location, time of day, current sunspot activity and other factors that can affect HF radio-wave propagation.
- **Multi-Frequency Link**— The multi-frequency link enables the operation of Link-11 on up to four frequencies. Normally, multi-frequency link uses three HF frequencies and one UHF frequency.

**REMOTE CONTROL UNIT**— The remote control unit is a personal computer based unit that allows the operator to control the data terminal from a remote location.

**THE JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM (LINK-16)**— Link-16 is a new data link that provides for the real-time exchange of tactical data between Naval, Joint Service, and NATO units. It includes many of the functions of the current Link-11 and Link-4A systems. Link-16 expands many of these functions and includes several new features that the other systems lack. These new features include the following:

- **Nodelessness**— Nodelessness means that no one unit is required to maintain link operations. Once the net is established, it can continue to operate regardless of the participation of any particular unit.
- **Jam resistance**— Link-16 data is not transmitted on any particular frequency, but changes frequency every 13 microseconds. For additional security, a pseudo-random pattern of noise and jitter is added to the signal. The combination of frequency hopping and the noise and jitter makes the transmitted signal hard to detect and jam.
- **Flexibility of communication operations**— Link-16 provides both data and voice communications circuits. In addition, different data packing methods allow for

variation in the amount of data transmitted during a given time slot.

- **Separate transmission and data security features**— Link-16 transmissions are protected by encrypting the data, frequency hopping, and adding a pseudo-random noise pattern to the signal before transmitting
- **Network navigation features**— The relative navigation module is a software routine run by the Link-16 terminal that compares the time of receipt of a transmission against the time it was sent and calculates the distance of the sending unit from the receiving unit. This information is correlated against reported geographic position and used to maintain net synchronization and improve positional accuracy.
- **Secure voice capabilities**— The Link-16 system secure voice communications have the same transmission safeguards as data transmissions.

Link-16 also provides the following new or enhanced capabilities:

- **Number of Participants**— The number of participants that can participate in a Link-16 net has been increased dramatically. Using a five-digit octal number for addressing, a possible 32,766 addresses are available.
- **Track Numbers**— Link-16 replaces the old four-digit (octal) track numbers used with Link-11 with a five-character alphanumeric track number. This increases the track number capacity from 4,092 to 524,284.
- **Track Quality**— Link-16 track quality is improved by comparing the reported position of a track with the actual position of the track. To achieve the maximum track quality, a track must be within 50 feet of its reported position.
- **Track Identification**— The information reported when identifying a track has been

expanded due to the increased size of the Link-16 data word. The new reports include fields for track activity, specific type, and the nationality of the track. Tracks can also be identified as “Neutral” and the unknown assumed enemy ID has been changed to “Suspect.”

- **Friendly Status**— Friendly forces reporting their status can add additional information, such as equipment status, ordnance inventory, radar and missile channels, fuel status, gun capability, and station ETA/ETD.
- **Granularity of Measurement**— Major improvements have been made in the precision, or granularity, of reporting positions.
- **Land Points and Tracks**— Link-16 allows for the designation and tracking of land points and tracks.

**EQUIPMENT CONFIGURATION**— The AN/URC-107(V)7 JTIDS terminal is the heart of the Link-16 system. This radio system provides, in a single equipment cabinet, the secure, jam-resistant, digital data and voice communications required for Link-16 operations. The terminal consists of the following four major groups: the digital data processor group, the receiver/transmitter group, the high-power amplifier group, and the power interface unit. The secure data unit is a separate assembly that is mounted on the front panel of the terminal.

**THE COMMAND AND CONTROL PROCESSOR (C2P)**— The C2P is a message distribution system that manages and controls the interfaces of the three tactical data links and the CDS computer. The C2P computer is placed in-line with the CDS computer and the data links communicate directly with the C2P computer. The C2P computer can reformat data from one data link for transmission on another data link. For example, a Link-11 message received by the C2P can be reformatted and transmitted as a Link-16 message. The C2P also sends all data from the three data links to the CDS computer.





# CHAPTER 6

## 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. 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 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. In either case, the computer normally has a hard disk and the software needed to run the network system. 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. 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 multiplexer 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 desirable 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.

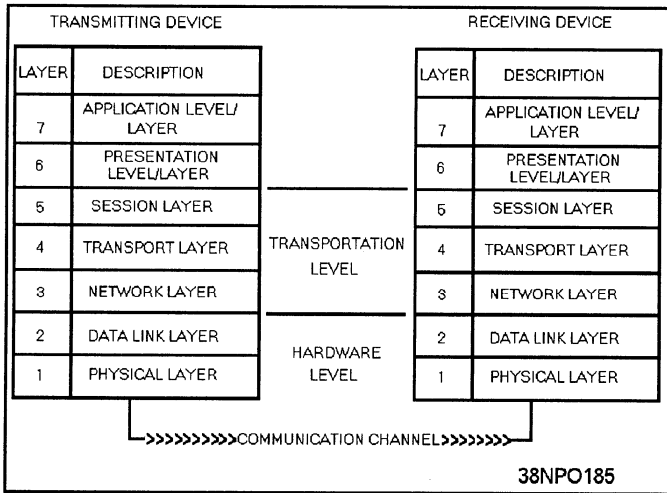
## **WORKSTATIONS**

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 (OSI) to provide some level of uniformity among computer manufacturers and network vendors. OSI is one of several governing organizations in this field that has developed such protocols. These seven layers of standards, shown in figure 6-1, 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 any one 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 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



**Figure 6-1.—The OSI model showing the seven layers.**

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 for getting 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 deals 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 6-2. 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 cabling 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.

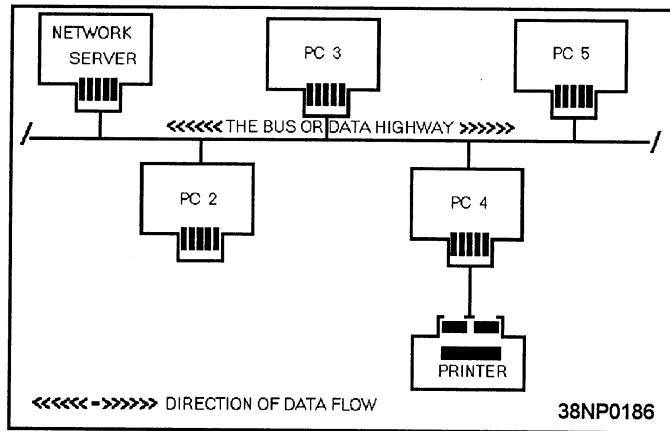


Figure 6-2.—A bus network topology.

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 compete 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. Finally, the bus network can be easily compromised by an unauthorized network user, since all messages are sent along a common data highway. For this reason, it is difficult to maintain network security.

### STAR NETWORK

In a star network, each component is connected directly to the central computer or network server, as shown in figure 6-3. 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.

