NONRESIDENT
TRAINING
COURSE

June 1993

Aviation Electronics Technician 1 (Organizational)

NAVEDTRA 14030

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

PREFACE

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

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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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."

CONTENTS

INSTRUCTIONS FOR TAKING THE COURSE

ASSIGNMENTS

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

SELECTING YOUR ANSWERS

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

SUBMITTING YOUR ASSIGNMENTS

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

Grading on the Internet: Advantages to Internet grading are:

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

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

http://courses.cnet.navy.mil

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

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

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

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

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

COMPLETION TIME

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

PASS/FAIL ASSIGNMENT PROCEDURES

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

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

COMPLETION CONFIRMATION

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

ERRATA

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

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

STUDENT FEEDBACK QUESTIONS

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

For subject matter questions:

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

For enrollment, shipping, grading, or completion letter questions:

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

If you are a member of the Naval Reserve, you will receive retirement points if you are authorized to receive them under current directives governing retirement of Naval Reserve personnel. For Naval Reserve retirement, this course is evaluated at 15 points. Points will be credited in units upon satisfactory completion of the assignments as follows:

12 points upon satisfactory completion of assignments 1 through 8.

3 points upon satisfactory completion of assignments 9 and 10.

(Refer to *Administrative Procedures for Naval Reservists on Inactive Duty*, BUPERSINST 1001.39, for more information about retirement points.)

COURSE OBJECTIVES

In completion this nonresident training course, you will demonstrate a knowledge of the subject matter by correctly answering questions on the following: communications, navigation, radar, antisubmarine warfare, indicators, infrared, weapons systems, computers, automatic carrier landing system, and the electrostatic discharge program.

Student Comments

Course Title: *Aviation Electronics Technician 1 (Organizational)*

NAVEDTRA: 14030 **Date**: ______________________

We need some information about you:

Rate/Rank and Name: ______________________ SSN: _____________ Command/Unit ___________________

Street Address: ___________________________ City: _____________ State/FPO: _________ Zip ________

Your comments, suggestions, etc.:

Privacy Act Statement: Under authority of Title 5, USC 301, information regarding your military status is requested in processing your comments and in preparing a reply. This information will not be divulged without written authorization to anyone other than those within DOD for official use in determining performance.

NETPDTC 1550/41 (Rev 4-00)

CHAPTER 1

COMMUNICATIONS

As an Aviation Electronics Technician, you will be tasked to operate and maintain many different types of airborne communications equipment. These systems may differ in some respects, but they are similar in many ways. As an example, there are various models of AM radios, yet they all serve the same function and operate on the same basic principles. It is beyond the scope of this manual to discuss each and every model of communication equipment used on naval aircraft; therefore, only representative systems will be discussed. Every effort has been made to use not only systems that are common to many of the different platforms, but also have not been used in the other training manuals. It is the intent of this manual to have systems from each and every type of aircraft in use today.

RADIO COMMUNICATIONS

Learning Objective: *Recognize the various types of radio communications. Identify the various frequency bands and their uses and limitations.*

In basic terms, communication is defined as the meaningful transfer of information from one location (the sender, source, originator) to another location (the destination or receiver). Electronic communication uses electrical energy to transmit the information to be communicated Since this electrical energy travels at the speed of light, the transfer can occur within a fraction of a second. The information must be converted from its original form of sound, light, or mechanical energy into electrical energy. This electrical energy can then be transmitted via wires or radiated through space to a receiver. The receiver must then convert the electrical energy back into its original form to complete the communication cycle.

TYPES OF RADIO COMMUNICATIONS

Radio communications has become a highly sophisticated field of electronics. All Navy aircraft have the capability to use the commonly used ship-to-ship, ship-to-air, air-to-air, air-to-ground, and ship-to-shore communication circuits. These operations are accomplished through the use of compatible and flexible communication systems.

Radio is the most important means of communicating in the Navy today. There are many methods of transmitting in use throughout the world. This manual will discuss three types. They are radiotelegraph, radiotelephone, and teletypewriter.

Radiotelegraph

Radiotelegraph is commonly called CW (continuous wave) telegraphy. Telegraphy is accomplished by opening and closing a switch to separate a continuously transmitted wave. The resulting “dots” and “dashes” are based on the Morse code. The major disadvantage of this type of communication is the relatively slow speed and the need for experienced operators at both ends.

Radiotelephone

Radiotelephone is one of the most useful military communication methods. It is used by aircraft, ships, and shore stations because of its directness, convenience, and ease of use. The equipment used for tactical purposes usually operate on frequencies that are high enough to have line-of-sight characteristics. This cuts down not only on the possibility of the enemy intercepting the messages, but also cuts down on the distance between the transmitter and receiver.

Teletypewriter

Teletypewriter (TTY) signals may be transmitted by either landlines (wire), cable, or radio. The Navy uses radio teletypewriter (RTTY) for high-speed automatic communications. The keyboard used with a TTY system is similar to that of a typewriter. When the operator strikes a key, a sequence of signals is transmitted. At the receiving station, the signals are translated back into letters, figures, and symbols that are typed onto paper for use.

Table 1-1.-Radio-Frequency Spectrum

FREQUENCY	DESCRIPTION
30 GHz – 300 GHz	Extremely high frequency (EHF)
3 GHz – 30 GHz	Super high frequency (SHF)
300 MHz – 3 GHz	Ultrahigh frequency (UHF)
30 MHz – 300 MHz	Very high frequency (VHF)
3 MHz – 30 MHz	High frequency (HF)
300 kHz – 3 MHz	Medium frequency (MF)
30 kHz – 300 kHz	Low frequency (LF)
3 kHz – 30 kHz	Very low frequency (VLF)
300 Hz – 3 kHz	Voice frequency
up to 300 Hz	Extremely low frequency (ELF)

NAVY FREQUENCY BAND USE

Table 1-1 shows the radio-frequency spectrum broken down into bands that are used by the military. Each band of frequencies has its own characteristics. Navy Electricity and Electronics Training Series, Module 17, *Radio-Frequency Communications Principles,* discusses all the bands. This chapter will only discuss the bands that are of interest to the Aviation Electronic Technician.

VLF and LF Band Communications

The very low frequency (VLF) and low frequency (LF) bands were originally used for radio telegraphy. Because the wavelengths were in the kilometer range and higher (30 kHz has a wavelength of 10 kilometers, or about 6.2 miles), enormous antennas had to been used. With today's technology, this is no longer a factor.

MF and HF Band Communications

The medium-frequency (MF) and high-frequency (HF) bands are not only used by the Navy, but portions are also used by commercial AM broadcasting stations. These spectrums also include the international distress frequencies (500 kHz, 2182 kHz, 8364 kHz, 3023.5 kHz and 5680 kHz).

Signal radiation in these frequency ranges have the important property of being reflected by the ionosphere. The ionosphere is a layer of electrically charged particles at the top of the earth's atmosphere. The layer is caused by the strong solar radiation entering the upper atmosphere. When a radio wave in the MF or HF range hits this layer, it is reflected back to earth. Multiple reflections between this layer and earth are are possible, allowing great distances to be obtained in these ranges, particularly the high-frequency band.

The disadvantage of this type of propagation is that it depends on the characteristics of the ionosphere, which varies widely, especially during daylight hours. As a result of this varying, the waves are reflected differently and take different paths over a period of time. This causes the signal at the receiver to vary in strength, which causes the output to fade in and out.

VHF and UHF Band Communications

Signal radiation in these frequency ranges get very little ionospheric reflection. As a result, communications in these ranges tend to be line-of-sight and over a short distance. Line-of-sight means exactly what the name says–the transmitter and receiver must be within a straight visual sighting line from each other. Buildings and uneven terrain may affect the transmission. The lower part of the UHF band and the VHF band is also used for mobile communications and television.

INTERCOMMUNICATION SYSTEM (ICS)

Learning Objective: *Recognize components and operating features of an intercommunication system used in naval aircraft.*

The intercommunication system that will be discussed in this section is the OK-248( )(V)/AI, Intercommunication-Communication Control Group (ICCG). This system is found on the S-3 aircraft.

The OK-248( )(V)/AI provides intercommunications for crew members and maintenance personnel. It also controls operation and signal interfacing for all radio sets, and controls operation and signal interfacing for aural monitoring of the navigation aids.

MAJOR COMPONENTS

The following is a discussion on the various components in the OK-248( )/AI system.

C-8760/AI Intercommunication-Communication Control Panel

The C-8760/AI (fig. 1-1) is commonly called the integrated radio control (IRC). The IRC panel performs the following functions:

- Controls HF radio modes and functions
- Controls UHF radio modes and functions
- Displays In-Flight Performance Monitor (IFPM) status of communication subsystems and components
- Initiates on-line operating configuration of communication systems

There are eight switches for the HF system function selections, along with a squelch knob. These switches are used to select the various modes of operation for the HF system on board. The squelch knob is turned clockwise to increase squelch and counterclockwise to decrease squelch.

The next section of switches (labeled UHF) on the IRC panel are used to control the UHF radios. There are twelve of these switches but only eleven are used. The switch labeled SPARE is not used.

The next section consists of a numerical keyboard, five switches, and three sets of indicators. The keyboard is where the operator inputs the desired channel and frequencies for the HF and UHF radios. The CLR button

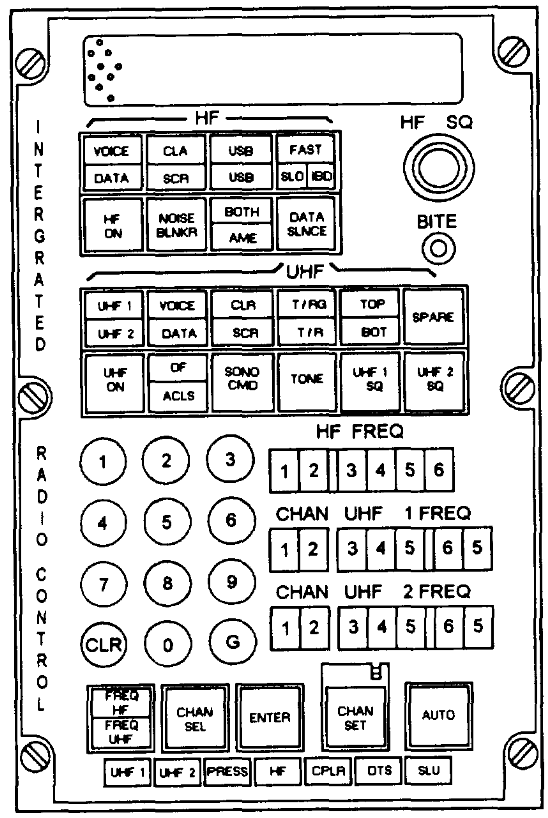


Figure 1-1.-C-8760/AI intercommunication-communication control panel.

is used to clear an error and start over with the selection. The G button is used to select a guard channel. The three indicator groups display the following:

- HF FREQ—displays the selected frequency for the HF radio set
- CHAN UHF 1 FREQ—displays the selected channel and frequency for the UHF 1 radio set
- CHAN UHF 2 FREQ—displays the selected channel and frequency for the UHF 2 radio set

The five switches are used to select what type of information the operator is inputting via the keyboard. After the operator inputs the channel or frequency, the ENTER switch must be pressed.

The last section of the panel contains seven fault indicator lights. These indicators are labeled UHF1, UHF2, PRESS, HF, CPLR, DTS, and SLU. Each one is the fault indicator for the system or component for which it is labeled. It will illuminate when a fault occurs in its corresponding system or component.

Located directly under the HF squelch knob is a BITE indicator. This indicator will illuminate when a fault is detected in the IRC.

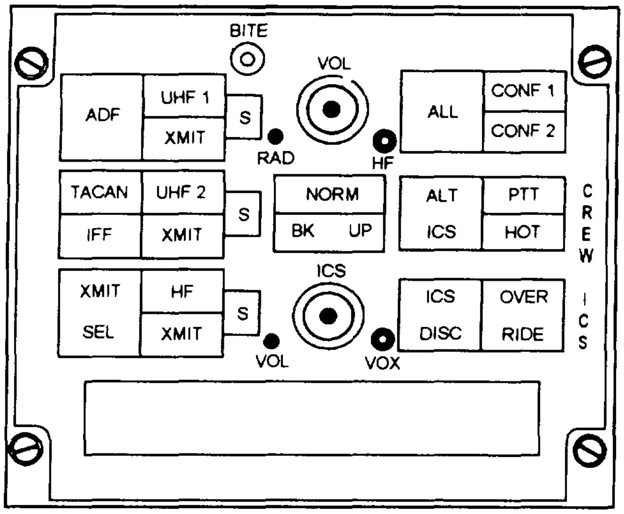


Figure 1-2.-LS-601/AI crew control panel.

LS-601/AI Crew Intercommunication System (ICS) Panel

Each of the crew members has a LS-601/AI ICS panel (fig. 1-2). These ICS panels enable the crew members to do the following:

- Select six ICS modes
- Select three radios to monitor
- Select navigation aids and IFF to monitor
- Select either hot microphone or push-to-talk keyline operation
- Control the volume for ICS, radios, navigational aids, and the IFF aural functions

Control signals from the crew's ICS control panels consist of multiplexed binary words in the Manchester format and hard wired ground and analog voltages.

The crew's control panel has 14 switchlights that are self-explanatory. The two volume knobs are dual-purpose knobs. Each one controls two volumes, depending whether you turn the inner or outer knob. The BITE indicator will illuminate when a fault is detected in the control panel.

Each panel is identical, and they can be swapped between stations. There are differences in operation, depending on the station. The SENSO station cannot transmit so the XMIT SEL switchlight is disabled at that station. The ALT ICS switchlight will place the pilot and copilot's headsets and microphones in parallel. The SENSO and TACCOs will similarly be tied together as a pair. The NORM BK UP switchlight only operates at

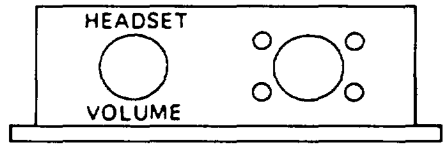


Figure 1-3.-LS-602/AI control panel.

the pilot and copilot's stations. The pilot will connect directly to the UHF-1 radio, and the copilot will connect directly to the HF system.

LS-602/AI Control Panel

There are three LS-602/AI panels (fig. 1-3) located in the aircraft. These panels are for maintenance/ground handling functions. They provide the communication between the outside of the aircraft and the crew stations. The only control located on this panel is a volume knob, which adjusts the volume in the headset for each individual panel.

CV-3048( )/AI Converter-Interconnecting Box

The CV-3048( )/AI is the switching logic unit (SLU) for the intercommunication system. The SLU is the signal interface unit for the communication system. Its functions are as follows:

- Voice signal conditioning
- Receive/transmit mode control
- Antenna configuration control
- Signal switching between components
- Binary control signal coding and decoding
- Component mode forcing

FUNCTIONAL DESCRIPTION

This intercommunication system uses various computer-formatted signals in its operation. As a senior technician, you will be required to understand the various types of languages used by this system.

Intercommunication-Communication Control Group (ICCG) Signal Interface

The ICCG signal interface consists of a discrete hardwired signal interface and a multiplexed binary word signal interface. Each will be discussed in the following text.

BINARY-CODED WORD INTERFACE.— The control signals in the ICCG interface are primarily in a binary-coded word format. The binary words are shifted into and out of the crew ICS panels, the IRC panel, and the SLU on pairs of multiplex lines. The crew ICS panels and the IRC have unique binary word addresses that are identified by a roll call sequence performed in the SLU. Every 25 milliseconds, each crew panel and the IRC are interrogated for a change-of-status by the SLU. This change-of-status data is stored in the SLU until it is transferred to the general-purpose digital computer (GPDC) for permanent storage. The GPDC will be discussed in a later chapter of this TRAMAN. The change-of-status data is then processed by the SLU to produce mode forcing signals that are sent to the appropriate peripheral and ICCG components.

HARD-WIRE SIGNAL INTERFACE.— The volume control signals and backup mode control and status signals are interfaced by separate lines between the components. These signals are analog voltages and ground circuits. These signals produce changes in the components as the controls are adjusted or pressed without being processed first.

ICCG Indicators

Most of the indicators in the ICCG are either mode or function status indicators that come on amber and green. When the indicator comes on green, it means that the corresponding function is available for selection. When that function is selected, the indicator will turn to amber. With the indicator off, that function is not available for selection.

On the IRC, the IFPM indicators will illuminate when a fault is detected in the corresponding component. The S indicators on the crew panels will illuminate red when the secure mode of operation is selected for that particular radio system. The indicators in the frequency selection section of the IRC come on red when frequency selection is available.

Encoded and Decoded Word Format

All the components in the ICCG, except for the three LS-602/AI panels, have identical binary encoding and decoding circuits. The encoding circuits transform a signal function into a binary word in the Manchester format for transmission to another component. The decoding circuits transform the Manchester signal functions from another component into basic signal functions for application to processing and control circuits within that component.

Each of the components in the ICCG, except the LS-602/AI, have a unique binary word address. The component responds to an interrogation by the SLU only when its specific address is recognized. The addresses are incorporated into the 36-bit ICCG word format. Each bit is a status or control function, or a part of the 5-bit component address that has a permanently assigned slot in the 36-bit format.

The 36-bit words are serially generated and serially transmitted binary bit words. Each bit is either a 1 or a 0. A logic 1 corresponds to a voltage level between 5.0 and 8.5 volts dc. A logic 0 corresponds to a voltage level between -0.5 and –1.5 volts dc.

ENCODED WORD FORMAT.— Encoded word format is setup for 36-bits that are either status/control function information or component addresses. Bit 1 is the control bit and is always a 1.

Bits 2 through 6 are the address bits. Each component has its own unique binary configuration. One example of this is that the SLU recognizes the binary number 01010 as the pilot crew ICS panel. Should this configuration show up in bits 2 through 6, then the SLU will process on the command data from the pilot ICS panel during the 36-bit word cycle. Each component address word is designated by the decimal equivalent to its binary value. With the above example, the pilot ICS panel address 01010 is equal to decimal 10. Therefore, the pilot ICS panel designation is word 10.

Bit 7 is the tag bit needed for binary word housekeeping. It is always 0 for encoded words.

Bit 8 is the enter bit for binary housekeeping. In the encoded words it is always 1.

Bits 9 through 34 are the command functions, status, or spare bits. Bit 35 is a command function, status, spare, or set-zero housekeeping bit.

Bit 36 is the parity bit used for self-check in the binary circuitry. This system uses the odd parity check. If there are an even number of 1's in the first 35 bits, bit 36 will be a 1. If the total number of 1's in the first 35 bits is odd, bit 36 will be a 0. When a component receives the 36-bit encoded word, its decoder checks the parity by counting the 1's. If it comes up with an even number of 1's, the word is not processed and a BITE indicator is illuminated on the component that transmitted the faulty data word.

DECODED WORD FORMAT.— The decoded word format is similar to the encoded word format with just a few differences. Bit 1, bits 9 through 34, bit 35 and bit 36 are the same as in the encoded word. Bits 2

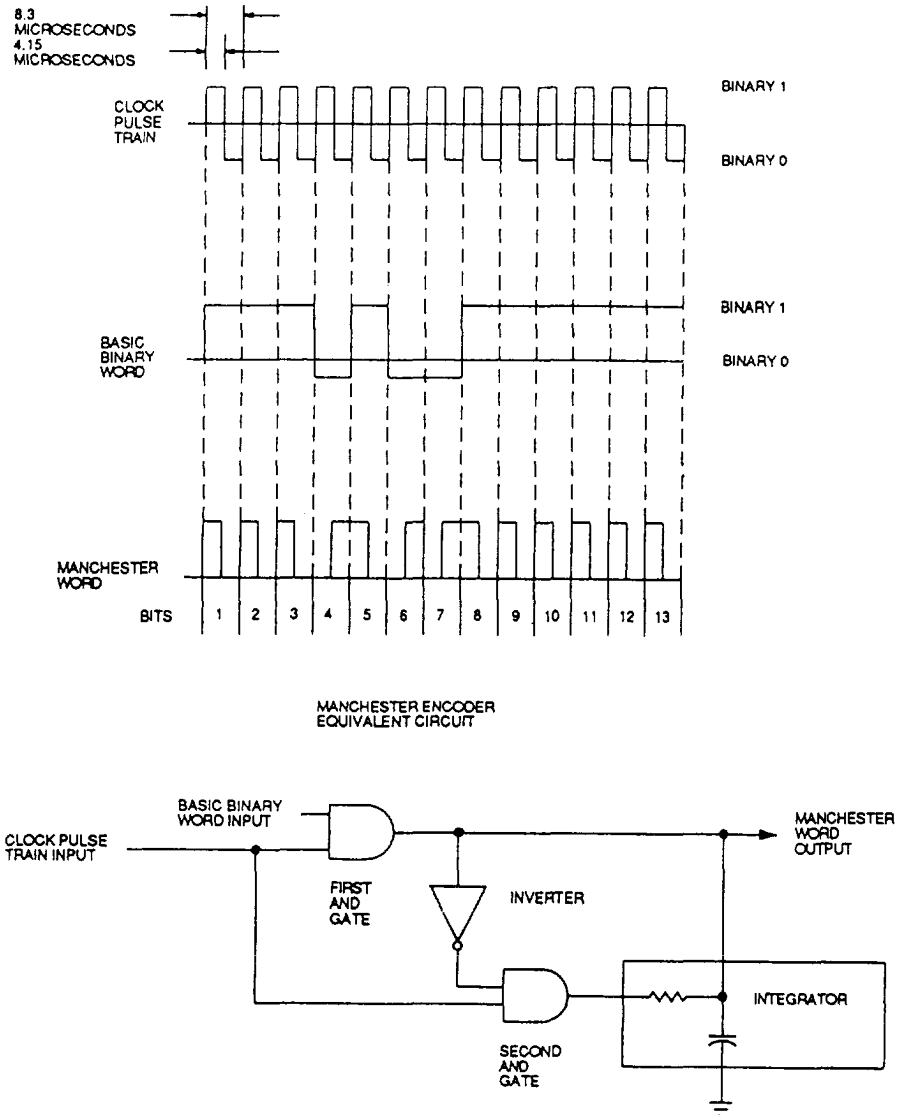


Figure 1-4.-Manchester encoding.

through 6 are the decoded address bit, but it is not the same configuration as the encoded word. Bit 7 is the tag bit and is always 1 in the decoded word. Bit 8 is the enter bit and is always 0 for the decoded words.

The ICCG components process binary command and status words that cause changes in operation and display configuration. Word exchanges between components are done by binary word data encoded in Manchester format.

Manchester Word Encoding

The Manchester word format is a modification of the 36-bit encoded word generated in the components. This is done for transmission of the information from one component to another. The modification is accomplished by combining the basic 36-bit word with a master clock pulse train. The clock pulse rate is 120 kHz, and the pulse width is 8.3 microseconds.

Figure 1-4 shows a Manchester encoder equivalent circuit and its input and output signals. When both inputs to the first AND gate are 1, the Manchester word bit is also 1 for the 4.15-microsecond duration of the positive clock pulse. The resulting Manchester pulse occurs during the first half of the bit period. The output pulse of the first AND gate is applied to both the inverter input and the Manchester word output. The inverter produces a 0 output to keep the output of the second AND gate at 0, while a Manchester pulse is being produced. Since the clock pulse is negative during the second half of the bit period, the output of the second AND gate remains at 0.

When the basic binary word bit at the first AND gate is 0 and the clock pulse is 1, the output of the first AND gate is 0. This causes the output of the inverter to be 1.

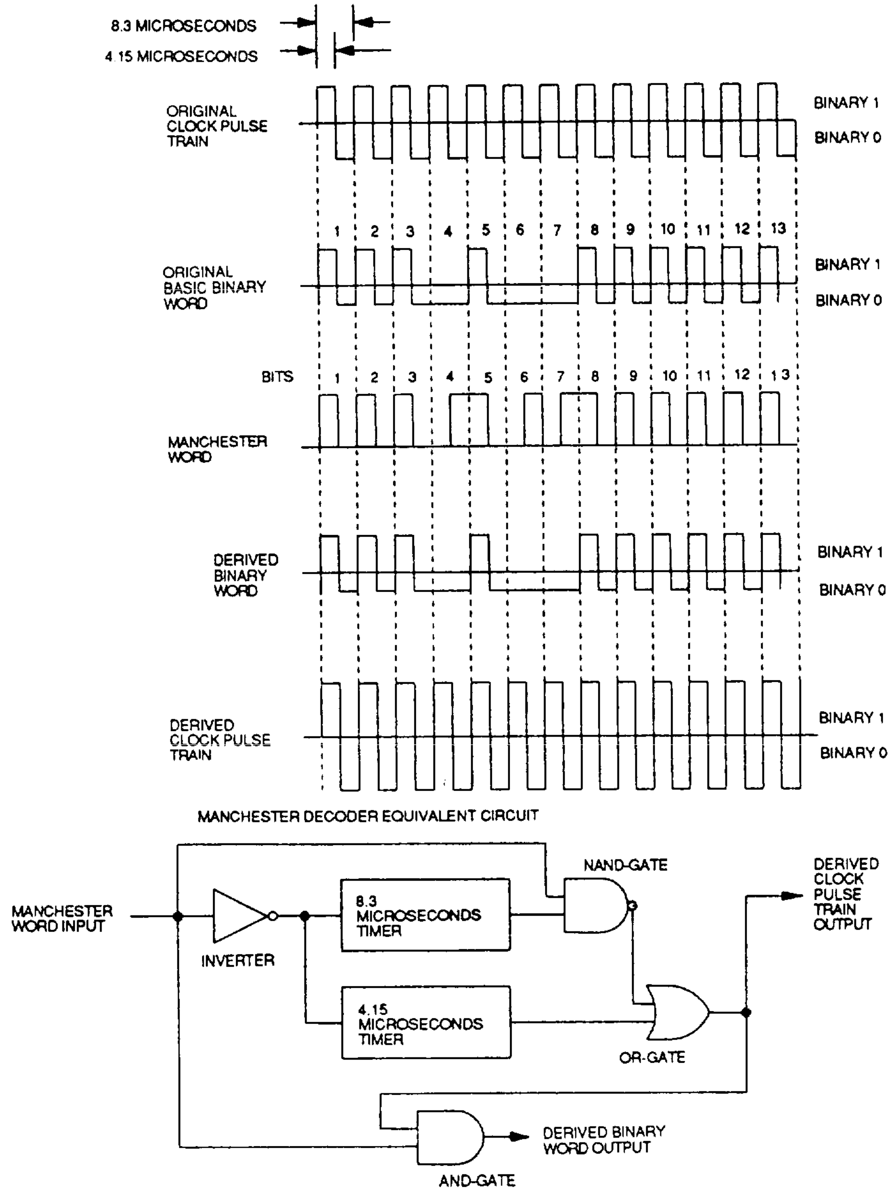


Figure 1-5.-Manchester decoding.

Because this makes both inputs to the second AND gate to be 1's, the output of the second AND gate will be 1. This 1 will cause the integrator to charge, producing a Manchester word bit of 1 during the second half of the clock pulse. This type of bit is generated for timing purposes only.

Manchester Word Decoding

When component receives a Manchester word, the digital control circuits must decode the word into the basic binary word and the clock pulse train. This process is required prior to any further processing of the signal by the component. A Manchester decoder equivalent circuit and its input and output signals are shown in figure 1-5.

The first input bit of the Manchester is always a 1. This produces a 0 at the output of the inverter and the inputs of the two timers. The same Manchester input bit is applied to one input of the NAND gate. The 0 output of the 8.3 timer is applied to the other input of the NAND gate, giving an output of 1 from the NAND gate. This 1 is applied to the OR gate, making its output a 1. The 1 from the OR gate represents the first derived clock pulse bit. This 1 is also applied to one of the inputs of the AND gate. The other input is the original 1 from the Manchester word. With both inputs to the AND gate being 1, the output will be a 1. This 1 represents the first bit of the derived basic data bit.

When the Manchester bit goes to 0, the inverter output goes to 1 and starts the two timers. If the next Manchester bit is 1, the two timers are restarted before they can complete a full cycle. The decoding process is repeated, causing another derived clock pulse bit and another derive basic binary word bit to be generated.

When a Manchester bit is a binary 0, it cannot reset the timers through the inverter. The 4.15-microsecond timer times out and produces a binary 1 at one input of the OR gate. The OR gate output is a binary 1 that represents the next derived clock pulse. Since there is a binary 1 at one input and a binary 0 at the other input of the AND gate, the resulting output is a binary 0 that represents the next derived data bit. The 8.3-microsecond timer is still running because a binary 1 has not been produced in the Manchester word. The 8.3-microsecond timer times out and produces a 1 on one input of the NAND gate. The other input is a 0, which produces a 1 at the output. This 1 produces a 1 at the output of the OR gate, which represents a 1 for the derived clock pulse.

Multiplex Transmission

Multiplex transmission data consists of 32 roll call words with a period of 800 microseconds for each word. The total period of time required for all the words is 25.6 milliseconds. Therefore, any one of the specific roll call periods occurs every 25.6 milliseconds. A roll call word consists of an inhale word and an exhale word, each being 400 microseconds long. Each inhale and exhale word consists of 48 clock intervals of 8.3 microseconds each. These clock intervals correspond to data bits. Of the 48 bits, 6 bits precede the 36-bit Manchester word and 6 bits follow the word. This means that there are 12 bits between the inhale word and the exhale word, which totals 79.6 microseconds. This period of time allows the component to prepare itself to receive or transmit data.

The SLU controls the ICCG. The roll call for the communication systems is generated there. Between the SLU and the other components of the ICCG, the exhale word is a status word Between the GPDC and the SLU, the exhale word is also a status word. The inhale word between the SLU and the other components of the ICCG is a command word that tells the SLU to change configuration or frequency.

The status is the configuration that the communication systems are in at any specific instant, and is indicated by the color of the switchlight (amber, green, red, or dark). A configuration change occurs whenever a switchlight is depressed. For example, changing HF USB to HF LSB is a configuration change.

Each component in the ICCG has a digital control section that controls all data entering or leaving the component. The IRC and the SLU are the only components that respond to more than one roll call address. In contrast, the crew ICS panel only has to respond to one roll call address. Because of this, the crew ICS panels use comparators instead of input register decoders. The address logic is hardwired into the aircraft cable connectors for each crew ICS panel. This allows only one address to compare true at each station, which makes the crew ICS panels interchangeable.

Roll Call

The ICCG logic flow and roll call sequence are described in the following text.

ROLL CALL 0.– Roll call 0 is a spare on both the inhale and exhale words. When the 800 microseconds have elapsed, the roll call generator produces roll call 1.

ROLL CALL 1.– The first part of roll call 1 is exhaled from the SLU. Roll call 1 informs the GPDC that a change in configuration or status has occurred since the last roll call 1. The GPDC buffer and/or multiplex lines (port 2) receives the exhale word from the SLU. There are three components of the ICCG hooked up to port 2. The IRC is the only ICCG component that recognizes roll call 1, and it processes the roll call through the digital control section, line receiver, and inhale word register. In the inhale word register, the Manchester word is decoded into the clock pulses and the data word. The roll call is matched against the address, and the decision is made whether or not to proceed with the processing. The other two components are processing the roll call 1 at the same time, but because the address will not match, only the IRC will continue processing.

In the IRC, the derived data is sent to the input register under the control of the derived clock pulses. Word validation begins at this time. As part of the word validation process, the tag bit is examined. The tag bit of roll call 1 is a binary 1 that identifies the word as a status word from the SLU. A tag bit identification word in the IRC is sent to the inhale/exhale word gate. At the same time, the roll call 1 is sent to the exhale word inhibit gate that starts a 500-microsecond timer. When the timer times out, the exhale AND gate is enabled and the data word is shifted into the exhale word assembly register.

The second part of roll call 1 is generated in the IRC. The data originates in the exhale word generator, and it represents the HF configuration. The configuration of the data bits in the exhale word register is shown in table 1-2. Data bits 15 and 16 are USB and LSB. When the USB/LSB switchlight is depressed to change from USB to LSB, a pulse is generated that sets the bit 16 one-shot circuit. As long as the switchlight is depressed, the

Table 1-2.-Exhale Word Register Configuration

BIT NUMBER	BIT NOMEMCLATURE	BIT CONFIGURATION	
1	Control bit	1	
2	Address bit	1	
3	Address bit	0	
4	Address bit	0	
5	Address bit	0	
6	Address bit	0	
7	Tag bit	0	
8	Enter bit	1	
		FUNCTION SELECTED	**FUNCTION NOT SEL.**
9	Auto	0	1
10	HF on	1	0
11	Voice	1	0
12	Data	1	0
13	Clear	1	0
14	Secure	1	0
15	USB (Upper Sideband)	1	0
16	LSB (Lower Sideband)	1	0
17	Both	1	0
18	AME	1	0
19	Noise blanker	1	0
20	Fast	1	0
21	Slow	1	0
22	IBD (In-Band Diversity)	1	0
23	Data silence	1	0
24	Spare	1 or 0	
		POSITION **0 1 2 3 4 5 6 7**	
25	HF squelch	0 1 0 1 0 1 0 1	
26	HF squelch	0 0 1 1 0 0 1 1	
27	HF squelch	0 0 0 0 1 1 1 1	
		BIT CONFIGURATION	
28	Spare	1 or 0	
29	Spare	1 or 0	
30	Spare	1 or 0	
31	Spare	1 or 0	
32	Spare	1 or 0	
33	Spare	1 or 0	
34	Spare	1 or 0	
35	Set zero	0	
36	Parity	1 or 0	

one-shot circuit output is directly applied to the lamp drivers. The lamp drivers cause the LSB lamp to come on amber and the USB lamp to come on green. Once the switchlight is released, an enter pulse is inserted into the word storage of the exhale word generator. If the IRC is in the manual mode, this enter pulse will cause the parallel transfer of the data bits from the one-shot circuits to the word storage register. When the switchlight is released, parallel data from the one-shot data is inhibited from the lamp drivers. The indicators change to the color configuration represented in the status configuration memory. The lamps go off momentarily because of the 25-millisecond cycle time of the roll call sequence required for updating the status registers. The parallel data goes from the word storage register to the parallel-to-serial word converter, and then, under control of the clock and roll call control, to the exhale word inhibit AND gate. From here it is transferred to the exhale word assembly register, where the roll call address and tag bit are added. A parity bit is also added if the first 35 bits are even. The clock pulse and data are combined and then shifted out on the multiplex line.

The second part of the roll call 1 data is now in Manchester format and is applied to the other components on port 2. Only the SLU recognizes roll call 1 in its digital control section. Roll call 1 is an exhale word with respect to the IRC, but it is an inhale word in respect to the SLU.

The inhale word enters the SLU through the line receiver and is transferred to the inhale word register. Here the data and the clock pulses are separated, and the data is shifted to the input register under the control of the derived clock pulses. This is the only function of the derived clock pulses. Once the data is shifted to the input register, the master clock is used to shift the data from one buffer to another.

The roll call word is shifted into the valid word register. This register validates the word by ensuring that there are 36 bits, the address is 5 bits long, the address has a control list and a tag bit, and the word parity is odd. If any of these conditions are not met, the word is sent to the not-valid register. If the input word is invalid three times, the status register sets the BITE indicator on the component that sent the word. If the word is valid, a valid word signal is generated, and the enter bit of the derived data is examined. If the enter bit is not a binary one, no further processing is done. The SLU only processes data if a change is present on the inhale word. If a change is present, the enter bit is a binary one.

If the inhale word is valid and it has an enter bit, it is sent to the HF configuration buffer. Here it is loaded into the multiplex register by the clock pulses and unique strobe G24. The multiplex input register shifts the data to the word decoder, where it is converted from serial binary format to parallel binary format. This parallel data is used to make the configuration change. The data is also converted back to serial binary format and stored for use in the exhale word assembly register for the next roll call 1.

ROLL CALL 2.– After the second part of roll call 1 is processed by the SLU, the first part of roll call 2 is processed. Roll call 2 originates during word storage in the HF conjuration buffer of the SLU. The exhale word is sent from the SLU on the common multiplex line. Each component on the common multiplex line compares the address of roll call 2 with its own address. Only the IRC recognims roll call 2.

The IRC processes the word in its digital control section the same way as the SLU did. The derived data is then sent to the input register where it is validated. The input register senses that the tag bit is a binary one. The binary one starts a 300-microsecond selective strobe counter and a 500-microsecond exhale word counter.

The valid roll call 2 word is sent to all the display registers in the IRC, but because of the address, only the HF configuration status display register will receive clock pulses. The clock pulses will shift the roll call word into the inhale word decoder and storage register. Here it will wait until the selective strobe pulse transfers the parallel word to the lamp drivers. The selective strobe pulse is sent when the 300-microsecond counter times out, signaling the end of the inhale word time. The lamp drivers turn on the lamps by applying aground to the low side of the lamps. The high side of the lamps is supplied by the lamp dimmer control circuit.

When the 500-microsecond timer times out, the IRC exhale word is applied to the multiplex lines. This word is the SLU inhale word, and it is processed exactly like the inhale word for roll call 1. The SLU will ensure that the enter bit is a binary one, and if so, will check the frequency to see if it is a legal frequency. If the frequency is legal, the word is processed and sent to the HF radio set in binary-coded-decimal (BCD) format. If the word is an illegal frequency, the frequency that is set upon the thumbwheel switches (on the SLU face) is sent to the HF set in BCD format. The operating frequency status word, which is the next word to be exhaled by the SLU, will equal the frequency that was sent to the HF radio set. If the frequency selected on the IRC is legal, it will be used; if not, the frequency indicated by the SLU is used

ROLL CALL 3.– The first part of roll call 3 is the SLU exhale word 3. This consists of the HF frequency status data. The word is built in the same manner as the first two words. This word is then inhaled by the IRC and processed and displayed. The IRC then exhales a roll call 3 word in the same manner as the first two, and the cycle continues. The only exception is the UHF status words. The status display is shared by both UHF radio sets, but only the UHF set that is on-line will be displayed.

ROLL CALL 4 THROUGH 12.– The digital control and input register sections of the SLU process the inhale and exhale words, making the same decisions as they did on the first three words. The buffers react differently, depending on the current word or situation.

Another difference during UHF configuration changes occurs in the channel set/channel select and frequency buffers. If the UHF frequency word has bits 32 and 33 at binary zero, the word is sent directly to the UHF frequency buffer. There is a separate buffer for each of the radio sets. When the word arrives at the buffer, it is checked for validity. If the frequency is illegal, the frequency command sent to the UHF set is a fixed-logic 300-MHz word that comes from the random access memory (RAM) in the SLU. In either case, the frequency is sent out in BCD format from the SLU to the radio set. The status is sent to the IRC in the same manner as for the HF status.

If the channel set bit (bit 32) is a binary one, the frequency and channel number is sent to the RAM for storage. There is storage for 22 channels and frequencies in the RAM. Each UHF radio set has its own RAM. The channel set data remains stored in the RAM until called by bit 33. When bit 33 is a binary one, the channel number attached to the word addresses the frequency associated with that channel in the RAM. If the channel and frequency have been previously stored in the RAM, the frequency code is sent to the UHF frequency buffer for processing. If they have not been set, the 300-MHz frequency code is sent to the UHF frequency buffer for processing.

The IRC/SLU roll call exchange ends with the first part of roll call 8. The SLU/crew ICS panels roll call exchange includes the last part of roll call 8 through the first part of roll call 12. Roll call 8 is recognized by the IRC and the copilot's crew ICS panel. For the IRC, it is a status word as established by the tag bit. The copilot crew ICS panel also recognizes the word and prepares to send an exhale word to the SLU. Further processing of the inhale word is inhibited by a transmit reset signal.

A crew ICS panel responds to a single word; therefore, the digital control section can be greatly simplified. Instead of an inhale word register, it has inhale word logic. The address coming in is compared with the fixed identification logic. If the word is recognized, the inhale word logic is stored for 800 microseconds, and the transmit detector is set. At the end of 500 microseconds, the exhale word assemble register is enabled

The exhale generator functions the same as the exhale word generators in the IRC. The exhale word generator shifts the data under clock control to the exhale word assembly register, where the housekeeping bits are added. When the word is clocked out of the parity circuit, the reset-transmit detectors set. Resetting the transmit detector enables the inhale word logic. The data word arriving at the SLU from the crew ICS panel is processed and sent to the ICS buffer. The ICS buffer processes the word and places the microphone and headset in a selected configuration. The bit change counter for TACAN, IFF, XMIT SEL, CONF 1, and CONF 2 switchlight selection is located in the ICS buffer. This counter counts the times that the bit associated with the function changes from binary one to binary zero. The times the counter changes determines which function has been selected by a multiple function selector switch.

The status word from the SLU to the crew ICS panel is constructed and transmitted the same way as all other words. When the first part of roll call 9 is on the multiplex line, it is recognized by the TACCO crew ICS panel, but it is also present in the copilot crew ICS panel. It is there because the word logic is still held open by the address detector, which recognized roll call 8. Only the TACCO crew ICS panel will process the data.

Processing of the roll calls continues in this fashion until the roll call rolls back to zero. At this point it starts all over again.

VHF COMMUNICATIONS

Learning Objective: *Recognize components and operating principles of a VHF radio system.*

The AN/ARC-197 VHF communication system provides an aircraft with two-way, plain voice radio communications in the very high-frequency range. Its actual frequency range is from 116.000 to 151.975 MHz.

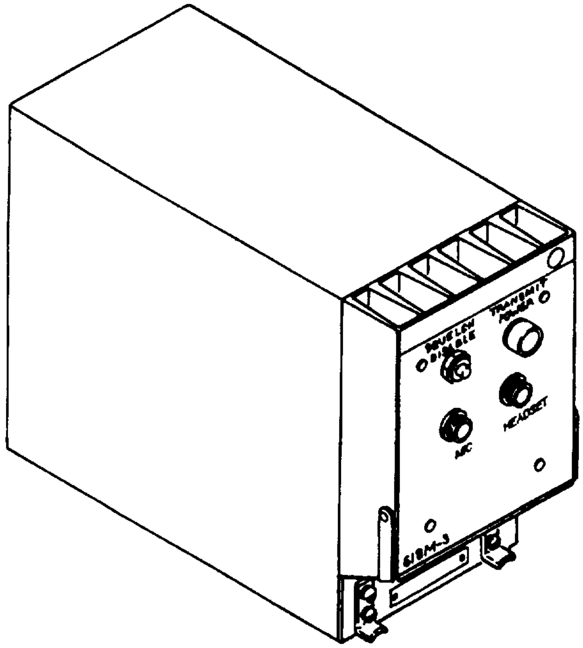


Figure 1-6-RT-1397/ARC-197 transceiver.

In the P-3C aircraft, this system interfaces with four of the intercommunication stations in the transmit/receive functions. The pilot, copilot, TACCO, and NAV/COMM stations can transmit and receive over this radio. The other stations in the aircrafl have receive function only.

MAJOR COMPONENTS

There are three components to the AN/ARC-197 system. These components are the RT-1397/ARC-197 transceiver, the C-11067/ARC-197 VHF-AM control panel, and the 949880 VHF antenna.

RT-1397/ARC-197 Transceiver

The RT-1397/ARC-197 transceiver (fig. 1-6) is a solid-state unit, consisting of a power supply, frequency synthesizer, receiver modulator, and transmitter. There is one indicator, one push button, one microphone jack, and one headphone jack on the unit. The indicator is labeled TRANSMIT POWER, which illuminates when output power is greater than 10 watts. The push button is labeled SQUELCH DISABLE, which will disable the squelch for low signal levels. The microphone and headphone jacks are used for maintenance and emergency VHF communication in case of ICS failure in-flight.