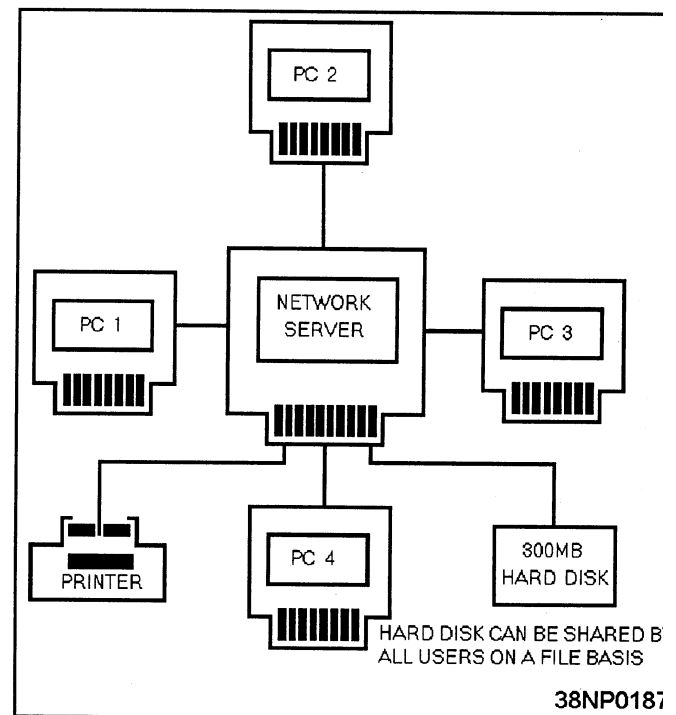


Figure 6-3.—A star network topology.



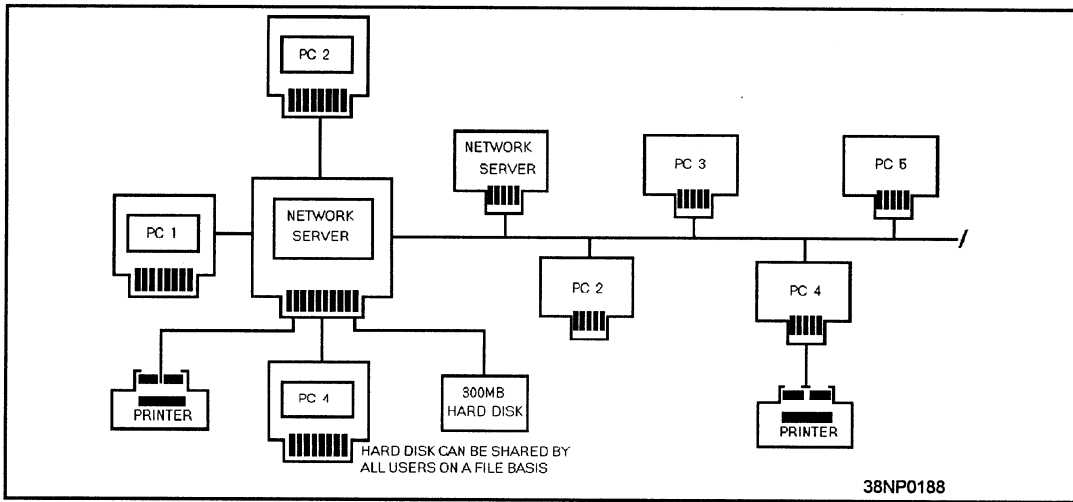


Figure 6-4.—A distributed star (tree) network topology.

## DISTRIBUTED STAR

The distributed star, or tree, topology is shown in figure 6-4. 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 6-5. This topology allows a node to send a message to another node on the ring. 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 continuing 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 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

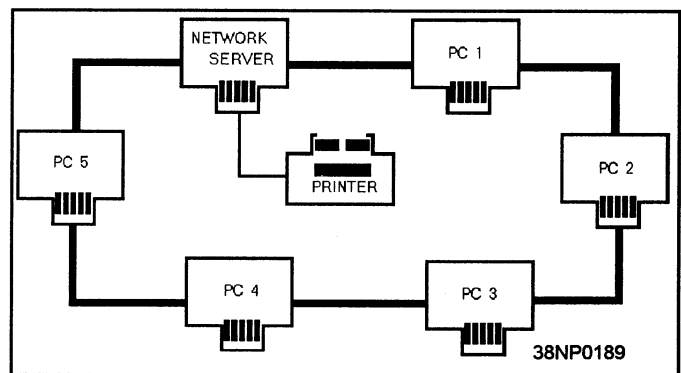
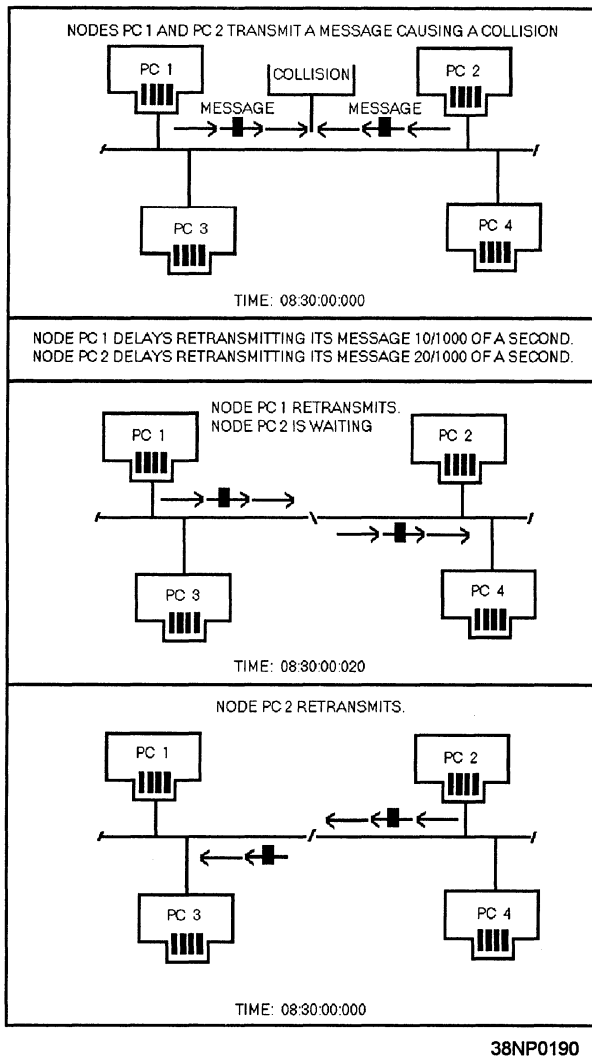


Figure 6-5.—A ring network topology.



**Figure 6-6.—A bus network using the CSMA/CD access method.**

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 6-6. 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.

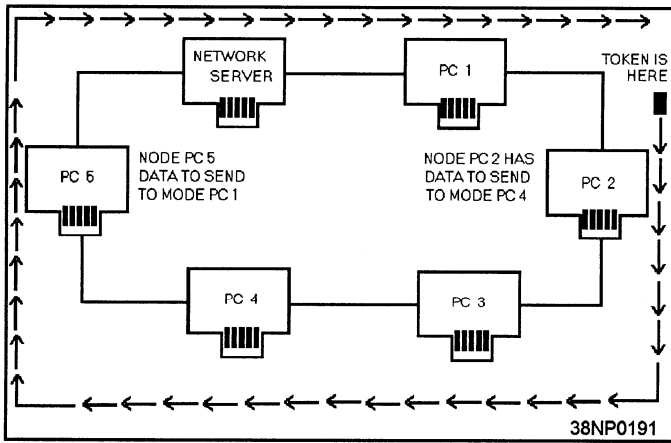
### Token Passing

Token passing is an orderly access method and is shown in figure 6-7. 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 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 maybe 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 elements, 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.

## LAN SYSTEMS



**Figure 6-7.**—A ring network using the token passing access method.

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.

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.

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 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 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's 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.

### **SUMMARY—LOCAL-AREA NETWORKS**

This chapter introduced you to local-area networks. The following information summarizes the important points you should have learned.

**LOCAL-AREA NETWORKS—** LANs are a combination of hardware and software which allows personal computers to share information. The total number of computers and the total distance the network can cover are determined by several factors, including the type of cable used and the network operating system software.

**CABLES—** Several types of cables can be used to create a local-area network. They are twisted-pair, shielded twisted-pair, coaxial, and fiber-optic. The type of cable used determines maximum data transfer rates and can be a factor when the number of nodes in the network is determined.

**NETWORK INTERFACE CARD—** The network interface card attaches the PC to the network. Most network interface cards have built-in microprocessors that control network communications. This frees the PC's main processor of time-consuming I/O operations.

**NETWORK SERVERS—** The modern network server controls all operations of the network. These operations include controlling network

communications, storing and retrieving files from shared memory resources, and controlling common printers. In older systems, each of these functions required a separate server.

**WORKSTATIONS—** Workstations are the personal computers connected to the network. Even if a PC is part of a network, it can still be used in a stand-alone configuration.

**OPEN SYSTEM INTERCONNECTION OSI REFERENCE MODEL—** The open systems interconnection reference model defines the protocols network hardware and software manufacturers use to create a network operating system. There are seven layers in the OSI model. These layers are contained in the five levels.

**HARDWARE LEVEL—** The hardware level contains the first two layers of the OSI reference model. These are the physical layer and the data link layer. The physical layer defines the electrical, mechanical, and functional interfaces for the transmission of data through the cable. The data link layer is responsible for error detection and correction of the transmitted data.

**TRANSPORT LEVEL—** The next three layers of the OSI reference model are contained in the transport level, also referred to as the *subnet*. The three layers of the transport level are the network layer, the transport layer, and the session layer.

The network layer monitors network activity and controls which path the data is to be transmitted over. The software, controlling the network interface card, stores the data to be transmitted, builds the data packets, and routes the data to the correct destination.

The transport layer ensures the integrity of the data packets. The session layer provides for the interface between two or more applications to communicate across the network.

**PRESENTATION LEVEL/LAYER—** The presentation level contains the presentation layer. The presentation layer formats the data presented to the application level. The presentation layer provides

standardized data encoding, data compression, and data encryption and decryption as required.

**APPLICATION LEVEL/LAYER**— The final level of the OSI reference model is the application level and it consists of the application layer. This layer directly supports the users and application tasks.

**USING THE OSI MODEL**— When you use a layered architecture (such as the OSI reference model) to design a communications network, it is possible to update specific items in the network without having to replace the entire system.

**LAN TOPOLOGIES**— The physical arrangement of the components of a LAN is called its topology. The three basic topologies used in building a LAN are the linear bus, the star, and the ring. Hybrid topologies can be created by combining different features of each.

**LINEAR BUS**— The linear bus topology connects all the nodes to a common straight cable. All the nodes on the network share the common bus. This topology is very reliable since a failure of one or more nodes does not affect the bus. The disadvantages of the linear bus are the need for minimum distances between nodes to avoid signal interference, and the loss of data caused by the simultaneous transmission by two nodes.

**STAR NETWORK**— In a star network, each node is connected directly to the central computer. All communications between the nodes have to pass through the central computer. Star networks allow the network administrator to give selected nodes higher priority and also allow centralized running of diagnostic programs.

**RING NETWORK**— In a ring network, all nodes are connected to a common cable, and the cable starts and ends at the network server. In this type of network, communications are always in one direction, and the data being transmitted is passed through each node in the ring. A major disadvantage of this network is that when a node fails, it can completely halt all communications on the network.

**ACCESS METHODS**— Once the topology of a network is determined, the method by which the nodes access the network must be determined. In some cases, the access method is determined by the topology of the network. Some of the access methods used in networks are as follows: carrier sense multiple access (CSMA), carrier sense multiple access with collision detection (CSMA/CD), and token passing.

In the CSMA method, each node monitors the network line for activity. When the node detects that there is no activity on the network, it will send its data. A problem occurs when two or more nodes attempt to use the network at the same time. This situation causes a collision of the data packets and a possible loss of data. In the CSMA/CD method, when a collision is detected, each node ceases transmission and retransmits when it senses that activity on the network is completed.

In token passing, a software token is passed to each node in an orderly manner. The method is similar to the Roll Call mode of operation of the Link-11 system described in chapter 2. When the node with the token has no data to transmit, it passes the token to the next unit. When the node has data, it transmits it when it receives the token, and when it completes its transmission, passes the token to the next node.

**LAN SYSTEMS**— There are several types of systems that can be installed in a LAN. The topology used has a major effect on the system the LAN will be capable of using. A few of the LAN systems available are as follows: EtherNet, STARLAN, ARCnet, and the IBM Token Ring. EtherNet is generally a linear bus network using the CSMA/CD protocol for network access. STARLAN is a star topology that also uses the CSMA/CD access protocol. ARCnet is a distributed star network that uses a token passing access protocol. The IBM Token Ring network is a star ring network that uses the token passing access protocol.

**NETWORK OPERATING SYSTEM BASICS**— The network operating system has five basic subsystems to control the operation of the

network. These are the control kernel, the network interfaces, the file systems, the system extension, and the system services.

The control kernel coordinates the various functions and processes of the network. The network interfaces provide the low-level subnet protocols for bridging hardware devices with the network operating system. The file systems module controls the methods of organizing, storing, and retrieving data

from the various types of storage systems used by the network. System extensions are defined by the network operating system manufacturers to allow third party modifications to the operating systems. This allows the network user to customize the network. The network services module contains all the functions that do not fit in any of the other subsystems. These include, but are not limited to, system security, system reliability, error conditions, and access violations.



## APPENDIX I

# GLOSSARY

This glossary defines abbreviations and acronyms as they are used in this training manual.