C-11067/ARC-197 VHF-AM Control Box

The control box (fig. 1-7) controls the operation of the system. There are two dual function knobs and a display window on the control panel. The display window shows the selected frequency of the system.

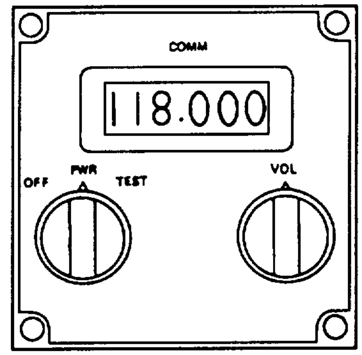


Figure 1-7.-VHF-AM control box.

The outer ring of the dual function knob on the left applies system power and selects the test function. The inner knob changes the frequency of operation in 1-MHz steps over the range of control. The outer ring of the dual function switch on the right is labeled VOL, and it is not used in the P-3 aircraft. Volume is controlled by the ICS system. The inner knob of this control is used to change the frequency of operation in 25-kHz steps over the range of control.

949880 VHF Antenna

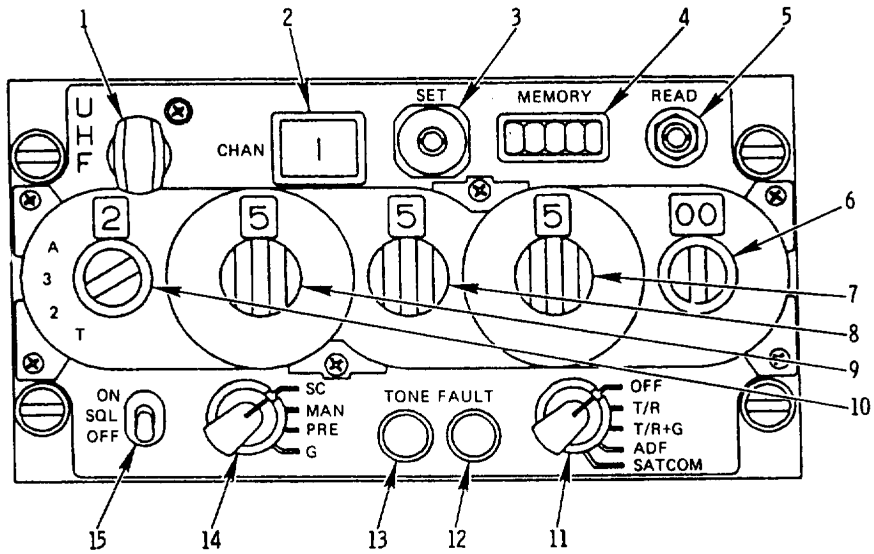
The 949880 antenna is located in the tailcap on top of the vertical stabilizer of the P-3 aircraft. This antenna radiates and receives the VHF radio frequency signals. Signals routed to and from the antenna go through a VHF bandpass filter, which reduces the crosstalk between the VHF and UHF systems.

VHF FUNCTIONAL DESCRIPTION

There are two modes of operation with the AN/ARC- 197 radio. These two modes are receive and transmit.

Receive Mode

In the receive mode, the received RF signals from the antenna are routed through the filter, and applied to the receiver circuits in the transceiver. The frequency selected on the control box is applied to the frequency synthesizer. The synthesizer uses a single phase-locked loop to generate RF injection frequencies, in 25-kHz steps, from 116.000 to 155.975 MHz. The RF injection frequencies, along with dc tuning voltages, electronically tune the receiver to the selected frequency. The AM detected audio is applied to the audio amplifier circuit. Squelch circuits disable the output amplifier if the required signal-to-noise ratio or carrier level is not present. The output audio is then applied to the ICS interconnection box for distribution to the various stations.



1. Preset channel selector switch
2. CHAN indicator
3. Set switch
4. MEMORY read display
5. Memory READ switch
6. Manual frequency selector switch
7. Manual frequency selector switch
8. Manual frequency selector switch
9. Manual frequency selector switch
10. Manual frequency selector switch
11. Function selector switch
12. FAULT status indicator
13. TONE switch
14. SONOBUOY COMMAND/MANUAL/PRESET/ GUARD
15. SQUELCH ON-OFF switch

Figure 1-8.-C-11950/ARC-187 control box.

Transmit Mode

In the transmit mode, the VHF XMTR control signal from any one of the four ICS master control panels applies a ground to the transceiver as the VHF key signal. This VHF key signal provides the push-to-talk command to the transceiver to switch it from the receive to the transmit mode of operation. The synthesizer generates transmitter drive frequencies from 116.000 to 155.975 MHz in 25 kHz steps. Audio from any of the four ICS master control boxes are applied to the modulator circuit. The modulator circuit provides 90-percent amplitude modulation. The compressor and limiter circuits are included to prevent over-modulation. The transmitter uses five stages of amplifiers to raise the output to 20 watts. The RF output is routed to the antenna, through the filter, for radiation. The transceiver also produces a sidetone output, which is provided to the ICS system in the same manner as the receiver audio.

UHF COMMUNICATIONS

Learning Objective: *Recognize components and operating principles of the UHF radio system.*

The AN/ARC-187 UHF radio system consists of the UHF-1 radio set, UHF-2 radio set, and the interfacing equipment. The UHF communication system provides amplitude modulation, frequency modulation, and frequency shift key (FSK) operations. The frequency range of this radio system is 225.000 to 399.975 MHz.

MAJOR COMPONENTS

Each radio set in the system consists of an RT-1571/ARC-187 receiver transmitter, a C-11950(V)3/ ARC-187 radio control, an AT-879/ARC antenna, and a 740645 antenna switching relay. The UHF-2 radio set also contains a 974924 antenna select panel. The antenna and the antenna switching relay will not be discussed in detail in this manual.

RT-1571/ARC-187 Receiver Transmitter

The RT-1571/ARC-187 receiver transmitter contains all the circuitry for the normal operation of the UHF radio set.

C-11950/ARC-187 Radio Control Box

The C-11950/ARC-187 control box (fig. 1-8) provides all the controls for normal operation of the radio set. We will be discussing each of the controls and indicators in the following text. Each number corresponds to a pointer in figure 1-8.

1. Preset channel selector switch–Selects anyone of 20 preset channels.

2. CHAN indicator–Indicates channel selected by the preset channel selector.

3. SET switch–Sets anyone of the available 7000 normal mode frequencies.

4. MEMORY read display–Displays the frequency that has been selected by preset channel selector.

5. Memory READ switch–Allows selected frequency to be displayed.

6. Manual frequency selector switch–Selects hundredth and thousandth's digit of the desired manual frequency in steps of 25 (00, 25, 50, or 75).

7. Manual frequency selector switch–Selects the tenth's digit of desired manual frequency (0 through 9).

8. Manual frequency selector switch–Selects unit's digit of the desired manual frequency (0 through 9).

9. Manual frequency selector switch–Selects ten's digit of the desired manual frequency (0 through 9).

10. Manual frequency selector switch–Selects hundred's digit of the desired manual frequency (either 2 or 3). In the A position, the radio set in an anti-jamming mode. In the T position, the radio set is enabled for transmission and reception for one minute.

11. Function selector switch–Selects operating modes.

   a. OFF–Shuts down the radio set.

   b. T/R–Enables main receiver and transmitter.

   c. T/R+G–Enables main receiver, transmitter, and guard receiver.

   d. ADF–Sets the receiver transmitter to the AM mode for automatic direction finding operations.

   e. SATCOM–Allows Satellite Communications by setting the receiver transmitter to the SATCOM mode.

12. FAULT status indicator–Steady illumination indicates an RT fault, a slow flash (1/sec) indicates an interface fault, and a fast flash (4/sec) indicates a control box fault.

13. TONE switch–Enables transmission of an audible tone on the selected frequency.

14. SONOBUOY COMMAND/MANUAL/PRESET/GUARD–This switch selects the mode of frequency selection.

   a. SONOBUOY COMMAND–This position causes the radio set control to deliver a serial data stream corresponding to a preset frequency in the controls memory.

   b. MANUAL–In this position the frequency is manually selected using the five manual frequency selector switches.

   c. PRESET–The frequency is selected using the preset channel selector switch. This position is also used for programming the 20 preset channels.

   d. GUARD–This automatically tunes the main receiver and transmitter to the guard frequency and disables the guard receiver.

15. SQUELCH ON-OFF switch–Enables and disables the squelch circuits of the main receiver.

UHF-2 Antenna Select Panel

The UHF-2 antenna select panel (fig. 1-9) selects which antenna the UHF-2 radio set will use during operation. There is one two-position switchlight on this panel. The switchlight is marked UP ANT and LOW ANT. When the upper tailcap antenna is selected, the UP ANT portion of the switchlight will be illuminated amber. When the lower antenna is selected, the LOW ANT portion will be amber.

UHF MODES OF OPERATION

Figure 1-10 shows a simplified block diagram of the UHF system.

The UHF-1 radio set provides the following modes of operation: plain voice, cipher voice, ADF navigation, plain voice guard, cipher voice guard, and secure SATCOM. The UHF-2 radio set provides plain voice, cipher voice, sonobuoy command, wide-band audio, plain voice guard, cipher voice guard, link 11 plain data, link 11 cipher data, TTY plain data, TTY cipher data, and IACS data.

Operation of these radio sets is supported by various equipment on board the aircraft. Mode selection for UHF-1 is accomplished by the control box and the A344 voice selector. Mode selection for UHF-2 is

Figure 1-9.-UHF-2 antenna select panel.

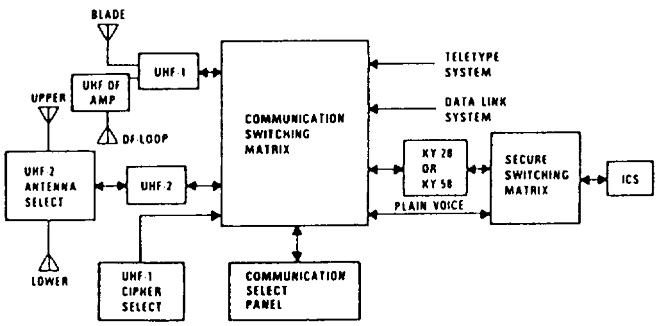


Figure 1-10.-UHF block diagram.

accomplished through the control box and the A516 communications system selector. Some of the peripheral equipment include the AN/AIC-22 intercommunication system, the AN/AGC-6 teletypewriter set (TTY), the AN/ACQ-5 data terminal set (DTS), the AN/ASA-76 generator transmitter group (CASS), and the security equipment TSEC/KY-28 or TSEC/KY-58.

In general, both radio sets are UHF transceivers that provide two-way voice and data communication in the frequency range of 225.000 to 399.975 MHz. They automatically tune 7,000 channels at 0.025-MHz intervals. Built in self-test circuits detect the presence or absence of required operation signals and voltages, then illuminate fault indicators upon detection of faults.

Voice and Data Signals

Voice and data signals at the UHF-2 radio set are linked to the TTY, ICS, and DTS. The UHF security unit is linked between both radio sets and the ICS. This security unit ciphers and deciphers secure voice information. The UHF-2 radio set is used as a backup transmitter for sonobuoy command signals for the CASS system. The secure switching matrix controls the signal flow between the signal processing equipment and the voice, data source, and monitoring equipment.

Transmit Functions

During transmit, the keying and transmit signals from the voice or data source are coupled by the COMM switching matrix to the UHF RT. In the UHF-1 set, the keying signal is interlocked by the UHF-1 RF switch. The voice or data signal modulates the carrier signal generated in the RT, and the output signal is amplified and coupled to the antenna. The UHF-1 output goes through the UHF falter and UHF-1 RF switch to the antenna. UHF-2 output goes through the UHF filter and the UHF-2 RF switch. To provide operating frequency and mode control information, both radio set control boxes generate a digital bit stream that is decoded in the radio's RT. This decoded stream gates the appropriate selected carrier modulation mode and operating frequency. It also gates input voice or data signals by activating the appropriate lines in the RT for the selected operating mode.

The COMM system selector interfaces the UHF-2 radio set with the other systems by controlling the keyline and voice or data signal relay gates in the COMM switching matrix. The UHF-1 set control and the UHF- 1 voice selector interface the UHF-1 radio set with the voice or data sources.

The satellite communications (SATCOM) relay panel is activated to the SATCOM mode of operation by the UHF-1 control box. The control sends an FM select signal to the relay panel, and this switches the panel to the SATCOM mode. The UHF-1 RT is connected to the top antenna through the internal preamplifier to receive the UHF RF signals.

UHF-DF Operation

The UHF-DF operation is accomplished by connecting the UHF-1 radio set to the AN/ARA-50 automatic direction finder set. The ADF received signals are routed through the UHF-1 RT, complete with sidetone to the ICS system for monitoring. During UHF-DF operations, the operator can break in to the mode to transmit. When the mike is keyed to transmit, the UHF-1 RT is automatically connected to the top UHF antenna for transmission. When the mike key is released, the UHF-1 RT is automatically switched back to the ARA-50 antenna for resumption of DF operations.

UHF-1 Receive

During receive, the RF from the top antenna is coupled through the SATCOM relay panel, the RF SWITCH, and the UHF filter to the RT. In the RT, the signal is applied to both the main receiver and the guard receiver. The main receiver consists of two modules-the receiver and a 70-MHz I/O. The receiver is capable of providing reception of 7,000 channel frequencies. The

Table 1-3.-UHF-1 and UHF-2 Operating Modes

UHF-1		
MODE	**TRANSMIT**	**RECEIVE**
Plain voice	AM	AM
Cipher voice	AM	AM
ADF navigation	Not applicable	Wide-band audio
Plain voice guard	Fixed AM	Fixed AM
Cipher voice guard	Fixed AM	Fixed AM
Secure SATCOM	FM	FM
UHF-2		
MODE	**TRANSMIT**	**RECEIVE**
Plain voice	AM	AM
Cipher voice	AM	AM
Sonobuoy command	AM	Not applicable
Wide-band audio	Not applicable	Wide-band AM
Plain voice guard	Fixed AM	Fixed AM
Cipher voice guard	Fixed AM	Fixed AM
Link plain data	FM	FM
Link cipher data	FM	FM
TTY plain data	AFSK	AFSK
TTY cipher data	AFSK	AFSK
IACS data	AFSK	

guard receiver is a separate module and is a complete and independent fixed-tuned, crystal-controlled receiver that operates on the guard frequencies. The receiver sections receive command signals from the control box, placing it in the proper condition for the mode selected. All receiver outputs derived from guard, FM, FSK, wide-band, and voice modes are routed through the audio interface, and then switched through the COMM switching matrix to the external equipment.

UHF-2 Receive

The RF signal received at the UHF tailcap or UHF lower antenna is coupled into the UHF-2 RT through the antenna switching relay, and the UHF filter. From this point on, the operation is the same as in the UHF-1 radio set.

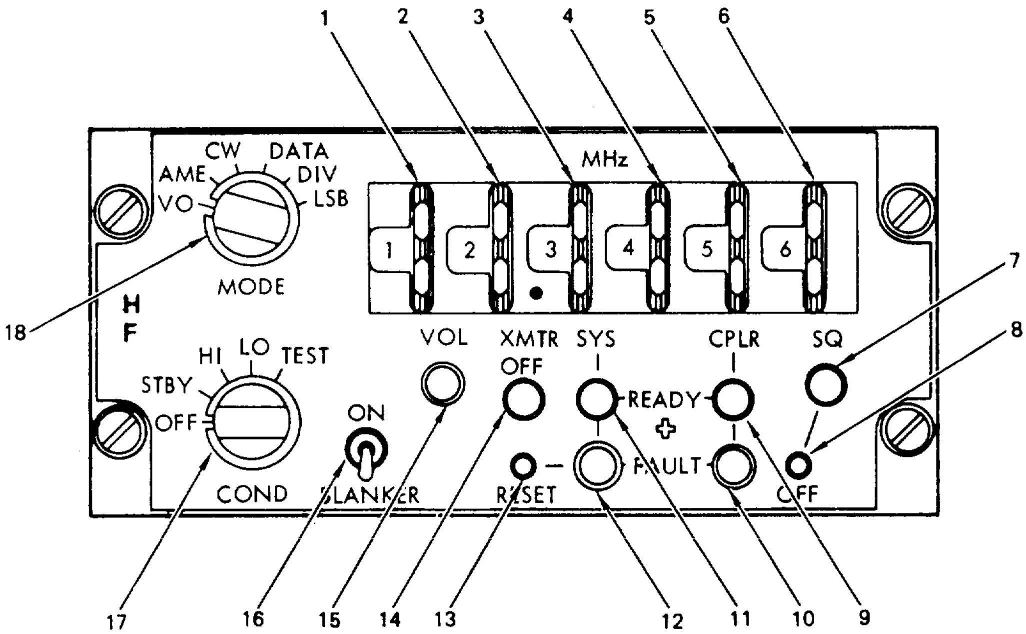
Modes of Operation

Table 1-3 shows the modes of operation for the two radio sets.

HF COMMUNICATIONS

Learning Objective: *Recognize components and operating principles of the HF radio system.*

The AN/ARC-161 HF radio system provides two-way communications between the aircraft and any similarly equipped platform. It provides transmission, reception, and processing of intelligence and tactical data. The cipher voice communication is provided by the TSEC/KY-75 high-frequency security unit.



1. MHz select switch
2. MHz select switch
3. MHz select switch
4. MHz select switch
5. MHz select switch
6. MHz select switch
7. SQ control knob
8. SQ OFF switch
9. CPLR READY indicator
10. CPLR FAULT indicator
11. SYS READY indicator
12. SYS FAULT indicator
13. RESET switch
14. XMTR OFF indicator
15. VOL control
16. BLANKER ON switch
17. COND switch
18. MODE switch

Figure 1-11.-C-9245/ARC-161 control box.

The HF communication system consists of two radio sets and interfacing equipment. These sets are called HF-1 and HF-2. The two radio sets provide two-way, single-sideband (SSB) and plain voice (AME) communication in the frequency range of 2.0000 to 29.9999 MHz, and they automatically tune 280,000 channels at 100-HZ intervals. The HF-1 antenna has four degraded frequency ranges at which coupling might not be possible: 4.8000 to 6.0000 MHz, 12.0000 to 13.2000 MHz, 19.1000 to 20.3000 MHz, and 26.5000 to 27.7000 MHz. The HF-2 antenna has two degraded frequency ranges where coupling might not be possible: 7.9000 to 9.1000 MHz and 18.9000 to 20.1000 MHz.

HF MAJOR COMPONENTS

Each AN/ARC-161 radio set in the HF communications system consists of the following components: a RT-1000/ARC-161 receiver transmitter, an AM-6561/ARC-161 RF amplifier, a C-9245/ ARC-161 control box, a CU-2070/ARC antenna coupler (which includes a lightning arrester), and a long-wire antenna. Both radio sets share the use of a TSEC/KY-75 security unit and TSEC/KY-75 remote control unit.

RT-1000/ARC-161 Receiver Transmitter

The RT-1000/ARC-161 receiver transmitter controls the radio tuning, coupler tuning, and mode selection. It also contains all circuitry required for the generating of transmitter signals and the processing of received RF signals into audio/data signals.

AM-6561/ARC-161 Radio-Frequency Amplifier

This component amplifies the output of the RT prior to transmission.

C-9245/ARC-161 Control Box

The C-9245/ARC-161 control box (fig. 1-11) controls the operation of the HF radio set. There are two of these in the aircraft, one for each radio set. They are identical and interchangeable. Refer to figure 1-11 while reading the following text.

1 through 6. MHz select switches–Selects the desired frequency in the operating range of 2.0000 to 29.9999 MHz.

7. SQ control knob–Controls the amount of squelch threshold voltage in VO and AME operations.

8. SQ OFF switch–When this switch is pressed, the squelch circuits are disabled.

9. CPLR READY indicator–This indicator will illuminate when the associated coupler is properly tuned.

10. CPLR FAULT indicator–This indicator will illuminate to indicate improper tuning of the associated coupler.

11. SYS READY indicator–This indicator will illuminate when the radio set has passed the self-test routine.

12. SYS FAULT indicator–This indicator will illuminate anytime the radio set fails self-test.

13. RESET switch–This switch resets the SYS FAULT indicator to a GO condition after a NO-GO condition was detected

14. XMTR OFF indicator–When this indicator is illuminated the radio set cannot be used to transmit. This indicator will come on during the 3-minute warmup period (the first 3 minutes of initial power up), and anytime the operating frequency is changed by more than 1 MHz. Other than that, anytime there is a fault in the system that affects the transmitter, this indicator will illuminate.

15. VOL control–This control knob is not used in the P-3 aircraft configuration.

16. BLANKER ON switch–This switch is not used in the P-3 aircraft configuration.

17. COND switch–This switch selects the radio set's condition of operation.

    a. OFF–This position removes primary power from the radio set.

    b. STBY–Applies power to the radio set's RF Amp final stage filament, frequency standard and other critical circuits.

    c. HI–Energizes the radio set and sets the transmitter for high-power output.

    d. LO–Energizes the radio set and sets the transmitter for low-power output.

    e. TEST–Initializes the radio set's self-test functions.

18. MODE switch–This switch selects the radio set's mode of operation.

    a. VO–This position permits forced mode selection by the COMM system selector panel.

    b. AME–This position permits AME transmission and reception.

    c. CW–With the switch in this position, the radio set will transmit and receive continuous-wave signals.

    d. DATA, DIV, LSB–In this position, permits forced mode selection by the COMM system selector panel.

CU-2070/ARC Coupler

The CU-2070/ARC coupler (fig. 1-12) provides impedance matching between the receiver transmitter and the antenna. The lightning arrester provides a spark gap to protect the radio if lightning strikes the long-wire antenna.

Long-wire Antenna

There are two antennas used in the P-3 aircraft for the HF system. Both are located external of the aircraft, and stretch from the top of the vertical stabilizer to the fuselage. The one on the left is used by HF-1, and the one on the right is for the HF-2 radio set. Both of the top mounts for the antennas are the breakaway type. If either antenna breaks in flight, the wire will depart the aircraft. This is designed for safety reasons. Should the wire get hung up and not depart the aircraft, structural damage could occur from the wire whipping against the fuselage.

TSEC/KY-75 Security Unit

The TSEC/KY-75 provides the encoding and decoding of the signals when the radio set is in the cipher mode.

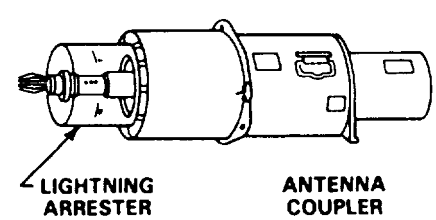
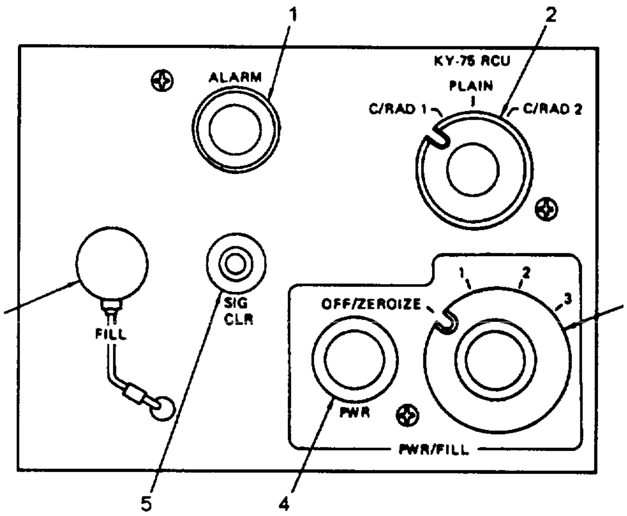


Figure 1-12.-CU-2070/ARC coupler.



1. ALARM indicator
2. TSEC/KY-75 RCU switch
3. PWR/FILL switch
4. PWR indicator
5. SIG CLR switch
6. FILL connector

Figure 1-13.-TSEC/KY-75 remote control unit.

TSEC/KY-75 Remote Control Unit

The TSEC/KY-75 remote control unit (RCU) is shown in figure 1-13. This unit enables the operator to operate the security unit without moving from the NAV/COMM station in the aircraft. The following is an explanation of the various controls and indicators on the RCU.

1. ALARM indicator–This indicator will illuminate whenever there is an alarm condition in the security unit.
2. TSEC/KY-75 RCU switch–This switch is not used.
3. PWR/FILL switch–This is a four-position switch used to select the key and storage locations for the various codes used.
   a OFF/ZEROIZE–This position will zeroize all variables stored in the TSEC/KY-75 security unit. To select this position, the operator must pull the knob out 1/4 inch and turn it counterclockwise. This prevents accidental zeroizing during flight.
   b. 1, 2, 3–These positions select a particular key for the cipher transmission or reception. They also select the storage area when the key is loaded into the TSEC/KY-75.
4. PWR indicator–This indicator will illuminate white when power is applied to the security unit and the PWR/FILL switch is not in the OFF/ZEROIZE position.
5. SIG CLR switch–This switch is pressed to enable the till operation if the TSEC/KYK-13 or TSEC/KOI-18 is attached If a fill device is not attached pressing this switch will cause the security unit to preamble.
6. FILL connector–This connector connects the filling device to the TSEC/KY-75 security unit electrically. This enables the operator to load keys into the security unit.

HF FUNCTIONAL DESCRIPTION

Both radio sets function in the same manner; the only difference between the two is the peripheral equipment used. Figure 1-14 shows a system block diagram.

Receive Function

The RF signal is received by the antenna, coupled through the coupler and the de-energized transmit-receive relay in the RF amplifier, and finally to the receiver transmitter receiver RF input. RF-to-audio conversion is accomplished in the receiver section using inputs from the frequency synthesizer. The recovered audio component is amplified to a power level sufficient to be used as an audio input to the peripheral equipment.

Transmit Function

During the transmit function, voice or data signals from the peripheral equipment are switched through the COMM switching matrix to the USB and LSB transmit audio inputs to the receiver transmitter. A keying signal is also applied from the peripheral equipment. For emergency or maintenance operations, voice and keying signals can originate at the mic/headset assembly connected directly to the receiver transmitter.

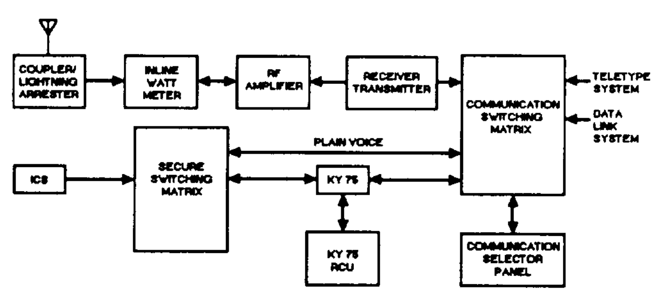


Figure 1-14.-HF system block diagram.

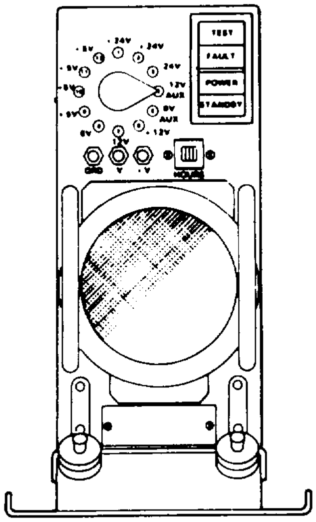


Figure 1-15.-PP-6140/ACQ-5 power supply.

Audio-to-RF conversion is accomplished when the carrier frequency is modulated by the audio input. The modulated RF is amplified by the RF amp to the selected power level of 400 or 1000 watts, depending on the mode selected on the control box, and then coupled to the antenna for transmission.

DATA LINK SYSTEM

Learning Objective: *Recognize components and operating principles of a data link system.*

The data link system serves as a communications link that allows computer-to-computer exchange of data between participating units. Airborne platforms capable of data link include Air Force AWACS, P-3 patrol aircraft, and most carrier aircraft. Surface or subsurface platforms equipped with Navy tactical data systems (NTDS) may also receive and transmit information over data link. The data transmitted is sent by the central computer to a communications interface, which reformats the data into serial digital data (standard NTDS) transmission language. The serial data is then encrypted and passed through a modulator/demodulator to make it compatible with the P-3 radios. Either HF-1, HF-2, or UHF-2 may be used to transmit and receive data link.

In general, the data link system is designed exclusively to transmit tactical symbology. This symbology is available in the aircraft for display on the TACCO display. An additional function is plain text. This allows transmission for text information through link net. This information is available only to certain airborne platforms (P-3, E-2) and shore-based anti-submarine warfare operating centers (ASWOCs).

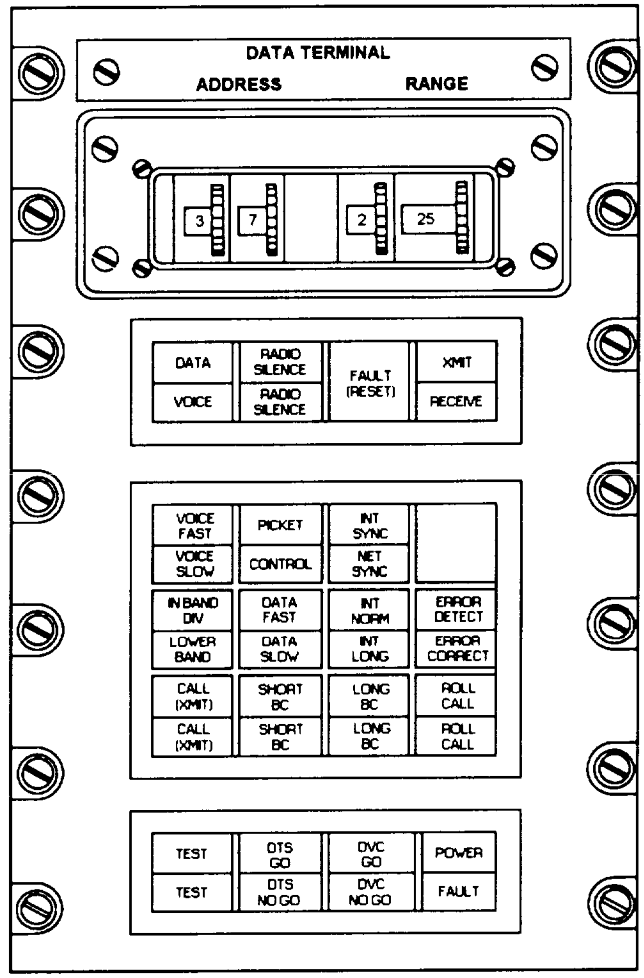


Figure 1-16.-C-7790/ACQ-5 control monitor panel.

Control of the data link setup and monitoring of the active link net is the responsibility of the NAV/COMM. Once it is set up and operating, the only software function available to the NAV/COMM is plain text transmission and reception. The TACCO controls the transmission of all tactical data from the aircraft.

DATA LINK SYSTEM COMPONENTS

The major components of the data link system are discussed in the following text.

Data Terminal Set Converter-Control, CV-2528/ACQ-5

This component is a modulator/demodulator (modem) that takes 26-bit serial digital data from the data communications interface and converts it into audio

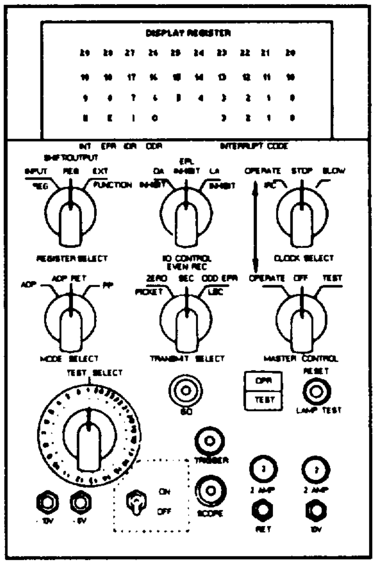


Figure 1-17.-Communications interface No. 2.

tones that can be transmitted over a voice radio. The digital numeric readouts and a test button on the front of the modem display fault indications when the system is operating in the TEST mode. The left display indicates digital control unit (DCU) faults, and the right display indicates modem faults.

Data Terminal Set Power Supply, PP-6140/ACQ-5

This component (fig. 1-15) provides primary power to the modem and to the data terminal set control panel. The power supply is mounted next to the modem. Two switchlights and a wafer switch are on the front panel. The POWER/STANDBY switch applies power to the power supply if the data terminal set (DTS) control panel is in OFF. If the DTS control panel is ON, the power supply supplies primary power to the system. The TEST/FAULT switch initiates a test of the power supply voltage selected on the wafer switch.

Data Terminal Set Control-Monitor Panel, C-7790/ACQ-5

Located at the NAV/COMM station, this unit (fig. 1-16) allows control over the modem. It enables control of operating mode, self-test functions, and operational system monitoring. The DTS control panel was designed to be a single control box for multiple systems; therefore, it has many functions that are not currently used.

Communications Interface No. 2

This unit (fig. 1-17) provides the connection between the central computer and the data link system. It converts 30-bit parallel binary computer data words into 26-bit serial data transmission language. Several wafer switches and indicators are provided on the box for troubleshooting. The two switches on the right side of the box, labeled CLOCK SELECT and MASTER CONTROL, must be in the OPERATE position for normal data link operation. When these switches are in OPERATE, all other switches are inoperative.

DATA LINK SYSTEM DESCRIPTION

A block diagram of the data link system is shown in figure 1-18.

The NAV/COMM has primary responsibility for the hardware setup of the data link system, In general, during preflight the NAV/COMM selects an HF or UHF

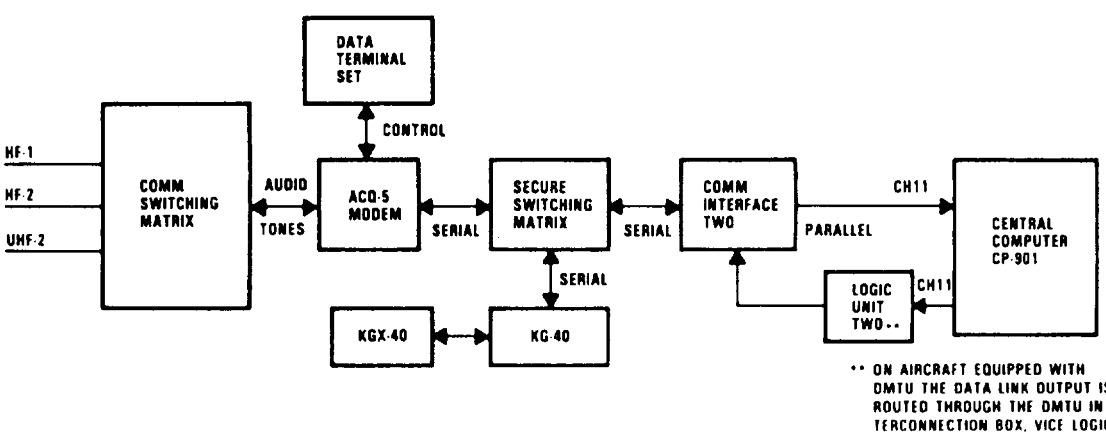


Figure 1-18.-Data link system block diagram.

link frequency. A picket unit (PU) address is obtained from the net controller and inserted into the data terminal set. An appropriate data mode is then selected on the communication selector panel and the cipher data selected amber for encrypted operation. Once these steps are completed, the hardware is setup and ready for the software initialization.

The data link system formats tactical information into blocks of fixed length, called "frames." Each frame contains a 4-bit header block which serves as a control code to tell the modem what type of data follows, and 26 bits of serial information. The 26 bits of data include an address that identifies the originating PU or the DNCU, type of information, the tactical data, and a check sum (parity check).

Data Link Terms

There are four commonly used data link terms that you must be familiar with to work with data link systems. These four terms are discussed in the following paragraphs.

Participating unit is any ship, aircraft, or shore station that is active in the data-link net.

Data Net Control Unit (DNCU) is the participating unit that has overall control over the link net. Only one DNCU maybe active in the net.

Picket Unit (PU) is any station in the net that is not the DNCU. As many as 20 units are allowed as PUs.

Data Link Reference Position (DLRP) is the latitude and longitude position that is used as a reference for all data transmitted on the net. When a participating unit is operating below 60 degrees north or south latitude, this position must be within 1024 minutes of latitude of the unit. Above 60 degrees north or south latitude, 2048 minutes of latitude is allowed.

Modes of Operation

Roll call is the normal system operation mode. The DNCU sends out a message requesting each PU, in a certain order, to respond with tactical data. The transmitted data is available for use by all units in the net, but is displayed only if the participating unit is entered into the individual system. In the P-3C, participating units must be entered in the data link control tableau to have their data accepted for display by the computer. All received data is sent to the central computer, which then looks at the label portion of the data message to determine if the information should be ignored or displayed.

When acting as a DNCU, the participating unit selects CONTROL and ROLL CALL on the DTS. The hardware/software system automatically transmits the request-for-transmit message to each unit entered in the data link control tableau.

When a surface ship or an antisubmarine warfare operating center (ASWOC) is DNCU, PICKET is selected on the DTS. The hardware/software transmits only when a request for data is received from the DNCU. If no request is received, the modem does not transmit.

Two modes of operation used for data link net transmission are LONG BROADCAST and SHORT BROADCAST. LONG BROADCAST, when selected, transmits continuously as long as the function remains active. SHORT BROADCAST transmits a single set of data when the switchlight is pressed. A broadcast net is normally used to preserve emission control (EMCON) conditions (roll call not being conducted by the DNCU) until one of the PU's obtains significant information for transmission to the net. The picket unit or DNCU then transmits the data to the net continuously until deactivated in the long broadcast mode or to the net one-time in the short broadcast mode. The DNCU may elect to use the broadcast functions while conducting roll call to increase the probability of data reception by pickets. Pickets do not use the broadcast functions during roll call by the DNCU since the transmissions will not be synchronized with the roll call and may interfere with transmission from the DNCU.

When radio silence is selected, the DTS will receive data only. Even if a request for data is received the system cannot transmit. All information received is sent to the central computer.

TELETYPE SYSTEM

Learning Objective: *Recognize components and operating principles of a teletype system.*

The teletypewriter system is an integrated communications system that provides the ability to transmit and receive encrypted information with compatible ships, aircraft, and ground stations. The keyboard portion of the teletype inputs data into a central computer.

There are basically two modes of teletype operations: on-line and off-line. In the on-line mode, data is sent from the central computer through the teletype system. Received data is routed to the computer. In the off-line mode, the characters that are typed into

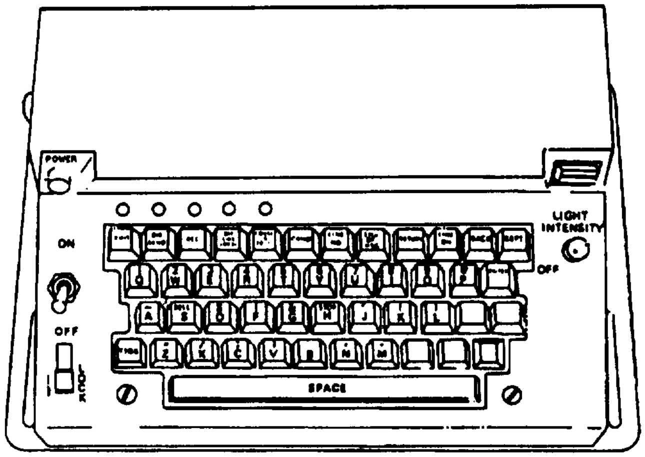


Figure 1-19-Keyboard transmitter TT-568/AGC-6.

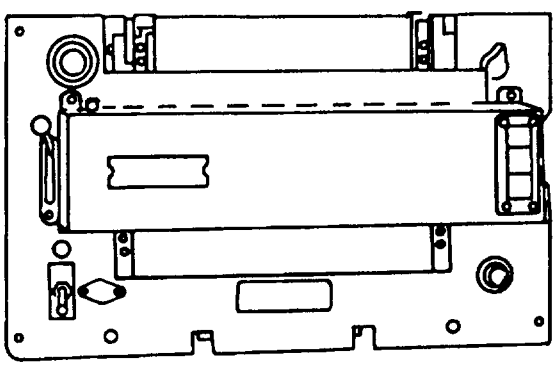


Figure 1-20.-Teleprinter TT-567.

the keyboard are sent directly. Received data is printed on the high-speed printer adjacent to the keyboard

Three radios are available in the aircraft for TTY transmission and reception: UHF-2, HF-1, and HF-2. The TSEC/KW-7 security unit provides encryption and decryption for all teletype data. The teletype information is always routed through the TSEC/KW-7 for encryption and decryption.

SYSTEM COMPONENTS

The following is a brief description of the major components of the teletype system.

Keyboard Transmitter TT-568/AGC-6

The keyboard transmitter is shown in figure 1-19. This unit controls the TTY system. In addition to a standard keyboard, there are special function keys provided.

Teleprinter TT-567

This unit (fig. 1-20) is a high-speed printer. It contains the necessary hardware and logic circuitry to process baudot inputs and produce hard-copy outputs.

TTY Signal Data Converter

This unit (fig. 1-21) provides an interface between the TTY and the radios. It converts teletype language (baudot code) into audio tones, which can be transmitted

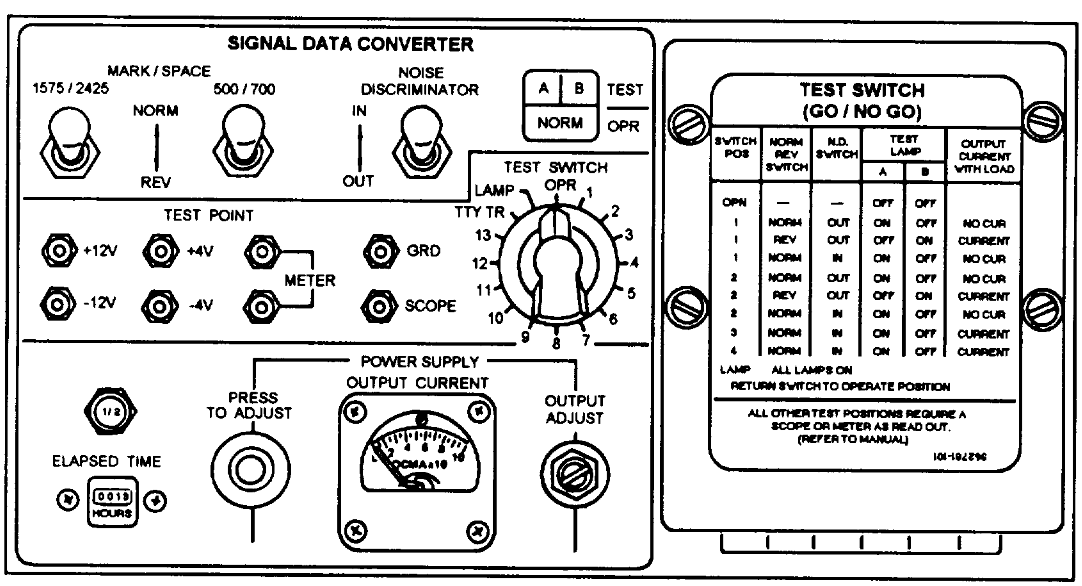


Figure 1-21.-TTY signal data converter.

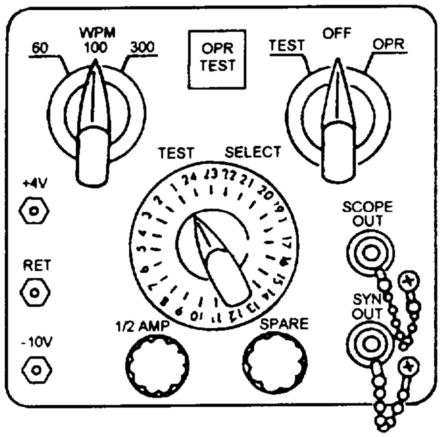


Figure 1-22.-COMM interface No. 1.

over voice radio. Switches on the front of the box provide control over data conversion,

TSEC/KW-7 Security Unit

This unit provides encryption and decryption of the baudot code. It is used whenever the teletype is in operation.

TSEC/KWX-7 security Unit Remote Control Unit (RCU)

This unit is located next to the TTY keyboard and enables the operator to control the TSEC/KW-7 without having to leave his/her seat.

Teleprinter Secure Interface

Mounted under the TTY keyboard, this unit provides remote selection of secure or clear TTY operation. By placing the red guarded TTY/TPR switch to the BYPASS position, the operator closes a relay to bypass the TSEC/KW-7.

Communications Interface No. 1

This unit (fig. 1-22) connects the TTY system with the central computer. It converts the baudot code into 30-bit, parallel, binary computer language. The switches and controls on the front of the interface are inoperative in the OPERATE mode.

TELETYPE SYSTEM OPERATION

Figure 1-23 shows the teletype system block diagram.

Off-line operation of the TTY system requires the operator to select an appropriate frequency on the HF-1, HF-2, or UHF-2 control panel and to select TTY mode on the communications selector panel. The selected radio is automatically mode forced into a data transmission mode. The operator selects words per minute (WPM) speed (normally 100) and TTY on the HSP, and DIR SEND on the TTY keyboard. Phasing the TSEC/KW-7 sends a synchronization signal that is received by all other units on the frequency. Once all units are synchronized, they are ready to accept data. When a key is depressed on the TTY keyboard, the corresponding baudot code is generated. This is sent to

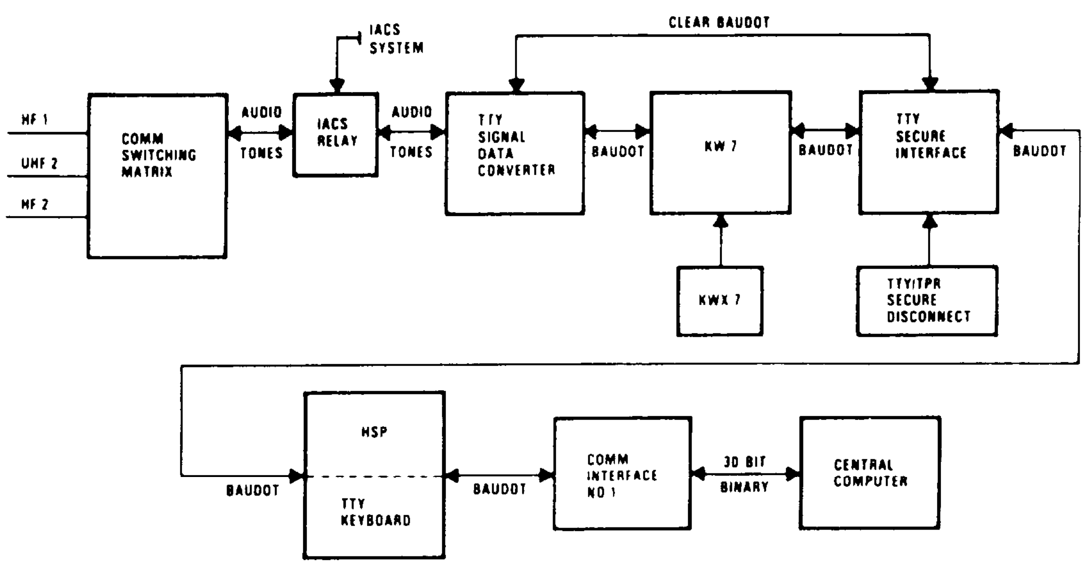


Figure 1-23.-Teletype system block diagram.

the signal data converter, where it is converted to audio tones and then transmitted out over the selected radio. When the message is complete, REC (receive) is selected on the keyboard. This selection allows the system to receive phase tones and incoming messages from other stations on the frequency.

The on-line mode is designed to simplify the work of the operator. Actual system operation is covered in various software publications. In general, the operator types an outgoing message in the central computer. The operator performs all the operations described above, except XMIT is selected on the TTY keyboard. Depression of the XMIT switch on the keyboard directs the central computer to send the stored message through Communications Interface No. 1 into the TTY system. In the same manner, when REC is selected on the keyboard and CMPTR selected on the HSP, any incoming messages are sent to the central computer. Currently, the computer has the ability to store one message of approximately 800 characters for review by the operator.

In addition to teletype data, the TTY system can send and receive data to and from the central computer. In input data, the operator simply selects CONST & EDIT on the keyboard. Any keyboard depressions are then sent to the central computer via the communications interface.

To produce hardcopy of computer data, CMPTR is selected on the HSP. Software functions then allow the central computer to print data on the HSP via Communications Interface No. 1. This data is sent at 3,000 words per minute regardless of the WPM SPEED switch on the HSP.

REVIEW QUESTIONS

Q1. What is the most important means of communicating in the Navy today?

Q2. What frequencies are included in the super high-frequency band?

Q3. How many LS-602/AI panels are there in a typical aircraft?

Q4. What type of encoding/decoding is used in the ICCG system?

Q5. What is the actual frequency range of the AN/ARC-197 radio set?

Q6. How many preset channels are available with the AN/ARC-187 radio set?

Q7. What fault is indicated when the fault indicator on the C-11950/ARC-187 control box flashes at a slow rate?

Q8. The HF-2 long-wire antenna has degraded operation at which frequencies?

Q9. What is the purpose of the lightning arrester used in the HF system?

Q10. What radio sets can be used with the data link system?

Q11. Who has primary responsibility for the hardware setup of the data link system?

Q12. Which unit in the TTY system provides the interface with the radios?

Q13. Which unit connects the TTY system with the central computer?

CHAPTER 2

NAVIGATION

The term *navigation* is defined as the process of directing the movement of a craft from one point to another. Air navigation, unlike sea or naval navigation, involves movement above the surface of the earth. There are unique conditions encountered in air navigation that have a special impact on the navigator.

- Need for continued motion. A ship can stop and resolve any uncertainty of motion or wait for more favorable conditions if necessary. Most aircraft must keep going.

- Limited endurance. Most aircraft can remain aloft for relatively short periods of time, usually figured in hours.

- Greater speed. Because of the high rate of speed, the navigation methods and procedures must be done quickly and accurately.

- Effect of weather. Visibility affects the use of landmarks. The wind has a more direct effect on aircraft position than on ships or vehicles. Changes in atmospheric pressure and temperature affect the height measurement of aircraft using barometric altimeters.

Some type of navigation has been used ever since humans started to venture away from their homes. Exactly how they managed to find their way will remain a matter of conjecture, but some of their methods are known. The Greeks used primitive charts and a crude form of dead reckoning. They used the Sun and the North Star to determine direction. The early explorers used the astrolabe (fig. 2-1). It was not until the early 1700's that an accurate timepiece (chronometer) and the sextant were invented, which made accurate navigation possible, even when far from land.

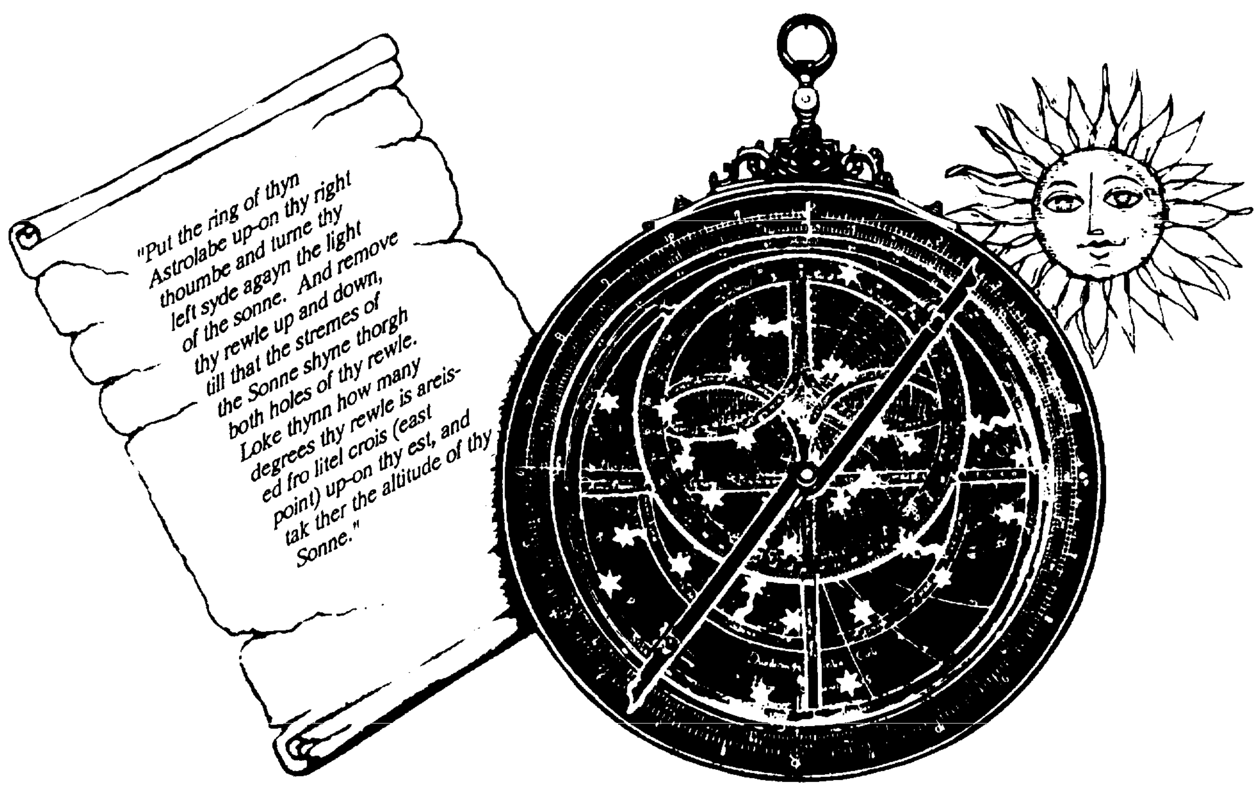


Figure 2-1.-The ancient astrolabe.

Navigation is both an art and a science. The science part is the development of instruments and procedures of navigation, along with the computations involved. The art is the skillful use of the instruments and the interpretation of the data. This combination has led some to call navigation a "scientific art."

The beginning navigators practiced the science of navigation, in that they gathered data and used it to solve a navigational problem in a mechanical way. It takes many hours of flying for navigators to realize that their total role involves not only the mechanics of navigation, but an integration based on judgement. They build accuracy and reliability into their performance by applying sound judgment based on experience. Navy navigators must be able to plan missions covering every possible situation. In flight, they must evaluate the progress of the aircraft and plan for the remainder of the mission. High-speed navigation demands that they have the ability to anticipate changes in flight conditions and make the correct decisions immediately ahead of those changes.

The purpose of air navigation is to determine the direction of travel needed to end up at the desired location, to locate positions, and to measure distance and time as a means to that end. This chapter deals with the various types of navigation and the equipment used in aviation navigation. You must know and understand this information in order to train your subordinates.

METHODS OF NAVIGATION

Learning Objective: *Recognize the various methods of navigation.*

There are certain terms that you must know to understand navigation. The navigator uses these terms to express and accomplish the practical aspects of air navigation. These terms are *position, direction, distance,* and *time.* These terms are defined as follows:

Position is a point defined by stated or implied coordinates. It always refers to some place that can be identified. A navigator must know the aircraft's immediate position before he/she can direct it to another position.

Direction is the position of one point in space relative to another without reference to the distance between them. Direction is not in itself an angle, but it is measured in terms of its angular distance from a reference direction.

Distance is the spatial separation between two points and is measured by the length of a line joining them. On a plane surface, this is a simple problem. However, consider distance on a sphere, where the separation between points may be expressed as a variety of curves. The navigator must decide how the distance is to be measured. This distance can be expressed in various units; miles, yards, etc.

Time is defined in many ways, but for our purposes, it is either the hour of the day or an elapsed interval.

These terms represent definite quantities or conditions that can be measured in several different ways. The position of an aircraft may be expressed as coordinates such as latitude and longitude, or as being 10 miles south of a certain landmark. It is vital that navigators learn how to measure quantities and how to apply the units by which they are expressed.

EARTH'S SIZE AND SHAPE

For navigational purposes, the earth is assumed to be a perfect sphere, although it is not. There is an approximate 12-mile difference between the highest point and the lowest point of the earth's crust. The variations in the surface (valleys, mountains, oceans, etc.) give the earth an irregular appearance.

Measured at the equator, the earth is approximately 6,887.91 nautical miles in diameter. The polar diameter is approximately 6,864.57 nautical miles. This difference of 23.34 nautical miles is used to express the ellipticity of the earth.

Great Circles and Small Circles

A great circle is defined as a circle on the surface of a sphere whose center and radius are those of the sphere itself. It is the largest circle that can be drawn on the sphere; it is the intersection with the surface of the earth of any plane passing through the earth's center.

The arc of a great circle is the shortest distance between two points on a sphere, just as a straight line is the shortest distance between two points on a plane. On any sphere, an infinite number of great circles may be drawn through any point, though only one great circle may be drawn through any two points that are not diametrically opposite (fig. 2-2).

Circles on the surface of the sphere other than great circles may be defined as small circles. A small circle is a circle on the surface of the earth whose center and/or radius are not that of the sphere. A special set of small circles, called latitude is discussed later.

The intersection of a sphere and a plane is a circle—a great circle if the plane passes through the center of the sphere, and a small circle if it does not.

Latitude and Longitude

The nature of a sphere is such that any point on it is exactly like any other point. There is neither beginning nor ending as far as differentiation of points is concerned. So that points may be located on the earth, some points or lines of reference are necessary so that other points may be located in regard to them. The location of New York City with reference to Washington, D. C., is stated as a number of miles in a certain direction from Washington, D.C. Any point on the earth can be located the same way.

This system does not work well in navigation. A point could not be precisely located in mid-Pacific Ocean without any nearby geographic features to use as a reference. A system of imaginary reference lines is used to locate any point on earth. These reference lines are the parallels of latitude and the meridians of longitude.

LATITUDE.— Each day the earth rotates once on its north-south axis. This axis terminates at the two poles. The equator is constructed at the midpoint of

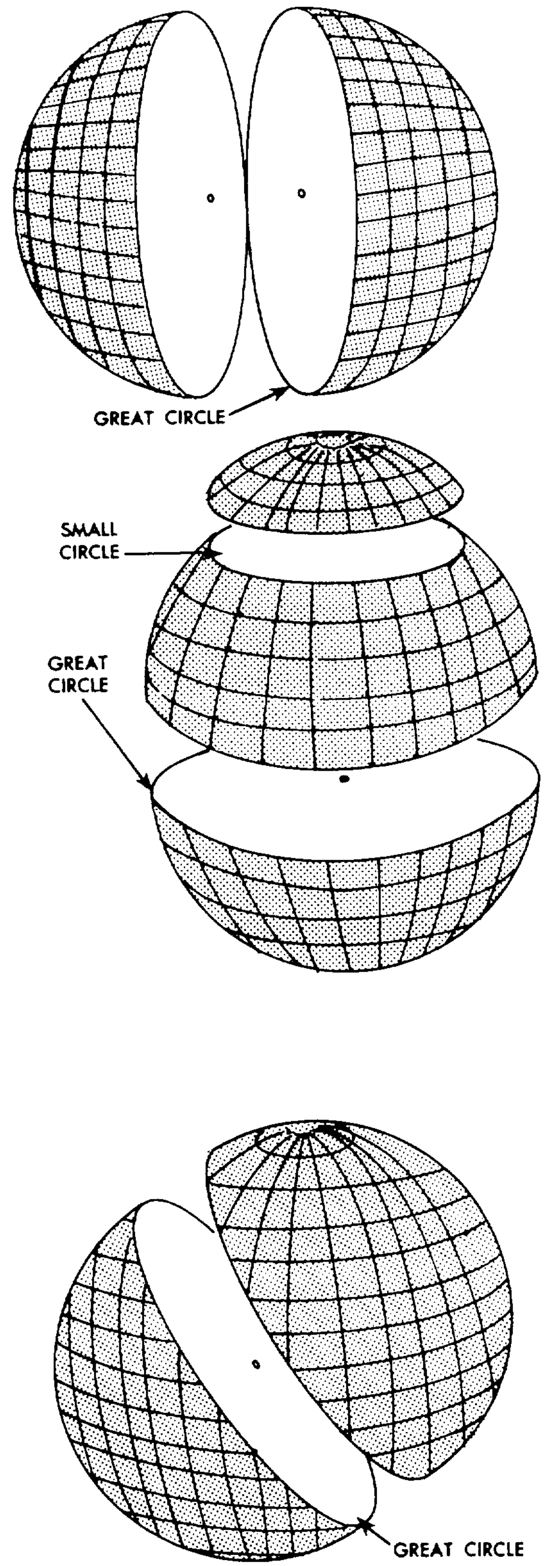


Figure 2-2.-A great circle is the largest circle in a sphere.

this axis at right angles to it (fig. 2-3). A great circle drawn through the poles is called a meridian, and an infinite number of great circles maybe constructed in this manna. Each meridian is divided into four quadrants by the equator and the poles. Since a circle is divided into 360 degrees, each quadrant contains 90 degrees.

Take a point on one of these meridians 30 degrees north of the equator. Through this point passes a plane perpendicular to the north-south axis. This plane will be parallel to the plane of the equator, as shown in figure 2-3, and will intersect the earth in a small circle called a parallel or parallel of latitude. This particular parallel of latitude is called 30°N, and every point on this parallel will be at 30°N. Parallels can be constructed at any desired latitude.

The equator is the great circle midway between the poles. The parallels of latitude are small circles constructed with reference to the equator. The angular distance measured on a meridian north or south of the equator is known as latitude and forms one component of the coordinate system.

LONGITUDE.— The latitude of a point can be shown as 20°N or 20°S of the equator, but there is no way of telling whether one point is east or west of another. This is resolved by the use of the other component of the coordinate system—longitude. Longitude is the measurement of this east-west distance.

There is not a natural starting point for numbering longitude. With latitude, the starting point is the equator. This problem was solved by selecting an arbitrary starting point. Many places had been used, but when the English speaking people began to make charts, they chose the meridian through their principal observatory in Greenwich, England. This meridian has now been adopted by most other countries as the starting point. This Greenwich meridian is sometimes called the prime meridian or first meridian, though actually it is the zero meridian. Longitude is counted east or west from this meridian through 180 degrees. The Greenwich meridian is the 0-degree meridian on one side of the earth and the 180th meridian after crossing the poles (180 degrees east or west of the 0-degree meridian).

If a globe has the circles of latitude and longitude drawn on it according to the principles described, and the latitude and longitude of a certain place have been determined, this point can be located on the globe in its proper position (fig. 2-4). In this way, a globe can be formed that resembles a small-scale copy of the earth.

Latitude is measured in degrees up to 90, and longitude is expressed in degrees up to 180. The total number of degrees in any one circle cannot exceed 360. A degree (°) of arc may be subdivided into smaller units by dividing each degree into 60 minutes (') of arc. Each minute can be divided into 60 seconds (") of arc. Measurement may also be made in degrees, minutes, and tenths of minutes.

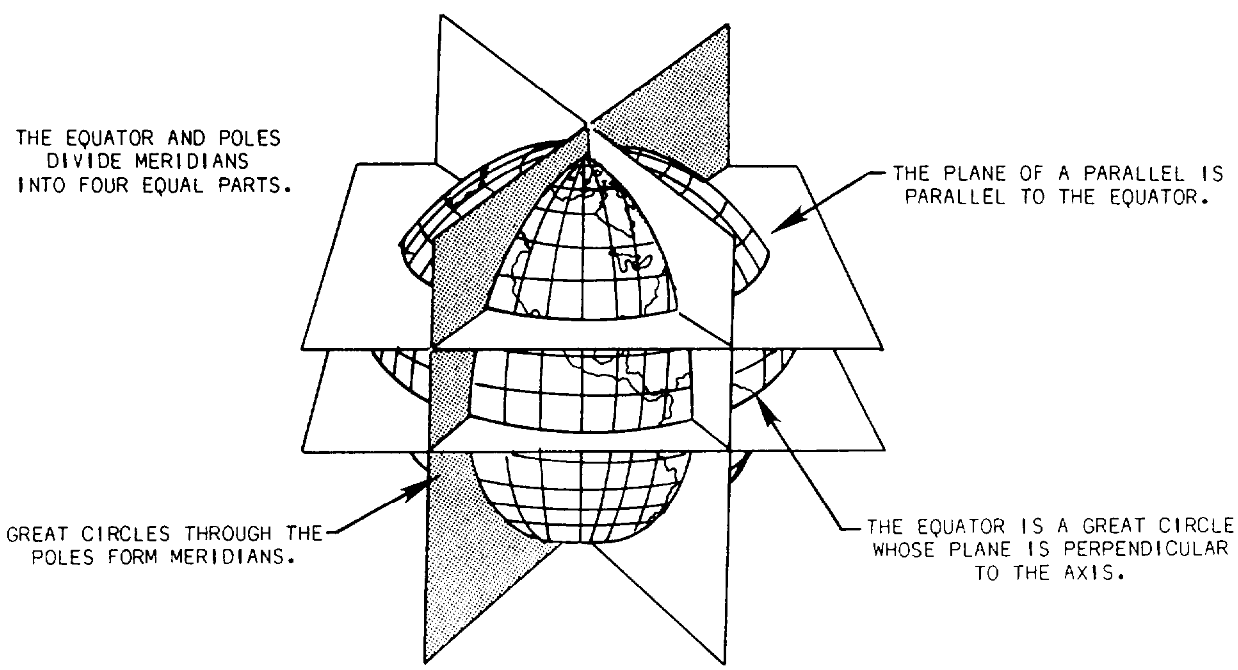


Figure 2-3.-Planes of the earth.

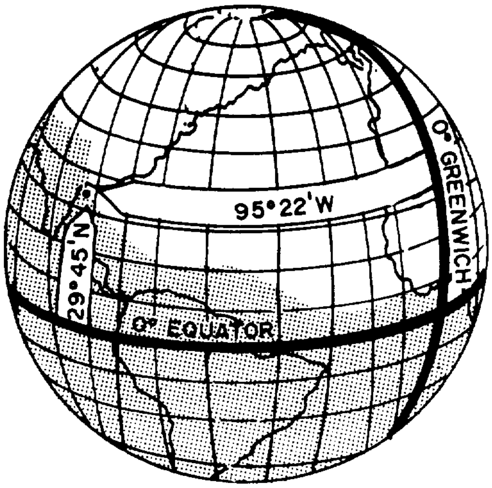


Figure 2-4.-Latitude is measured from the equator; longitude from the prime meridian.

A position on the surface of the earth is expressed in terms of latitude and longitude. Latitude is the distance, either north or south, from the equator. Longitude is the distance, either east or west, from the prime meridian.

Distance

Distance as previously defined is measured by the length of a line joining two points. In navigation, the most common unit for measuring distance is the nautical mile. For most practical navigation, all of the following units are used interchangeably as the equivalent of 1 nautical mile:

- 6,076.10 feet (nautical mile)
- One minute of arc of a great circle on a sphere having an area equal to that of the earth
- 6,087.08 feet. One minute of arc on the earth's equator (geographic mile)
- One minute of arc on a meridian (1 minute of latitude)
- Two thousand yards (for short distances)

It is sometimes necessary to convert nautical miles into statute miles or statute miles into nautical miles. This conversion is made with the following ratio

$$\frac{\textit{Nautical mile}}{\textit{Statute mile}} = \frac{6076\,ft}{5280\,ft} = 1.15$$

This means that 1 nautical mile equals 1.15 statute miles.

The rate of change of position is determined by speed. Speed is expressed in miles per hours, either statute miles or nautical miles. If the measure of distance is nautical miles, it is customary to use the term *knots*. A speed of 200 nautical miles per hour and a speed of 200 knots are the same. The phrase "200 knots per hour" is incorrect unless you are referring to acceleration.

Direction

Direction is the position of one point in space relative to another without reference to the distance between them. The time-honored system for specifying direction as north, northwest, west, etc., does not meet the needs of modern navigation. A numerical system meets the needs better for most purposes. The numerical system (fig. 2-5) divides the horizon into 360 degrees, starting with north as 000 degrees. Going clockwise, east is 090 degrees, south 180 degrees, west 270 degrees, and back to north.

The circle, called a compass rose, represents the horizon divided into 360 degrees. The nearly vertical lines represent the meridians, with the meridian of position A passing through 000 degrees and 180 degrees. Position B lies at a true direction of 062 degrees from A, and position C is at a true direction of 295 degrees from A.

Determination of direction is one of the most important parts of the navigator's job. In order for the navigator to accomplish this task, the various terms involved must be clearly understood. Unless otherwise stated, all directions are called true (T) directions.

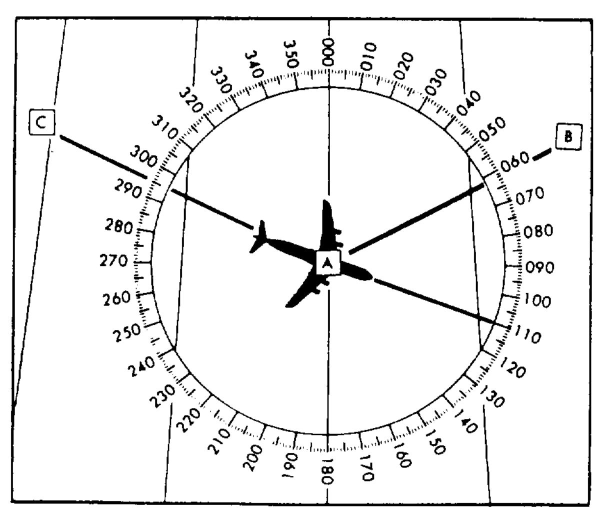


Figure 2-5.-Numerical system used in air navigation.

- Course is the intended horizontal direction of travel.

- Heading is the horizontal direction in which an aircraft is pointed. Heading is the actual orientation of the longitudinal axis of the aircraft at any instant, while the course is the direction intended to be made good.

- Track is the actual horizontal direction made by the aircraft over the earth.

- Bearing is the horizontal direction of one point to another (fig. 2-6). The direction of the island from the aircraft is marked by the line of sight (visual bearing). Bearings are usually expressed in terms of one of two reference directions: (1) true north, or (2) the direction in which the aircraft is pointed. If true north is being used as the reference, the bearing is called a true bearing. If the heading of the aircraft is the reference, the bearing is called a relative bearing.

DEAD RECKONING

Dead reckoning (DR) navigation is a very simple way of navigating. It uses speed and heading measurements to compute position changes from an initial position fix. One of the oldest automatic navigation systems is the dead reckoning analyzer, which takes its speed from the ship's log and its heading from the ship's gyrocompass to compute latitude and longitude.

The error in dead reckoning, as a percentage of distance traveled, commonly reaches 2 to 5 percent. As the distance between fixes increases, the accuracy of the dead reckoning must be increased to maintain a small absolute position error.

The two major causes of error in position computed by dead reckoning are errors in the measurements of heading and speed. A heading error of 1 degree introduces an error of 1.75 percent of distance traveled. A speed error of 1 percent introduces an error of 1 percent of distance traveled. The total system error becomes about 2 percent of distance traveled. Increasing the accuracy of the speed and heading measurements will increase the system accuracy.

The various methods of dead reckoning and the devices that are used are described in detail in *Aviation Electronics Technician 2 (Organizational)*, NAVEDTRA 12330. It is strongly recommended that you take the *AT2(0) Nonresident Training Course*, NAVEDTRA 82330, to get a better understanding of the above information.

ELECTRONIC ASSISTED NAVIGATION

While a navigator can successfully navigate an aircraft using basic mechanical instruments and the dead reckoning procedures, the use of electronic positioning equipment will greatly increase the accuracy of the navigation. The various fixing devices such as loran, TACAN, omega, VOR, etc., will be discussed in detail later in this chapter.

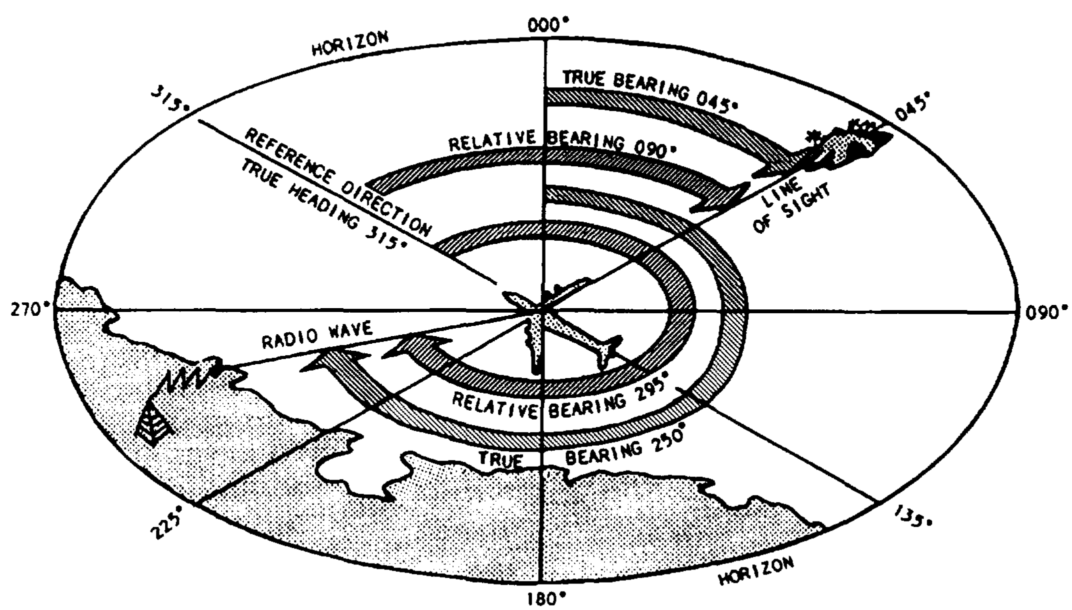


Figure 2-6.-Measuring true and relative bearing.

The first radio systems were developed to keep the pilots informed of weather information along the flight path. The development of directional equip ment produced the ability to have a system of radio beams that formed aerial highways. World War II fostered the development of several new radio aids, which includes loran and radar.

The development of computers and more sophisticated radio/radar aids produced the ability to go from point A to point B faster and more direct than ever before.

AIRBORNE NAVIGATION SYSTEMS

Learning Objective: *Recognize components and operating principles of the various navigational systems.*

Airborne navigation systems can be self-contained units or ground-referenced units. A self-contained unit is complete in itself and does not depend upon a transmission from a ground station. A ground-referenced unit needs a transmission from a ground station. Either way, they serve the same purpose—to aid the aircrew in completing their mission safely and efficienty.

ALTITUDE AND ALTIMETERS

Altitude is defined as the vertical distance of a level, a point, or an object measured from a given surface. Knowing the aircraft's altitude is imperative for terrain clearance, aircraft separation, and a multitude of operational reasons.

There are as many kinds of altitudes as there are reference planes from which to measure them. Only six concern the navigator—indicated altitude, calibrated altitude, pressure altitude, density altitude, true altitude, and absolute altitude. There are two main altimeters-pressure altimeter and the absolute (radar) altimeter. Every aircraft has a pressure altimeter. For you to understand the pressure altimeter's principle of operation, a knowledge of the standard datum plane is essential.

Standard Datum Plane

The standard datum plane is a theoretical plane where the atmospheric pressure is 29.92 inches of mercury (Hg) and the temperature is +15°C. The standard datum plane is the zero-elevation level of an imaginary atmosphere known as the standard atmosphere. In the standard atmosphere, pressure is at 29.92 inches of mercury at 0 feet, and decreases upward at the standard pressure lapse rate. The temperature is + 15°C at 0 feet, and decreases at the standard temperature lapse rate (fig. 2-7).

Altitude (feet)	Standard pressure (millibars)	Standard pressure (inches of mercury)	Standard tempera-ture (°C)	Standard tempera-ture (°F)
60,000	71.7	2.12	−56.5	−69.7
59,000	75.2	2.22	−56.5	−69.7
58,000	79.0	2.33	−56.5	−69.7
57,000	82.8	2.45	−56.5	−69.7
56,000	86.9	2.57	−56.5	−69.7
55,000	91.2	2.69	−56.5	−69.7
54,000	95.7	2.83	−56.5	−69.7
53,000	100.4	2.96	−56.5	−69.7
52,000	105.3	3.11	−56.5	−69.7
51,000	110.5	3.26	−56.5	−69.7
50,000	116.0	3.42	−56.5	−69.7
49,000	121.7	3.59	−56.5	−69.7
48,000	127.7	3.77	−56.5	−69.7
47,000	134.0	3.96	−56.5	−69.7
46,000	140.6	4.15	−56.5	−69.7
45,000	147.5	4.35	−56.5	−69.7
44,000	154.7	4.57	−56.5	−69.7
43,000	162.4	4.79	−56.5	−69.7
42,000	170.4	5.04	−56.5	−69.7
41,000	178.7	5.28	−56.5	−69.7
40,000	187.5	5.54	−56.5	−69.7
39,000	196.8	5.81	−56.5	−69.7
38,000	206.5	6.10	−56.5	−69.7
37,000	216.6	6.40	−56.5	−69.7
36,000	227.3	6.71	−56.3	−69.4
35,000	238.4	7.04	−54.3	−65.8
34,000	250.0	7.38	−52.4	−62.2
33,000	262.0	7.74	−50.4	−58.7
32,000	274.5	8.11	−48.4	−55.1
31,000	287.4	8.49	−46.4	−51.6
30,000	300.9	8.89	−44.4	−48.0
29,000	314.8	9.30	−42.5	−44.4
28,000	329.3	9.72	−40.5	−40.9
27,000	344.3	10.17	−38.5	−37.3
26,000	359.9	10.63	−36.5	−33.7
25,000	376.0	11.10	−34.5	−30.2
24,000	392.7	11.60	−32.5	−26.6
23,000	410.0	12.11	−30.6	−23.0
22,000	427.9	12.64	−28.6	−19.5
21,000	446.4	13.18	−26.6	−15.9
20,000	465.6	13.75	−24.6	−12.3
19,000	485.5	14.34	−22.6	−8.8
18,000	506.0	14.94	−20.7	−5.2
17,000	527.2	15.57	−18.7	−1.6
16,000	549.2	16.22	−16.7	1.9
15,000	571.8	16.89	−14.7	5.5
14,000	595.2	17.58	−12.7	9.1
13,000	619.4	18.29	−10.8	12.6
12,000	644.4	19.03	− 8.8	16.2
11,000	670.2	19.79	− 6.8	19.8
10,000	696.8	20.58	− 4.8	23.3
9,000	724.3	21.39	− 2.8	26.9
8,000	752.6	22.22	− 0.8	30.5
7,000	781.8	23.09	1.1	34.0
6,000	812.0	23.98	3.1	37.6
5,000	843.1	24.90	5.1	41.2
4,000	875.1	25.84	7.1	44.7
3,000	908.1	26.82	9.1	48.3
2,000	942.1	27.82	11.0	51.9
1,000	977.2	28.86	13.0	55.4
Sea level	1013.2	29.92	15.0	59.0

Figure 2-7.-Standard lapse rates.

The standard atmosphere is theoretical. It was derived by averaging the readings taken over a period of years. The list of altitudes and their corresponding values of temperature and pressure given in figure 2-7 were determined by these averages.

INDICATED ALTITUDE.— The term *indicated altitude* means the value of altitude that is displayed on the pressure altimeter.

CALIBRATED ALTITUDE.— Calibrated altitude is indicated altitude corrected for installation/ positional error.

PRESSURE ALTITUDE.— The height of the aircraft above the standard datum plane is called pressure altitude.

DENSITY ALTITUDE.— Density is mass per unit volume. The density of the air varies with temperature and with height. Warm air expands, and is less dense than cold air. Normally, the higher the pressure altitude, the less dense the air becomes. The density of the air can be expressed in terms of the standard atmosphere. Density altitude is the pressure altitude corrected for temperature. This calculation converts the density of the air to the standard atmospheric altitude having the same density. Density altitude is used in performance data and true airspeed calculations.

TRUE ALTITUDE.— True altitude is the actual vertical distance above mean sea level, measured in feet. It can be determined by two methods: (1) Set the local altimeter setting on the barometric scale of the pressure altimeter to obtain the indicated true altitude. The indicated true altitude can then be resolve to the true altitude by use of a DR computer. (2) Measure altitude over water with an absolute altimeter.

ABSOLUTE ALTITUDE.— The height above the terrain is called absolute altitude. It is computed by subtracting terrain elevation from true altitude, or it can be read directly from an absolute altimeter.

Pressure Altimeter

As stated earlier, every naval aircraft has a pressure altimeter. The altitude indicated is indicated altitude, not absolute altitude.

PRINCIPLES OF OPERATION.— The pressure altimeter is an aneroid barometer calibrated to indicate feet of altitude instead of pressure. The pointers are connected by a mechanical linkage to a set of aneroid cells. These aneroid cells expand or contract with changes in barometric pressure. The cells assume a particular thickness at a given pressure level, and thereby position the altitude pointers accordingly. On the face of the indicator is a barometric scale that indicates the barometric pressure (in.Hg) of the point or plane from which the instrument is measuring altitude. If you turn the barometric pressure set knob on the altimeter, it manually changes the setting on the scale. It also results in simultaneous movement of the pointers to the corresponding altitude reading.

Like all measurements, an altitude reading is meaningless if the reference point is unknown. The pressure altimeter face supplies both values. The position of the pointers indicate the altitude in feet, and the barometric scale indicates the pressure of the reference plane.

TYPES OF PRESSURE ALTIMETERS.— There are two different types of altimeters that you will be concerned with. They are the counter-pointer altimeter and the counter-drum-pointer altimeter.

Counter-Pointer Altimeter.—Ths altimeter has a two-digit counter display unit located in the 9 o'clock position of the dial. The counter indicates altitude in 1,000-foot increments from 0 to 80,000 feet (fig. 2-8). A single conventional pointer indicates hundreds of feet on the fixed circular scale. The pointer makes 1 revolution per 1,000 feet of altitude, and as it passes through the 900- to 1,000-foot area of the dial, the 1,000-foot counter is actuated. The shaft of the 1,000-foot counter actuates the 10,000-foot counter at each 10,000 feet of altitude change. To determine the indicated altitude, you read the

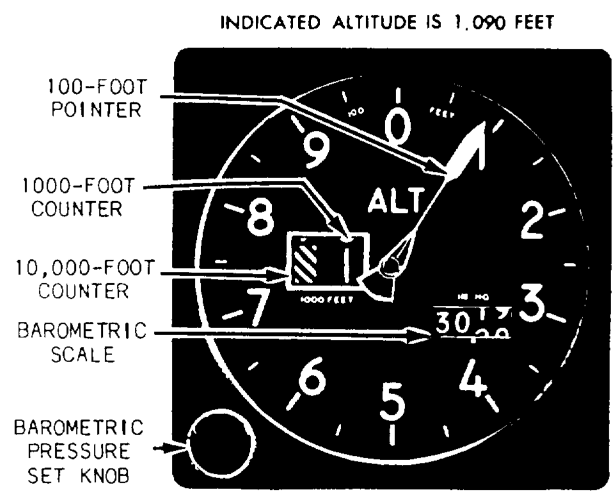


Figure 2-8.-Counter-pointer altimeter.

1,000-foot counter and then add the 100-foot pointer indication.

CAUTION

It is possible to misinterpret the counter-pointer altimeter by 1,000 feet immediately before or after the 1,000-foot counter moves. This error is possible because the 1,000-foot counter changes when the foot-pointer is between the 900- and 1,000-foot position.

Counter-Drum-Pointer Altimeter.— The only real difference between this altimeter and the counter-pointer altimeter is the addition of a 100-foot drum (fig. 2-9). This drum follows the 100-foot pointer, and it is this drum that actuates the 1,000-foot counter. In this way it prevents the reading error when the 1,000-foot counter switches.

There are two methods of reading the indicated pressure altitude. One way is to read the counter-drum window without referring to the 100-foot pointer. This will give a direct readout of both thousands and hundreds of feet. The second way is to read the counter window and then add the 100-foot pointer indication. The pointer serves as a precise readout of values less than 100 feet.

This sample altimeter has a servoed mode and a pressure mode of operation. The mode of operation is controlled by a spring-loaded, self-centering mode switch, placarded RESET and STBY. In the servoed mode, the altimeter displays altitude, corrected for position error, from the synchro output of the air data computer. In the standby mode, the altimeter operates as a standard altimeter. In this mode, it uses static pressure from the static system that is uncorrected for position error.

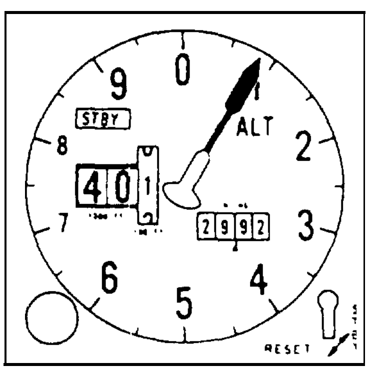


Figure 2-9.-Counter-drum-pointer altimeter.

The servoed mode is selected by placing the mode switch to RESET for 3 seconds. The ac power must be on. During standby operation, a red STBY flag appears on the dial face. The altimeter automatically switches to standby operation during an electrical power loss or when the altimeter or altitude computer fails. The standby operation is selected by placing the mode switch to STBY. An ac-powered internal vibrator automatically energizes in the standby mode to lessen friction in the display mechanism.

PRESSURE ALTIMETER ERRORS.— There are five categories of errors relating to pressure altimeters. They are the mechanical error, the scale error, installation/position error, reversal error, and hysteresis error.

Mechanical Error.— Mechanical error is caused by misalignments in gears and levers that transmit the aneroid cell expansion and contraction to the pointers of the altimeter. This error is not constant, and it must be checked before each flight by the setting procedure.

Scale Error.— Scale error is caused by irregular expansion of the aneroid cells. It is recorded on a scale correction card maintained for each altimeter in the instrument maintenance shop.

Installation/Position Error.— Installation/position error is caused by the airflow around the static ports. This error varies with the type of aircraft, airspeed, and altitude. The magnitude and direction of this error can be determined by referring to the performance data section in the aircraft NATOPS manual.

An altimeter correction card is installed in some aircraft that combines the installation/position and the scale errors. This card shows the amount of correction needed at different altitudes and airspeeds.

Reversal Error.— Reversal error is caused by inducing false static pressure into the system. This normally occurs during abrupt or huge pitch changes. This error appears on the altimeter as a momentary indication in the opposite direction.

Hysteresis Error.— Hysteresis error is a lag in altitude indication due to the elastic properties of the material within the altimeter. This occurs after an aircraft has maintained a constant altitude for an extended period of time and then makes a large, rapid altitude change. After a rapid descent, altimeter readings are higher than actual. This error is negligible during climbs and descent at a slow rate or after maintaining a new altitude for a short period of time.