<b>ACDS</b> — Advance combat direction system	<b>DIV</b> — Diversity
<b>AFTS</b> — Audio-frequency tone shift	<b>DLRP</b> — Data link reference unit
<b>ASCII</b> — American Standard Code for information interchange	<b>DPG</b> — Data processing group
<b>BER</b> — Bit error rate	<b>DTS</b> — Data Terminal Set
<b>BFSK</b> — Binary frequency-shift keying	<b>EDAC</b> — Error detection and correction
<b>CAINS</b> — Carrier Aircraft Inertial Navigation System	<b>elf</b> — Extremely low frequency
<b>CCA</b> — Circuit card assembly	<b>ehf</b> — Extremely high frequency
<b>C<sup>2</sup></b> — Command and Control	<b>EMMSD</b> — Embedded mass memory storage device
<b>C<sup>2</sup>P</b> — Command and Control Processor	<b>EMS</b> — Embedded memory subsystem
<b>CDG</b> — Control/display group	<b>ETA</b> — Estimated time of arrival
<b>CDS</b> — Combat Direction System	<b>ETD</b> — Estimated time of departure
<b>CRT</b> — Cathode-ray tube	<b>FDM</b> — Frequency-division multiplexing
<b>CPS</b> — Continuous phase shift	<b>FFT</b> — Fast Fourier transform
<b>CS</b> — Carrier suppression	<b>FSK</b> — Frequency-shift keying
<b>CSMA</b> — Carrier sense multiple access	<b>Ghz</b> — Gigahertz
<b>CU</b> — Control unit	<b>GRU</b> — Gridlock reference unit
<b>dB</b> — Decibel	<b>hf</b> — High frequency
<b>dBm</b> — Milliwatt reference (600-ohm load)	<b>HPAG</b> — High power amplifier group
<b>DDC</b> — Digits-to-digital converter	<b>HPIB</b> — Hewlett Packard Interface Bus
<b>DDPG</b> — Digital data processor group	<b>Hz</b> — Hertz
	<b>ID</b> — Track identification

**IDA**— Input data acknowledge

**IDR**— Input data request

**IEEE**— Institute of Electrical and Electronics Engineer

**I/O**— input/output

**ISO**— International Standards Organization

**JTIDS**— Joint Tactical Information Distribution System

**JU**— JTIDS unit

**kHz**— Kilohertz

**lf**— Low frequency

**LAN**— Local area network

**log**— Logarithm

**LMS**— Link monitor system

**LSB**— Lower sideband

**mf**— Medium frequency

**MHZ**— Megahertz

**MODEM**— MOdulator Demodulator

**MCM**— Monitor control message

**MRM**— Monitor reply message

**MUF**— Maximum useable frequency

**NATO**— National Alliance Treaty Organization

**NIC**— Network interface card

**NICP**— Network interface computer program

**NCS**— Net control station

**NTR**— Network time reference

**ODR**— Output data request

**OSI**— Open system interconnection

**POFA**— Programmed operational and fictional appraisal

**PIU**— Power interface unit

**PU**— Participating unit

**R/T**— Receiver/transmitter group

**RGB**— Red, green, and blue

**RCV**— Receive

**SDLC**— Synchronous data link control

**SDU**— Secure data unit

**SNR**— Signal-to-noise ratio

**SGS**— Shipboard Gridlock System

**shf**— Superhigh frequency

**SINS**— Ship's Inertial Navigation System

**TADIL**— Tactical Data Information Link

**TDM**— Time-division multiplexing

**TDMA**— Time-division multiple access

**TQ**— Track quality

**uhf**— Ultra-high frequency

**USB**— Upper sideband

**μsec**— Microsecond

**UTM**— Universal test message

**vhf**— Very high frequency

**vlf**— Very low frequency

**XMT**— Transmit

## APPENDIX II

# REFERENCES USED TO DEVELOP THE TRAMAN

NOTE: Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. Therefore, you need to be sure that you are studying the latest revision.

### Chapter 1

Black, Uyles D., *Data Networks, Concepts, Theory, and Practice*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1989.

Navy Electricity and Electronics Training Series, Module 11, *Microwave Principals*, NAVEDTRA 172-16-00-84, Naval Education and Training Program Management Support Activity, Pensacola, FL, 1984.

Navy Electricity and Electronics Training Series, Module 17, *Radio-Frequency Communications Principles*, NAVEDTRA 172-17-00-84, Naval Education and Training Program Management Support Activity, Pensacola, FL, 1984.

*Understanding Link-11, A Guidebook for Operators, Technicians, and Net Managers*, Navy Center for Tactical Systems Interoperability, San Diego, CA, 1991.

### Chapter 2

*Data Communication System AN/USC-30*, NAVSEA 0967-563-9010, Government Telecommunications Division, Collins Radio Group, Rockwell International, Dallas, TX, 1975.

*Instruction Manual, Data Terminal Set, AN/USQ-59(V)2*, SPAWAR 0967-LP-563-9020, Space and Naval Warfare Systems Command, Washington, D. C., 1973.

*Link-11 Seminar for Operators and Technicians, Instructor Notes*, Link-11 Waterfront Seminar, Logicon, Inc., San Diego, CA, 1990.

*Operation and Maintenance Instructions, Organizational Level, Link 11 Data Terminal Set AN/USQ-76(V)3*, SPAWAR EE640-DW-OMI-01B/E110-USQ76V3, Space and Naval Warfare Systems Command, Washington, D.C., 1990.

*System Operation and Maintenance Manual, AN/USQ-74, 74A, Data Terminal Set*, SPAWAR EE600-AA-OMI-010, Space and Naval Warfare Systems Command, Washington, D. C., 1990.

*Technical Manual, Operation, and Maintenance with Illustrated Parts Breakdown, Data-Terminal Set Control, C-9063/USQ-59*, NAVSEA 0967-LP-563-9050, Naval Sea Systems Command, Washington, D. C., 1977.

*Technical Manual, Operation, Maintenance Manual with Illustrated Parts Breakdown, Digital To Analog Converter, CV-2969A(P)/U*, NAVSEA 0967-LP-563-9070, Naval Sea Systems Command, Washington, D. C., 1977.

*Technical Manual, Installation, Operation, and Maintenance with Illustrated Parts Breakdown, Computer Adapter MX-9222/U*, NAVSEA 0967-LP-563-9060, Naval Sea Systems Command, Washington, D. C., 1977.

*Technical Manual, Operation, Maintenance with Illustrated Parts Breakdown, Address Control - Indicator, C-9062/U*, NAVSEA 0967-LP-563-9040, Naval Sea Systems Command, Washington, D. C., 1977.

*Understanding Link-11, A Guidebook for Operators, Technicians, and Net Managers*, Navy Center for Tactical Systems Interoperability, San Diego, CA, 1991.

### **Chapter 3**

*LMS-11 Troubleshooter's Guide for Link-11 Operations*, Logicon, Inc., San Diego, CA, 1990.

*Operator/O-Level Maintenance Training Course, Trainee Guide for the Link Monitor System, AN/TSQ-162(V)1*, Logicon, Inc., San Diego, CA, 1990.