Absolute (Radar) Altimeter

Accurate absolute altitude is important for navigation, photography, and bombing, as well as for safe piloting. Absolute altitude can be computed from the pressure altimeter readings, but the results are often inaccurate. Under changing atmospheric conditions, corrections applied to pressure altimeter readings to obtain true altitudes are only approximate. Also, any error made in determining the terrain elevations results in a corresponding error in the absolute altitude.

The radar altimeter, AN/APN-194(V), is a pulsed, range-tracking radar that measures the surface of terrain clearance below the aircraft. It is reliable in the altitude range of 20 to 5,000 feet. This altimeter develops its information by radiating a short duration radio frequency (RF) pulse from a transmit antenna and measuring the time interval it takes to receive the reflected signal. The altitude information is then continuously sent to the indicator in feet of altitude. The height indicator is disabled when the aircraft is above 5,000 feet. When the aircraft is on the ground, the system is disabled by the weight-on-wheels switch.

HEIGHT INDICATOR.— The AN/APN-194(V) uses the ID-1760A/APN-194(V) as its height indicator (fig. 2-10, view A). The only operating control is in the lower left-hand corner. This control knob is a combination power switch, self-test switch, and a positioning control for low altitude limit index (limit bug). The adjustable limit bug is set to a desired altitude for use as a reference for flying at a fixed altitude. The indicator displays the altitude on a single-turn dial that is calibrated from 0 to 5,000 feet. If the aircraft is above 5,000 feet, or the signal becomes unreliable, the OFF flag appears and the pointer goes behind the dial mask.

If you rotate the control knob clockwise, it will apply power to the system. If you continue to rotate the knob, it will set the limit bug to the desired reference altitude. While the aircraft is in the air, you can close the self-test switch by pressing the control knob. When this occurs, the indicator will read 100 ±10 feet. This self-test will not work on the ground

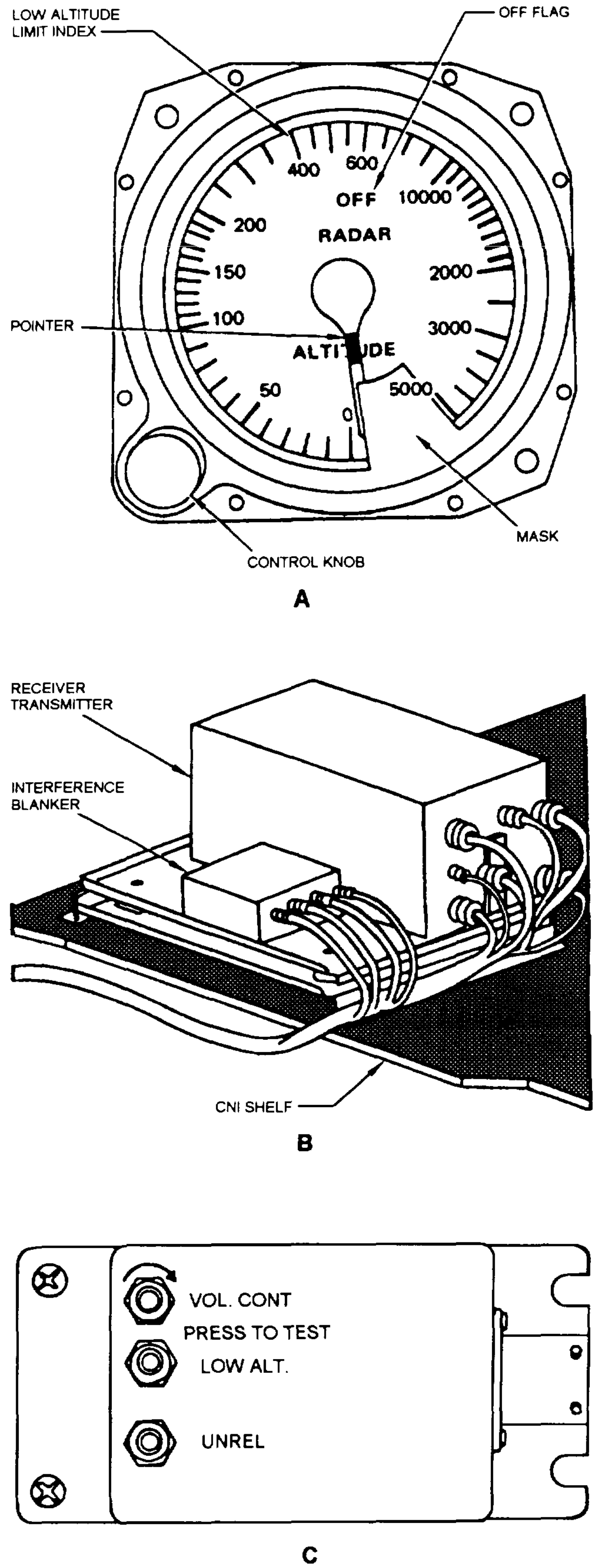


Figure 2-10.-AN/APN-194(V) components. A. ID-1760A/ APN-194(V). B. RT-1042/APN-194 (V), MX-9132A/ APN-194(V). C. BZ-157A.

because the system is disabled by the weight-on-wheels switch.

RECEIVER-TRANSMITTER.— This system uses the RT-1042/APN-194(V) as its receiver-transmitter (fig. 2-10, view B). It is an airtight unit that contains all the electronic components for the generation, detection, and time difference computations of the radar pulses.

There are two altitude modes of operation-one for low level and one for high level. The low-level mode is for altitudes less than 1,000 feet. In this mode, the RT transmits a very narrow, low-powered pulse to get maximum range resolution. The high-level mode is for altitudes above 1,000 feet. In this mode, the output pulse is a wider, high-powered pulse, which ensures sufficient ground return energy for tracking.

There are two ranging modes of operation—one for search and one for tracking. In the search mode, the system successively examines increments of range with each cycle of operation until the complete altitude range is searched for ground return. When the range is found, the system switches to the track mode. In the track mode, the system locks onto and tracks the leading edges of the ground return pulses. It then sends continuous altitude information to the indicator.

In most aircraft with this system, there is an Interference Blanker, MX-9132A/APN-194(V), located next to the RT (fig. 2-10, view B). This blanker attenuates any RF from direct antenna leakage and provides isolation of the receiver from the transmit antenna.

LOW ALTITUDE AUDIBLE ALARM.— Some of the aircraft with the APN-194(V) system have the BZ-157A low altitude audible alarm installed (fig. 2-10, view C). In the EA-6A aircraft, this box is on the ICS relay box behind the EWO's seat. This alarm will apply a tone to the intercommunication system when the aircraft falls below the altitude that the limit bug is set. The tone is a 2-second tone alternating between 700 and 1700 Hz at 2-Hz intervals. This alarm will also sound when there is an unreliable condition in the system. This tone alternates between 700 and 1700 Hz at 8-Hz intervals. The alarm will also send a signal to the indicator to cause the OFF flag to appear. The unreliable condition warning signal takes precedence over the low altitude warning signal.

The BZ-157A has three switches on it. The first one is the volume control, which controls the volume of the alarm. The other two are press-to-test switches. Depressing the LOW ALT switch will cause the alarm to be heard. Depressing the UNREL switch will cause the alarm to be heard and the OFF flag to appear.

LOW ALTITUDE WARNING LIGHT.— The low altitude warning light is mounted on the pilot's instrument panel. This light will illuminate whenever the aircraft falls below the altitude that the limit bug is set.

RADAR ALTIMETER WARNING SET

The radar altimeter warning set (RAWS) works in conjunction with the radar altimeter systems that do not have the BZ-157A alarm unit. The P3-C aircraft uses the AN/APQ-107 system. This system provides the pilot and copilot with warning signals whenever any of the following conditions exists:

- Aircraft flies below preselected altitudes.
- Input power to radar altimeter fails.
- RAWS warning circuit indicates unreliability.

When the aircraft descends to 380 (±20) feet (high-altitude index), the radar altimeter signal to RAWS is interrupted. This causes the AUTOPILOT/RADAR ALTM warning lights to flash and a 1-kHz interrupted tone to be heard over the ICS. Both signals occur at a rate of two pulses-per-second for a 3-second duration. This also happens as the aircraft descends through 170 feet (low-altitude index). The warnings will continue as long as the aircraft remains below the low index. When the nosegear is down or the flaps are in the approach, takeoff, or landing position, the warning signals are disabled.

If the radar altimeter receiver signal is too weak to provide reliable altitude information or the altimeter malfunctions, the RAWS will give both warnings. This occurs unless the signals are disabled by the nosegear or flap position.

There are two RAWS press-to-test switches located in the aircraft. One on the RAWS itself, and one on the forward load center. If you depress the switch on the RAWS, it will actuate both signals, unless the nosewheel is down and locked-then only the aural warning occurs. Depressing the switch on the forward load center results in both the visual and the aural warnings.

The barometric switch in the RAWS automatically resets its altitude reference pressure to ground level before flight. When 700 feet above takeoff altitude has been reached, the switch actuates and changes the RAWS reliability circuit. At this point, the radar altimeter reliability signal is inhibited. This prevents nuisance warnings when the aircraft is flying above the operating range of the switch.

AUTOMATIC DIRECTION FINDER (ADF)

The Direction Finder Set, AN/ARN-83, is known as a low frequency automatic direction finder (LF/ADF). This system is a radio navigational aid that operates in the low-to-medium-frequency range. It continuously indicates the bearing to a selected radio station, acts as a manual direction finder, and as a conventional low-frequency radio receiver for voice and unmodulated transmissions. The LF/ADF is sometimes referred to as a radio compass.

Major Components

The AN/ARN-83 direction finder set consists of four major components. The y are the R-1391/ARN-83 receiver, the C-6899/ARN-83 control panel, the AS-1863/ARN-83 loop antenna, and the ADF sense antenna.

RADIO RECEIVER R-1391/ARN-83.— The radio receiver is remotely controlled from the ADF control. It does all processing of signals received by the loop and sense antennae and sends bearing information to the navigation indicator group.

DIRECTION FINDER CONTROL PANEL C-6899/ARN-83.— The control panel controls all functions of the system (fig. 2-11). Selection of the three modes of operation is accomplished here. Manual control of the loop antenna is done using the LOOP knob. The tune knob tunes the receiver for the station, and it is visually indicated through the frequency dial. The tuning meter indicates the strength of the receiver signal. The BFO switch causes a tone to be produced for tuning purposes.

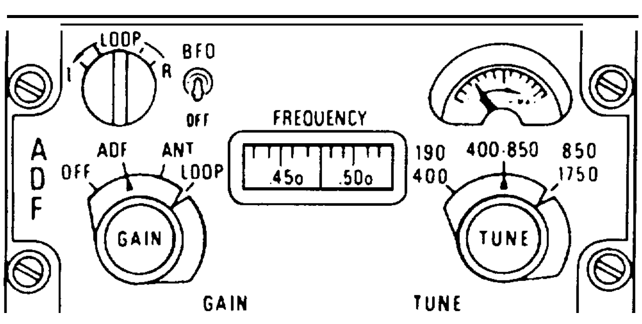


Figure 2-11-Direction finder control panel C-6889/ARN-83.

LOOP ANTENNA AS-1863/ARN-83.— This antenna is a flat, one-piece, sealed unit. It consists of four ferrite-cored coils arranged in a rectangle. Two coils line up parallel to the fore-aft axis of the aircraft, and the other two are perpendicular to the axis. Each pair of coils provides a signal that is sent to the receiver for processing.

ADF SENSE ANTENNA.— The ADF sense antenna element is basically an aluminum panel connected to the input of the lightning arrester. This panel is encased in fiber glass and mounted flush with the fuselage. The loop antenna is physically mounted on the sense antenna.

Functional Description

There are three functional modes with the LF/ADF. These modes are (1) ADF mode, (2) loop mode, and (3) antenna mode. The direction finder set provides audio to the intercommunication system in all three modes of operation.

ADF MODE.— In the ADF mode, the loop antenna signals are mixed with the nondirectional sense antenna signal in the receiver. This signal is then detected for audio to be sent to the headsets. The bearing coordinate data is produced by the receiver error correction servomotor network. This is then sent to the navigation indicator for display.

LOOP MODE.— In the loop mode, the fixed loop antenna RF signal is modulated and detected in the receiver. The resulting audio error signal is used to produce an audio tone signal that is fed to the intercommunication system. The servomotor net work is then manually controlled to null the audio tone. At the null, the output of the receiver will represent relative bearing to the radio station.

ANTENNA MODE.— This mode causes the system to act just like a normal radio receiver. It receives a voice or continuous wave (CW) signal at the sense antenna, which is detected and amplified by the receiver. The receiver then sends the audio to the ICS. In this mode of operation, there is no bearing data signal being developed.

TACTICAL AIR NAVIGATION (TACAN)

The TACAN Set, AN/ARN-84(V), is a radio navigational set that operates in conjunction with a TACAN ground station. Together they provide the aircrew with continuous bearing and range from the aircraft to the station. The TACAN set can also operate as both the interrogator and transponder with another aircraft equipped with TACAN.

The ground station, acting as a reference position, develops a complex signal on which bearing information is superimposed (fig. 2-12). This signal may be on any of 126 channel frequencies in the X mode. Pulse coding gives ground equipment the capability of an additional 126 channels in the Y mode. Channels are separated at 1-MHz intervals in these modes. The station identifies itself by transmitting its call letters, in Morse code, every 37.2 seconds. Knowing the time that has elapsed between the interrogation signal and the reply signal facilitates calculation of slant range from the aircraft to the station.

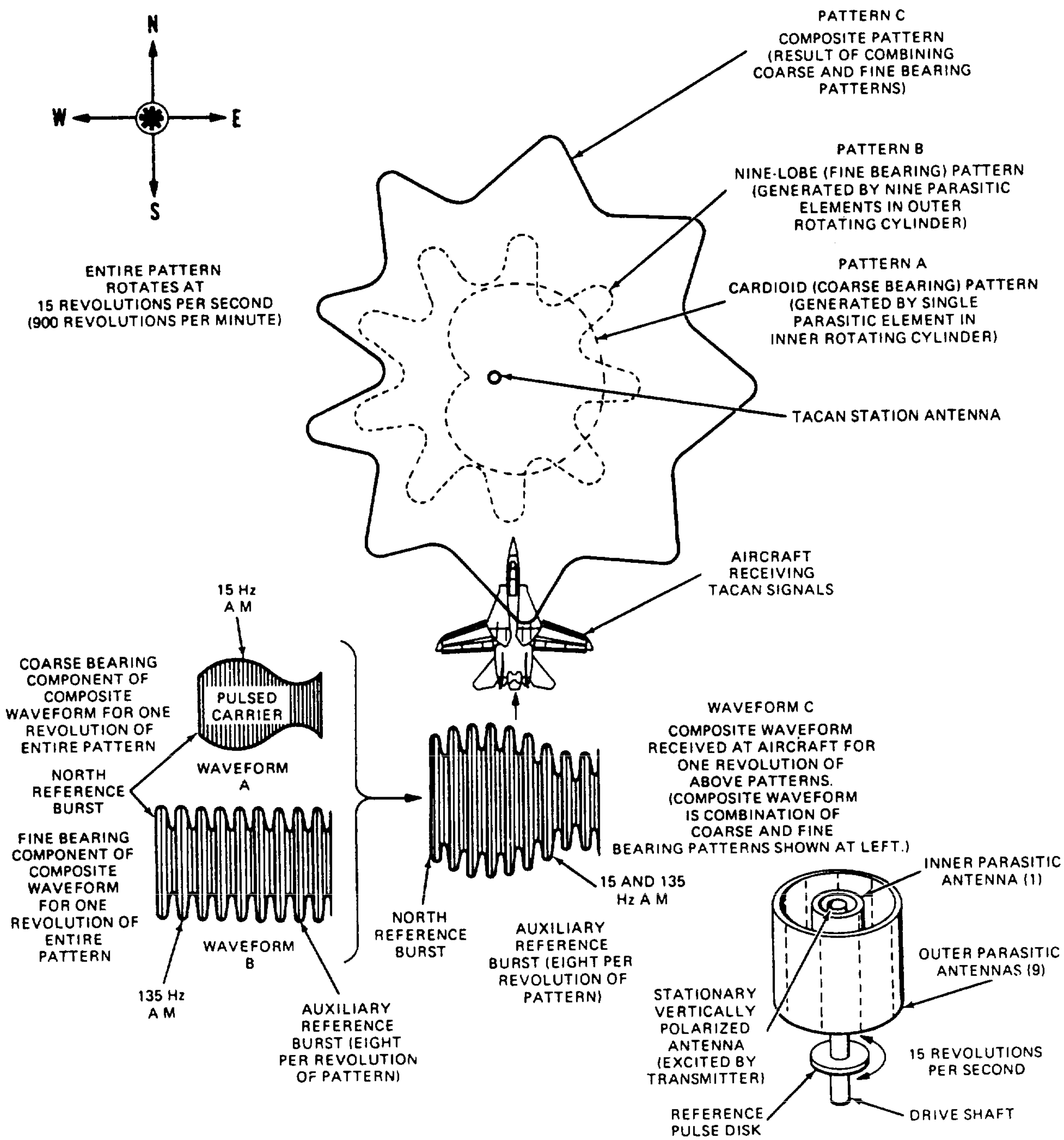


Figure 2-12.-Typical TACAN station bearing antenna and radiation pattern.

Major Components

The AN/ARN-84(V) TACAN set consists of five major components. They are the control panel, C-9054/ARN-84(V); the receiver-transmitter, RT-1022/ARN-84(V); the signal data converter, CV-2837/ARN-84(V); the RF transmission line switch, SA-1818/A; and the antenna assembly, AS-26281A.

TACAN CONTROL C-9054/ARN-84(V).— The TACAN control box (fig. 2-13) contains the controls to turn the system on and off, to make mode and channel selections, to control identity tone volume, and to initiate self-test. The control panel includes the GO and NO-GO indicators for the self-test.

RECEIVER-TRANSMITTER RT-1022/ ARN-84(V).— The RT (fig. 2-14) consists of 10 removable modules mounted on a chassis assembly. The front panel contains a spare fuse, temperature gauge, elapse time meter, built-in test (BIT) indicators, and a BIT switch. The front panel also contains the antenna connector jack and a blower motor.

The RT transmits and receives the pulsed RF signals. It detects, decodes, and demodulates the signals after reception. Bearing and slant-range information is computed in the RT along with processing of the beacon identification signals. When the self-test switch is pressed on the control box, the RT processes the test signals.

SIGNAL DATA CONVERTER CV-2837/ ARN-84(V).— The signal data converter (fig. 2-14) is mounted to the back of the RT. There is an elapse time meter on the left side of the converter. This converter electrically connects the mount and the RT.

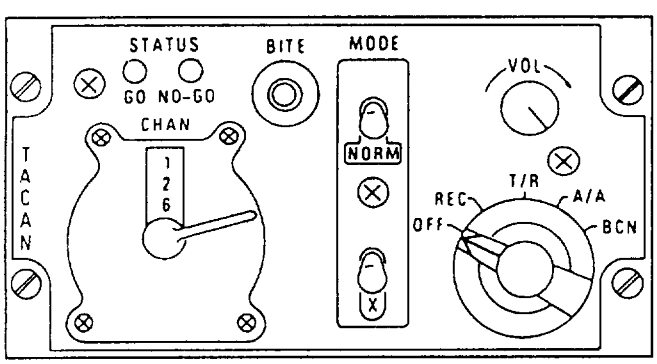


Figure 2-13.-TACAN control panel C-9054/ARN-84(V).

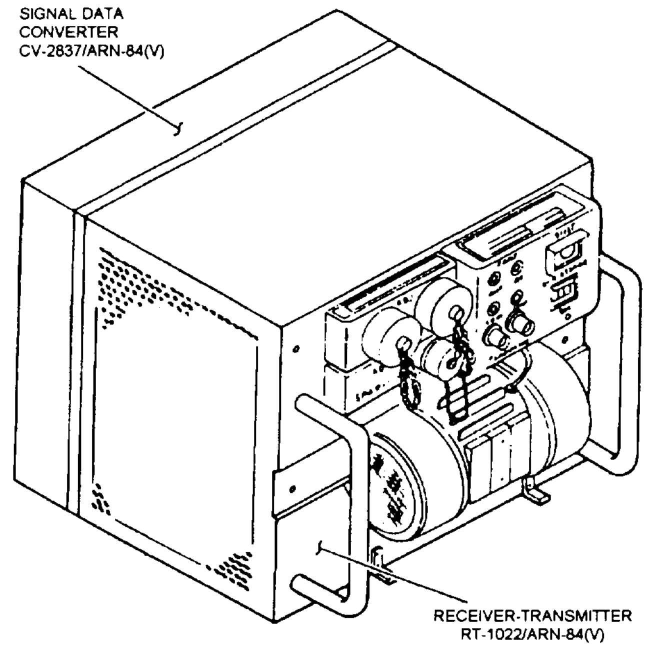


Figure 2-14.-TACAN receiver transmitter and signal data converter.

The signal data converter contains the range and bearing couplers, an interface, and a buffer. This box sends the range and bearing data to the indicator group to be displayed on the indicator. The buffer regulates the power for the system and acts as an interface between the RT and the mount. The interface network enables the range, bearing, operating mode, channel number, data link, and digital data to be transferred to the indicator group.

RF TRANSMISSION LINE SWITCH SA-1818/A.— This switch is an auxiliary unit of the system. It enables the TACAN set to select the antenna receiving the strongest signal.

ANTENNA ASSEMBLY AS-2628/A.— The UHF L-band blade antennae house the antenna elements used by the TACAN antenna system. These antennae are used by both the TACAN and the UHF communication sets.

Operation

Only three of the operating modes will be discussed here. They are the receive, transmit/ receive, and air-to-air modes. The fourth mode, beacon, is not used in most aircraft.

RECEIVE MODE.— In the receive mode, the system will provide bearing and station identity only. The transmitter is disabled to ensure that radio silence is assured. The TACAN set receives coded AM RF pulse pairs from the ground station. It then detects, decodes, and demodulates the signal to extract the bearing and identity signals. The bearing signal is then sent to the indicator group, and the identity signal is sent to the ICS group.

TRANSMIT RECEIVE MODE.— In the T/R mode, the system provides range and bearing to the ground station and station identity information. To measure the slant-range to the ground station, the TACAN transmits an interrogation signal to the station. The station then sends a reply signal, which is detected and decoded by the TACAN set. The range is computed by measuring the elapsed time between transmission of the interrogation pulse and the reception of the reply. The range and bearing information is then sent to the indicator group, and the station identification signal is sent to the ICS group.

AIR-TO-AIR MODE.— The TACAN set is used to measure range between two or more similarly equipped aircraft in the air-to-air mode. To accomplish this, each TACAN set transmits interrogation pulses, receives interrogation pulses from other TACAN sets, and transmits a reply pulse when interrogated. Interrogation signals consist of a coded pulse pair, and the reply is a single pulse. The system will measure the elapsed time between the transmitted interrogation and the reply received to compute range. When using this mode, one aircraft must use a channel that is either 63 channels higher or lower than the other aircraft.

Self-Test

There are two types of self-test used by the TACAN system. They are the readiness monitoring and the interruptive self-test.

READINESS MONITORING.— Readiness monitoring is continuously ongoing self-test. The self-test module is monitoring critical system performance parameters without interrupting system operation. If any one of the continuously monitored parameters degrades beyond limits, a NO-GO indicator will light on the control panel, as well as on the RT faceplate. When the power supply reaches + 125°C (±5°C), the self-test module will light the TEMP indicator on the RT faceplate.

INTERRUPTIVE SELF-TEST.— This self-test is initiated by the operator depressing either of the BIT switches on the control panel or the RT. The test can be performed on any of the channels or in any of the modes of operation. If there are no faults found, range will display 1.8 nautical miles, bearing will display 4 degrees, and the GO indication will be displayed for 9 seconds on the TACAN control panel. If there is a fault, the NO-GO indicators will light in the same manner as in readiness monitoring.

LONG RANGE NAVIGATION (LORAN)

The name loran is an appropriate description of the hyperbolic system of electronic navigation. It provides lines of position over the surface of the earth. Over water, usable loran signals can be received at ranges up to 2,800 miles. This is done with low-frequency radio waves. At these operating frequencies, radio waves are capable of following the curvature of the earth.

Loran lines of position can be crossed with each other, or with lines of positions determined by other means, to provide fixes. Loran lines are stationary with respect to the earth's surface. Their determination is not dependent upon compass or chronometer, and it is not necessary to break radio silence to obtain them. Loran signals are available for reception in all types of weather, except during very severe electrical storms.

For more information on the theory of operation of loran, refer to *Aviation Electronics Technician 2 (Organizational),* NAVEDTRA 12330, chapter 3.

Major Components

The AN/ARN-81 loran receiving set consists of three major components. They are the R-1336/ARN-81 receiver, the IP-796/ARN-81 display indicator, and the C-6604/ARN-81 control indicator.

The receiver processes the input signals and routes them to the display. The display provides a means to align the pulses to determine the aircraft position. The control indicator provides selection of power, operating modes and channels, and delay times.

System Functions

The loran receives signals through the ADF sense antenna. The signals are routed from this antenna to the R-1336/ARN-81 receiver. At the receiver, the signals are amplified, heterodyned, and detected to provide video output signals, which are applied to the video amplifier. This signal is then applied to a high-gain amplifier that supplies two outputs. One of the outputs is used for the automatic frequency control (AFC) circuits. The other output is routed to the summing network, which provides a composite video output to the display indicator.

The display indicator displays the video on the CRT. The operator can then set the position by aligning the master and slave pulses and reading the time delay. This information is then plotted on a chart to determine aircraft position.

Loran-D uses the same theory of operation,but it is used in conjunction with the navigational computer. With this system, the indicator automatically displays the latitude and longitude of the aircraft. The operator just has to plot this information on a chart to determine position.

OMEGA

The omega navigation system is an outgrowth of the loran A and loran C systems. It is a worldwide network of eight transmitting stations that provide a means of navigation accurate to within 4 nautical miles anywhere in the world.

Theory of Operation

The AN/ARN-99(V) omega navigation set provides digital data representative of aircraft phase displacement to any combination of eight selected omega ground stations. These eight ground stations broadcast 10 kW in the VLF band at 10.2 kHz, 11.3 kHz, and 13.6 kHz. These stations are strategically positioned around the world so their combined propagation will cover the entire surface of the earth.

Each station transmits burst of the three different frequencies during a 10-second period, which are multiplexed so that only one station is on at one time on one frequency. All signals are transmitted starting at zero time (omega time), and maintained at the exact starting time by using atomic clocks at each station.

The omega system in an aircraft must synchronize itself to this pattern. Synchronization is done by analyzing all the signals received in the 10.2-kHz frequency over one 10-second period. This period is broken up into 100 intervals of 0.1 second each. The beginning of each of these 0.1-second intervals is then considered a possible starting point. The signal levels are averaged over small intervals during the remaining 9.9 seconds of the pattern for each of the 100 intervals, and then all are compared with the predicted levels.

Only one start time fits into the predicted pattern. When this start time is found, the omega system knows where each frequency is originating from during each burst. It can then make the proper measurements from each station. If the system cannot synchronize at 10.2 kHz, it will try to synchronize at 11.3 kHz and then at 13.6 kHz.

The omega system uses the great circle distances to all stations. This is done to ensure that the effects of modal interference (interference between the primary wave and the sky wave and/or ground wave) and wrong way propagation do not bias the measurements. The stations less than 600 or more than 7,200 nautical miles from the aircraft are not used for the measurements. They are deselected and their strength readings indicate zero. Station range and bearings are recomputed every 10 seconds in the burst filter routine, and station selection/reselections correspondingly made.

The omega system can use either the hyperbolic or the circular (RHO-RHO) method to process this data. The P-3C uses the circular measurement process, which measures phase from each station directly. With RHO-RHO processing, a line of position is generated from each station by direct measurement of the omega signal received from that station. Using another station and again generating another line of position, the position fix is found. The advantage of this method is that only two stations are required to establish a geographical fix. The disadvantage of this method is its need to establish the oscillator error of its receiver before the omega signals can be used.

Since circular processing measures phase directly, it must subtract oscillator error from the measurement to be accurate. The RHO-RHO method uses a software routine based on many measurements to solve for this error. The omega on the P-3C is totally dependent on the central computer for operation. There are no operating controls or indicators other than the elapsed time meter and the power control panel.

Components

The AN/ARN-99(V) consists of three major components. These components are a control panel, an antenna coupler, and a receiver-converter.

OMEGA POWER CONTROL PANEL.— The 960767 omega power control panel (fig. 2-15) controls the power to the omega system. When switched on, it supplies 115 volts ac and 28 volts dc to the omega receiver.

ANTENNA COUPLER.— The AS-2623/ ARN-99(V) antenna coupler has two loop antennas mounted at 90-degree angles to each other and at 45-degree angles to the aircraft centerline. These antennae are directional, and the proper antenna selection is based upon location to the station being received, relative to the heading to the aircraft. One of the four antenna lobes is selected (A+, B+, A-, or B-) to give the receiver-converter the maximum signal strength from the desired omega ground station. Once the omega has been synchronized, the antenna selection process is automatically controlled by the central computer.

RECEIVER-CONVERTER.— The OR-90/ ARN-99(V) receiver-converter consists of five sections. These sections are the receiver section, correlator and digital converter section, computer communication section, discrete storage section, and the power supply section.

Receiver Section.— The receiver section consists of the antenna switching matrices, RF amplifiers, IF amplifiers, and a precision frequency generator.

The antenna switching matrices sum and phase shift the incoming signals to provide an antenna configuration that will be best oriented to a specific omega station. These circuits also enables test signals to be injected into the omega system. There are three of these matrices in this section, one for each of the operating frequencies.

The RF amplifiers remove the IF image and provide attenuation to remove signals far from the operating frequency. There are three of these circuits, one for each frequency, with the only difference between them being the tuning of the bandpass filters and the notch filters. The heterodyne mixers are identical for all three.

The local oscillator frequencies produce a 1.33 kHz IF signal. Each frequency used has its own IF amplifier circuit; these circuits are identical for all three frequencies. The limiters in the circuit control the dynamic signal level in the amplifier, preventing saturation of the linear filters.

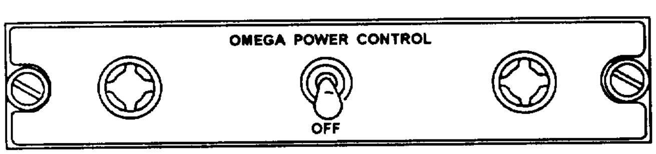


Figure 2-15.-Omega power control panel.

The precision frequency generator generates the precision frequency signals required for operation of the system. The generator consists of a 10.608 MHz crystal oscillator and counters. The counters divide the oscillator frequencies to provide a 13.6 kHz RF test signal, a 1.133 kHz IF reference signal, a 14.733 kHz local oscillator signal, a 176.8 kHz receiver-computer input/output clock signal, a 11.333 kHz RF test and local oscillator signal, and a 10.2 kHz RF test and local oscillator signal.

Correlator and Digital Converter Section.— This section converts the phase of the IF signals into digital form. The three channels use identical phase converters. The phase of the IF signal is the navigation information needed by the central computer.

Computer Communication Section.— The receiver-converter operation is computer controlled and cannot be operated manually. This section provides a means of communication between the receiver-converter and the central computer. This section receives data requests from the computer and sends the desired data to the computer.

Discrete Storage Section.— This section provides a means of storing and controlling antenna switching and test signal gating commands from the central computer for use in the receiver-converter. The discrete storage consist of control line drivers and a decoder circuit. It acts as an interface between the communication section and the receiver sections.

Power Supply Section.— The power supply generates regulated and unregulated dc voltages for the system. The power supply also provides for short-circuit protection and for overvoltage protection. The short-circuit protection is for the three regulators, (+16, +5, and -16 Vdc regulators). A short in any of these will cause the regulator to be clamped to ground, and the power supply will need to be reset. The overvoltage protection is for the +5 Vdc circuit. When the output of the +5 Vdc exceeds the breakdown voltage of the Zener, a relay is energized that removes the input power. When this occurs, system power needs to be cycled to reset the protection circuits.

DOPPLER

In the following text we will discuss the AN/APN-153(V) navigation set. For more information on the basics of the Doppler theory, refer to *Aviation Electronics Technician 2 (Organizational),* NAVEDTRA 12330.

The AN/APN-153(V) navigation set is a self-contained, airborne, pulsed Doppler radar system. It is designed to provide navigation data to the navigation computers onboard various aircraft. This system automatically and continuously provides ground speed and drift angle information to the computer. This information is then used for the dead reckoning of the aircraft without the aid of wind estimates or true airspeed.

The system operates without the use of ground installations over an unlimited geographical range. Weather does not affect the system performance. The navigation set is accurate from 40 feet to 50,000 feet over land and water that has a sea state of 1 or greater. Ground speed is accurate from 80 to 800 knots, with the drift being accurate to 40 degree right or left. This system is difficult to jam because of the directivity and narrow width of the microwave beam transmission and the variation of PRF.

Theory of Operation

The Doppler system determines the ground speed and drift angle components by measuring the frequency shift in received echoes. In other words, the system beams signals to the ground, receives the return echoes, and then measures the frequency shift produced by the relative motion between the aircraft and the earth. Since the aircraft moves both along its length and across its length, more than one beam is required. The AN/APN-153(V) uses four. These four beams strike the ground at the corners of a rectangle. The system is pulsed so that only two beams (diagonally opposite) are transmitted or received at a time. Of these, aircraft motion shifts the forward beam up in frequency and the rearward down in frequency. These two shifts are compared, and a difference signal for the pair is formed. Then the other two beams are used. The two difference signals are then compared, and an azimuth motor rotates the antenna to make and keep them equal. This keeps the antenna aligned with the ground track. Since the drift angle is derived directly from antenna position, drift angle accuracy is not affected by signal quality, terrain, or sea state, as long as any echo at all is received. Once the antenna is aligned with the ground track the measured frequency shift is used to derive ground speed. The drift angle and the ground speed information is then sent to the navigation computer as inputs for dead reckoning navigation.

Major Components

There are three major components in the AN/APN-153(V) system. They are the Receiver-Transmitter RT-680A/APN-153(V), Antenna AS-1350/APN-153(V), and the Control Indicator C-4418A/APN-153(V).

RECEIVER-TRANSMITTER.— The RT-680A/APN-153(V) contains the transmitter, receiver, and the frequency tracker circuits (fig. 2-16, view A). It is essentially a conventional radar system that uses a magnetron power oscillator whose PRF is varied by a sawtooth voltage. The receiver is a superheterodyne receiver, where the two signals are amplified, mixed, and detected. The resultant detector signal is a single audio signal. This audio signal is then filtered, amplified, and sent to the frequency tracking circuits. Here, the signal is mixed with the output frequency generator in the main tracking loop. Any difference between the two is amplified and phase detected. The resulting voltage is fed to the frequency generator, which makes its frequency equal to the received audio. The received audio is a function of the Doppler shift, and, therefore, is the ground speed.

ANTENNA.— The AS-1350/APN-153(V) contains the microwave plumbing, pitch and roll rotary couplers, antenna arrays, and the pitch and roll servo networks that maintain the arrays in level position during aircraft motion (fig. 2-16, view B). The antenna pitch and roll data used for leveling are obtained from the course attitude data transmitter group of the aircraft.

The antenna takes the RF pulses from the RT and radiates them in two patterns emitted alternately at half-second intervals. It then receives the return echoes and feeds them to the RT. The antenna also takes the signal from the detector in the main tracking loop to position the antenna arrays parallel to the aircraft's ground track. The array position, which now represents aircraft drift angle, is fed to a servo follow-up in the control panel.

CONTROL INDICATOR.— The C-4418A/APN-153(V) contains the controls and indicators required for system operation (fig. 2-16, view C). The control indicator applies system power, selects the mode of operation, indicates ground speed and drift angle, and indicates when the system is in the search mode.

The signal representing drift angle from the antenna is fed to the servo follow-up in the indicator and positions the DRIFT angle dial to the correct drift angle. The RT develops a voltage proportional to the frequency of the frequency generator, which is then fed to a servomotor in the indicator. This servomotor positions the GND SPEED dial to indicate the ground speed. The mode switch should be set to the LAND position when the aircraft is overland, and to the SEA position when over the sea.

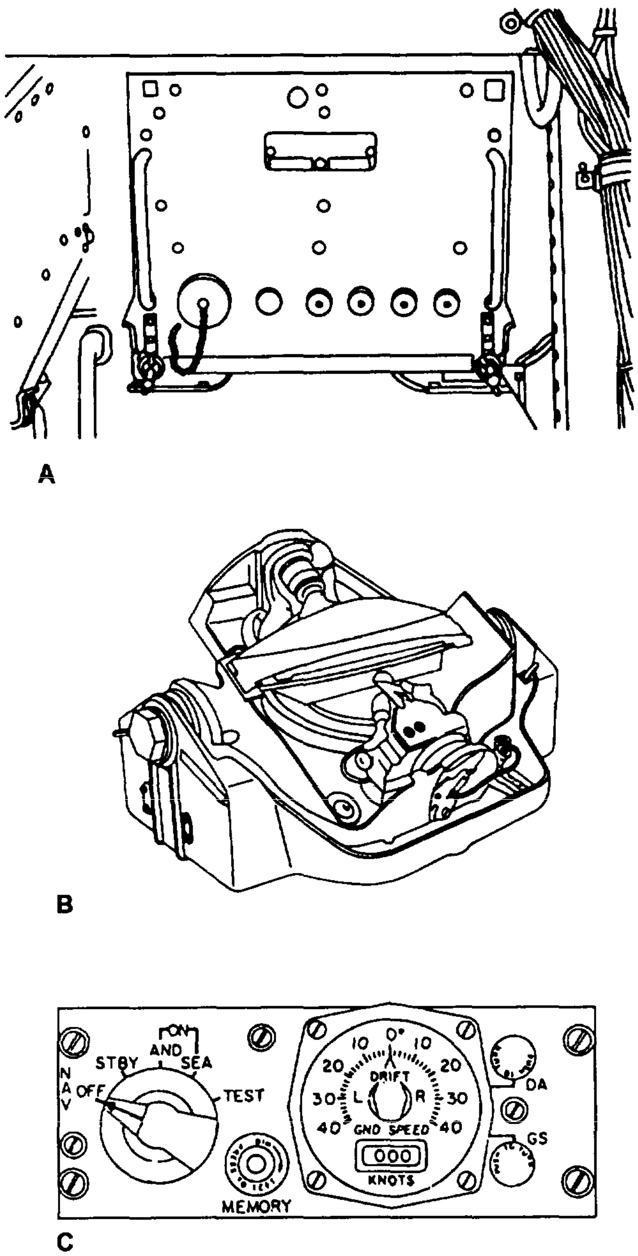


Figure 2-16.-AN/APN-153(V) components. A. RT-680A/APN-153(V). B. AS-1350/APN-153(V). C. C-4418A/APN-153(V).

With the mode switch in the TEST position, you should get the following indications after a 1-minute delay:

- MEMORY light is off.
- GND SPEED dial indicates 121±5 knots.
- DRIFT angle dial indicates 0±2°.

The memory light indicates that the audio from both radiated patterns is lost. This means that the system cannot provide accurate information. The two indicators will be locked at the present readings until the RT starts to receive good signals.

REVIEW QUESTIONS

Q1. *What is the definition of direction?*

Q2. *What is the difference in miles between the highest and lowest points of the earth's crust ?*

Q3. *What are the imaginary reference lines used to locate points on the earth called?*

Q4. *What is the definition of absolute altitude?*

Q5. *In the counter-pointer display, how many revolutions does the pointer make per 1,000 feet of altitude?*

Q6. *What is the reliable altitude range for the AN/APN-194(V) radar altimeter?*

Q7. *How is the barometric switch in the RAWS system reset prior to flight?*

Q8. *What are the operating modes of the ADF system?*

Q9. *What TACAN operating mode ensures that radio silence is maintained?*

Q10. *What are the three operating frequencies used in the omega system?*

Q11. *What are the two pieces of data information provided by the AN/APN-153(V) Doppler system?*

CHAPTER 3

RADAR

As an avionics supervisor, you must be knowledgeable of the operation principles of various complex search radars, fire control radars, IFF sets, and the associated peripheral equipment. Chapter 2 of *Aviation Electronics Technician 2 (Organizational),* NAVEDTRA 12330, explains the basics of radar. This chapter discusses the search radar found on the P-3C aircraft, the fire control training device 11D13A, and the IFF system found on the S-3 aircraft. The peripheral equipment, such as the tactical displays, computers, and navigational systems, are discussed in other chapters of this TRAMAN. (See table of contents.)

SEARCH RADAR SYSTEM

Learning Objective: *Recognize components, operating principles, and characteristics of a typical search radar system.*

The AN/APS-115B radar set used in the P-3C aircraft is an airborne, X-band search radar system. It provides detection and surveillance of submarines operating under snorkel conditions, surface vessels, and aircraft. It is made up of two radar receiver-transmitters, two antennas, two radar controls, an antenna control, an antenna position programmer, an antenna parking control, an antenna scan control, and a radar interface unit. The receiver-transmitters are selective, long and short pulse-type radar receiver-transmitters. The antennas are located in the nose and the aft of the aircraft, providing 360-degree azimuth coverage. Radar search scan and data pickup are performed independently by each radar set.

The antenna position programmer (APP) combines video information from both radar sets. The APP then sends this information to the radar interface unit (RIU), which sends it to the sensor data display (SDD) for display.

The two antennas are tilt-stabilized by servomechanisms, receiving pitch and roll data from the central repeater system (CRS). The tilt of the antenna can move from 20 degrees down to 10 degrees up, referenced to the horizontal. Antenna scan is selectable to either full (360 degrees) or sector (45-degree scan about a selected heading). With only one antenna system, the scan can be no more than 240 degrees in azimuth. Either antenna may be stopped to searchlight a specific area. With both antennas in full scan, the crossover points are at 90 and 270 degrees relative to aircraft heading. In sector scan, crossover points are at 120 and 300 degrees when the antennas are rotating in a clockwise direction. The crossover points are 60 and 240 degrees when they are rotating in a counterclockwise direction (fig. 3-1).

The nonacoustic sensor operator station displays the search radar information. The display presentation is true north or aircraft heading stabilized, with a computer-generated symbol depicting aircraft true course. The nonacoustic operator station contains the radar systems operating controls.

AN/APS-115B MAJOR COMPONENTS

The APS-115B search radar system includes the following equipment:

- C-7511A/APS-115 radar antenna control panel
- MX-7930/APS-115 antenna position programmer
- RT-889/APS-115 receiver-transmitter
- AS-2146/APS-115 antenna
- A361 antenna elevation parking control
- C-7512/APS-115 radar control panel
- C-7557/ASA-69 radar scan converter control
- MX-7974/ASA-69 radar interface unit

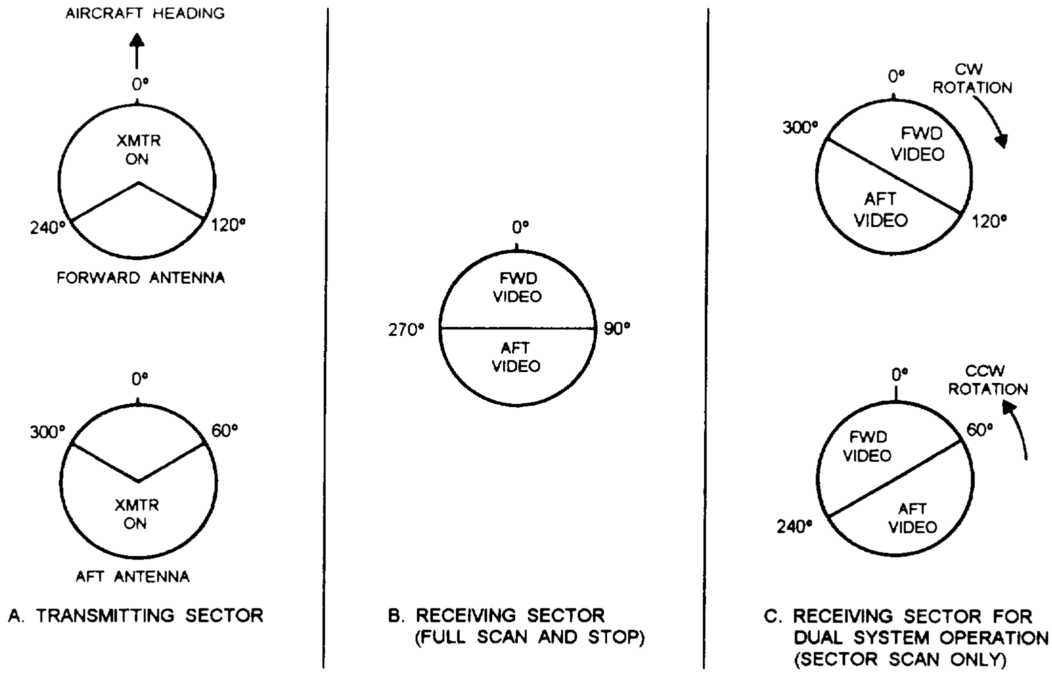


Figure 3-1.-Azimuth scan coverage.

C-7511A/APS-115 Radar Antenna Control Panel

The C-7511A/APS-115 (fig. 3-2) controls both of the radar antennas. There are six controls available to the operator for getting the presentation desired.

TILT KNOB.— This knob gives the operator the ability to vary the tilt of the antenna manually. The range of manual tilt is from +10 degrees to –20 degrees from aircraft horizontal.

NORTH STAB/HEADING STAB PUSH BUTTON.— With NORTH STAB selected (illuminated amber), the presentation displayed will be north stabilized. 000° displayed will be true north. With HEADING STAB selected (illuminated amber), the presentation will be heading stabilized. 000° displayed will be aircraft heading. Pressing the push button will alternately select NORTH or HEADING.

STAB/OUT SWITCH.— With STAB selected, the antennas will automatically correct for aircraft pitch and roll attitude changes. Mechanical limit for antenna stabilization is ±30 degrees, with respect to the aircraft. With OUT selected, the antenna stabilization is disabled.

SCAN SWITCH.— There are three selections possible to the operator. The FULL selection causes the antenna scan to be 360 degrees during dual system operation. The antenna scan will be 240 degrees during single system operation. In the SECTOR position, the antennas will scan 45 (±4) degree sectors. This sector will center around the position established by the ANT HEADING control. With STOP selected,

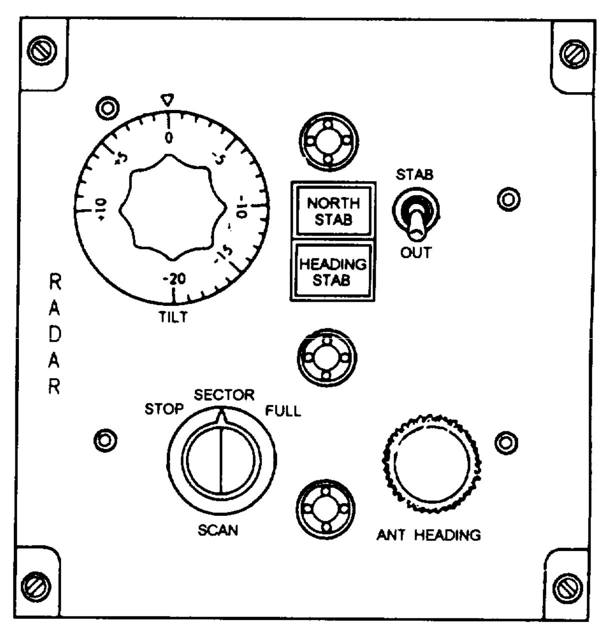


Figure 3-2.-C-7511A/APS-115 radar antenna control panel.

the antennas will stop at the position established by the ANT HEADING control.

ANT HEADING KNOB.— This knob provides control to change the heading of the antenna if the SCAN switch is in the SECTOR or STOP position.

TILT ALIGN ADJUSTMENT SCREW.— This control is located on the right side of the control box. It provides a limited amount of adjustment to align the tilt axis of the aft antenna to the tilt axis of the forward antenna due to boresight errors.

MX-7930/APS-l15 Antenna Position Programmer (APP)

The antenna position programmer (fig. 3-3) ties the forward and aft systems together. It generates the azimuth and tilt drive signals for the antenna drive motors. The APP also generates timing and synchronization signals for the receiver-transmitters, radar interface unit (RIU), and IFF. It combines the forward and aft video returns into composite signals for full 360-degree coverage. The APP contains self-test circuits for automatic fault detection and isolation, along with logic circuits for proper radar functions (pulsewidth, PRF, scan speed, and so forth).

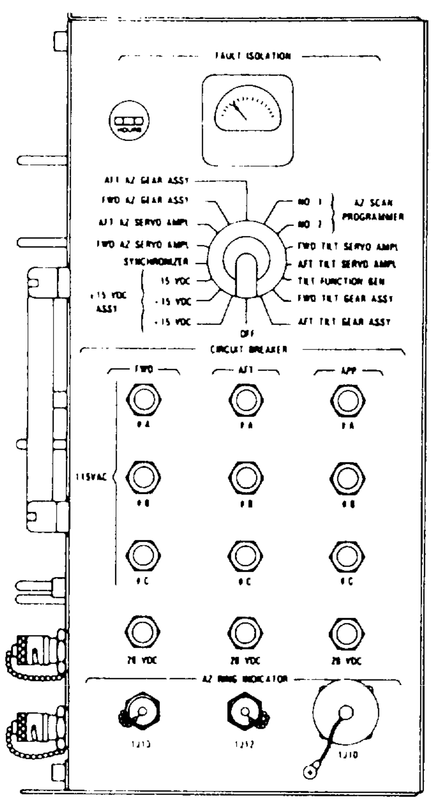


Figure 3-3.—MX-7930/APS-115 antenna position programmer.

On the face of the AFP, there are several operating devices. These are the circuit breakers, fault isolation meter, fault isolation switch, and an elapsed time meter.

CIRCUIT BREAKERS.— There are nine breakers on the APP. Three are for applying power to the forward system, three for applying power to the aft system, and three for applying power to the APP itself. Each circuit breaker applies one phase of 115 volts ac to its appropriate place.

FAULT ISOLATION METER.— The fault isolation meter provides GO/NO-GO indications of the BITE signals selected by the fault isolation switch.

FAULT ISOLATION SWITCH.— The fault isolation switch enables the technician to select the desired BITE signal for display on the fault isolation meter. This allows the technician to perform maintenance on the radar systems. Ensure that this switch is positioned to OFF for normal mode of operation.

WARNING

Rotation of the fault isolation switch will override radome safety interlock switches, possibly causing personnel injury.

CAUTION

Rotate fault isolation switch on the antenna position programmer clockwise only. Equipment damage may otherwise result.

RT-889/APS-115 Receiver-Transmitter

The receiver-transmitter generates the high energy RF radar transmission pulses, and receives the reflected target pulses. A pressurized waveguide system connects each RT to its respective antenna. Each RT is controlled by its own control box through the APP.

There are four major functional subsections in each receiver-transmitter. These subsections are the transmitter, the receiver, the waveguide pressurization system, and the BITE circuitry.

The transmitter contains a high-voltage power supply, modulator control circuitry, the modulator, and the magnetron RF output stage. Output pulses and transmitter output frequencies are generated in the transmitter. The magnetron output RF is waveguide coupled to the antenna for propagation.

The transmitter consists of the necessary components to accept the synchronization signals from the APP and generate an output pulse. This pulse is then fed into the waveguide system and radiated out of the antenna. The transmitter system is conventional except for the frequency agile magnetron. The magnetron is mechanically modulated at 75 Hz to vary the output pulse frequency over a 60 MHz (nominal) range. This is accomplished with a motor-driven tuner that physically changes the interior characteristics of the magnetron. This agility enhances the clutter elimination capabilities of the system, and it is an option available to the operator.

The basic transmitter characteristics are as follows:

Frequency:	8.5 to 9.6 GHz, manually tunable
Peak Power:	143 kW minimum
PRF:	1600 Hz, line locked with 0.5 microsecond pulsewidth (short pulse)
Agility:	60 MHz nominal, 40 MHz minimum

The receiver system includes an AFC-controlled local oscillator, IF amplifiers, video detecting and processing circuits, range mark generating circuit, and BITE circuitry. The receiver processes received echo pulses, converts them to video, and delivers them to the APP for subsequent distribution and display. A solid-state, frequency-agile AFC system allows continuous tuning of the receiver local oscillator to track the transmitter and provide a 60-MHz IF amplifier input. The receiver agile modulator-demodulator generates the synchronization, which locks the transmitter and the receiver AFC together.

The waveguide pressurization system consists of an air pump and a replaceable, air-drying desiccant cartridge. The pump furnishes dry pressurized air for the waveguides between the RT and the antenna. This pressurized air prevents arcing in the waveguide when the aircraft is flying at high altitudes.

The BITE circuits perform continuous monitoring of vital functions within the RT. The fault isolation meter and switch provide a means of monitoring selected functions to aid the technician in the removal and replacement of faulty components.

Figure 3-4 shows the controls on the RT-889/APS-115. There is a fault isolation switch and meter for checking the operation of the receiver-transmitter. The AFC section allows the operator to select the AFC required. There is also an elapsed time meter and two power reset circuit breakers.

CAUTION

Return fault isolation switch to the OFF position during normal operation. Failure to do so will result in improper operation of the system.

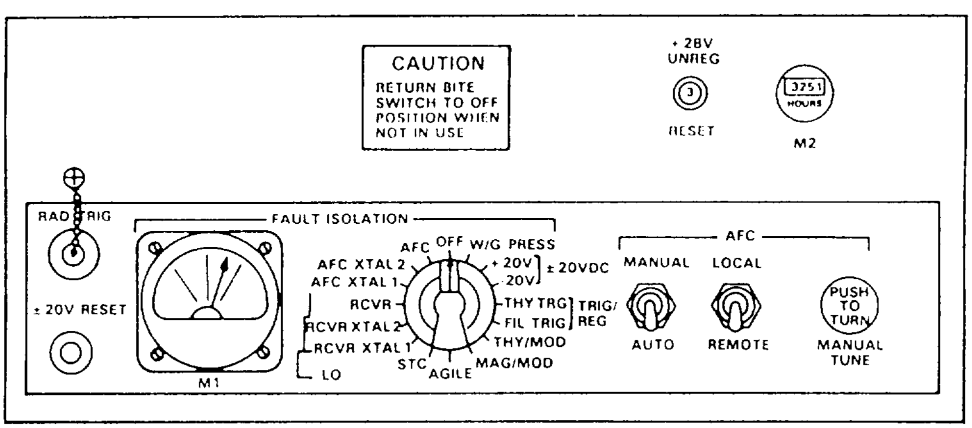


Figure 3-4.-RT-889/APS-115 receiver-transmitter control panel.

AS-2146/APS-115 Antenna

The radar antenna radiates the transmitter pulses in either a pencil beam mode or a cosecant squared (spoiled) beam mode. The mode of radiation is not operator selectable. A spoiler must be physically added to the antenna dish if the spoiled beam operation is required. This spoiler causes the beam to be a wide vertical beam.

The basic characteristics of the antenna are as follows:

Scan speed:	6 RPM with 2.5 microsecond pulsewidth or 12 RPM with 0.5 microsecond pulsewidth
Radiation pattern:	Pencil beam 2.5 by 3.8 degrees; spoiled beam 2.5 by 20 degrees
Scan modes:	45-degree sector, 360-degree full scan, 240-degree sector (single system operation)
Manual tilt:	+10 to –20 degrees
Tilt stabilization:	Pitch and roll ±30 degrees

A361 Antenna Elevation Parking Control

The antenna elevation parking control is used to stow the aft antenna in a zero-degree elevation attitude, relative to the aircraft, when the aft radar is in the standby mode.

C-7512/APS-115 Radar Control Panel

There are two radar control panels (fig. 3-5), one for the forward and one for the aft system. This control panel enables the operator to turn the system on and control most of the functions of each system. There are 12 function switches and 2 fail lights on each control box.

WARNING

Ensure power is applied to the RADAR SCAN switch on the C324 TACCO control panel prior to applying power to the APS-115 radar system. If the RADAR SCAN switch is left off and then turned on after power is applied to the APS-115, the system will automatically cycle to high voltage on.

FREQ PUSH BUITON.— This push button has two positions. With FIXED selected, the system will be in the fixed frequency mode of operation. With AGILE selected, the system will be operating in the sweep frequency mode. This mode is used in high clutter areas to improve target definition.

PULSE PUSH BUTTON.— The operator uses this button to select either LONG or SHORT pulsewidths for the system. In the LONG mode, the system has a 2.5 μsecond pulsewidth, 400 pps PRF, and 6-RPM antenna scan rate. In the SHORT mode, the system has a 0.5 μsecond pulsewidth, 1600 pps PRF, and 12-RPM antenna scan rate.

HV PUSH BUTTON.— This is the high-voltage select switch. There are three indications on the switch, of which only two are selectable. As soon as the system power is turned on, the WARMUP section illuminates. This section will remain illuminated until the system has warmed up. The operator cannot apply high voltage until the system has warmed up sufficiently. After approximately 3 minutes of

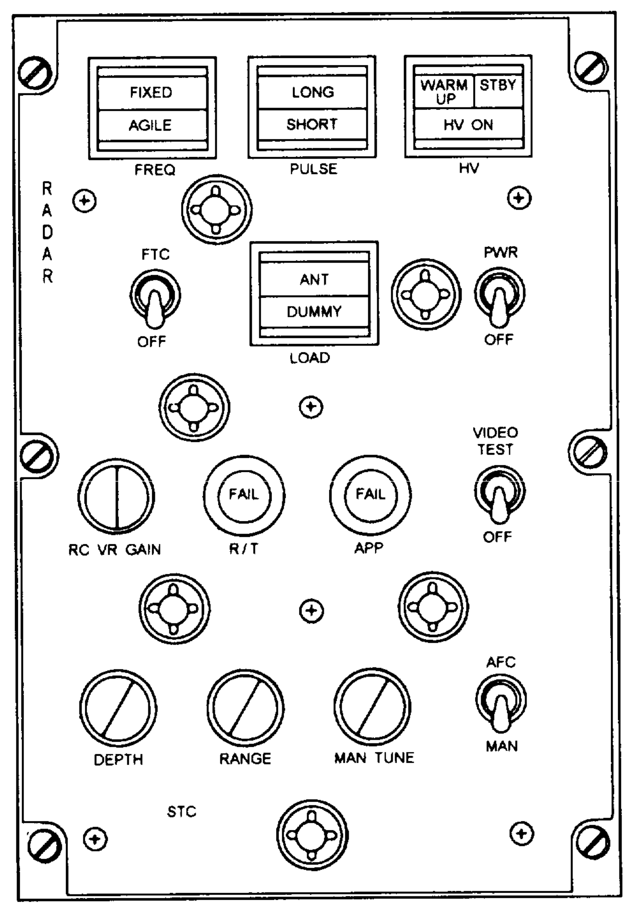


Figure 3-5.-C-7512/APS-115 radar control panel.

warm-up time, the WARM-UP section will extinguish, and the STBY section illuminates. This tells the operator that the system is ready for use. Press the HV push button now to apply the radar operating power. When the operating power is applied, the HV ON section will illuminate. Press the push button to alternately select HV ON and STBY.

FTC SWITCH.— This switch controls the receiver's fast time constant circuitry. With this switch in the FTC position, the targets displayed have strong leading edges and attenuated trailing edges. This improves the display when the target is near a landmass.

LOAD SWITCH.— This switch controls the waveguide switch on the ante ma unit. When the ANT section is illuminated, the RF energy is actually radiated by the antenna. In the DUMMY mode of operation, the RF energy is fed into the dummy load on the antenna. In this mode, there is no radiation out of the antenna

CAUTION

Ensure the radar system is in STBY prior to selecting or deselecting DUMMY Load to avoid damaging equipment.

PWR SWITCH.— This is the system power switch. It applies power to the system and starts the warm-up period.

RCVR GAIN KNOB.— This knob controls the receiver gain of the system. The operator will adjust the gain until the radar noise levels are matched between the forward and aft radars.

VIDEO TEST SWITCH.— This switch will select the video self-test circuitry in its respective RT for an overall performance check. If the PULSE push button is in the LONG position, the display should show simulated targets 1 nautical mile apart. In the OFF position, the system is in the normal mode of operation.

STC DEPTH KNOB.— This knob will vary the amount of receiver attenuation for close-in targets. It is used in conjunction with the STC RANGE knob.

STC RANGE KNOB.— This knob varies the range to which the intensity of target return is effectively reduced. It will vary the range between 0 and 20 nautical miles. If both the DEPTH and the RANGE knobs are rotated fully clockwise, close-in targets could be blanked from the display.

AFC/MAN SWITCH.— This switch selects either the AFC mode or the manual tuning mode of operation. In the AFC position, the local oscillator has the automatic frequency control circuitry connected to it. With this switch in the MAN position, the operator can manually tune the local oscillator. If the system is manually tuned correctly, there should be no difference in the video in either position. The system is locked in the fixed-mode of operation if this switch is in the MAN position, regardless of the position of the FREQ push button.

MAN TUNE KNOB.— This is the knob the operator rotates to manually tune the local oscillator when the AFC/MAN switch is in the MAN position.

FAIL LIGHTS.— There are two lights located on the control panel to indicate there is a problem with the system. One is the RT light, and the other is the APP light. The RT light will illuminate when the receiver-transmitter BITE circuitry detects a failure in the RT. The APP light will illuminate when the BITE circuitry detects a failure in the antenna position programmer.

C-7557/ASA-69 Radar Scan Converter Control

The radar scan converter (fig. 3-6) and associated components provide the interface between the data processing system and the APS-115 radar set. It also

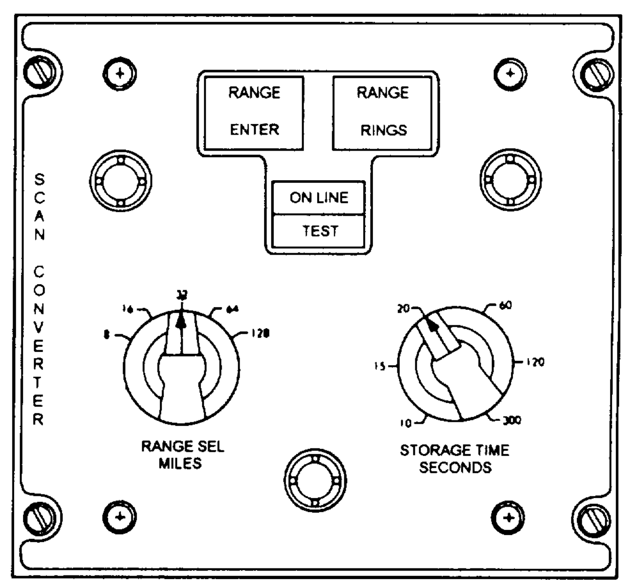


Figure 3-6.-C-7557/ASA-69 radar scan converter control

completes the processing of radar and IFF video for on-line/off-line display. It works in conjunction with the radar interface unit (RIU). The converter control routes the on-line/off-line selection to the RIU. There are five controls on the converter, of which four are used for off-line operation.

ON LINE/TEST SWITCH.— This push button is used to select on-line/off-line operation of the radar set. When the ON LINE section is illuminated, the RIU is slaved to the nonacoustic operator's keyset. In this mode of operation, all the manual selections on the RIU front panel are deactivated. The only exception to this is the power switch.

If you press the push button switch, it will illuminate the TEST section of the switch. With this section illuminated, the radar set is in the off-line mode of operation. This means the RIU will respond to inputs from the RIU front panel.

RANGE SEL MILES SWITCH.— This switch enables the operator to select radar range during off-line operation. The operator has the option of selecting either 8, 16, 32, 64, or 128 nautical miles.

RANGE ENTER PUSH BUTTON.— This push button enters the radar range, selected on the RANGE SEL MILES switch, into the RIU logic circuits during off-line operation. The indicator push button will illuminate amber, when pressed, denoting entry into RIU logic. The indicator will return to green when released.

RANGE RINGS PUSH BUTTON.— Range rings are added to radar video during off-line operation when this push button is pressed. The indicator will illuminate amber, denoting that the range rings are selected. If you press the push button again, it will deselect the range rings and return the indicator to green. Two range marks are developed for the 8 nautical mile range, four marks for the 16 and 32 nautical mile range, and eight marks for the 64 and 128 nautical mile range.

STORAGE TIME SECONDS SWITCH.— This switch is not used at this time.

MX-7974/ASA-69 Radar Interface Unit

The function of the radar interface unit (RIU) is to provide radar data interface and the command decoding interface. Figure 3-7 shows the control panel located on the RIU. The RIU combines raw radar video from the APS-115 and IFF video from the IFF synchronizer. This video is then amplified and routed to the nonacoustic operator's display.

There are nine operating controls on the control panel of the RIU, of which three are not used. These three are the OFFSET switch, the STOR switch, and the OFFSET X/Y switch. Of the other six, five are deactivated during on-line operation. Only the POWER switch is activated.

POWER SWITCH.— With this switch in the ON-NORMAL position, operating power is applied to the RIU. In the OFF position, there is no operating power applied.

ENTER PUSH BUTTON.— This switch enables the operator to enter commands selected on the front switch panel into the RIU logic circuits. It must be pressed after each selection.

HV ON/OFF SWITCH.— This switch enables high voltage to be turned on or off in the off-line mode. The HV ON/OFF position of the COMMAND SELECTION switch must be selected prior to changing the position of this switch.

COMMAND SELECTION SWITCH.— This rotary switch enables the operator to select the various commands for entry into the RIU logic circuits. The

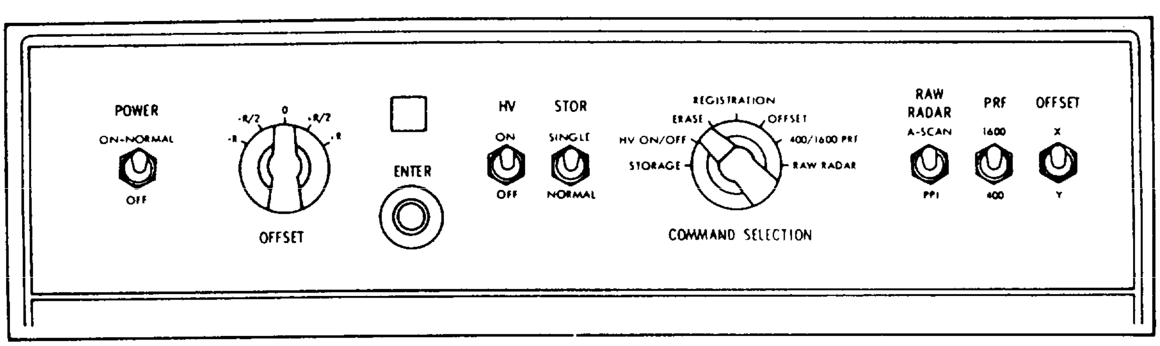


Figure 3-7.-MX-7974/ASA-69 radar interface unit control panel.

operator rotates the switch to the particular command to be changed, changes the corresponding switch, and then presses the ENTER push button.

NOTE: The ENTER push button must be pressed after each selection on the COMMAND SELECTION switch to route each command to the RIU logic.

There are seven positions on this rotary switch. Only three of these positions are used. The usable positions are the HV ON/OFF position, the 400/1600 PRF position, and the RAW RADAR position.

RAW RADAR SWITCH.— This switch allows the operator to select the type of display presentation. The options available are either an A-scan, selected by the A-SCAN position, or a PPI scan, selected by the PPI position.

PRF SWITCH.— This switch enables the operator to select either a 1600 or 400 PRF (long or short pulse mode).

SEARCH RADAR FUNCTIONAL DESCRIPTION

The signal flow block diagram is shown in figure 3-8. The following section will explain in more detail the functional signal flow of the various components.

The forward and aft radar control boxes and the antenna control box provide mode control to the APP for execution and distribution throughout the radar set. The APP processes and coordinates forward and aft antenna position and scan functions, the application of power to both sets, and controls transmit and receive modes of the two RT's.

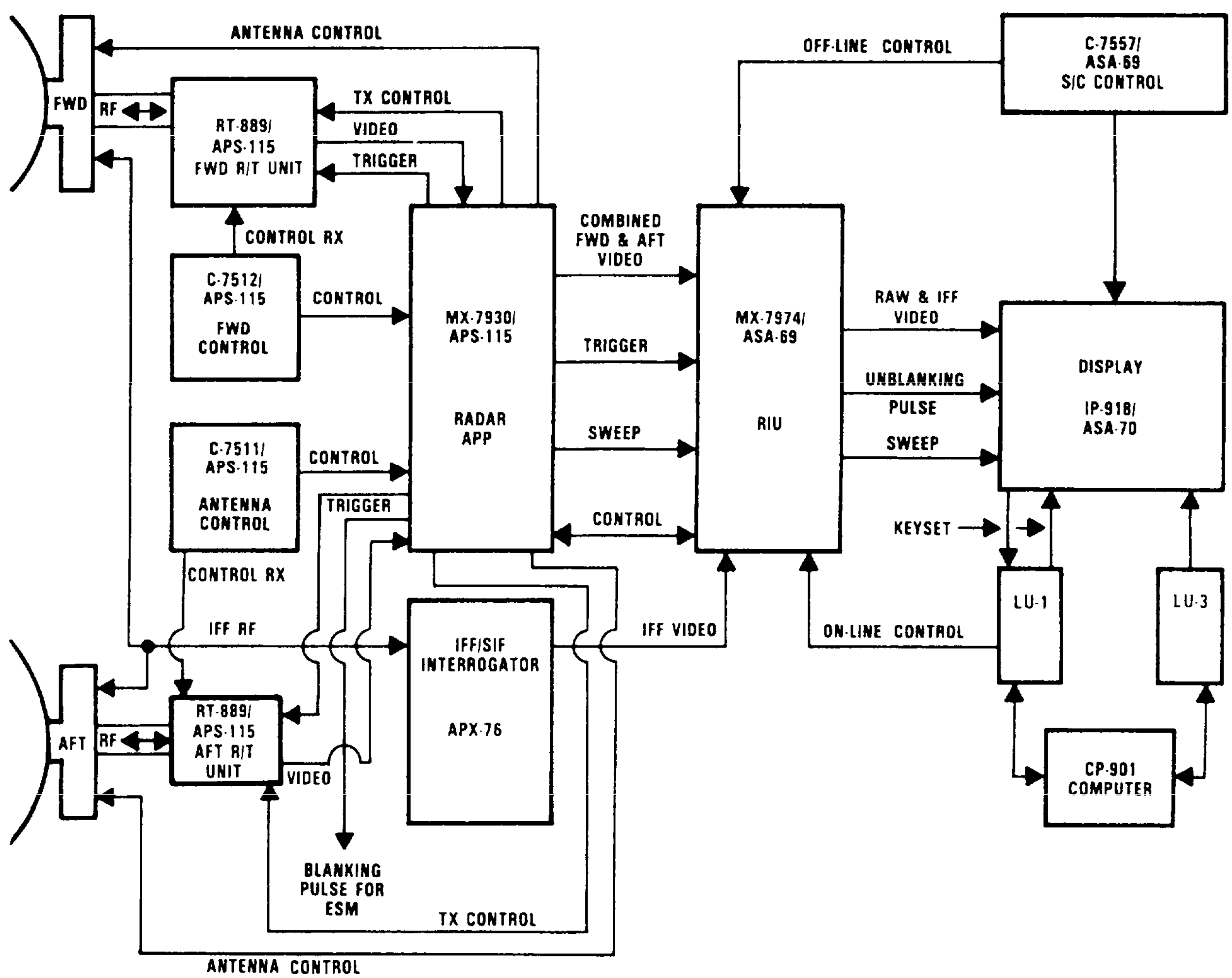


Figure 3-8.-APS-115 radar signal flow diagram.

In the on-line mode, the sensor station 3 keyset generates primary control signals, which are processed through the central computer, logic unit No. 1 (LU 1), and the RIU. The antenna control provides signals to control the radar scan functions and tilt servo loop stabilization. The two radar control boxes control the sensitivity time adjustments, receiver gain, fast time constant, automatic frequency control, and video test of the respective RT.

FIRE CONTROL RADAR

Learning Objective: *Recognize operating modes and system controls used in a fire control radar.*

The 11D13A radar maintenance trainer device is discussed in the following text. This system was selected because an actual operational system would require that classified information be included. Because the trainer is different from an operational system in some respects, these differences are noted when discussion will not violate security regulations.

The 11D13A trainer device includes all the elements essential for basic search radar ranging—transmitter, receiver, antenna, and synchronizer circuits. Additional elements, including tracking, stabilization, and target generation (simulated targets), allow operation as either a fire control (intercept) radar or a bomb director radar. The target generator unit, although not usually contained in operational radar systems, produces a three-dimensional target that is controllable in azimuth, range, and elevation in a manner typical of analog computing systems. It contains both mechanical and electronic elements found in analog computing systems. A block diagram of the trainer is shown in figure 3-9. The ranges in the trainer vary from 0 to 80,000 yards. An actual weapons control radar has much longer ranges, which are normally expressed in miles.

OPERATING MODES

The 11D13A trainer is capable of operating in three basic modes-search (PPI), fire control, and bomb director. Fire control is divided into five

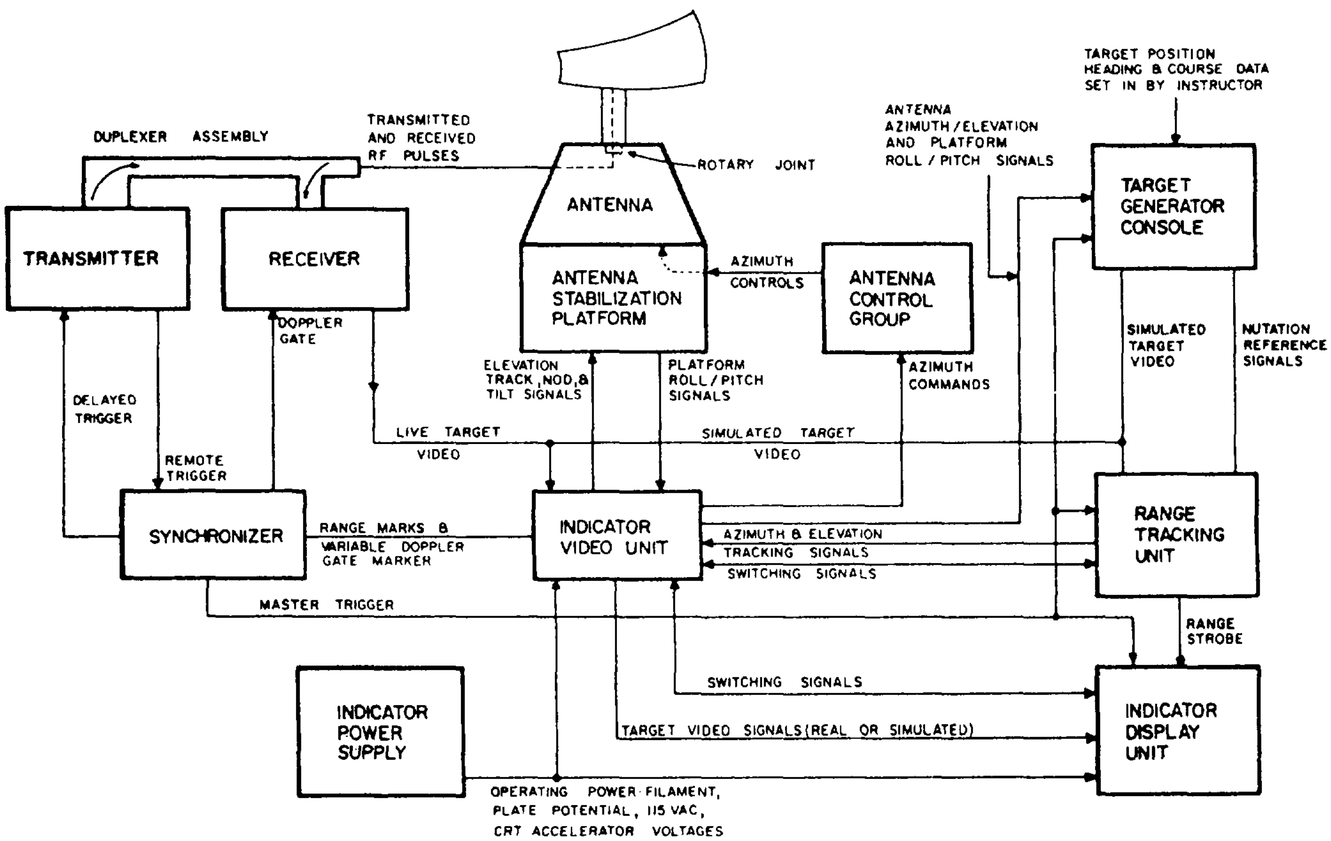


Figure 3-9.-Trainer 11D13A functional block diagram.

submodes—automatic search, manual search, lock on, automatic track, and breakaway. These submodes parallel the general submodes found in actual weapons control systems.

The trainer has no standby mode as such. (The purpose of a standby mode is to apply filament voltages for initial warm-up before selecting an operating mode.) Most radar sets include an automatic time-out (time-delay) circuit, which prevents application of power to the high-voltage sections prior to the necessary warm-up period.

Search Mode

Search operation for airborne and ground targets is provided with ranges of 0 to 6,000 yards and 0 to 12,000 yards. In this mode the antenna automatically scans the horizon, rotating in a clockwise direction at 6 RPM. Manual control of the antenna in this mode provides manual tracking of detected targets. There are some minor differences in the methods of manual control; however, they are of little consequence. Range marks are selectable in 1,000-, 2,000-, or 3,000-yard increments. In the basic search mode, the B-scope, which is also included in the indicator unit, is deactivated.

Fire Control Mode

When the fire control mode is selected, the target simulator provides a three-dimensional target (target with range, azimuth, and elevation information). In the fire control mode, there are five submodes—automatic search, manual search, lock on, automatic track, and breakaway. The five submodes permit the simulated target to be detected initially, manually tracked and acquired, and tracked automatically until minimum range is reached. At this time, a breakaway signal in the form of a large X is displayed on the B-scope indicator, warning the operator to break away from the target. In an actual weapons radar, the breakaway X also means that the aircraft is too close to the target to allow time for an air-to-air missile to properly track the target.

Minimum range in fire control operation is 3,500 yards. Three ranges are provided for target information while operating in the fire control mode-0 to 10,000, 0 to 40,000, and 0 to 80,000 yards. During this mode of operation, target information is displayed on both the PPI and B-scope of the indicator display unit. The B-scan display uses a dual-gun arrangement (to be discussed later), which provides steering information in addition to the normal plot display.

Bomb Director Mode

Operation in the bomb director mode covers the same ranges provided in the fire control mode. Aiming information is displayed on the PPI display. Switching circuits, which are energized at the time of mode selection, cause the presentation to be altered to conform to typical bomb director system presentations. The PPI display has a depressed-center sector scan at twice the scale of the fire control mode. The indicator includes controllable range and azimuth marks (strobes), which act as cross hairs to facilitate aiming (aim point tracking).

SYSTEM CONTROLS

Through the manipulation of the basic controls, the operator has available all of the previously mentioned modes of operation. The controls of the trainer are decentralized to simplify construction and operation, but these controls can be grouped into five major categories according to their function. The five major control functions are as follows:

1. Power switch
2. Mode switch
3. Receiver gain control
4. Antenna control (hand control)
5. Auxiliary controls

Power Switch

The power switch is the system's off-standby-operate switch. The off position, of course, removes all power from the system. The standby position, as previously described, would apply filament power and keep alive voltage to the TR tubes. For purposes of training, the 11D13A has a power switch for each of the major units antenna transmitter, and so forth). This allows for operation of each of the units or any selected combination of units for training. During the discussion throughout this chapter, the appropriate control will be noted, along with its function and its relationship to one of the four major function controls, if necessary.

Mode Switch

The mode switch is practically self-explanatory. In the trainer, this switch sets up one of the basic operating modes available, such as search, bomb director, or fire control.

Receiver Gain Control

The receiver gain control is one of the most important controls available to the operator, whether the pilot in the aircraft or an operator on a trainer. This control, if not properly adjusted, will prevent the entire system from operating at peak performance. Some radar systems include a built-in test function, which provides a reasonable check of the adjustment of the receiver gain control. This control is normally adjusted for best definition of the weakest target available. There is only one acceptable method for adjusting this control to obtain peak detection, which provides maximum range. In each particular radar, this method is part of the minimum performance test.

Antenna Control (Hand Control)

The hand control of an actual radar installation allows the operator to select manual search operation and selection of targets. Through the use of this control, the operator may command the radar to acquire and/or release the target. The 11D13A has two controls, one for azimuth and one for range.

During automatic search, these controls have two functions---(1) to position the antenna in elevation and azimuth, and (2) to select the area to be searched in relation to the horizon. You can see that these controls and the receiver gain control are very important because they will affect target detection performance.

The hand controls have complete control of the antenna during manual search, and, in addition, also control the acquisition symbol to acquire the target.

Auxiliary Controls

Through the use of a scan switch in an operational radar, the operator may select either full azimuth or sector scan. The trainer, likewise, incorporates a scan switch that may be used to select the type of scan desired. In the trainer, the selections are automatic sweep at a 6-RPM rate, variable sweep from zero to 6 RPM manually controlled, or sector scan.

INDICATOR DISPLAYS

A description of the indicator displays (PPI or B-scope) in the three basic modes of operation and the submodes of fire control is given in the following paragraphs. The indicators are used to monitor system performance during simulated operation in all weather conditions.

Basic Search

In the basic search mode, information is displayed on the PPI only. As shown in figure 3-10, the PPI scan presentation may be a maplike picture of the earth's surface being seamed. The range sweep line rotates in synchronization with the antenna through a full 360-degree cycle. Targets appear on the face of the CRT as an intensified light spot. The range of the target is indicated by its position on the radius of the range sweep line, and target azimuth position is indicated by the angle of the sweep line at the time the target is painted. The top of the scope is 0 degree, and may indicate dead ahead.

If 1,000-yard marks are selected, the two range marks shown in the figure are 1,000 yards apart. The first range mark, which starts from the center of the scope and moves outward toward the edge of the scope face, indicates targets from zero to 1,000 yards. There are two targets shown in figure 3-10 that are between the 1,000- and 2,000-yard marks. Other targets are shown at greater ranges and at different

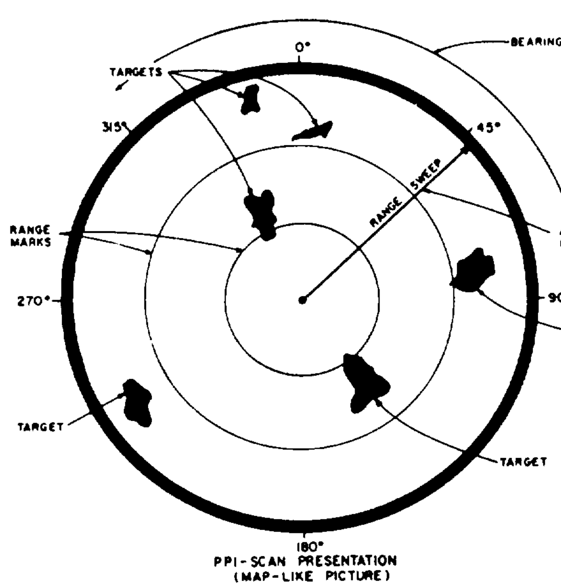


Figure 3-10.-PPI scan presentation basic search.

azimuth positions. The presentation shown could be a ground map of an area of the earth's surface showing several islands. The shape of the target appearing on the scope will be almost the actual shape of the target as viewed visually. If, however, the antenna were scanning above the horizon, an airborne target would be a very small bright spot, and the target shape would not be defined.

Fire Control (Automatic Search)

In the automatic search submode of fire control, information is displayed on both indicators. The PPI presents target range and azimuth information as before. Now, the B-scope also presents information that, if the system were operating in an aircraft, would be required to make a successful attack on an airborne target. This information is shown in figure 3-11.

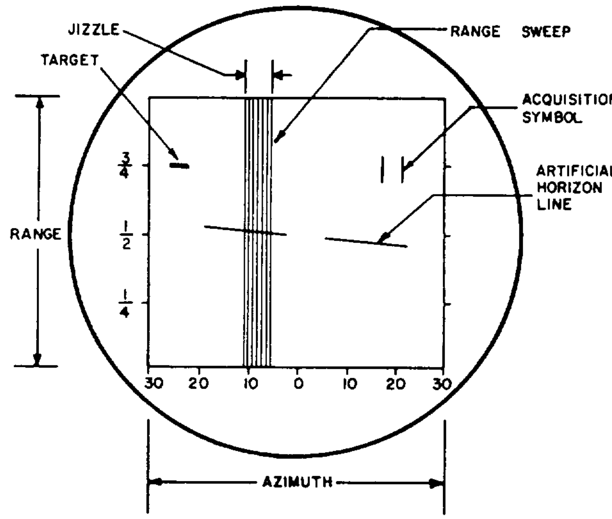


Figure 3-11.-B-scan presentation in automatic search.

In figure 3-11, which is a normal B-scan search display, four items of interest are painted electrically on the face of the CRT. The first is the range sweep line, sometimes referred to as the B-trace. This time, however, the sweep is from the bottom of the scope to the top. Range on a B-scope is measured from the bottom of the scope to the top. The length of the trace then is equal to the range selected. If the 0- to 10,000-yard range is selected, the length of the range sweep line is 10,000 yards. The position of the sweep line on the face of the scope, as was the sweep line on the PPI, indicates the azimuth position of the antenna. The trace scans back and forth, following the antenna.

You should notice that the scan line is not a single line, but is made up of several lines, causing it to become a 1/4-inch-wide scan line. This is called "jizzle," and is the result of simulated antenna spin modulation. In an actual radar system, this is accomplished by nutation of the antenna feed horn or reflector dish. In the trainer a scan generator produces the effect of the antenna nutation, but the antenna is not actually nutated. Figure 3-12, view A, shows an antenna pattern that is simulated in the trainer. In view B of figure 3-12, a boxlike pattern is produced. This is accomplished by introducing a nod at the end of the scan.

The second item on the scope is video (targets). As the antenna scans back and forth, any target within the range of the radar appears as a bright spot on the face of the CRT. The range of the target is indicated by its vertical distance from the bottom of the scope. The azimuth position of the target is indicated by the position of the target either to the left or to the right of the center. For example, if the target appears as shown in figure 3-11, its range is 7,500 yards (on the 10,000- yard range scale), and it is to the left of the attacking aircraft. Most radars installed in fighter-type aircraft also have an indication of the antenna tilt, which is used to indicate elevation position of the target relative to the attack aircraft. If the target were above the attacking aircraft, the antenna would have to be tilted up to receive a target echo. The amount of tilt can then be read from the indicator, and the pilot may steer the aircraft accordingly to intercept the target.