*Technical Manual, System Operation and Maintenance Instructions, Organization Level, Link Monitor System, AN/TSQ-162(V)1*, SPAWAR EE-190-AB-OMI-010/TSQ-162(V)1, Space and Naval Warfare Systems Command, Washington, D. C., 1989.

*User's Manual, Link-11 Monitor System, Rack-mountable (LMS-11R)*, Logicon, Inc., San Diego, CA, 1990.

### **Chapter 4**

*Operation and Maintenance Manual for the Link Monitor System (LMS-4) for Link-4A*, Logicon, Inc., San Diego, CA, 1990.

*Technical Manual, Volume 1, Digital Data Communications Control Set, AN/SSW-1D(U)*, NAVSEA 0967-LP-555-4010, Naval Sea Systems Command, Washington, D. C., 1973.

### **Chapter 5**

*Operating and Service Manual, C-12428/USQ-125 Control Unit*, Cedar Technology Inc., Longmont, CO, 1995.

*Operation and Maintenance Instructions, MK512PV, Link-11 Data Terminal*, General Atronics Corp., Philadelphia, PA, 1992.

*Preliminary Technical Manual, System Maintenance, Organization Level, AN/UYQ-62(V)1, 2, Command and Control Processor (C<sup>2</sup>P) Subsystem*, SPAWAR EE600-AB-SLM-010, Space and Naval Warfare Systems Command, Washington, D. C., 1992.

*Understanding Link-16, A Guidebook for New Users*, Logicon, Inc., San Diego, CA, 1994.

## **Chapter 6**

Black, Uyles D., *Data Networks, Concepts, Theory, and Practice*, Prentice-Hall, Inc., Englewood Cliffs, NJ, 1989.

Hancock, Bill, *Designing and Implementing Ethernet Networks*, QED Information Sciences, Inc., Wellesley, MA, 1988.

Heath, Steve, *Effective PC Networking*, Butterworth-Heinemann Ltd., Oxford, England, 1993.

Woodward, Jeff, *The ABC's of Novell NetWare*, Sybex Inc., Alameda, CA, 1989.

Durr, Michael, *Networking Personal Computers*, 3d ed, Que Corp., Carmel, IN, 1989.



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# *Assignment Questions*

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**Information:** The text pages that you are to study are provided at the beginning of the assignment questions.



# ASSIGNMENT 1

Textbook Assignment: “Fundamentals of Data Communications,” chapter 1, pages 1-1 through 1-13;  
“The Link-11 System,” chapter 2, pages 2-1 through 2-8.

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- 1-1. Which of the following are components of a communications system?
1. Receivers
  2. Transmitters
  3. Communications channels
  4. All of the above
- 1-2. The conversion of data to a form that can be sent over a communications channel is a function of which of the following communication system components?
1. The transmitting equipment
  2. The receiving equipment
  3. The communications channel
  4. The computer
- 1-3. Data sent over a communications channel may be in which of the following forms?
1. Analog only
  2. Digital only
  3. Either analog or digital, depending on the type of system
  4. Alphanumeric characters
- 1-4. A communications channel signal that varies continuously between a minimum and a maximum value is what type of signal?
1. Analog
  2. Digital
  3. Numeric quantities
  4. Alpha characters
- 1-5. To convey data, analog signals can be varied in which of the following ways?
1. Phase only
  2. Amplitude only
  3. Frequency only
  4. Phase, amplitude, or frequency
- 1-6. Which of the following communications signal types have a limited set of values and are transmitted as discrete pulses?
1. Analog
  2. Digital
  3. Both 1 and 2 above
  4. Alphanumeric characters
- 1-7. In which of the following types of communications channels is data in a single direction ONLY?
1. Simplex
  2. Duplex
  3. Half duplex
  4. Full duplex
- 1-8. Which of the following communications channels can transmit and receive data simultaneously?
1. Simplex
  2. Duplex
  3. Half duplex
  4. Full duplex

- 1-9. Which of the following types of communications channels transmits data in one direction, pauses, and then receives data coming in the opposite direction?
1. Simplex
  2. Duplex
  3. Half duplex
  4. Full duplex
- 1-10. What device converts digital data signals to tones and converts tones back to digital data signals?
1. Modem
  2. Modulator
  3. Demodulator
  4. Data converter
- 1-11. The modulator of a modem performs which of the following functions?
1. It converts data to be transmitted into discrete modifications of the tone or carrier signal
  2. It converts data-carrying tones into digital data
  3. It receives digital data from the demodulator
  4. It receives analog data from the computer
- 1-12. The operational characteristics of a radio communications system are determined by what means?
1. Low frequency
  2. High frequency
  3. Carrier frequency
  4. Radio frequency band
- 1-13. The tactical digital information links that the Navy uses generally require which of the following radio frequency bands?
1. LF
  2. HF
  3. UHF
  4. Both 2 and 3 above
- 1-14. The data signals must be \_\_\_\_\_ (a) \_\_\_\_\_ to the carrier signal at the transmitter and \_\_\_\_\_ (b) \_\_\_\_\_ from the carrier signal in the receiver.
1. (a) Modulated (b) modulated
  2. (a) Modulated (b) demodulated
  3. (a) Demodulated (b) modulated
  4. (a) Demodulated (b) demodulated
- 1-15. A radio frequency of 8,090 KHz is in which of the following frequency bands?
1. LF
  2. MF
  3. HF
  4. UHF
- 1-16. Which of the following radio frequency bands is limited to line-of-sight communications?
1. LF
  2. MF
  3. HF
  4. UHF
- 1-17. Decibels are the unit of measure of what function of an amplifier, communications equipment, or a system?
1. Gain
  2. Power
  3. Output
  4. Input

- 1-18. The bel most often expresses what value of any component, circuit, or system?
1. Power
  2. Input
  3. Output
  4. Ratio of input to output power
- 1-19. In the formula for bel, which of the following symbols would represent the output of an amplifier?
1. N
  2. PI
  3. P2
  4. Log10
- 1-20. In the formula for bel, which of the following symbols would represent the gain of an amplifier in bels?
1. N
  2. P1
  3. P2
  4.  $\text{Log}_{10}$
- 1-21. The decibel is equal to what total number of bels?
1. 1/10 bel
  2. 1/100 bel
  3. 1 bel
  4. 10 bels
- 1-22. A value of 1.5 bels is equal to what total number of decibels?
1. 1.5
  2. 15
  3. 150
  4. 1,500
- 1-23. What is the power ratio of an increase of a reference signal of 30 dBs?
1. 10
  2. 100
  3. 1,000
  4. 10,000
- 1-24. A power gain of -6 dB from a reference signal of 1,000 watts results in what maximum value of output signal?
1. 250 watts
  2. 500 watts
  3. 2,500 watts
  4. 5,000 watts
- 1-25. When dBm is measured, which of the following signals is normally the reference signal?
1. Input
  2. Output
  3. 1 milliwatt
  4. 1 millivolt
- 1-26. Which of the following signal levels indicates that the output signal is greater than the input signal?
1. 5 dB
  2. +3 dB
  3. Either 1 or 2 above
  4. -2 dB
- 1-27. A reading of 0 dB indicates that the output signal has what relationship to the reference signal?
1. Equal to
  2. Less than
  3. Greater than
  4. Not equal to