The third item on the B-scope is the acquisition symbol. During automatic search, the acquisition symbol is relatively unimportant, but it is movable, and could be used to mark the area of target return. The symbol, as shown in figure 3-11, is made of two short vertical lines slightly separated. Position of the symbol in the vertical indicates range, and is controlled by the range circuits, which, in turn, are controlled by the hand control in an actual radar system. Movement of the hand control back or forward decreases or increases range voltage, which causes the acquisition marks to move in or out in range. The acquisition marks are also controllable in azimuth by movement of the hand control either to the left or to the right. Therefore, the acquisition marks may be positioned anywhere on the face of the scope. This is described in greater detail later.

The fourth symbol on the face of the scope is the artificial horizon line. This symbol is a straight line with the center blanked out, and is positioned horizontally on the face of the indicator tube. The purpose of the horizon line is to indicate aircraft attitude. In automatic search, the horizon line represents the earth's horizon; when the aircraft rolls or pitches, the artificial horizon banks or moves up or down with the aircraft's movement. This movement of the horizon line is controlled by outputs from the aircraft vertical gyro or stable platform.

Fire Control (Manual Search)

Manual search allows the operator to stop the antenna from scanning and to direct it toward any desired target detected during automatic search. Tilt or elevation control of the antenna, which was provided in automatic search, is still available in manual search. In addition, control of the antenna in azimuth is now available. In the operation of an actual radar installation, control of the antenna in both elevation and azimuth is a function of the hand control. In the trainer, however, azimuth and elevation controls are separate. The provision of separate controls is of no great significance, except for convenience of operation.

When manual search is initiated, the acquisition marks bracket the range sweep line (B-trace), and both the B-trace and the acquisition marks move together in azimuth. The position of the acquisition marks in range is also available in the manual search mode. This allows them to be positioned anywhere on the B-trace from zero to maximum range, depending on range selected. For example, if the radar is operating in the 0- to 10,000-yard range, and a target appears at 5,000 yards, the acquisition marks may be moved to bracket the target by use of the range control.

The major display differences between automatic search and manual search are that the acquisition

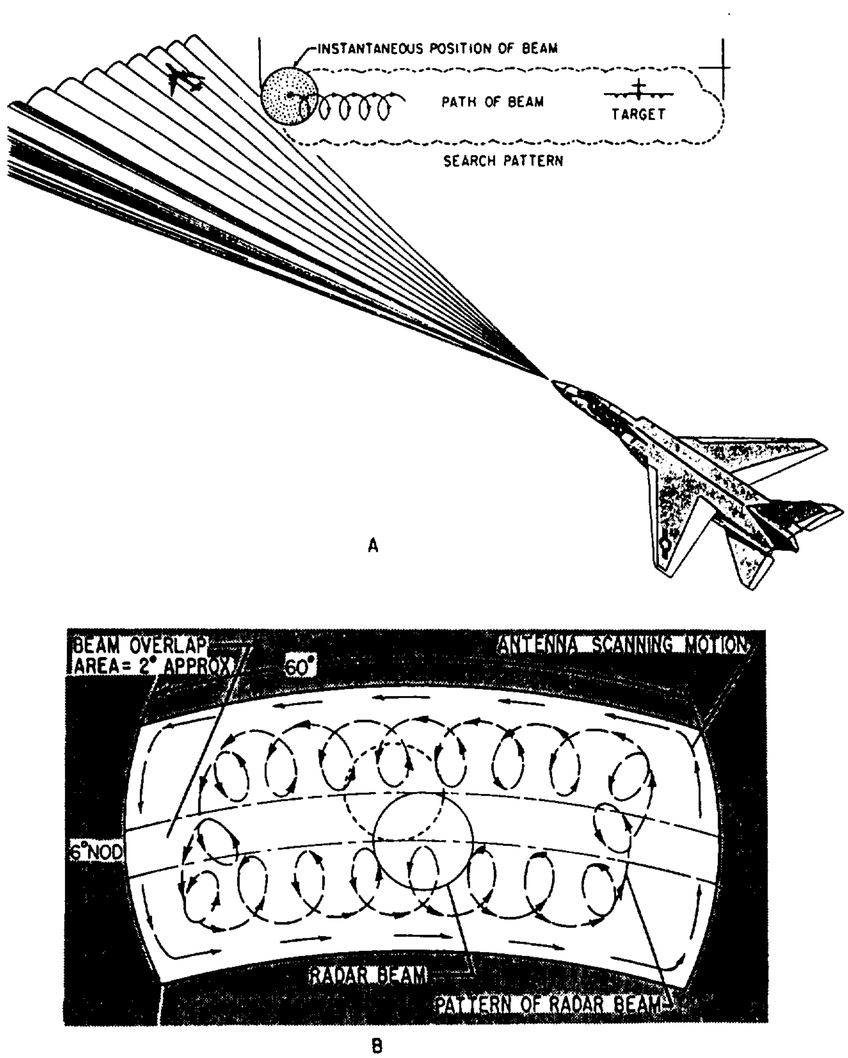


Figure 3-12.-A. Antenna scan pattern. B. Antenna coverage pattern.

marks bracket and move with the B-trace, and the antenna is controllable in azimuth. All symbols that were present in automatic search, including the artificial horizon, are present in manual search. The horizon line still functions to indicate aircraft attitude. It should also be reasonable to expect to see no targets other than the ones that appear on the range sweep line, since the antenna is no longer scanning.

Fire Control (Lock on)

The lock on mode is a momentary mode of operation between manual track and automatic track. Some radars combine the previously described manual operations and lock on mode into one mode called “acquisition.” The term *acquisition,* as used in operation of a radar set, refers to a momentary mode of operation. The time period for acquisition begins at the moment the operator depresses a control switch transferring antenna control from automatic search to manual search. During this period, the operator has complete control of antenna position, both in azimuth and elevation, and may also control a symbol on the indicator called an “acquisition symbol.” If the operator places the acquisition symbol over the selected target, it causes coincidence between the tracking gate and the target in the range and tracking circuits of the radar. Acquisition is complete when lock on occurs, and the system switches to automatic track. Lock on is accomplished by a change in the B-scope presentation and the blanking of the PPI scope. However, in the trainer, manual track may be continued after leek on, if desired.

On the B-scope, the acquisition symbol is removed and replaced with a range strobe or notch superimposed on the target, as shown in figure 3-13. The artificial horizon remains as before. Note there are two symbols present now that were not previously present. One of these is a small dot, called a steering dot. The purpose of the steering dot is to indicate antenna position, which also presents target position with respect to the attacking aircraft. For a pure pursuit course, the pilot need only maneuver the aircraft to cause the steering dot to remain in the center of the scope. When the steering dot is in the center of the scope on a pure pursuit course, the target is dead ahead of the attacking aircraft.

The second symbol, which was not present in the previous modes, is a circle. This circle is called a “range circle,” and its diameter is proportional to range. Normally, lock on occurs at near maximum range, which produces a range circle of maximum size. As the range between the attacking aircraft and the target decreases, the diameter of the circle also decreases, keeping the operator informed of the range to the target. In addition to these symbols, two other indications of range are presented at the time the radar locks on. A light, known as the lock on or acquisition light, is illuminated when the target has been acquired and lock on has been accomplished. Range is also presented in digital form in a small window similar to the mileage counter of an automobile.

Fire Control (Automatic Track)

The automatic track submode of fire control results from the manual track mode upon release of the manual controls (range and azimuth). Remember, prior to automatic tracking, the antenna had been manually controlled in both elevation and azimuth, and the range strobe (notch) had been controlled by the range control. To initiate automatic tracking, the operator releases the manual controls, and the radar switches to automatic track. At this time, the antenna is caused to track the target by the antenna servo system error circuits.

Range tracking is accomplished in the range tracking circuits. Automatic tracking continues until one of three things occurs. First, lock on will be lost if the attacking aircraft is closing on the target at a rate greater than 700 knots, or if an opening rate greater than 200 knots should occur. Second, the target will be lost, and the radar will unlock if the target does not remain within the tracking window (antenna limits in azimuth and elevation). Finally, the target will be lost if the range exceeds maximum tracking range.

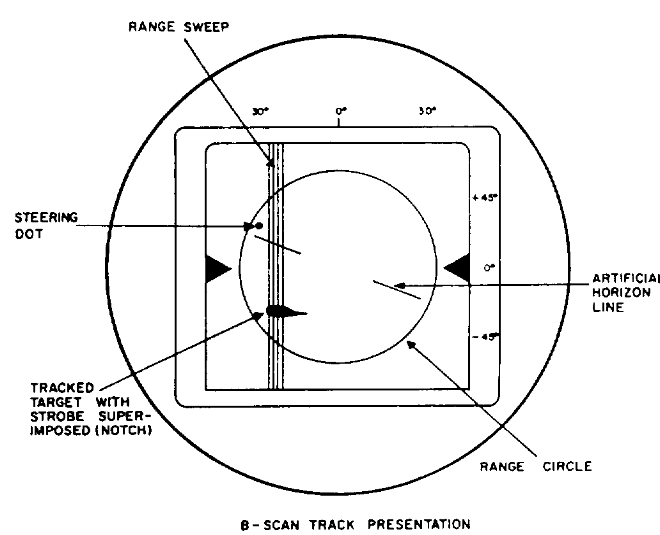


Figure 3-13.-B-scan presentation after lock on.

Maximum range for tracking is 40,000 yards. At ranges beyond 40,000 yards, the return echo will be too weak to maintain lock on. If unlock occurs, the system is automatically returned to automatic search, and the cycle of manual track and acquisition must be repeated to regain target tracking.

Fire Control (Breakaway)

The final submode of fire control is known as breakaway. This mode occurs automatically if the target is tracked to a range that would endanger the attacking aircraft. During automatic track of a target that has a decreasing range (attacking aircraft is closing on the target), the range circle is removed at the time the range to the target gets to 3,500 yards. In its place, a large **X** is displayed, which indicates time to breakaway from the attack (fig. 3-14). Also at this time, the steering dot will move to a position on the scope to indicate the safe direction for the attacking aircraft to turn to execute a safe breakaway. In the illustration, minimum range has been reached and the breakaway **X** has appeared. The steering dot is presently positioned to the right and above center.

Bomb Director Mode

When the bomb director mode of operation is selected, information is displayed on the PPI indicator. In this mode, the antenna automatically goes to sector scan, scanning a 60-degree arc, 30 degrees to each side of dead ahead. Antenna elevation is manually controlled. The PPI scope has a

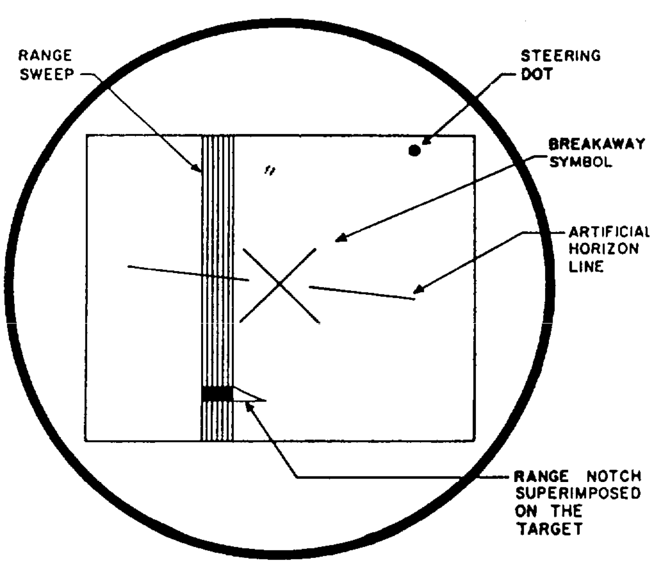


Figure 3-14.-B-scan presentation breakaway indication.

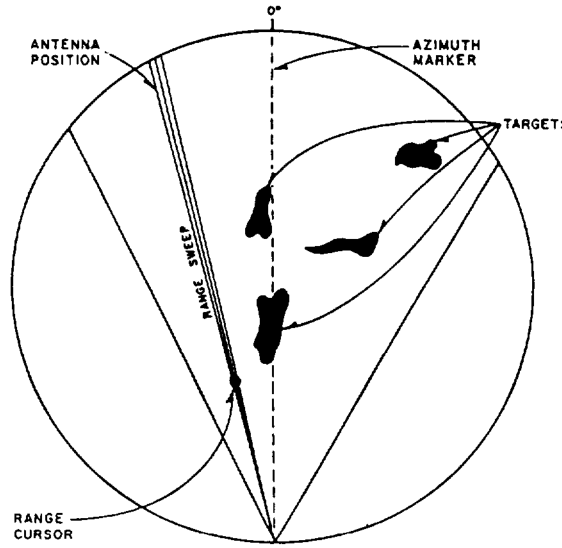


Figure 3-15.-PPI presentation in bomb director mode.

depressed center, which appears as a wedge-shaped scan on the indicator face, as shown in figure 3-15. The antenna is positioned in elevation so it will scan the surface of the earth during a bomb attack. The B-scope will only display the artificial horizon in the bomb director mode.

The target tracking range and azimuth strobes appear on the indicator; they are moved manually so the marks form a cross hair effect, and are centered over the target to be tracked. Tracking is maintained manually in the bomb director mode. The azimuth and range strobes are controllable from 0 to 80,000 yards, and, in azimuth, 25 degrees to either side of center.

IFF SYSTEMS

Learning Objective: *Recognize components and operating principles of an IFF transponder set and an IFF interrogator set.*

There are two systems that make up the IFF system on an S-3 aircraft. These systems are the AN/APX-76A and the AN/APX-72. Both systems work in conjunction with the radar set for total and secure identification.

TRANSPONDER SET AN/APX-72

The transponder set provides Identification Friend or Foe (IFF) radar replies when challenged by a valid IFF interrogator. The IFF transponder

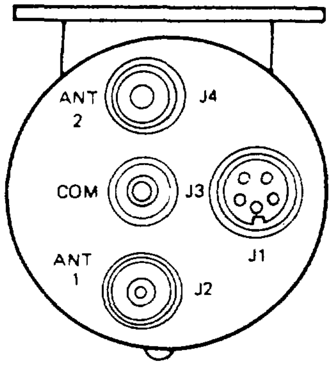


Figure 3-16.-SA-176/A RF transmission line switch.

processes valid IFF interrogations and provides coded pulse train replies to give automatic radar identification of the aircraft in one of five modes. The five modes are discussed later in this chapter.

The transponder set also provides the Selective Identification Feature (SIF) to permit a specific aircraft to be selected from other properly responding aircraft.

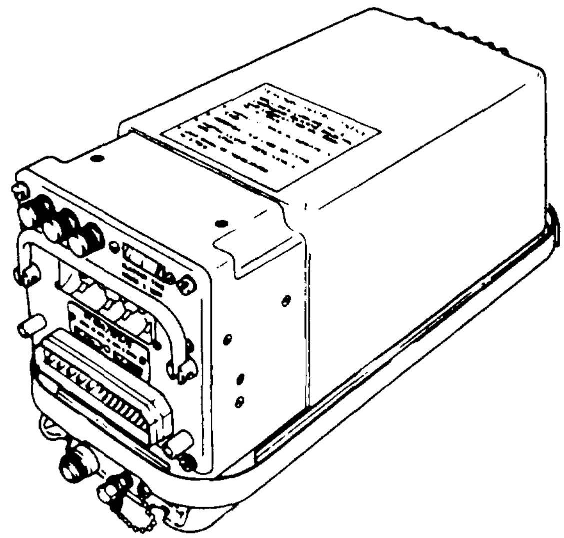
Major Components

The transponder set consists of four main boxes and a test set. These components will be discussed in the following text.

RF TRANSMISSION LINE SWITCH SA-1769/A.— The RF transmission switch (fig. 3-16) alternately connects the transponder set to the top or bottom UHF L-band antenna. This switching (lobing) operates at 38 Hz. The lobing action prevents the antenna system from being blanked out during aircraft maneuvers.

TRANSPONDER SET CONTROL C-6280(P)/APX.— The IFF control box (fig. 3-17) provides the IFF transponder operational and test controls. The IFF transponder control box controls the transponder in any of the five modes: modes 1, 2, 3A, C, and 4.

RECEIVER-TRANSMITTER RT-859/APX-72.— The receiver-transmitter (fig. 3-18) will



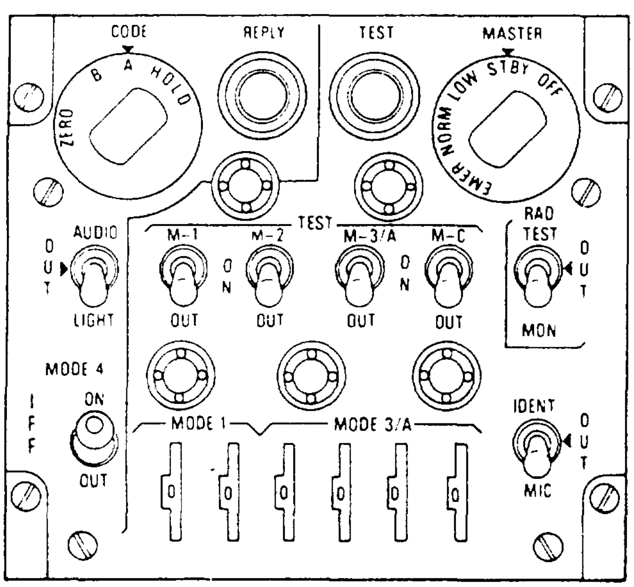


Figure 3-17.-C-6280(P)/APX transponder control box.

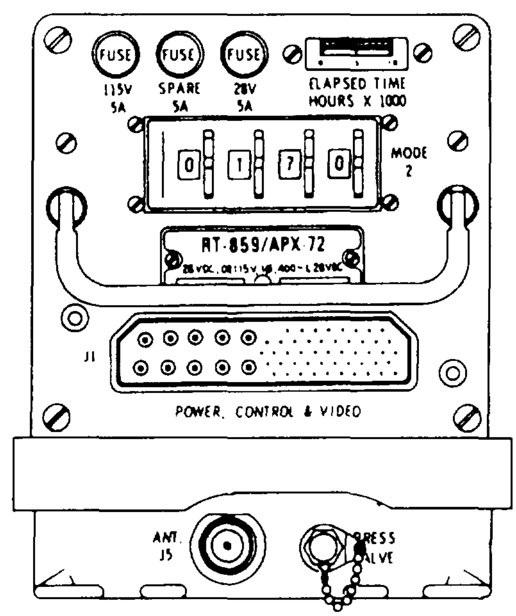


Figure 3-18.-RT-859/APX-72 receiver-transmitter.

transmit a reply when RF interrogation is received from an IFF interrogator. If the interrogation is valid, a coded reply is transmitted. This reply is received by the interrogator and processed for display for aircraft identification and location. The transponder is capable of operating in five modes and superimposing four special signals on the mode replies.

COMPUTER KIT-1A/TSEC.— This computer allows the IFF transponder to respond to mode 4 interrogations. Mode 4 is a secure mode of operation.

TRANSPONDER TEST SET TS-1843/APX.— The test set (fig. 3-19) generates properly coded test signals for the desired mode. These interrogation signals are then applied to the transponder. The test set then checks the replies for frequency, bracket-pulse spacing, power, and antenna standing-wave ratio. The resulting IFF system check will provide a GO/NO-GO indication on the IFF transponder control box.

Transponder Set Functional Description

The IFF transponder control box allows an automatic IFF capability when the aircraft is interrogated by a valid interrogation. Special modes and codes can be manually set on the IFF control box, receiver-transmitter, and on the computer. The control box also initiates the self-test function through the test set.

RECEIVED SIGNALS.— The interrogator-transmitted signals are received by the aircraft through the UHF L-band blade antennas. These signals are on a frequency of 1030 MHz. The receiver-transmitter recognizes the signals through pulsewidth and spacing detection. Modes 1, 2, 3/A, C, and TEST use two interrogation pulses and one side-lobe suppression pulse that are 0.8 (±0.1) microsecond wide. Pulse spacings between the two interrogation pulses are slightly different, depending on the mode. These spacings are as follows:

Mode 1:	3.0 (±0.2) microseconds
Mode 2:	5.0 (±0.2) microseconds
Mode 3/A:	8.0 (±0.2) microseconds
Mode C:	21.0 (±0.2) microseconds
TEST:	6.5 (±0.2) microseconds

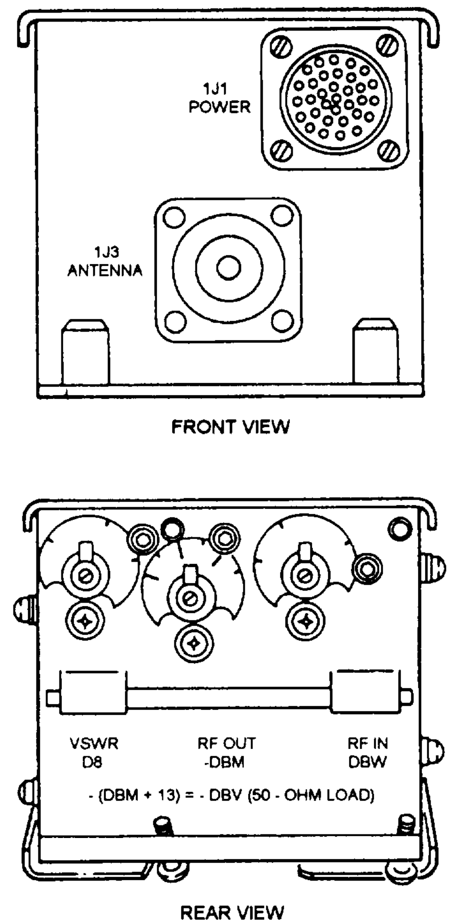


Figure 3-19.-TS-1843/APX test set.

IFF TRANSPONDER RECOGNITION.— Recognition of the interrogation mode is done by passing the first interrogation pulse through a time-delay circuit and matching this first pulse with the second pulse position. The delays are of 3, 5, 8, or 21 microseconds. Mode 4 capability is provided when the computer is operating in the system. Mode 4 interrogation pulse characteristics consist of four pulses 0.5 (±0.15) microsecond wide, referenced from the leading edge of the first pulse in multiples of 2 microseconds. The 4 pulses maybe followed by as many as 33 additional pulses spaced as close as 2 microseconds. The side lobe suppression pulse is placed 2 (±0.15) microseconds from the leading edge of the fourth pulse.

SIDE-LOBE SUPPRESSION.— The side-lobe suppression pulse allows the transponder to accept the main lobe and to reject minor lobe signals from the interrogation stations. This ensures correct operation of the system.

Table 3-1.-Correlation of Dial Settings with Pulse Position

Dial Setting				
	First Dial	A1	A2	A4
	Second Dial	B1	B2	B4
	Third Dial	C1	C2	C4
	Fourth Dial	D1	D2	D4
0		–	–	–
1		+	–	–
2		–	+	–
3		+	+	–
4		–	–	+
5		+	–	+
6		–	+	+
7		+	+	+

Note: + means pulse is present.
– means pulse is absent.

IFF TRANSPONDER RESPONSE.— Table 3-1 shows the correlation of dial settings with pulse positions. If you use this table, along with the examples given in figure 3-20, you will get an idea of what the pulse trains will look like for the various codes. Figure 3-21 shows the interrogation and reply pulse train characteristics.

Mode 4 reply pulse video characteristics are determined by the computer. The reply is framed by two pulses spaced 23 (±0.05) microseconds apart. In modes 1, 2, and 3/A, the presence or absence of information pulses at predetermined spacings is determined by the settings on the transponder control box. In mode C, this information is determined by the

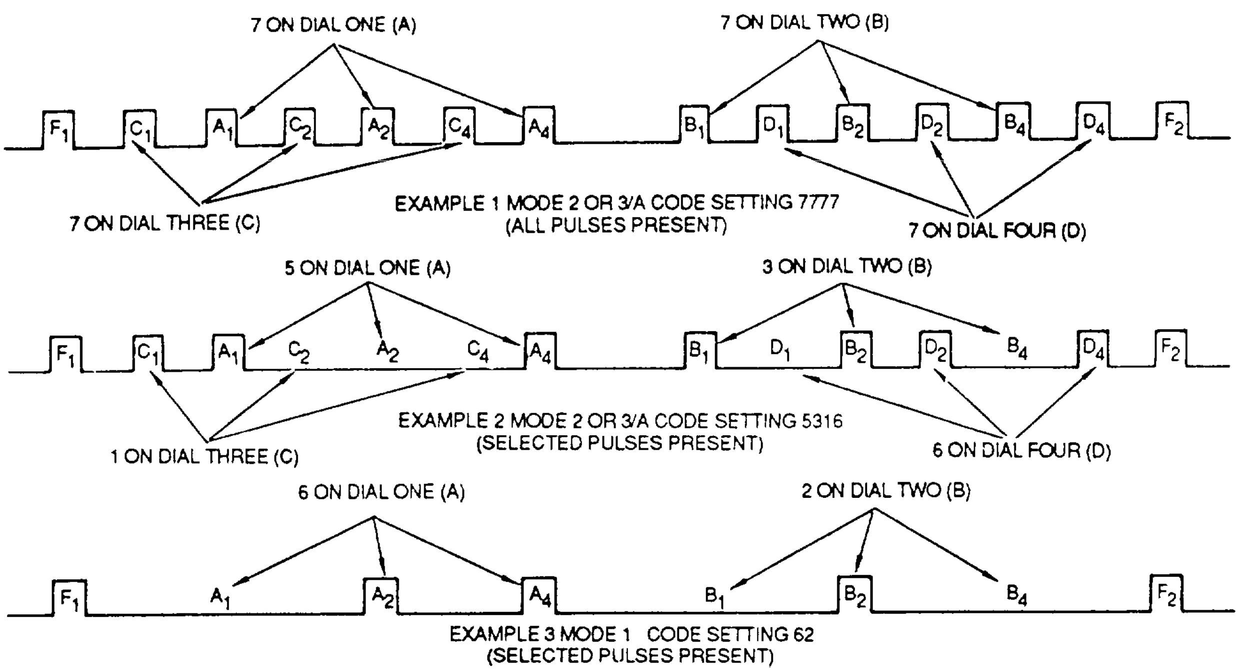


Figure 3-20.-Information pulse train examples.

airspeed-altitude computer. All framing and information reply pulses are 0.45 (±0.1) microsecond wide. All modes are transmitted by the RT at a frequency of 1090 MHz.

Mode 1.— The reply pulse train consists of from zero to five information pulses framed by two framing pukes. The spacing between the information pulses is in multiples of 2.9 (±0.05) microseconds from the initial framing pulse. The position where the sixth information pulse would be (17.4 [±0.05] microseconds from the initial framing pulse) is not used. There are 32 different codes available for use from the specified five information pulses.

Mode 2 and 3/A.— When transmitted, these reply trains contain from zero to 12 information pulses, plus the two framing pulses. The information pulse spacing is in multiples of 1.45 (±0.05) microseconds from the initial framing pulse. The position where the seventh information pulse would be (10.5 [±0.05] microseconds from the initial framing pulse) is normally not used. There are a possible 4,096 different codes available from the specified 12 information pulses.

Mode C.— When the Airspeed-Altitude Computer is connected in the system, the reply train consists of from 1 to 11 information pulses and 2 framing pulses. The information pulses are spaced in multiples of 1.45 (±0.05) microseconds from the initial framing pulses. The positions where the seventh and the ninth pulses are normally located (10.5 [±0.05] and 13.05 [±0.05] microseconds from the initial framing pulse) are not used. When there is a pulse in the thirteenth position (18.85 [±0.05] microseconds from the initial framing pulse), there is a special position indicator pulse also generated in the train. This pulse is located 24.65 (±0.05) microseconds from the initial framing pulse. There is a total of 2,048 possible codes available from the specified 11 information pulses. When the airspeed-altitude computer is not on-line, the reply train will be the framing pulses only.

Mode 4.— This reply train is determined by the KIT-1A/TSEC.

IDENT Function.— The identification-of-position (IDENT) function is used in modes 1, 2, and 3/A. The IDENT function, which can be selected by the pilot for transmission for approximately 20-second intervals, is used to distinguish between aircraft displaying the same coding. When used in mode 1, the reply pulse train containing the code in use is transmitted twice for each trigger puke received. The second train is 24.65 (±0.05) microseconds from the leading edge of the first framing pulse of the first reply train. The IDENT function in modes 2 and 3/A uses the special position indicator (SPI) pulse. The reply pulse train containing the code in use is followed by a pulse for each trigger received. This SPI pulse is 24.65 (±0.05) microseconds from the leading edge of the first framing pulse of the reply train.

Emergency Function.— The EMERGENCY signals are selected by the pilot to indicate an in-flight emergency. The emergency function is used with modes 1, 2, and 3/A. For modes 1 and 2, the reply pulse train containing the code in use is transmitted once for each trigger pulse received, followed by three sets of framing pulse pairs with no information pukes. The three sets of framing pulses are located 24.65 (±0.1), 44.95 (±0.15), 49.30 (±0.20), 69.60

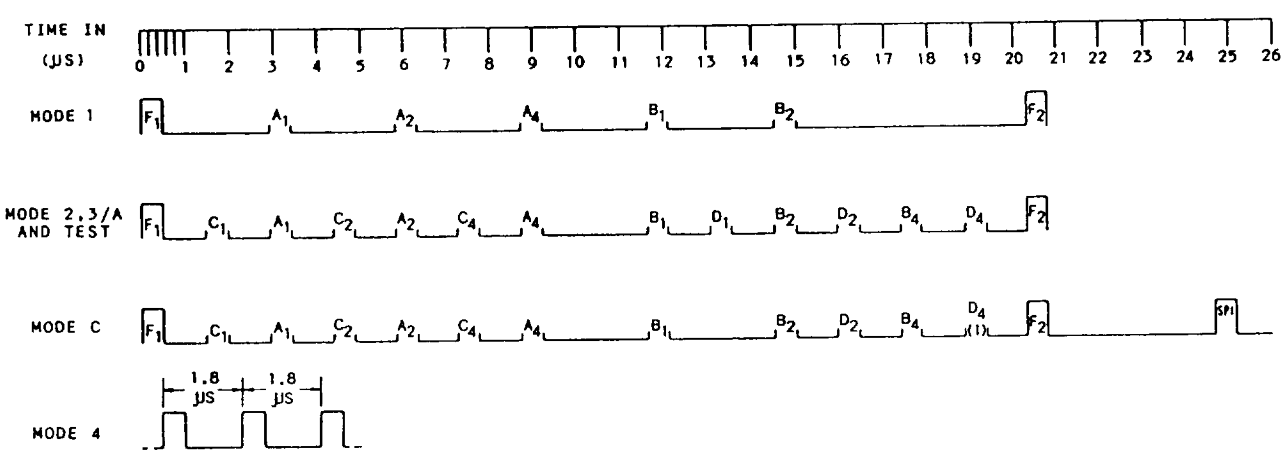


Figure 3-21.-Normal reply pulse characteristics.

(±0.25), 73.95 (±0.30), and 94.25 (±0.35) microseconds from the leading edge of the initial framing pulse. In mode 3/A, one reply pulse train containing the code 7700 is transmitted, followed by the three sets of framing pulse pairs with no information pulses. The location of these framing pulse pairs is the same as in modes 1 and 2.

Special Position Indicator.— The special position indicator (SPI) allows the air traffic controller to differentiate aircraft above or below a given altitude. This puke is present in the reply pulse train in mode C when a D4 pulse (18.85 [±0.05] microseconds from the initial framing pulse) is used. The SPI pulse is located 24.65 (±0.01) microseconds from the initial framing pulse. This pulse is sometimes called the mode C caboose pulse. This SPI pulse is the initial framing pulse for the second reply pulse train. The SPI pulse is the same pulse used in the mode 2 and 3/A IDENT function.

X-Pulse Function.— Special aircraft, such as drones, are identified by the transmission of the X-pulse. This pulse (10.15 [±0.05] microseconds from the initial framing pulse) appears in a normally unused position. This pulse is generated when the IFF transponder control box is modified by grounding a single external control lead. With this modification, all replies in modes 1, 2, and 3/A will include this pulse, along with the normal framing and information pulses.

SELF-TEST MODE.— When the TEST switches on the IFF transponder control box are enabled, an interrogation pulse pair is applied from the test set to the receiver-transmitter. Upon receiving these interrogation pulses, the RT replies to the test set. The test set then analyzes the replies for bracket-spacing frequency, power, and antenna circuit VSWR. The test set will give a GO/NO-GO indication on the control box. There is a switch for each of the modes 1,2, 3/A, and C.

MONITOR OPERATION.— When the RAD TEST-OUT-MON switch on the IFF transponder control box is set to the MON position, the transponder performance is checked. The test set will monitor the performance by detecting the replies generated in response to external interrogation signals. If a GO condition is detected, the TEST indicator on the transponder control box will illuminate. For a NO-GO condition, the TEST indicator remains off.

INTERROGATOR SET AFUAPX-76A(V)

The interrogator set is used in conjunction with the aircraft's radar set. It provides air-to-air modes 1, 2, 3/A, 4, SIF, and IFF mode 4 challenges. The IFF interrogator receives a basic trigger from the radar set, and a delayed radar trigger is returned to the radar after generation of the IFF interrogator trigger. The IFF replies are decoded and combined with the displayed radar return video. The interrogator set uses receiver side-lobe suppression (RSLS) and interrogator side-lobe suppression (ISLS). The video output is developed in the IFF interrogator, and is applied to the radar set for display.

Interrogator Set Major Components

The interrogator set consists of six major components. These six are discussed in the following text.

ANTENNA AS-2719/AP.— The interrogator set uses an antenna that is hard mounted to the radar set antenna The IFF portion of the antenna is imbedded in the upper part of the antenna dish, and consists of 10 IFF elements.

INTERROGATOR SET CONTROL C-7383/APX-76A(V).— The interrogator control box (fig. 3-22) provides operating mode selection of the SIF, or mode 4 code. The control box contains five thumbwheel switches to select the desired interrogation mode, or standby, and the desired code. A momentary two-position toggle switch (TEST/CHAL CC) allows for loop-testing the IFF, or to provide correct code challenge. The loop-testing allows for the interrogation of the onboard transponder set (AN/APX-72) by the IFF interrogator. Correct code challenge enables interrogations for which IFF display pulses are generated if the received

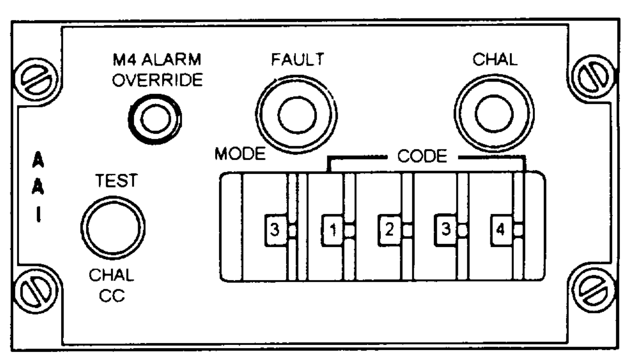


Figure 3-22.-C-7383/APX-76A(V) interrogator control box.

SIF reply code is identical to the code switch settings. There are two indicators (FAULT and CHAL) that indicate correct operating status of the system. The mode 4 alarm may be overridden by using the toggle switch M4 ALARM OVERRIDE.

RECEIVER-TRANSMITTER RT-868A/APX-76A(V).— The receiver-transmitter (fig. 3-23) takes the mode 1,2, 3/A, or 4 interrogation and ISLS pulses and modulates a 1030 MHz carrier wave with them. This is the transmitted signal from the interrogator set. The transponder reply signal, at the reply frequency of 1090 MHz, is amplified, detected, and processed by the receiver section. The reply video is then sent to the radar set for display on the various indicators.

There are three fault flags on the front of the RT that indicate malfunctions in one of the three functional sections of the receiver-transmitter.

SWITCH-AMPLIFIER SA-1568A/APX-76A (V).— The switch-amplifier (fig. 3-24) switches the interrogator's RF output from the sum antenna channel to the difference antenna channel for the duration of the ISLS pulse. During this time, the output is amplified by 4 to 7 dB. This amplification provides the required antenna output characteristics.

ELECTRONIC SYNCHRONIZER SN-416A/APX-76A(V).— The synchronizer (fig. 3-25) generates the initiation and interrogation cycles. The synchronizer provides a functional link between the radar trigger generation and the radar modulation circuits.

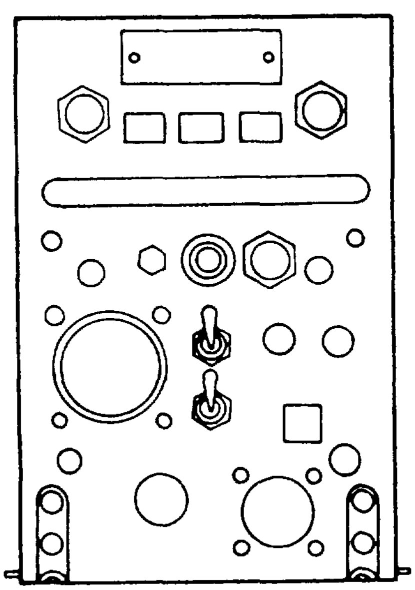


Figure 3-23.-RT-868A/APX-76A(V) receiver-transmitter.

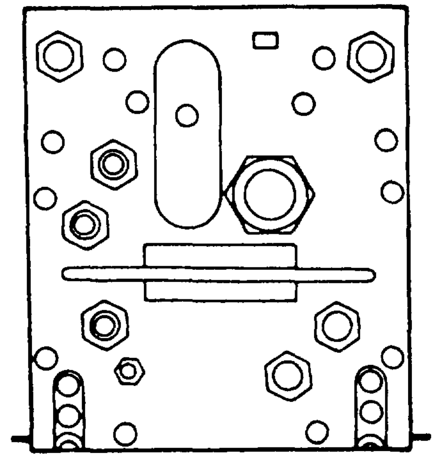


Figure 3-24.-SA-1568A/APX-76A(V) switch-amplifier.

COMPUTER KIR-1A/TSEC.— This computer is used for mode 4 security and decoding for secure operation.

Interrogator Functional Description

The IFF interrogator challenges and identifies properly equipped targets on the display groups. It challenges in modes 1, 2, 3/A, SIF, or mode 4. Target responses are shown on the display group next to the target in the form of numbered cues.

MODES 1, 2, AND 3/A TRANSMISSION.— When the TEST-CHAL CC switch on the interrogator control box is set to the CHAL CC position, the interrogation cycle is initiated and lasts for 5 to 10 seconds. The basic radar trigger is applied to the

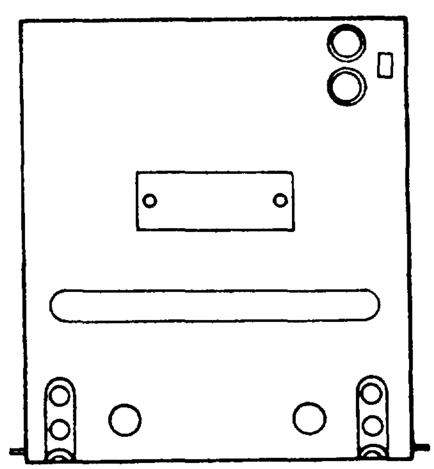


Figure 3-25.-SN-416A/APX-76A(V) synchronizer.

synchronizer, and a delayed radar trigger is sent back to the radar set after the interrogation trigger is generated. The synchronizer develops three basic signals:

- The interrogator trigger which, via the receiver-transmitter modulating circuit, modulates the transmission. The interrogation trigger consists of three pulses. P1 and P3 are interrogation pulses spaced either 3, 5, or 8 microseconds apart. In mode 1, the spacing is 3 microseconds, mode 2 has a 5-microsecond space, and mode 3/A has an 8-microsecond space. The ISLS pulse (P2) is always 2 microseconds after the P1 pulse.

- The gain time control (GTC) trigger, which initiates the receiver gate and the GTC circuits in the receiver-transmitter.

- The ISLS control gate, which controls switching of the antenna pattern for ISLS purposes.

The ISLS control gate, which precedes the P2 ISLS pulse by about 0.6 microsecond, is applied to the switch amplifier. When triggered by the interrogation trigger, the receiver-transmitter generates RF pulses at the transmitting frequency of 1030 MHz at a nominal peak power level of 2 kW. These pulses are applied to the sum channel of the switch-amplifier. The difference channel path between the receiver-transmitter and the switch-amplifier is not used during transmission. When the ISLS control gate is not present at the switch-amplifier, the RF pulses from the RT sum channel are passed straight to the antenna via the sum channel line for radiation out of the sum antenna pattern. This pattern is a main lobe with its axis along the antenna's boresight, and small side lobes on either side of the boresight. The P1 and P3 interrogation pulses are radiated in the sum pattern.

When the ISLS gate arrives at the switch-amplifier, shortly before the P2 pulse, the sum channel input at the switch-amplifier is switched to the difference channel coax to the antenna. The switch-amplifier amplifies the P2 ISLS pulse to a nominal peak power of 8 kW prior to its being sent to the antenna. This pulse is transmitted through the difference antenna pattern, which is two main lobes with their axes about 20 degrees on either side of the antenna's boresight, with a minimum signal strength along the boresight.

The reason for the two radiation patterns is to narrow the antenna beamwidth effectively in conjunction with the operation of the ISLS circuit at the transponder. The IFF transponder responds only to the P1 and P3 interrogation pukes, which are at least 9 dB above the P2 pulse. The transponder will not respond if the P2 pulse level exceeds the P1 level. If an IFF transponder is located more than a small angle off of the antenna's boresight, the P2 pulse will be received at a much higher level than the P1 and P3 pulses, and no reply will be generated.

MODE 4 TRANSMISSION.— Mode 4 operation is very similar to that of modes 1,2, and 3/A. The major difference is that the KIR-1A computer generates the interrogation trigger, GTC trigger, and the ISLS control gate instead of the synchronizer. The synchronizer generates a mode 4 pretrigger that is sent to the computer. The computer then prepares the challenge video, which is sent back to the synchronizer for entry onto the interrogator trigger line to the RT. Mode 4 transmission is the same as in the other modes as far as the patterns are concerned. Both the sum antenna pattern and the difference antenna pattern are used.

RECEPTION.— During reception, both the sum and difference antenna patterns are open for IFF transponder reply energy. The purpose of this is to effectively narrow the reply reception antenna bandwidth. This function is called RSLS. The reply RF energy is applied to the receiver-transmitter via the switch-amplifier's sum and difference channels. If the energy is above maximum receiver sensitivity, and the sum channel energy is greater than the difference channel energy by a fixed factor, the receiver will develop video pulses for decoding.

These video pulses are applied to the mode 4 decoding circuits within the receiver-transmitter and to modes 1, 2, and 3/A decoding circuits in the synchronizer. For modes 1, 2, and 3/A, the video pulses are checked for the presence of the standard IFF reply bracket pulses spaced 20.3 microseconds apart. If these pulses are there, a single video pulse is applied to the radar set for display. The coded pulses between the brackets are checked against the code selected at the IFF interrogator control. If the codes match, another single display video pulse is applied to the radar set for display. This second pulse is delayed 12 microseconds (or 28 microseconds if the long-range display is enabled) from the first pulse. When the correct code challenge is used to initiate the interrogation, the first pulse (bracket decode) is not sent to be displayed.

In mode 4, the reply video pulse is checked by the RT for proper pulse spacing and width. A single reply pulse is forwarded to the computer for further decoding. The mode 4 decoded video is applied to the synchronizer, where two pulses spaced 12 or 28 microseconds apart are generated for display by the radar set.