- 1-28. A reading of 0 dBm indicates an output value equal to which of the following signal values?
1. 0 dB
  2. 1 milliwatt
  3. 500 watts
  4. 1,000 watts
- 1-29. What framed transmission method is used to transmit ASCII characters?
1. Asynchronous
  2. Synchronous
  3. Message framed
  4. Alphanumeric framed
- 1-30. What framed transmission method is used to transmit long streams of uninterrupted data bits?
1. Asynchronous
  2. Synchronous
  3. Character framed
  4. Alphanumeric framed
- 1-31. When the asynchronous transmission method is used, each character sent has which of the following control bits?
1. Start bit(s) only
  2. Stop bit(s) only
  3. Both start and stop bits
  4. Parity bits

- 1-32. When the asynchronous transmission method is used, synchronization between the transmitting and the receiving devices is achieved by which of the following methods?
1. Synchronization reference signal in the preamble
  2. Synchronization reference in the stop codes
  3. Character-by-character synchronization
  4. External timing signals sent concurrently on a separate line
- 1-33. Which of the following codes indicates the beginning sequence of a synchronous message?
1. Sync bits
  2. Stop code
  3. Parity code
  4. Preamble

IN ANSWERING QUESTIONS 1-34 THROUGH 1-38. MATCH THE TERM OR STATEMENT IN COLUMN A WITH THE BASIC MODE OF MODULATION LISTED IN COLUMN B. RESPONSES IN COLUMN B MAY BE USED MORE THAN ONCE.

- | A. <u>TERMS/<br/>STATEMENT</u>   | B. <u>MODES</u>   |
|--|---|
| 1-34. The change in signal amplitude indicates a change in the 1 or 0 bits being transmitted | <ol style="list-style-type: none"> <li>1. Phase modulation</li> <li>2. Amplitude modulation</li> <li>3. Frequency modulation</li> </ol> |
| 1-35. Differential quadrature phase-shift keying   |   |

- 1-36. BFSK
- 1-37. AFTS
- 1-38. Interrupting the cycle at a degree point and changing the direction or amplitude of the sine wave
- 1-39. Which of the following modes of modulation can be used to modify carrier signals to convey data?
1. Phase modulation
  2. Frequency modulation
  3. Amplitude modulation
  4. All of the above
- 1-40. In which of the following modulation methods are frequencies above and below a center frequency used to indicate a logic 1 or 0 bit?
1. Amplitude modulation
  2. Frequency-shift keying
  3. Audio frequency tone shift
  4. Differential quadratic phase-shift keying
- 1-41. Which of the following modulation methods uses two discrete audio tones that are modulated to a constant frequency carrier signal?
1. FSK
  2. BFSK
  3. AFTS
  4. Phase-shift keying
- 1-42. When quadrature phase-shift modulation is used, a single tone transmits what total number of binary bits of data for each phase Shift?
1. One
  2. Two
  3. Three
  4. Four
- 1-43. When quadrature phase-shift modulation is used, which of the following phase shifts indicates a binary 00?
1. +135 degrees
  2. -135 degrees
  3. +225 degrees
  4. -225 degrees
- 1-44. Which of the following components of a modem converts the data bits into a carrier signal?
1. The transmitter
  2. The receiver
  3. Both 1 and 2 above
- 1-45. Each modem transmitter circuit outputs several carrier signals.
1. True
  2. False
- 1-46. Which of the following circuits allows ONLY the desired carrier signal to be received from the communications channel?
1. The demodulator
  2. The data decoder
  3. The band pass falter
  4. The receiver control circuit
- 1-47. The term baud describes the number of characters per second transmitted over a communications channel.
1. True
  2. False

1-48. Multiplexing data being transmitted over a communications channel performs which of the following functions?

1. It increases the baud rate
2. It allows multiple users of the same channel
3. Either 1 and 2 above
4. It changes the carrier frequency

1-49. Which of the following multiplexing methods divide(s) the asynchronous message into a fixed number of time slots?

1. Time division
2. Frequency division
3. Both 1 and 2 above
4. Quadrature phase-shift

1-50. Which of the following multiplexing methods transmits several tones over a single communications channel?

1. Time division
2. Frequency division
3. Both 1 and 2 above
4. Quadrature phase-shift

1-51. 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

1-52. 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

1-53. When Link-11 is operated with UHF radio, it is capable of over-the-horizon communications.

1. True
2. False

IN ANSWERING QUESTIONS 1-54 THROUGH 1-61, SELECT FROM THE FOLLOWING LIST THE EQUIPMENT THAT PERFORMS THE FUNCTION DESCRIBED IN THE QUESTION. ITEMS IN THE LIST MAY BE USED MORE THAN ONCE.

- A. CDS Digital Computer
- B. SGS Computer
- C. Cryptographic Device
- D. Data Terminal Set
- E. Communications Switchboard
- F. Radio Set

1-54. Selects the HF or the UHF transceiver.

1. B
2. C
3. D
4. E

1-55. 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

1-56. Correlates reported positions of local and remote tracks.

1. A
2. B
3. C
4. D



- 1-57. Outputs 24-bit data words to the security equipment via the SGS computer.
1. A
  2. B
  3. C
  4. D
- 1-58. Multiplexes and modulates parallel data into audio tones.
1. A
  2. B
  3. C
  4. D
- 1-59. Receives the audio tone package from the data terminal set and transmits the tones.
1. C
  2. D
  3. E
  4. F
- 1-60. Demodulates the audio tones and checks the six hamming bits for transmission errors.
1. A
  2. B
  3. C
  4. D
- 1-61. Decrypts the 24-bit data word and sends it to the CDS computer.
1. A
  2. B
  3. C
  4. D
- 1-62. 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
- 1-63. 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
- 1-64. 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
- 1-65. 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
- 1-66. 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

1-67. 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

1-68. 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

1-69. 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

IN ANSWERING QUESTIONS 1-70 THROUGH 1-75, SELECT FROM THE FOLLOWING LIST THE OPERATING MODE DESCRIBED IN THE QUESTION.

- A. Net Synchronization
- B. Net Test
- C. Roll Call
- D. Broadcast
- E. Short Broadcast
- F. Radio Silence

1-70. 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

1-71. In what Link-11 operating mode is each picket unit interrogated, in turn, by NCS?

1. A
2. B
3. C
4. D

1-72. What Link-11 operating mode provides an overall evaluation of net and equipment performance?

1. B
2. C
3. D
4. E

1-73. 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

1-74. 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

1-75. 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

## ASSIGNMENT 2

Textbook Assignment: “The Link-11 System,” chapter 2, pages 2-7 through 2-23; “Link-11 Fault Isolation,” chapter 3, pages 3-1 through 3-7.

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- 2-1. Net Sync continuously broadcasts which of the following signals?
1. Phase reference frames
  2. Start codes
  3. Stop code
  4. Preamble frames
- 2-2. 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
- 2-3. 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
- 2-4. The preamble of a Link-11 message consists of a total of how many frames?
1. Five
  2. Six
  3. Seven
  4. Eight
- 2-5. 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
- 2-6. To enable the DTS to detect frame transitions during the preamble, the 2,915 HZ sync tone is phase shifted how many degrees at each frame?
1. 90
  2. 180
  3. 270
  4. 360
- 2-7. 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

- 2-8. 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
- 2-9. Exactly how many data bits are contained in each Link-11 information frame?
1. 18
  2. 24
  3. 30
  4. 32
- 2-10. 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
- 2-11. 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
- 2-12. A call-up, or interrogation message consists of a total of how many frames?
1. Five
  2. Six
  3. Seven
  4. Eight
- 2-13. 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
- 2-14. 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
- 2-15. 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
- 2-16. 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

- 2-17. 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
- 2-18. 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
- 2-19. 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
- 2-20. Bits 4 and 5 of a 30-bit data word are carried by which of the following audio tone frequencies?
1. 935 Hz
  2. 1,155 Hz
  3. 1,265 Hz
  4. 1705 Hz
- 2-21. What is the basic unit of the Link-11 transmission?
1. Bit
  2. Tone
  3. Frame
  4. Doppler
- 2-22. 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.  $\pm$  44 degrees
  4.  $\pm$ 135 degrees
- 2-23. 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
- 2-24. 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
- 2-25. During the preamble, the 2,915 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

- 2-26. 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 dB
  3. - 6 dB
  4. 0 dB
- 2-27. 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
- 2-28. 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
- 2-29. 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
- 2-30. 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
- 2-31. 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
- 2-32. 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

2-33. 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

2-34. 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

2-35. When 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

2-36. 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

2-37. 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



- 2-38. 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
- 2-39. 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
- 2-40. 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
- 2-41. 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
- 2-42. 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
- 2-43. 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
- 2-44. 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

2-45. 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

2-46. 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

2-47. 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

2-48. 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

2-49. 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

2-50. 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

2-51. 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

- 2-52. 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
- 2-53. During receive operations, exactly how many EDAC bits are extracted from the received data tones?
1. One
  2. Two
  3. Five
  4. Six
- 2-54. The EDAC bits enable the DTS to correct a total of how many received bit errors?
1. One
  2. Two
  3. Three
  4. Four
- 2-55. 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
- 2-56. 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
- 2-57. The Link-11 radio set is in the transmit mode when the key line is clear.
1. True
  2. False
- 2-58. 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
- 2-59. Changing frequencies will always solve Link-11 problems.
1. True
  2. False

2-60. When you keeping the radio set tuned to output maximum power, it causes which of the following problems?

1. Increases RFI/EMI on the 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

2-61. When the NCS enters dummy PUs, which of the following net conditions will exist, if any?

1. Net efficiency increases
2. Netcycle time decreases
3. Netcycle time increases
4. None, dummy PUs have no effect on the net

2-62. 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 while 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

2-63. 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

2-64. When you run a single-station POFA with the radio set which of the following equipments is/are NOT checked?

1. Security device I/O path
2. Antenna coupler
3. DTS-to-radio audio lines
4. Radio-to-DTS audio lines

2-65. 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

2-66. 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

- 2-67. 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
- 2-68. 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"
- 2-69. The multi-station POFA is run in which of the following modes?
1. Net test
  2. Roll call
  3. Broadcast
  4. Short broadcast
- 2-70. 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
- 2-71. 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
- 2-72. 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
- 2-73. 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
- 2-74. 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
- 2-75. 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

## ASSIGNMENT 3

Textbook Assignment: "Link-11 Fault Isolation," chapter 3, page 3-7 through 3-22, "Link-4A," chapter 4, page 4-1 through page 4-10.

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- 3-1. A multi-station POFA is considered successful when the computed receive error factor is less than what percentage?
- 1
  - 5
  - 10
  - 15
- 3-2. Which of the following buffers is acceptable to be received from an unrecognized station (UNREC STA) when a multi-station POFA is running?
- One buffer of 200 words
  - One buffer of 230 words
  - Two buffers of 200 words
  - Two buffers of 230 words
- 3-3. The heading PARITY STATUS OF CORRECT WORDS lists which of the following error conditions?
- Words determined to be correct by the DTS parity check and found in error by the computer parity check
  - Words determined to have an error and corrected by the DTS
  - Words determined to be correct by both the DTS and the computer parity checks
  - Words determined to be in error by the DTS parity check and found correct by the computer parity check
- 3-4. The LMS-11 is designed to perform which of the following functions?
- Isolate problems to the component level in the Link-11 system
  - Provide a history of Link-11 net performance
  - Provide a real-time visual display of the Link-11 net operations
  - Provide the technician with a visual display of the Link-11 operation of one unit
- 3-5. The LMS-11 is a complex system designed to be permanently installed.
- True
  - False
- 3-6. The DPG and CDG equipment cases of the LMS-11 provide isolation from which of the following environmental forces?
- Shock only
  - Vibration only
  - Shock and vibration
  - Power surges
- 3-7. The LMS-11 system printer is part of which of the following equipment groups?
- Accessory
  - Control/display
  - Data processing
  - Support

- 3-8. 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
- 3-9. The HP9920U computer of the LMS-11 contains what additional amount of random access memory (RAM)?
1. 2 MB
  2. 4 MB
  3. 8 MB
  4. 12 MB
- 3-10. 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
- 3-11. 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
- 3-12. 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
- 3-13. 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
- 3-14. 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
- 3-15. The functional keys on the LMS-11 keyboard are color-coded to facilitate operator selections and entries.
1. True
  2. False
- 3-16. 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

- 3-17. 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
- 3-18. 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
- 3-19. 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
- 3-20. 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 an illegal address
- 3-21. 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
- 3-22. 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
- 3-23. 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
- 3-24. 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
- 3-25. Data frames are represented on the link monitor display by which of the following colors?
1. Yellow
  2. Red
  3. Cyan
  4. Green
- IN ANSWERING QUESTIONS 3-21 THROUGH 3-25, REFER TO FIGURE 3-7 IN THE TEXT.