PERFORMANCE MONITORING.— The IFF interrogator set includes performance monitoring circuits in each of the boxes. When a fault is detected, a signal is sent through the synchronizer to the control box. This signal will cause a FAULT light to illuminate instead of the normal CHAL light.

When the TEST-CHAL CC switch is set to TEST, the IFF interrogator and the IFF transponder are linked together. This is done by disabling the normal suppression, ISLS, and RSLS operations. The trigger timing is also modified to place the zero-range replies at approximately 4 nautical miles on the radar display. In this configuration, the two sets are checked by each other for proper performance.

REVIEW QUESTIONS

Q1. What type of search radar is the APS-115B?

Q2. What is the tilt range of the AS-2146/APS-115?

Q3. Which control switch on the C-7511A/APS-115 is used to select the antenna sector mode?

Q4. How many functional subsections are in a RT-889/APS-115?

Q5. What is the scan rate of the AS-2146/APS-115 in the long pulse mode of operation?

Q6. How many operating modes are available on the 11D13A?

Q7. What is the minimum range in fire control operations?

Q8. In the fire control (automatic search) mode, what name is given to the 1/4-inch scan line?

Q9. At what closing rate will lock on be lost in the fire control (automatic track) mode?

Q10. What indication on the scope indicates breakaway?

Q11. What are the five modes used in IFF operations?

Q12. What antenna(s) is/are used by the IFF transponder system?

Q13. The APX-76 interrogator uses what carrier frequency for transmission?

Q14. What light illuminates when one of the APX-76 components fail?

CHAPTER 4

ANTISUBMARINE WARFARE

The detection of enemy submarines is one of the Navy's major problems today. There are many types of equipment in use that aid in the detection and tracking of submarines. As an aviation electronics technician, you will need to understand the principles used in these equipments. Once again, every effort is made to discuss as many different platforms and equipments as possible.

SONAR PRINCIPLES

Learning Objective: *Identify factors that affect the behavior of a sound beam in water.*

The word *sonar is* derived from the initial letters of SOund, NAvigation, and Ranging. The word *sonar* is used to describe equipment that transmits and receives sound energy propagated through water. Airborne sonar equipment is commonly called "dipping sonar," and is used aboard various helicopters. Sonobuoys, also a form of sonar, will be discussed later in this chapter.

The operating principles of sonar are similar to that of radar, except sound waves are used instead of radio frequency waves. When the sound wave strikes an object, some of the energy reflects back to the source from which it came. Since the speed of the sound wave and the time it takes to travel out and back are known, range can be determined. By knowing the direction from which the sound echo is reflected, the operator can determine the bearing information.

The type of sonar equipment that depends primarily on a transmitted sound wave and the reception of an echo to determine range and bearing of a target is known as echo-ranging or active sonar equipment. Another type of sonar equipment is referred to as listening or passive sonar. This type of sonar uses the target as the sound source. Although most sonar equipment can be used in either mode of operation, surface ships and aircraft generally use the active mode, and submarines use the passive mode.

In echo-ranging sonar equipment, the source of the sound wave is a transducer. The sonar transducer is a watertight unit that is used to convert electrical energy into acoustical energy and acoustical energy back into electrical energy. The transducer acts like a loudspeaker in an office intercom system, alternately converting electrical energy into mechanical energy and mechanical energy into electrical energy. The transducer acts like an underwater loudspeaker during transmission and an underwater microphone during reception. The sound waves produced by a sonar transducer are represented by the circular lines shown in figure 4-1. Refer to this figure as you read the following text.

When the diaphragm of the transducer moves outward, it moves the water next to the diaphragm. This produces a high-pressure area or compression in the water. When the diaphragm of the transducer moves inward, the water next to the diaphragm moves inward. Thus, a low-pressure or rarefaction is produced in the water. As long as the diaphragm is vibrating, alternate compressions and rarefactions travel outward from the transducer in the water. The distance between two successive rarefactions or two successive compressions is the wavelength of the

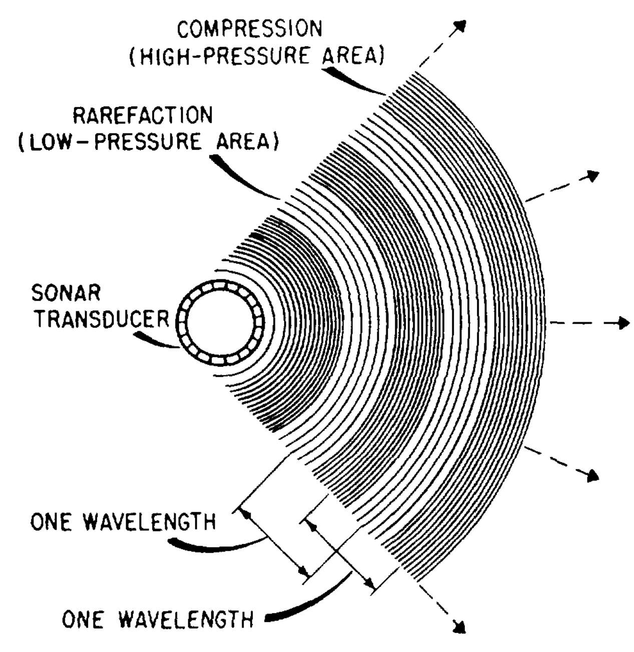


Figure 4-1.-Sound waves produced in water by a transducer.

sound wave. The frequency (in hertz) of the sound wave is the number of wavelengths that occur every second.

FACTORS AFFECTING THE SOUND BEAM

The particular sound waves of interest to the sonar operator are the waves that leave the sonar transducer in the form of a beam and go out into the water in search of a submarine. If the sound beam finds a target, it will return in the form of an echo.

The use of sonar equipment depends on the presence and the recognition of an echo from a target. Detection of the echo depends on the quality and relative strength (loudness) of the echo compared to the strength and character of other sounds, since they tend to mask or cover it.

The sonar operator should know what factors can weaken the sound beam as it travels through water, what factors in the seawater determine the path and speed of the sound beam, and what factors affect the strength and character of the echo. Any signal strength lost during the beam's travel through the water is known as "transmission loss." Some of the factors determining transmission loss are discussed in the following paragraphs.

Absorption and Scattering

Some of the sound energy emitted by the source will be absorbed while passing through the water. The amount absorbed this way depends on the sea state. Absorption is high when winds are great enough to produce whitecaps and cause a concentration of bubbles in the surface layer of the water. In areas of wakes and strong currents, such as riptides, the loss of sound energy is greater. Therefore, echo ranging through wakes and riptides is difficult because of the combined effect of false echoes, high reverberations, and increased absorption. Absorption is greater at higher frequencies than at lower frequencies.

Sound waves are weakened when they reach a region of seawater that contains foreign matter, such as seaweed, silt, animal life, or air bubbles. This foreign matter scatters the sound beam and causes loss of sound energy. The practical result of scattering is to reduce echo strength, especially at long range.

Reflection

Echoes occur when the sound beam hits an object or a boundary region between transmission mediums in such a manner as to reflect the sound or to throw it back to its origin. Reflection of sound waves sometimes happens when a wave strikes a medium of different density from that through which it has been traveling. This will occur in cases where the two mediums are of sufficiently different densities, and the wave strikes at a large angle. This happens because the sound wave travels at different speeds through the two different densities. For example, a sound wave traveling through seawater is almost entirely reflected at the boundary of the water and air. The speed of sound in seawater is about four times greater than the speed of sound in air, and the density of water is more than 800 times greater than that of air. Therefore, practically all of the sound beam will be reflected downward from the sea surface.

Similarly, when a sound wave traveling through the seawater strikes a solid object like a submarine, the difference in the density and the sound velocity in the two mediums is such that all but a small amount of the sound beam will be reflected. That portion of the beam that strikes surfaces of the submarine perpendicular to the beam will be reflected directly back to the origin as an echo.

In calm seas, most of the sound energy that strikes the water surface from below will be reflected back down into the sea. A scattering effect occurs as the sea gets progressively rougher. In these circumstances, part of any sound striking the surface is lost in the air, and part is reflected in scattering directions in the sea. In water less than 600 feet deep, the sound may also be reflected off the bottom. Other factors being equal, the transmission loss will be least over a smooth, sandy bottom and greatest over soft mud. Over rough and rocky bottoms, the sound is scattered, resulting in strong bottom reverberations.

Reverberation

When sound waves echo and re-echo in a large hall, the sound reverberates. Reverberations are multiple reflections. Lightning is an example of this from nature. When lightning discharges, it causes a quick, sharp sound; but by the time the sound of the thunder is heard, it is usually drawn out into a prolonged roar by reverberations.

A similar case often arises in connection with sonar. Sound waves often strike small objects in the sea, such as fish or air bubbles. These small objects cause the waves to scatter. Each object produces a small echo, which may return to the transducer. The reflections of sound waves from the sea surface and the sea bottom also create echoes. The combined echoes from all these disturbances are called "reverberations." Since they are reflected from various ranges, the y seem to be a continuous sound. Reverberations from nearby points may be so loud that they interfere with the returning echo from a target.

There are three main types of reverberation, or backward scattering of the sound wave. They are as follows:

1. There is reverberation from the mass of water. Causes of this type of reverberation are not completely known, although fish and other objects contribute to it.

2. There is reverberation from the surface. This is most intense immediately after the sonar transmission; it then decreases rapidly. The intensity of the reverberation increases markedly with increased roughness of the sea surface.

3. There is reverberation from the bottom. In shallow water, this type of reverberation is the most intense of the three, especially over rocky and rough bottoms.

Divergence

Just as the beam from a searchlight spreads out and becomes weaker with distance, so does sound. The farther the target is from the sonar transducer, the weaker the sound waves will be when they reach it. This is known as spreading or divergence.

Refraction

If there were no temperature differences in the water, the sound beam would travel in a straight line. This happens because the speed of sound would be roughly the same at all depths. The sound beam would spread and become weaker at a relatively constant rate.

Unfortunately, the speed of sound is not constant at all depths. The speed of sound in seawater increases from 4,700 feet per second to 5,300 feet per second as the temperature increases from 30°F to 85°F. Salinity and pressure effects on sound speed are not as extreme as the large effects produced by temperature changes in the sea. Because of the varying temperature differences in the sea, the sound beam does not travel in a straight line, but follows curved paths. This results in bending, splitting, and distorting of the sound beam.

When the sound beam is bent, it is said to be refracted. A sound beam is refracted when it passes from a medium of a given temperature into a medium with a different temperature. An example of this is a sound beam traveling from an area of warm water into an layer of cold water. The sound beam will bend away from the area of higher temperature (higher sound velocity) toward the lower temperature (lower sound velocity).

As a result of refraction, the range at which a submarine can be detected by sound may be reduced to less than 1,000 yards, and this range may change sharply with changing submarine depth.

Speed of the Sound Beam

As mentioned previously, sound travels much faster in seawater than in the atmosphere. Near sea level, sound travels through the atmosphere at approximately 1,080 feet per second. In seawater, that same sound beam will travel at approximately 4,700 to 5,300 feet per second.

There are three main characteristics of seawater that affect the speed of the sound wave traveling through it. These characteristics are as follows:

1. Salinity (the amount of salt in the water)

2. Pressure (caused by increased depth)

3. Temperature (the effect of which is calculated in terms of slopes, or gradients)

There is a high mineral content in seawater. The density of seawater is approximately 64 pounds per cubic foot, while fresh water has a density of about 62.4 pounds per cubic foot. This difference is caused by the salt in the seawater. Salt content in seawater is called the salinity of water.

The overall effect of increasing the salinity is an increase in the speed of the sound beam in the water. This means that as the sound travels through water of varying salinity, it travels faster through the water with more salt content. Such a change in salinity is considerable at the mouth of a river emptying into the sea. Elsewhere, the difference in salinity is too small to affect the rate of travel of the sound beam significantly, and may be ignored.

Since sound travels faster in water under pressure, the speed of sound in the sea increases proportionally with depth. This difference in speed is also very small and has little effect for the operator.

Temperature is the most important of the factors affecting the speed of the sound beam in water. The speed will increase with increasing temperature at the rate of 4 to 8 feet per second per degree of change, depending on the temperature.

The temperature of the sea varies from freezing in the polar seas to more than 85°F in the tropics. The temperature can also decrease by more than 30°F from the surface to a depth of 450 feet. Thus, the temperature is the most important factor because of the extreme differences and variations. Remember, the speed of sound in water increases as the temperature increases.

Depth and Temperature

Except at the mouths of great rivers where salinity may be a factor, the path of the sound beam will be determined by the pressure effects of depth and by temperature. The pressure effect is always present and always acts in the same manner; it tends to bend the beam upwards. Figure 4-2 illustrates the situation when the temperature does not change with depth. Even though the temperature does not change, the speed of the sound increases with depth. The speed increase is due entirely to the effect of pressure. Notice in figure 4-2 that the sound beam bends upward.

Figure 4-3 shows what happens when temperature increases steadily with depth. When the surface of the sea is cooler than the layers beneath it, the temperature increases with depth, and the water has a positive thermal gradient. This is an unusual condition, but when it does happen, it causes the sound beam to be refracted sharply upwards.

When the sea gets colder as the depth increases, the water has a negative thermal gradient. In this situation, the effect of temperature far outweighs the effect of depth, and the sound beam is refracted downward.

If the temperature remains the same throughout the water, the temperature gradient is isothermal

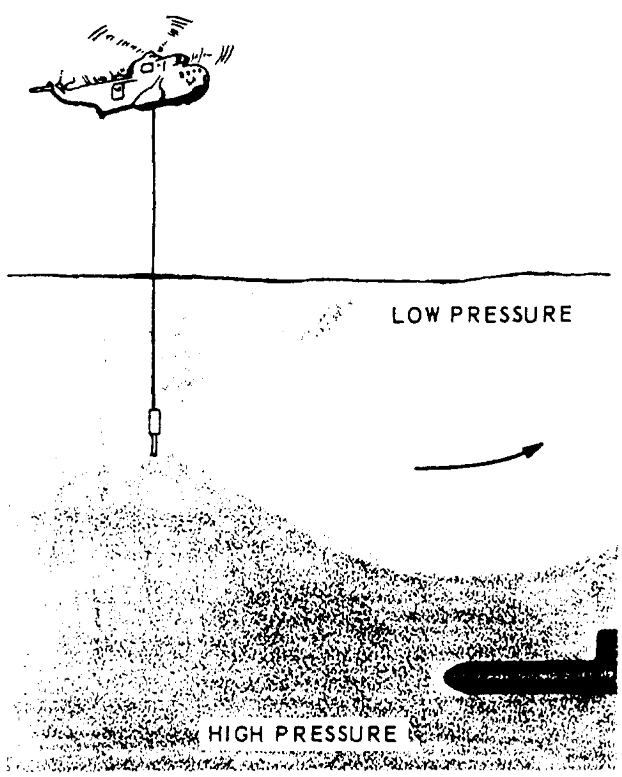


Figure 4-2.-Bending of a sound beam away from a high-pressure area.

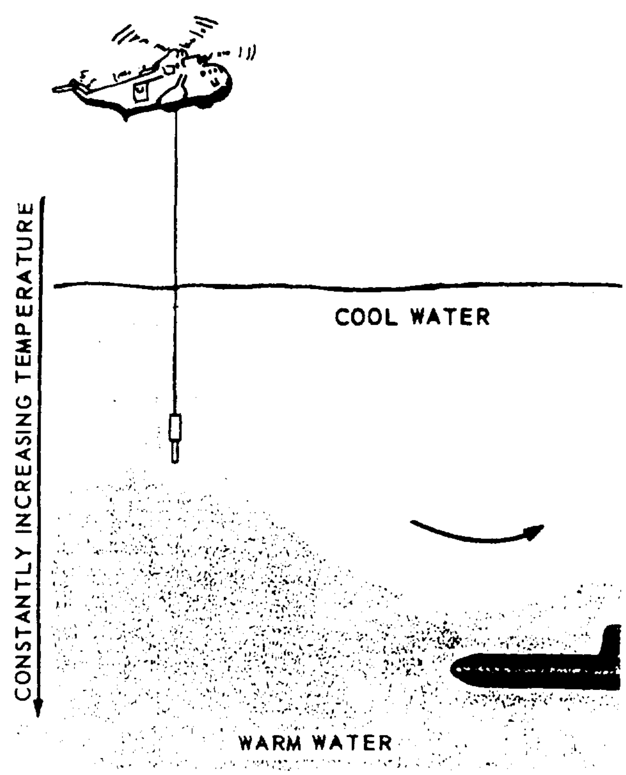


Figure 4-3.-The effect of a positive thermal gradient.

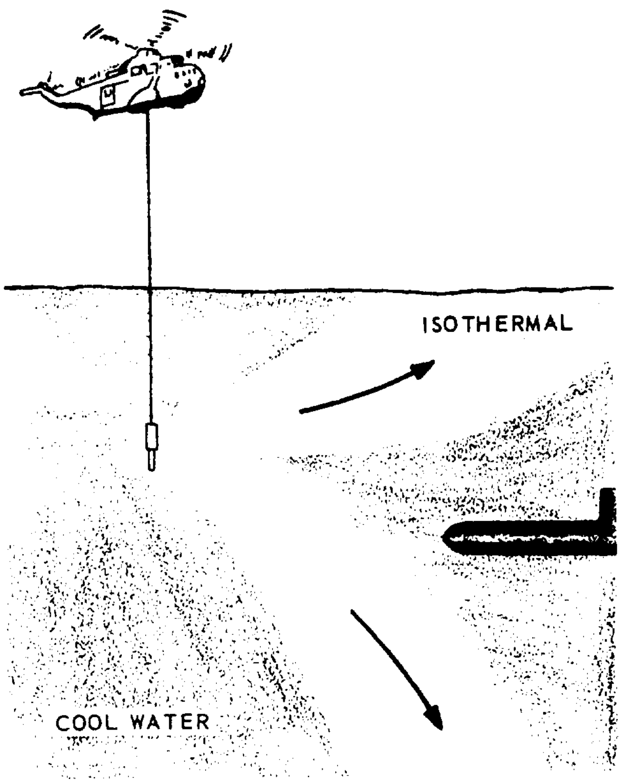


Figure 4-4.-Isothermal conditions.

(constant temperature). Refer to figure 4-4 as you read the following text. The surface layer of water in the figure is isothermal, but beneath this layer the temperature decreases with depth. This causes the sound beam to split and bend upward in the isothermal layer and downward below it.

Remember, when no temperature difference exists, the sound beam refracts upward due to pressure. When the temperature changes with depth, the sound beam bends away from the warmer water.

Under normal conditions the sea's temperature structure is similar to that shown in figure 4-5. This structure consists of three layers as follows:

1. A surface layer of varying thickness with uniform temperature (isothermal) or a relatively slight temperature gradient.

2. The thermocline, which is a region of relatively rapid decrease in temperature.

3. The rest of the ocean, with slowly decreasing temperature down to the sea floor.

If this arrangement changes, the path of the sound beam through the water will change.

Layer depth is the depth from the surface to the top of a sharp negative gradient. Under positive thermal gradient condition, the layer depth is the depth of maximum temperature. Above layer depth, the temperature may be uniform, or a weak positive or negative gradient may be present.

Layer effect is the partial protection from echo ranging and listening detection, which a submarine gains when it submerges below layer depth. Reports from surface vessels indicate that effective ranges on submarines are greatly reduced when the submarine dives below a thermocline, and that the echoes received are often weak and sound "mushy."

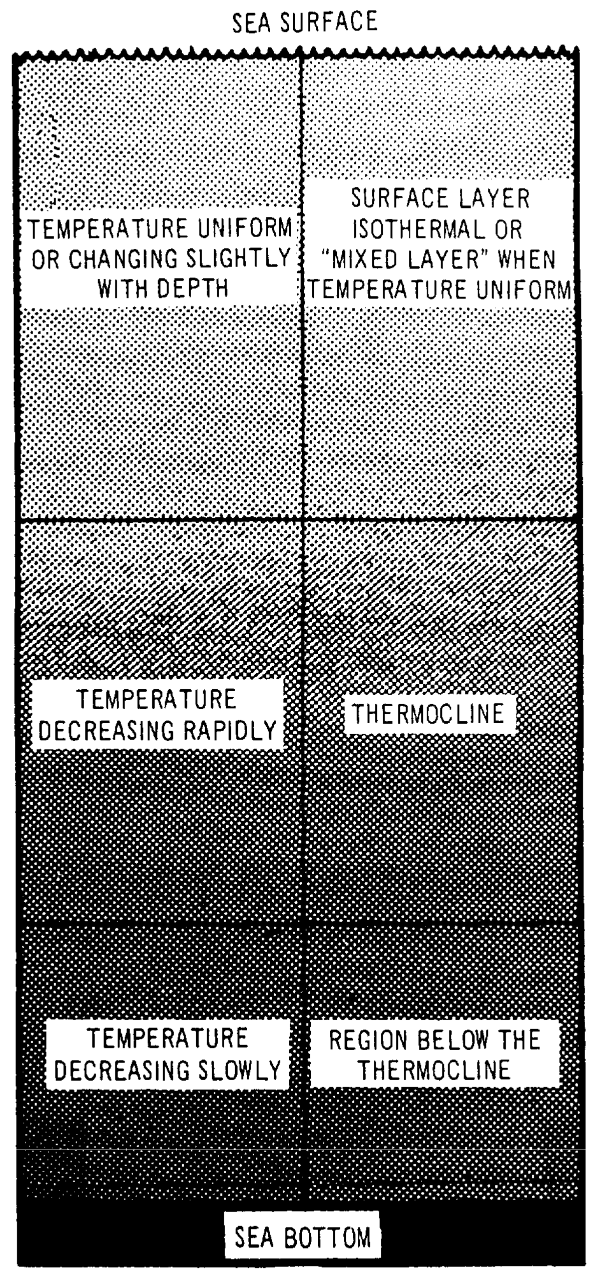


Figure 4-5.-Normal sea temperature structure.

DOPPLER EFFECT

When there is relative motion between the source of a wave of energy and its receiver, the received frequency differs from the transmitted frequency. When the source of wave motion is moving towards the receiver, more waves per second are received than when the source remains stationary. The effect at the receiver is an apparent decrease in wavelength and, therefore, an increase in frequency. On the other hand, when the source of wave motion is moving away from the receiver, fewer waves per second are encountered, which gives the effect of a longer wavelength and an apparent decrease in frequency. This change in wavelength is called the "Doppler effect." The amount of change in wavelength depends on the relative velocity between the receiver and the source. Relative velocity is the resultant speed between two objects when one or both are moving.

You have heard the term *Doppler effect* many times, but may not have known what the phenomenon was. An example of this is what you hear at a railroad crossing. As a train approaches, the pitch of the whistle is high. As the train passes you, the pitch seems to drop. Then, as the train goes off in the distance, the pitch of the whistle is low. The Doppler effect causes the changes in the pitch.

Sound waves generated by the whistle were compressed ahead of the train. As they came toward you, they were heard as a high-pitched sound because of the shorter distance between waves. When the train went by, the sound waves were drawn out, resulting in the lower pitch. Refer to figure 4-6 as you read the following explanation of Doppler effect.

If you examine 1 second of the audio signal radiated by the train whistle, you will see that the signal is composed of many cycles of acoustical energy. Each cycle occupies a definite period of time and has a definite physical wavelength. (Because of space limitations, only every 10th wave is illustrated in view A of figure 4-6.) When the energy is transmitted from a stationary source, the leading edge will move out in space the distance of one wavelength by the time the trailing edge leaves the source. The cycle will then occupy its exact wavelength in space. If that cycle is emitted while the source is moving, the source will move a small distance while the complete cycle is being radiated. The trailing edge of the cycle radiated will be closer to the leading edge.

Figure 4-6, view B, shows the effect of relative motion on a radiated audio signal. Notice the wavelength of the sound from the stationary emitter, as illustrated in condition (1) of view B.

In condition (2) of view B, the emitter is moving towards the listener (closing). When the cycle is compressed, it occupies less distance in space. Thus, the wavelength of the audio signal has been decreased, and the frequency has been proportionately increased (shifted). This apparent increase in frequency is known as UP Doppler.

The opposite is true in condition (3) of view B. The emitter is moving away from the listener (opening). The wavelength occupies more distance in space, and the frequency has been proportionately decreased. This apparent decrease in frequency is known as DOWN Doppler. The factors that determine the amount of Doppler shift are the velocity of the sound emitter, the velocity of the receiver, and the angle between the direction of motion of the receiver and the direction of motion of the sound emitter. This angle, known as angle 8, is used in a formula to determine the velocity of the emitted signal at the receiver and the frequency of the Doppler shift.

The Doppler shift works both ways. If you were on the train and had listened to a car horn at the crossing, the pitch of the horn would have changed. The effect is the same because the relative motion is the same.

The sonar equipment deals with three basic sounds. One of these sounds is the sound actually sent out by the equipment. The second sound is the reverberations that return from all the particles in the water—seaweed, fish, etc. The third sound is the most important one, the echo from the submarine.

The sound sent into the water (the actual ping) is seldom heard by the operator. Most of the equipment is designed to blank out this signal so that it doesn't distract the operator. This means there are only two sounds to deal within the discussion of Doppler effect in sonar.

Reverberations are echoes from all the small particles in the water. Consider just one of these particles for a moment. A sound wave from the transducer hits the particle and bounces back, just as a ball would if thrown against a wall. If the particle is stationary, it will not change the pitch of the sound. The sound will return from the particle with the same pitch that it had when it went out.

If the sonar transducer is stationary in the water and sends out a ping of 10 kHz, the particles all send back a sound that has the same pitch. Now suppose that the transducer acquires forward motion and a ping is sent out dead ahead. It is just as if the transducer were the oncoming train, and the particles were occupants of the car. Remember, that as the train came forward, the pitch of the whistle sounded higher to the occupants of the car. In the same way, the particles "hear" a higher note and reflect this higher note. Therefore, the sonar equipment will detect a higher note than the one sent out. If the transducer in this example is pointed dead astern, a lower note than the one sent out will be heard.

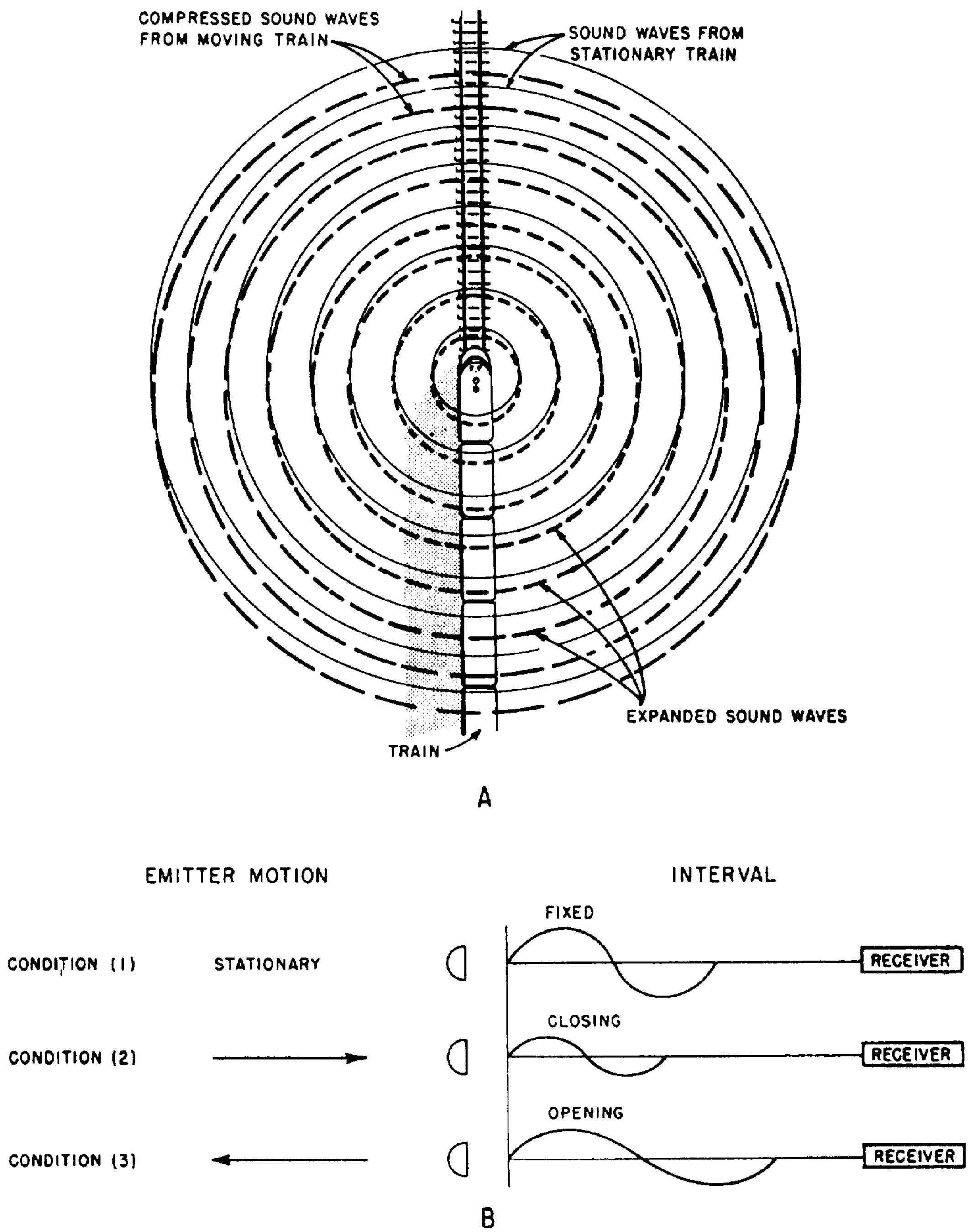


Figure 46-Doppler effect. A. One-second audio signal. B. One sine wave of the audio signal.

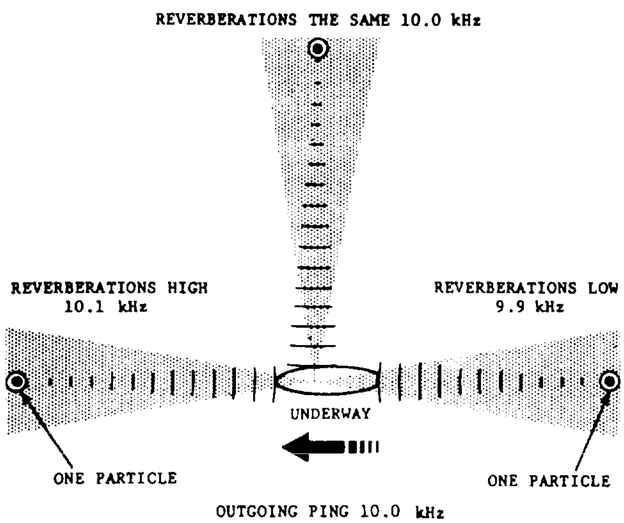


Figure 4-7.-Transducer installed on a moving ship.

If the transducer is aimed perpendicular to the direction of motion, the particles in the water will echo the same note sent out because the transducer is neither going toward the particles nor away from them. (See figure 4-7.)

Now consider the echo from the submarine, shown in figure 4-8. Again, the transducer is shown stationary. When the submarine is neither going toward nor away from the transducer, it must be either stopped or crossing the sound beam at a right angle. If it is in either condition, it reflects the same sound as the particles in the water. Consequently, the submarine echo has exactly the same pitch as the reverberations from the particles.

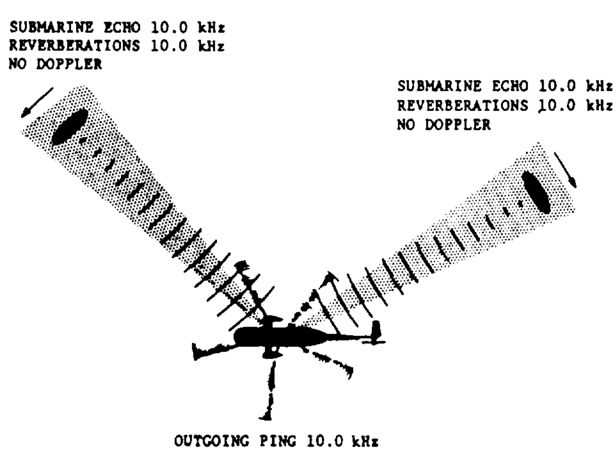


Figure 4-8.-Transducer supported by helicopter. Doppler effect is absent when submarine is stationary or moves at right angles to sound beam.

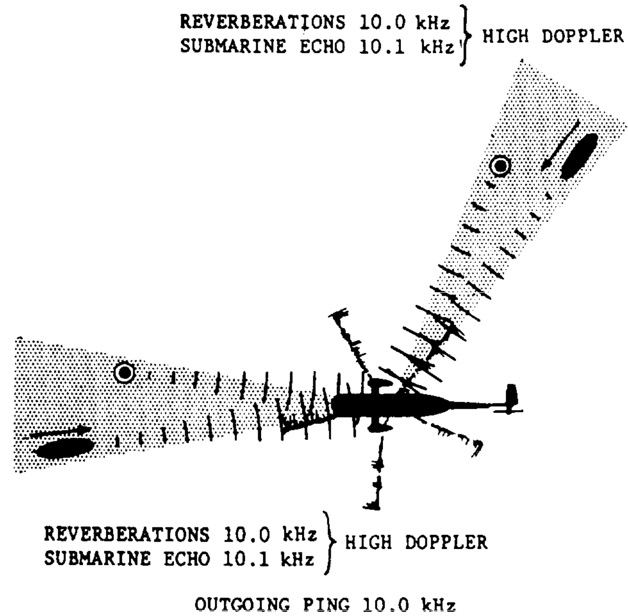


Figure 4-9.-Comparison of echo frequency and reverberation frequency when submarine moves toward transducer.

Suppose that the submarine is going toward the transducer, as shown in figure 4-9. It is as though the submarine is the train heading toward the car that is blowing its horn at the crossing. The horn sounds higher as the train approaches the car. In the same manner, the sound beam sounds higher to the submarine as it approaches the transducer.

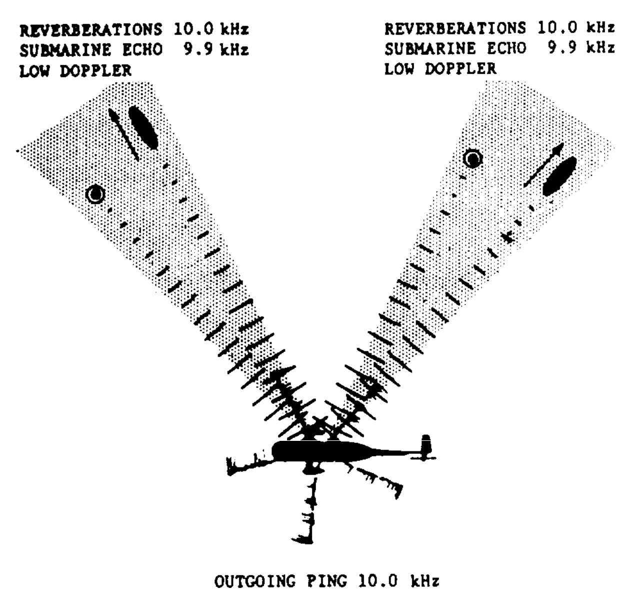


Figure 4-10.-Comparison of echo frequency and reverberation frequency when submarine moves away from transducer.

The submarine reflects an echo of higher pitch than that caused by the particles in the water, which are not moving. When the echo from the oncoming submarine is higher in frequency than the echoes from the reverberations, the Doppler is high. The opposite form of Doppler shift will occur when the submarine is heading away from the transducer. In this case, the pitch of the echo is lower than the pitch of the reverberations. (See figure 4-10.)

The degree of Doppler indicates how rapidly the submarine is moving relative to the transducer. For example, a submarine moving directly toward the transducer at 6 knots returns an echo of higher frequency than one moving at only 2 knots. Also, a submarine moving at 6 knots directly at the transducer returns an echo of higher frequency than one moving only slightly at the transducer. Refer to figure 4-11. This figure shows 12 submarines traveling at various speeds and courses with respect to a stationary transducer supported by the helicopter. Notice how the Doppler of each submarine is influenced by its speed and direction.

Doppler also makes it possible to distinguish the difference between a wake echo and a submarine echo. Relatively speaking, the submarine's wake is stationary. Therefore, its wake returns an echo with a frequency different from that of the Doppler shifted submarine echo.

AIRBORNE SONAR SYSTEM

Learning Objective: *Recognize components and operating principles of an airborne sonar system.*

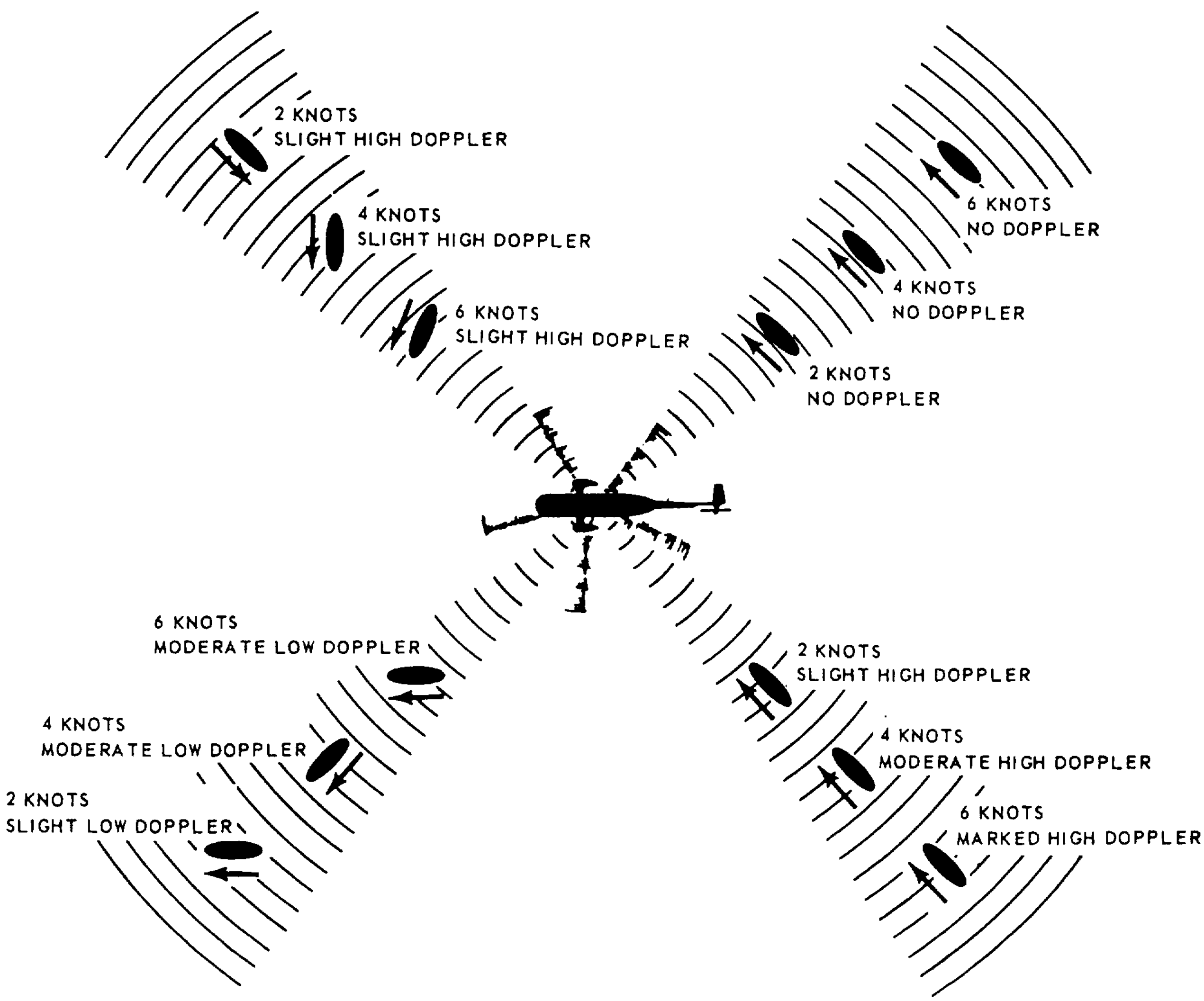


Figure 4-11-Varying degrees of Doppler effect due to differences in course and speed of submarines.

The Sonar Detecting-Range Set AN/AQS-13E is a lightweight, echo-ranging, dipping sonar set. It is capable of detecting, tracking, and classifying moving and stationary underwater objects. Also, this sonar set provides capabilities for underwater voice communication and generation of echo-ranging, aspect, and bathythermographic recordings.

MAJOR COMPONENTS

The following text will discuss the various components that makeup the AN/AQS-13E sonar detecting-range set.

Azimuth and Range Indicator

The azimuth and range indicator (fig. 4-12) is positioned at the sensor station. It provides the means for the operator to track targets. There are four controls on the left hand side of the indicator for operator comfort. The CURSOR INTENSITY switch controls the brightness of the cursor. The CRT INTENSITY controls the brightness of the overall CRT. The VIDEO GAIN controls the level of the video signal applied to the CRT. The AUDIO GAIN switch controls the level of the audio signal.

The right side of the indicator face contains a meter called the RANGE RATE-KNOTS meter. This meter displays the opening or closing speed of the selected target. The MTI THRESHOLD switch selects the range rate threshold of targets to be displayed on the CRT. The DISPLAY switch selects either sonobuoy signals or sonar signals to be shown on the CRT. To activate the sonar set, press the POWER switch. This activates the entire system with the exception of the dome control. The TEST switch initiates the built-in test functions and analyzes the results.

Bearing and Range Indicator

The bearing and range indicator (fig. 4-13) is mounted on the instrument panel, and presents the pilot with target bearing and range information. This information is supplied when the sonar operator sets the receiver TARGET switch to VERIFY.

The bearing is displayed on a three-digit display that shows degrees magnetic. The range is displayed on a five-digit display that shows yards to target. There is also a dimmer switch that controls the intensity of the display illumination.

Cable Assembly and Reel

The special purpose cable is 500±5 feet long, and is pretensioned on the reel. The cable contains 30 shielded conductors in a braided steel strength member, and is protected by a waterproof outer covering of polyurethane. There are colored bands spaced along the length of the cable to aid in checking the amount of cable payed out.

Dome Control

This control box (fig. 4-14) allows the operator to raise and lower the transducer (dome). There are three switches and two indicators on the face of this control box. The DEPTH-FEET indicator advises the operator on how far the transducer is lowered in feet.

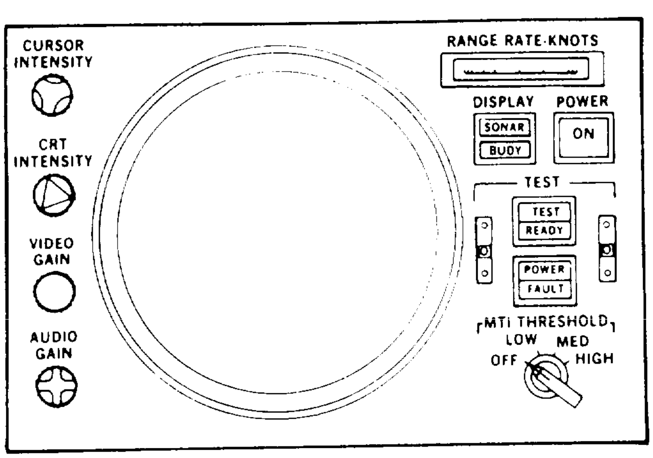


Figure 4-12.-Azimuth and range indicator.