- 3-26. 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
- 3-27. 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
- 3-28. 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
- 3-29. 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
- 3-30. 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
- 3-31. 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
- 3-32. The Net Display mode of the LMS-11 is capable of displaying two separate types of information.
1. True
  2. False
- 3-33. 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

- 3-34. 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
- 3-35. 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
- 3-36. 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
- 3-37. 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
- 3-38. 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
- 3-39. 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 contain 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
- 3-40. 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

- 3-41. 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
- 3-42. 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
- 3-43. 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
- 3-44. 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
- 3-45. 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
- 3-46. 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
- 3-47. 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
- 3-48. The incidence of bit errors will increase as the signal-to-noise ratio increases.
1. True
  2. False

- 3-49. 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
- 3-50. 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
- 3-51. 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
- 3-52. 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
- 3-53. 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
- 3-54. Link-4A is what type of tactical digital information link?
1. Ship-to-aircraft
  2. Ship-to-submarine
  3. Ship-to-shore
  4. Ship-to-ship
- 3-55. 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
- 3-56. 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

- 3-57. 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
- 3-58. 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
- 3-59. 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
- 3-60. 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
- 3-61. 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
- 3-62. 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
- 3-63. 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
- 3-64. 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
- 3-65. 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

- 3-66. The standard CDS control message is \_\_\_\_\_(a)\_\_\_\_\_ milliseconds in duration, while the reply message is \_\_\_\_\_(b)\_\_\_\_\_ milliseconds in duration.
1. (a) 2 (b) 14
  2. (a) 2 (b) 18
  3. (a) 14 (b) 14
  4. (a) 14 (b) 18
- 3-67. The CAINS receive cycle duration is equal to what total number of milliseconds?
1. 2
  2. 4
  3. 14
  4. 18
- 3-68. The transmit frame is divided into what total number of 200 usec time slots?
1. 13
  2. 56
  3. 70
  4. 200
- 3-69. What total number of time slots make up the sync preamble of each transmit frame?
1. 13
  2. 42
  3. 56
  4. 70
- 3-70. What total number of transmit frame time slots contain message data bits?
1. 8
  2. 13
  3. 56
  4. 70
- 3-71. 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
- 3-72. The reply message contains what total number of data time slots?
1. 13
  2. 42
  3. 56
  4. 70
- 3-73. 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
- 3-74. 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
- 3-75. 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

## ASSIGNMENT 4

Textbook Assignment: “New Technology in Data Communications,” chapter 5, pages 5-1 through 5-17;  
“Local-Area Networks,” chapter 6, pages 6-1 through 6-18.

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- 4-1. 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
- 4-2. 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
- 4-3. 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
- 4-4. The CP-2205(P)(V)/USQ-125 is capable of data encryption.
1. True
  2. False
- 4-5. 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
- 4-6. 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
- 4-7. 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
- 4-8. 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

4-9. 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

4-10. The normal configuration of the multi-frequency link options uses (a) HF frequencies and (b) UHF frequencies.

1. (a) 2 (b) 1
2. (a) 3 (b) 1
3. (a) 2 (b) 2
4. (a) 3 (b) 2

IN ANSWERING QUESTIONS 4-11 THROUGH 4-15, SELECT FROM THE FOLLOWING LIST THE SYSTEM TEST OPTIONS OF THE CP-2205(P)(V)/USQ-125 DATA TERMINAL SET DESCRIBED IN THE QUESTION. NOT ALL ITEMS IN THE LIST ARE USED.

- 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

4-11. This option is selected when a single station POFA is running without the radio.

1. A
2. B
3. C
4. D

4-12. 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

4-13. 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

4-14. 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

4-15. This option performs an internal self-test of the DTS audio circuits.

1. A
2. B
3. C
4. D

4-16. 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



- 4-17. 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
- 4-18. Each unit participating in a Link-16 net is identified by assigning it what type of designator?
1. A PU number
  2. A JU number
  3. A link identifier
  4. A hull number
- 4-19. What is the duration of each time slot in a Link-16 message?
1. 7.8125 msec
  2. 7.8125  $\mu$ sec
  3. 7.8125 seconds
  4. It varies, according to the amount of data transmitted
- 4-20. During the transmission of data, exactly how often does Link-16 change frequency?
1. Every 13  $\mu$ sec
  2. Every 13 msec
  3. Daily
  4. When the frequency is excessively noisy
- 4-21. 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
- 4-22. A Link-16 data word is comprised of what number of data bits?
1. 50
  2. 60
  3. 70
  4. 80
- 4-23. 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
- 4-24. Which of the following message types are used for Link-16 voice communications?
1. Fixed format
  2. Free text
  3. Variable format
  4. Unformatted
- 4-25. Which of the following message types are used to exchange tactical data?
1. Fixed format
  2. Free text
  3. Variable format
  4. Unformatted
- 4-26. 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

- 4-27. 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
- 4-28. 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
- 4-29. 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
- 4-30. 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
- 4-31. 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
- 4-32. 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
- 4-33. 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
- 4-34. 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
- 4-35. 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
- 4-36. 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

4-37. 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

4-38. Using the Link-16 Model-5 system, what component 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

IN ANSWERING QUESTIONS 4-39 THROUGH 4-42, SELECT FROM THE FOLLOWING LIST THE EQUIPMENT COMPONENT GROUPS OF THE JTIDS TERMINAL THAT PERFORMS THE FUNCTION OR OPERATION DESCRIBED IN THE QUESTION. NOT ALL ITEMS IN THE LIST ARE USED.

- A. Digital data processor group
- B. Receiver/transmitter group
- C. High power amplifier group
- D. Power interface unit
- E. Secure data unit

4-39. A removable assembly that stores cryptovariabiles.

1. B
2. C
3. D
4. E

4-40. Generates a 75 MHz intermediate frequency for internal communications.

1. A
2. B
3. C
4. D

4-41. Provides the interface with the antenna.

1. A
2. B
3. C
4. D

4-42. Performs digital-to-analog and analog-to-digital conversion of voice signals.

1. A
2. B
3. C
4. D

4-43. 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

4-44. Messages received by the C2P over the Link-11 net cannot be retransmitted over the Link-16 net.

1. True
2. False

4-45. 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

- 4-46. 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
- 4-47. 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
- 4-48. 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
- 4-49. 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
- 4-50. 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
- 4-51. 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
- 4-52. 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
- 4-53. 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
- 4-54. 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
- 4-55. 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

- 4-56. When designing and building a LAN system, all workstations must be from the same manufacturer.
1. True
  2. False
- 4-57. 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
- 4-58. 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
- 4-59. 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
- 4-60. 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
- 4-61. 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
- 4-62. 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
- 4-63. 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
- 4-64. 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
- 4-65. Which of the following is NOT a LAN topology?
1. Linear
  2. Ring
  3. Star
  4. EtherNet

4-66. 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

4-67. 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

4-68. 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

4-69. 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

4-70. 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

4-71. 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

IN ANSWERING QUESTIONS 4-72 THROUGH 4-74, SELECT FROM THE FOLLOWING LIST THE NETWORK OPERATING SYSTEM COMPONENT THAT PERFORMS THE FUNCTION DESCRIBED IN THE QUESTION. NOT ALL ITEMS IN THE LIST ARE USED.

- A. Control kernel
- B. Network interfaces
- C. File systems
- D. File extensions

4-72. Provides low-level subnet protocols and translation for bridging hardware drivers with the network operating system.

1. A.
2. B.
3. C.
4. D.

4-73. Controls data organization, storage, and retrieval on the various storage systems available to the network.

1. A.
2. B.
3. C.
4. D.

4-74. The main subsystem of the network operating software.

1. A.
2. B.
3. C.
4. D.

4-75. 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