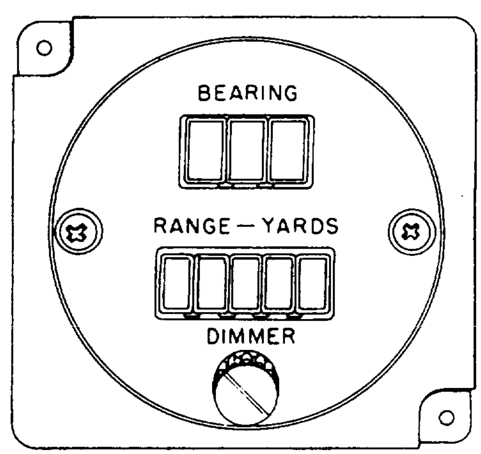


Figure 4-13.-Bearing and range indicator.

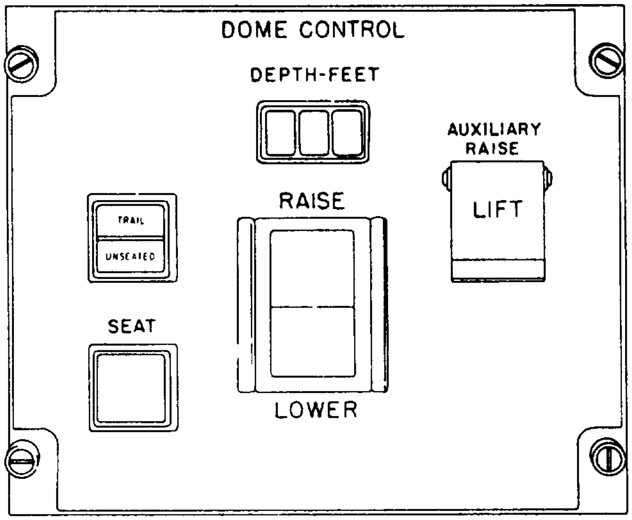


Figure 4-14.-Dome control.

The TRAIL/UNSEATED indicator advises the operator of the transducer's position.

The RAISE/LOWER switch activates the reeling machine to either raise or lower the dome. The SEAT s witch/indicator is used to raise the transducer from the trail position to the seat position, and then indicates that the transducer is in the seat position. When the operator selects the AUXILIARY RAISE switch, the transducer will be electrically raised in the event of a hydraulic malfunction.

Hydraulic Cable Reeling Machine

The hydraulic cable reeling machine (fig. 4-15) uses a hydraulic motor to raise and lower the dome. The sequence of raising or lowering is accomplished by energizing solenoids on the hydraulic control package, which programs hydraulic pressure to release or retrieve the dome.

The reel rotates to pay out or retrieve the cable. As the cable goes out or comes in, a level wind assembly, mounted on the frame, moves laterally to wind or unwind the cable evenly. The level wind is chain-driven from the gearbox assembly.

A standard one-half inch, square-drive speed wrench, which comes with the reeling machine, can be used to manually release or retrieve the cable. When the handcrank is used, the electrical circuits are disabled.

Recorder

The RO-358/ASQ-13A recorder (fig. 4-16) is located at the sensor operator's station and displays information on chart paper. This recorder is used for both the sonar system and the magnetic anomaly detection (MAD) system. MAD will be discussed later in this chapter.

The recorder contains the following switches and indicators on its faceplate: The CHART MOVE switch provides for rapid chart movement. The MODE switch selects the mode in which the recorder will operate. The RANGE RATE switch compensates for target range rate when in the aspect mode. A PULSE switch enables the operator to select transmit pulse duration while in the aspect mode. The CONTRAST control allows the operator to control the intensity of the recorded trace, while the PATTERN SHIFT knob shifts the information to the left. The SAD indicator/switch indicates when a SAD signal is being processed, and it resets the SAD indication. The REFERENCE switch enables the operator to select a new stylus during MAD operations.

Sonar Hydrophone and Sonar Projector

The underwater transmitting and receiving element consists of a projector (transmitting array) and a hydrophone (receiving array). The combination of these two components, which are electrically and

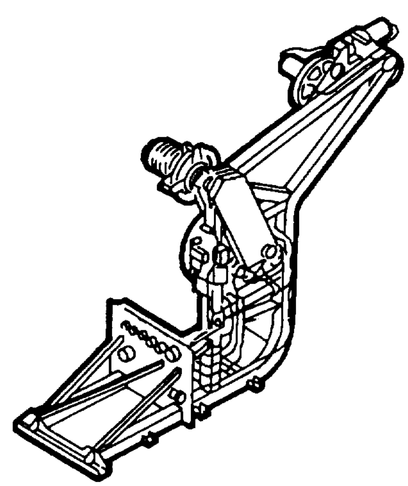


Figure 4-15.-Hydraulic cable reeling machine.

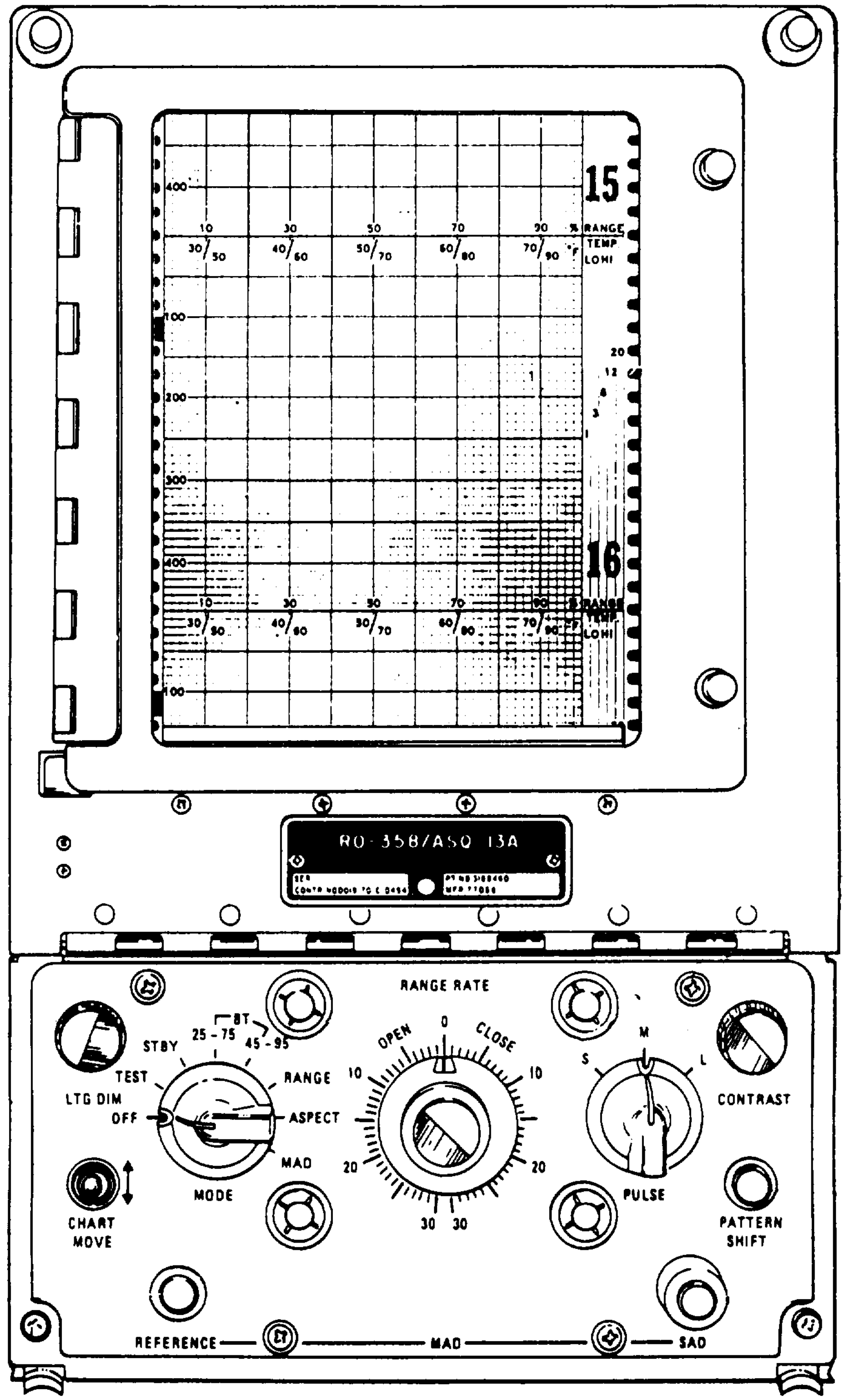


Figure 4-16.-RO-358/ASQ-13A.

mechanically connected, is referred to as the DOME (fig. 4-17).

The projector assembly of the dome contains a projector, a flux gate compass, and a pressure potentiometer. The projector is composed of six matched ceramic rings (barium titanate) and a tuning transformer. The projector converts the electrical pulses from the sonar transmitter to acoustic pulses that are radiated in an omnidirectional pattern through the water. The flux gate compass forms a portion of the display stabilization loop, providing an output to

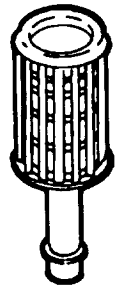


Figure 4-17.-Hydrophone and projector.

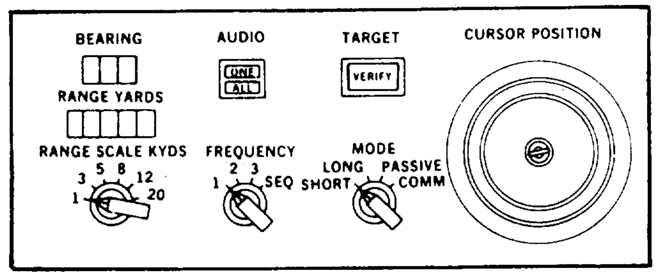


Figure 4-18.-Sonar receiver.

indicate the sonar dome azimuth deviation from magnetic north. The pressure potentiometer provides an output to indicate depth of the dome in water. The projector is covered with a black neoprene boot that is filled with oil.

The hydrophone assembly consists of 16 stave assemblies bolted to a cork-lined fiber glass barrel, an end bell, a temperature sensor, and an electronic package. The staves, filled with oil and hermetically sealed, convert the received acoustic pulses to low-level ac signals. These signals are amplified and applied through the special purpose electrical cable to the receiver located in the helicopter. The stave housings are stainless steel, each containing 12 matched ceramic rings with trimming capacitors, and they are mounted on a printed-circuit board. The output of each stave is applied to a preamplifier, which is on the electronics package. A temperature sensor for measuring temperature of the water is located on the end bell.

The dome requires no adjustments. All inputs and outputs are made through the special electrical connector on top of the electronic housing.

Sonar Receiver

The sonar receiver (fig. 4-18) consists of all electronic circuits required for the processing of input signals of the sonar set.

The following switches and indicators are mounted on the front panel of the receiver:

1. A RANGE SCALE-KYDS switch for selecting the desired operating range.

2. A MODE switch for selecting the operating mode of the sonar.

3. A FREQUENCY switch for selecting the desired frequency.

4. A dual CURSOR POSITION control for controlling the cursor circle on the CRT in both azimuth and range.

5. A three-digit BEARING display that indicates cursor circle bearing in degrees from magnetic north.

6. A five-digit RANGE-YARDS display that indicates the range of the cursor circle in yards.

7. An AUDIO switch/indicator for selecting audio from all eight sectors, or only the sector selected by the cursor circle position.

8. A TARGET switch/indicator for applying bearing and range information to the pilot's bearing and range indicator.

Sonar Transmitter

The transmitter (fig. 4-19) develops the signals to be transmitted by the system. A POWER circuit breaker, located on the front cover of the transmitter,

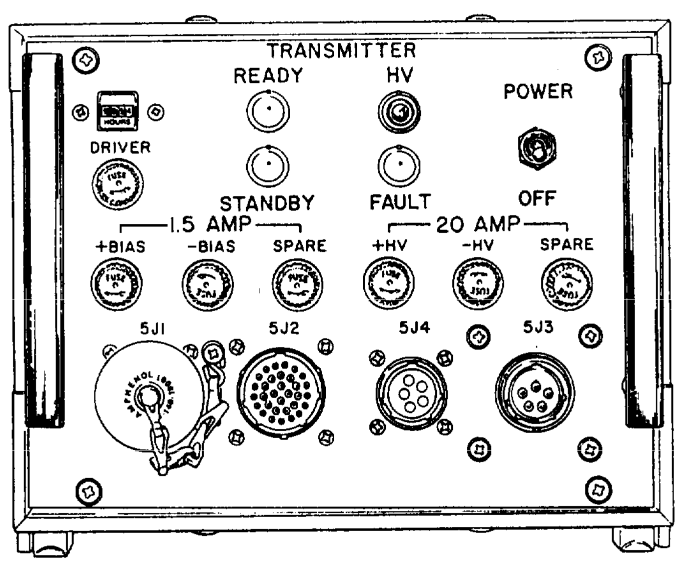


Figure 4-19.-Sonar transmitter.

applies 115 volts ac to the transmitter. When high voltage is being used, the HV indicator will be lit, The READY indicator shows when the transmitter is ready for operation. There are also STANDBY and FAULT indicators to show when there is a malfunction in the transmitter.

Sonar Data Computer

The sonar data computer is used with the sonar set to provide processing and display of LOFAR, DIFAR, and CASS sonobuoy signals on the sonar's CRT. These sonobuoys will be discussed later in this chapter. The sonar data computer is also used to provide a more accurate fix on the target by providing a digital readout of target range, speed, and bearing.

MODES OF OPERATION

The sonar set provides three operational modes of operation: echo ranging (LONG and SHORT), PASSIVE, and COMM. A fourth mode, TEST, is used to determine that the sonar set is in operational status. Three recording modes are also available: low (25°F to 75°F) or high (45°F to 95°F) BT (bathythermograph), RANGE, and ASPECT. A fourth recording mode, TEST, is used to determine that the recorder is in operational status.

Echo-Ranging Mode

The sonar set produces recurrent 3.5- (SHORT) or 35- (LONG) millisecond acoustic pulses that are radiated through the water from the projector portion of the dome. Returning target echoes are received by the hydrophone and processed into a left and right half-beam for each sector. Target bearing is determined by the phase difference existing between the left and right half-beams formed for each sector seamed. Bearing of the target is resolved from the edge of each of the eight 45-degree sectors scanned. Target range is determined from the elapsed time between transmission of a given pulse and the return of the target echo. Target and range are presented simultaneously as a single target pip on the CRT. Variations of the speed of sound in water due to the temperature of the water surrounding the dome are compensated for automatically.

An audio signal is developed for each returning target echo. These audio signals are applied to the helicopter's intercommunication system in such a manner that signals representing the left four sectors of the CRT are applied to the left earphone, and the signals for the right four are applied to the right earphone. A different nonharmonic tone is generated for each of the four sectors in each CRT half when the AUDIO switch is in the ALL position. In the ONE position, the audio representing the CRT sector in which the cursor is positioned is applied to both earphones.

The nature of the object causing the echo can be determined by the outline and intensity of the target display on the CRT, as well as by the quality and intensity of the audio. The opening or closing speed of the target within the cursor circle is displayed automatically on the RANGE RATE-KNOTS meter.

Passive Mode

In the passive mode, active echo-ranging is disabled, and underwater sounds may be received and displayed on the CRT. Bearing information is presented in this mode of operation and appears in the form of a noise spoke on the CRT. Audio is presented in the same manner as in the echo-ranging mode.

Communication Mode

The COMM mode is used for two-way underwater voice communication with other appropriately equipped helicopters, ships, or submarines operating within range.

Voice communication operation is activated by placing the MODE switch to COMM. Voice transmission is accomplished by depressing a foot switch and speaking into the microphone. Releasing the foot switch permits monitoring voice signals from other similar underwater communications systems.

When the audio switch is set to ONE, reception of underwater voice signals is accomplished by placing the cursor circle in the CRT sector in which the noise spoke appears and by regulating the AUDIO GAIN control.

Test Modes

The test modes check the operational status of the system as a whole and the various components of the system as individual units. These test modes use internally generated signals.

During normal operation, the test circuits sample major system functions and voltages. If a sampled function exceeds preset limits, the FAULT indicator illuminates for the length of time that the fault exists.

Recorder Bathythermographic Mode

The recorder bathythermographic (BT) mode is used to obtain graphs of temperature gradients appearing beneath the surface of the surrounding water to depths of 450 feet. Temperature and depth signals obtained from the dome are processed by the receiver and dome control. These signals are applied to the recorder circuits when the recorder MODE selector switch is moved to the BT position. The recorder chart drive circuits automatically position the chart paper to provide correct chart registration. Recorded scale marks on the chart paper denote the temperature scale being used for each temperature recording. The recorder plots temperature on the vertical axis and depth on the horizontal axis of the moving chart.

Recorder Range Mode

The recorder RANGE mode is used to obtain continuous strip-chart displays of target echo ranges. Range scale control signals from the receiver RANGE SCALE-KYDS switch are accepted by the recorder sweep circuits to correlate the range sweeps. As the chart paper moves, range scale marks are recorded on the chart paper to denote the range scale being used for each range recording. Target echo video signals are applied to the styluses when they appear in time, as related to the range sweep. The video signals are recorded each time a stylus passes over the range position of a target. The chart advances a small increment for each stylus sweep.

Recorder Aspect Mode

The recorder ASPECT mode is used to obtain continuous strip-chart displays of target echo signals. Timing and control signals, generated within the recorder, slave the receiver timing circuits to alternate sweep ramps between transmit and receive cycles. During each transmit sweep ramp, a train of short keying pulses is generated, and pulsewidth is regulated in the recorder. This pulse train is applied to the receiver. During each receive sweep ramp, the train of received target echo video pulses is applied to the recorder styluses. Target echo signal level is neither limited nor affected in the system. This permits varying intensity recordings (highlights) of target structural characteristics for optimum target classification.

Recorder Test Mode

The sonar operator uses the recorder TEST mode to check the operational status of the recorder. The TEST mode effectively checks the operation of the recorder stylus drive, stylus write, and chart drive operations. In addition, all front panel controls on the recorder can be checked by the operator for operational compliance and accuracy.

MAGNETIC ANOMALY DETECTION

Learning Objective: *Recognize components and operating principles of magnetic anomaly detection (MAD).*

By the beginning of World War II, it had become apparent that the aircraft was a deadly antisubmarine weapon. This was true even though the ability to search and detect submarines was solely dependent on visual sightings. The development of radar extended the usefulness of airborne antisubmarine measures, making detection of submarines possible at night or under conditions of poor visibility. However, visual or radar detection was possible only when the submarine was surfaced. Thus, some method of detecting submerged subs from an aircraft was needed. The use of sonar wasn't feasible because there was no direct contact between the fast-moving aircraft and the surface of the water. The most feasible way of detecting a submerged submarine was to detect its disturbance of the local magnetic field of the earth.

PRINCIPLES OF MAGNETIC DETECTION

Light, radar, and sound energy cannot pass from air into water and return to the air in any degree that is usable for airborne detection. On the other hand, lines of force in a magnetic field are able to make this transition almost undisturbed because the magnetic permeability of water and air are practically the same. Specifically, the lines of force in the earth's magnetic field pass through the surface of the ocean essentially undeviated by the change of medium, and undiminished in strength. Consequently, an object under the water can be detected from a position in the air above if the object has magnetic properties that distort the earth's magnetic field. A submarine has sufficient ferrous mass and electrical equipment to cause a detectable distortion (anomaly) in the earth's field. The function of the MAD equipment is to detect this anomaly.

Magnetic Anomaly

The lines comprising the earth's natural magnetic field do not always run straight north and south. If traced along atypical 100-mile path, the field twists at places to east and west, and assumes different angles with the horizontal. Angles of change in the east-west direction are known as *angles of variation*, while angles between the lines of force and the horizontal

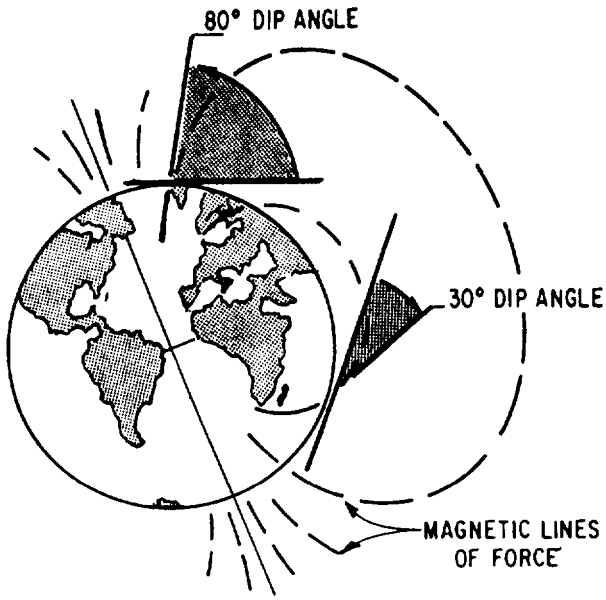


Figure 4-20.-Dip angles.

are known as *angles of dip* (fig. 4-20). At any given point between the equator and the magnetic poles, the relationship of the angle between the earth's surface and the magnetic lines of force is between 0° and 90°. This angle is determined by drawing an imaginary line tangent to the earth's surface and to the line of force where it enters the earth's surface. The angle thus formed is called the DIP ANGLE.

If the same lines are traced only a short distance, 300 feet for instance, their natural changes in variation and dip over such a short distance (short-trace) are almost impossible to measure. However, short-trace variation and dip in the area of a large mass of ferrous material, though still extremely minute, are measurable with a sensitive anomaly detector. This is shown in figure 4-21. The dashed lines represent lines of force in the earth's magnetic field.

View A shows the angular direction at which natural lines of magnetic force enter and leave the surface of the earth. Note that the angles of dip are considerably steeper in extreme northern and southern latitudes than they are near the equator. View B represents an area of undisturbed natural

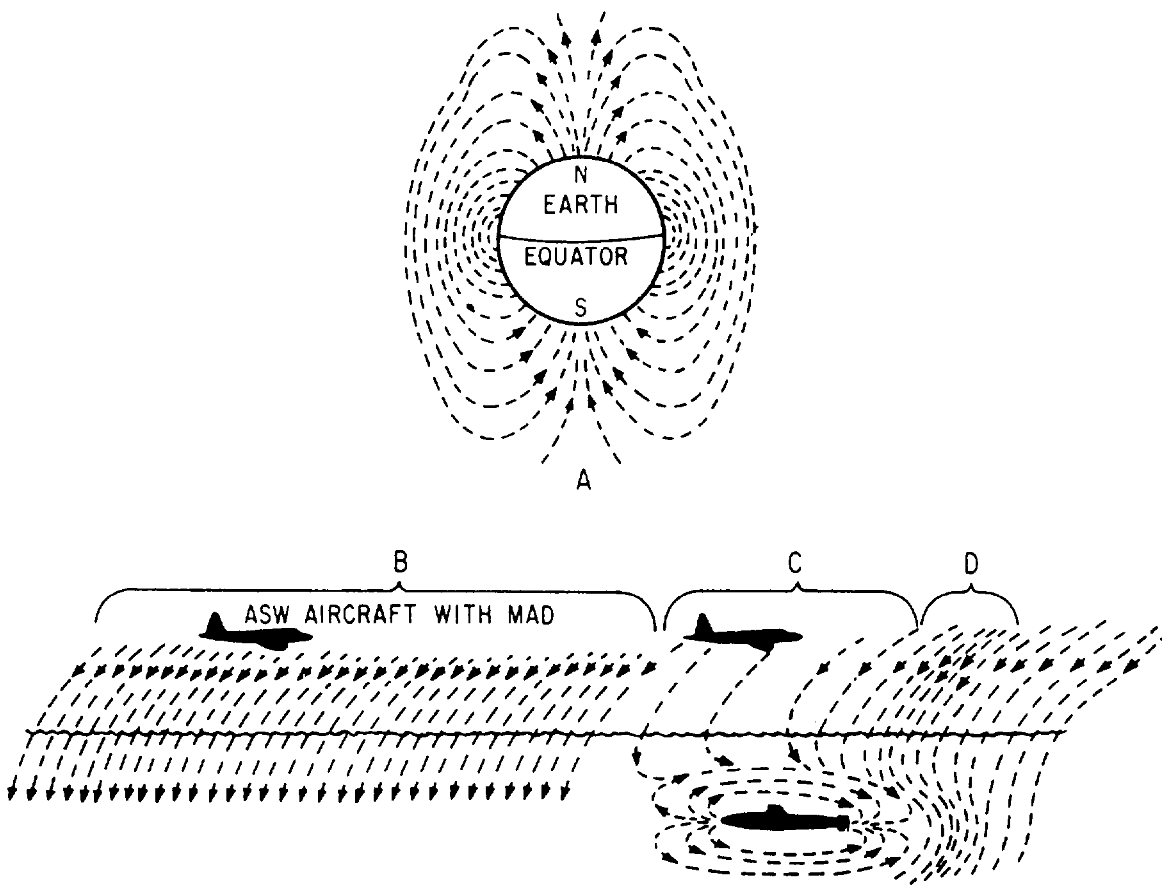


Figure 4-21.-Simplified comparison of natural field density and submarine anomaly.

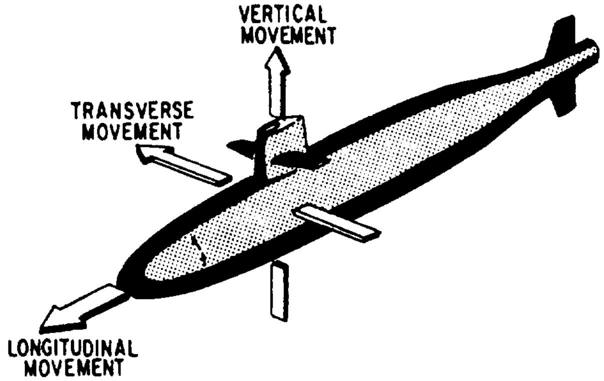


Figure 4-22.-Submarine's magnetic moment.

magnetic strength. In views C and D, the submarine's magnetic field distorts the natural field as shown. The density of the natural field is decreased in view C and increased in view D. The natural angle of dip is also affected, but only very slightly.

Submarine Anomaly

The maximum range at which a submarine may be detected is a function of both the intensity of its magnetic anomaly and the sensitivity of the detector.

A submarine's magnetic moment (magnetic intensity) (fig. 4-22) determines the intensity of the anomaly. It is dependent mainly on the submarine's alignment in the earth's field, its size, the latitude at which it is detected, and the degree of its permanent magnetization.

MAD equipment, in proper operating condition, is very sensitive; but the submarine's anomaly, even at a short distance, is normally very weak. The strength of a complex magnetic field (such as that associated with a submarine) varies as the inverse cube of the distance from the field's source. If the detectable strength of a field source has a given value at a given distance and the distance is doubled, the detectable strength of the source at the increased distance will then be one-eighth of its former value. Therefore, at least two facts should be clear. First, MAD equipment must be operated at a very low altitude to gain the greatest proximity possible to the enemy submarines. Second, the searching aircraft should fly at a predetermined speed and follow an estimated search pattern. This ensures systematic and thorough searching of the prescribed area so that no existing anomalies are missed.

Anomaly Strength

Up to this point, the inferred strength of a submarine's anomaly has been exaggerated for purposes of explanation. Its actual value is usually so small that MAD equipment must be capable of detecting a distortion of approximately one part in 60,000. This fact is made apparent by pointing out that the direction of alignment of the earth's magnetic lines of force is rarely changed more than one-half of 1 degree in a submarine anomaly.

Figure 4-23, view A, represents a contour map showing the degree of anomaly caused by a submarine. The straight line is approximately 800

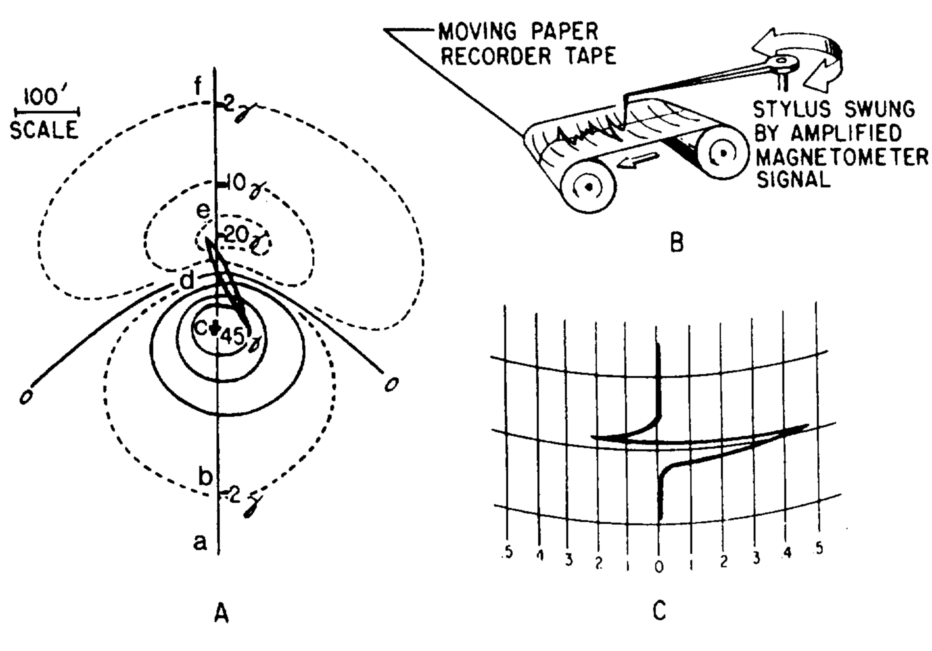


Figure 4-23.-A. Degree of anomaly. B. Anomaly stylus. C. Sample anomaly record.

feet in length and represents the flight path of a searching aircraft through the area of the submarine anomaly. If the submarine were not present, the undisturbed magnetic intensity in the area due to its assumed natural characteristics would be 60,000 gammas. (The gamma is the measure of magnetic intensity and is symbolized by the Greek letter γ.) All variations in the field, when the submarine is present, would then be above or below this natural intensity. Therefore, 60,000 gammas is the zero reference drawn on the moving paper tape shown in view C of figure 4-23.

Refer to view A of figure 4-23. Starting with the aircraft at point A, where the anomaly is undetectable, the earth's field concentration decreases to an intensity of 2γ (59,998) at point B. Its intensity then increases until a peak value of $+45\gamma$ is reached at point C. From that point it decreases to zero at point D. After point D, another zone of what amounts to magnetic rarefaction is encountered. The earth's field is less intense than its normal value. Consequently, anomalous values in this zone are considered as minus quantities. A peak minus intensity is reached at point E, and thereafter the signal rises back to its normal, or undetectable, intensity at point F.

As the varying degrees of intensity are encountered, they are amplified and used to drive a swinging stylus, as shown in figure 4-23, view B. The tip of the stylus rides against the moving paper tape, leaving an ink trace. The stylus is swung in one direction for positive γ, and the other for negative γ. The magnitude of its swing is determined by the intensity of the anomaly signal. Figure 4-23, view C, is a sample of paper recording tape showing the approximate trace caused by the anomaly in view A.

In the illustration just given, the search aircraft's altitude was 200 feet. At a lower altitude the anomaly would have been stronger, and at a higher altitude, it would have been weaker.

MAGNETIC NOISE

For the purposes of this discussion, any noise or disturbance in the aircraft or its equipment that could produce a signal on the recorder is classified as a magnetic noise.

In an aircraft there are many sources of magnetic fields, such as engines, struts, control cables, equipment, and ordnance. Many of these fields are of sufficient strength to seriously impair the operation of MAD equipment. Consequently, some means must be employed to compensate for "magnetic noise" fields. The noise sources fall into two major categories: maneuver noises and dc circuit noises.

Maneuver Noises

When the aircraft maneuvers, the magnetic field of the aircraft is changed, causing a change in the total magnetic field at the detecting element. The aircraft maneuver rates are such that the signals generated have their major frequency components within the bandpass of the MAD equipment. Maneuver noises may be caused by induced magnetic fields, eddy current fields, or the permanent field.

The variations in the induced magnetic field detected by the magnetometer are caused by changes in the aircraft's heading. This causes the aircraft to present a varying size to the earth's magnetic field, and only the portion of the aircraft parallel to the field is available for magnetic induction.

Eddy current fields produce maneuver noise because of currents that flow in the aircraft's skin and structural members. When an aircraft's maneuver causes an eddy current flow, a magnetic field is generated. The eddy current field is a function of the rate of the maneuver. If the maneuver is executed slowly, the effect of the eddy current field is negligible.

The structural parts of the aircraft exhibit permanent magnetic fields, and, as the aircraft maneuvers, its composite permanent field remains aligned with it. The angular displacement between the permanent field and the detector magnetometer during a maneuver produces a changing magnetic field, which the detector magnetometer is designed to detect.

DC Circuit Noise

The dc circuit noise in an aircraft comes from the standard practice in aircraft design of using a single-wire dc system, with the aircraft skin and structure as the ground return. The resulting current loop from the generator to load to generator serves as a large electromagnet that generates a magnetic field similar to a permanent magnetic field. Whenever the dc electrical load of the aircraft is abruptly changed, there is an abrupt change in the magnetic field at the detector.

COMPENSATION

Regardless of its source, strength, or direction, any magnetic field may be defined in terms of three axial coordinates. That is, it must act through any or all of three possible directions—longitudinal, lateral, or vertical—in relation to the magnetometer detector.

Compensation for magnetic noises is necessary to provide a magnetically clean environment so that the detecting system will not be limited to the magnetic signal associated with the aircraft itself.

Experience has shown that the induced fields and eddy current fields for a given type of aircraft are constant. That is, from one aircraft to another of the same type, the difference in fields is negligible. These fields may be expected to remain constant throughout the life of the aircraft, provided significant structural changes are not made. In view of these factors, it is present practice for the aircraft manufacturer to provide compensation for induced fields and eddy current fields.

Eddy current field compensation is usually achieved by placing the magnetometer (detecting head) in a relatively quiet magnetic area. In some aircraft the detecting head is placed at least 8 feet from the fuselage. This is done by enclosing the detecting head in a fixed boom (fig. 4-24, view A), or in an extendable boom (fig. 4-24, view B). Helicopters tow the detecting head by use of a cable (fig. 4-24, view C).

Induced magnetic field compensation is accomplished by using Permalloy strips. The aircraft is rotated to different compass headings, and the magnetic moment is measured. The polarity and the variation of the magnetic moment are noted for each heading, and Permalloy strips are oriented near the detector magnetometer to compensate for field changes due to aircraft rotation. Additional

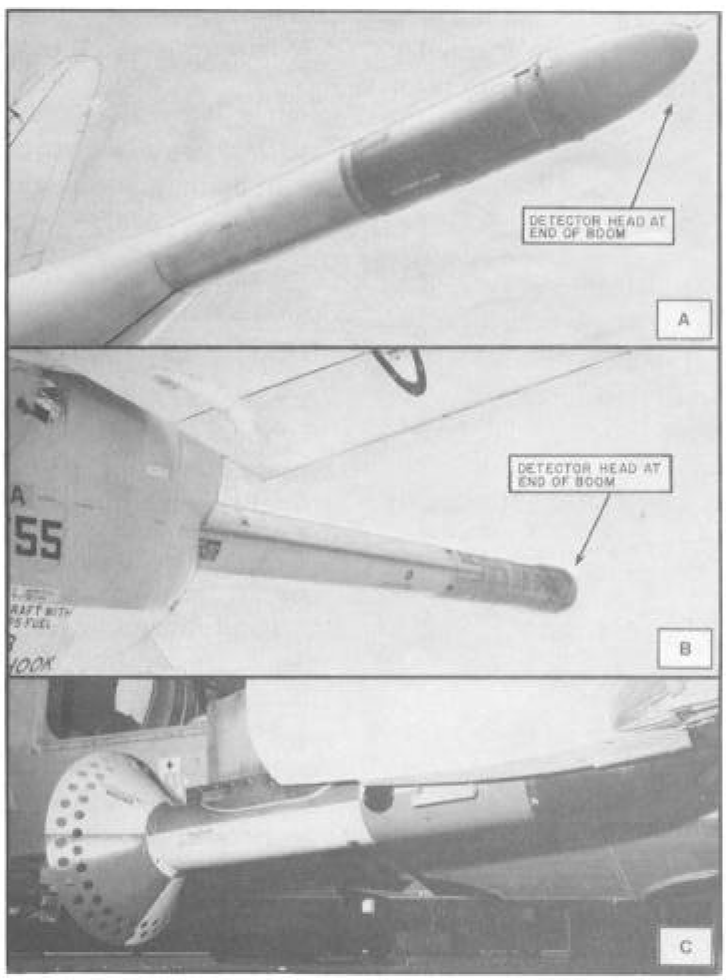


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Figure 4-24.—A. Stationary detector boom. B. Extendable detector boom. C. Cable-deployed towed detector.

compensation is needed for the longitudinal axis and is provided for by the development of outrigger compensators of Permalloy near the detecting element.

Permanent field compensation must be done in three dimensions rather than in two, and it is accomplished by three compensating coils mounted mutually perpendicular to each other (fig. 4-25, view A). The aircraft is rotated in 5-degree and 10-degree steps around its three axes. Adjustment of the field strength is accomplished by controlling the amount of direct current that flows through a particular coil. Figure 4-25, view B, shows a circuit for a single compensating coil.

Compensation for the dc magnetic field is accomplished by using electromagnetic compensating loops. The loops are arranged to provide horizontal, vertical, and longitudinal fields, and they are adjusted to be equal and opposite to the dc magnetic field caused by the load current. The compensating loops are connected across a variable resistor for a particular distribution center, and they are adjusted to allow current flow proportional to the load current for correct compensation. Different types of aircraft have several sets of compensation loops, depending upon the number of distribution centers. In newer aircraft, production changes have been made to use ground return wires to minimize loop size.

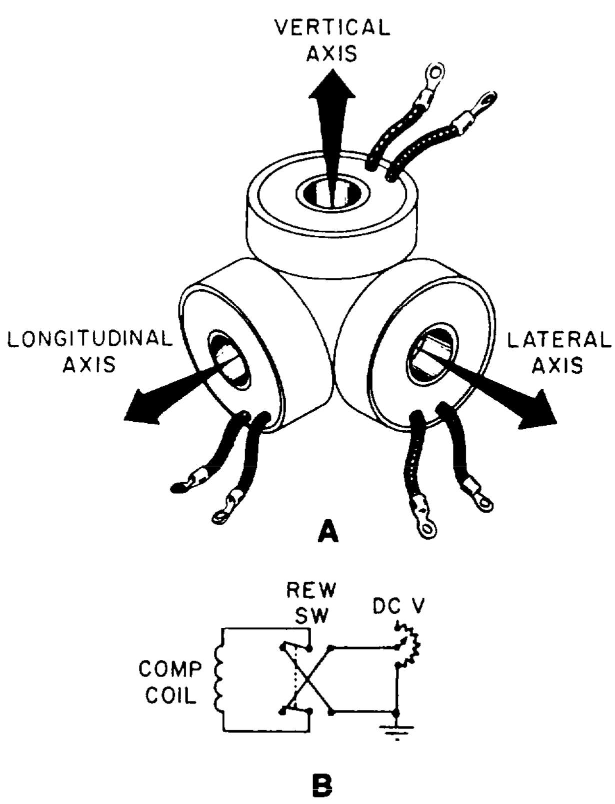


Figure 4-25.-A. Arrangement of compensating colts. B. Compensating coil circuit.

The procedure for adjustment of the dc compensation system makes use of straight and level flight on the four cardinal headings. For example, actuation of a cowl flap motor will cause dc field changes representative of those caused by any nacelle load. The load is energized, the size and polarity of the signal are noted, and the compensation control is adjusted. The load is reenergized, and the compensation control is adjusted again. Adjustments are continued until the resulting signals from the dc field are minimized.

Under ideal conditions, all magnetic fields that tend to act on the magnetometer head would be completely counterbalanced. In this state the effect on the magnetometer is the same as if there were no magnetic fields at all. This state exists only when the following ideal conditions exist:

1. The aircraft is flying a steady course through a magnetically quiet geographical area.

2. Electric or electronic circuits are not turned on or off during compensation.

3. Direct current of the proper intensity and direction has been set to flow through the compensation coils, so that all stray fields are balanced.

To approximate these conditions, the compensation of MAD equipment is usually performed in flight, well at sea. In this way, the equipment is compensated under operation conditions, which closely resemble those of actual ASW search flights.

From the foregoing, it should be clear that the objective of compensation is to gain a state of total balance of magnetic forces around the magnetometer. Thereafter, any sudden shift in one of the balanced forces (such as an anomaly in the earth's field force) upsets the total balance. This imbalance is indicated on the recorder. Unfortunately, a shift in ANY of the balanced forces will be indicated. Shift in any of the forces other than the earth's natural field are regarded as noise.

MAJOR COMPONENTS

The MAD system consists of the AN/ASQ-81 MAD set, AN/ASA-64 submarine anomaly detecting (SAD) group, AN/ASA-65 magnetic compensator group, AN/ASA-71 selector control group, and the RO-32/ASQ MAD recorder.

AN/ASQ-81 MAD Set

The AN/ASQ-81 set consists of the DT-323 magnetic detector, the AM-4535 amplifier-power supply, and the C-6983 detecting set control box.

DT-323 MAGNETIC DETECTOR.— The detection element includes six separate helium absorption cells and six IR detectors, arranged in pairs, with the pairs oriented at 90° to each other. This configuration ensures that one or more of the pairs is at least partially in line with the earth's field regardless of aircraft attitude or direction of flight. The signals from all three detector pairs are combined in a summing amplifier. The final output to the amplifier-power supply is not affected by aircraft maneuvers because of the arrangement.

AM-4535 AMPLIFIER-POWER SUPPLY.— The amplifier-power supply (fig. 4-26) serves two purposes. The first purpose is the power supply portion. This section provides the necessary power to the MAD subsystem. The amplifier section contains the necessary electronics to detect the anomaly signal from the detector output signal.

There are three fail indicators on the amplifier-power supply. The FAIL light comes on when there is a fault in the assembly being tested with the BITE switch. The FAIL DETECTOR and the FAIL AMP PWR SUPPLY lights indicate failure of the magnetic detector or the amplifier-power supply. The ALT COMP dial is used to vary the amplitude of the altitude compensation signal. The BUILT IN TEST switch provides a self-test of quick replaceable assemblies in the amplifier-power supply. The two circuit breakers provide circuit protection for the dc power to the magnetic detector and the 115-volt ac power to the amplifier-power supply.

On the right side of the amplifier-power supply, there is a hinged door that covers a maintenance panel. When this door is closed, the equipment operates in the normal mode. On the maintenance panel there is a RES OSC ADJ switch that is used to manually adjust the resonance oscillator frequency during maintenance procedures. There is also a MODE SELECT switch that selects various system configurations necessary for proper maintenance and troubleshooting.

C-6983 CONTROL BOX.— The detecting set control box (fig. 4-27) contains the operating switches and indicators for the MAD system. Across the top of the faceplate are five indicators that indicate faults in the other units. The indicator labeled 3 indicates a magnetic detector failure when lit. The indicator labeled 2 indicates amplifier failure. The next two indicators indicate a control box fault. The SYS READY indicator illuminates when the system is ready for operation. This indicator will blink during warm-up.

There are three toggle switches across the middle portion of the control box. The one on the right is the power switch. This switch applies power to the system. The middle switch is labeled CAL. It selects the calibration signal for use. The switch on the left is

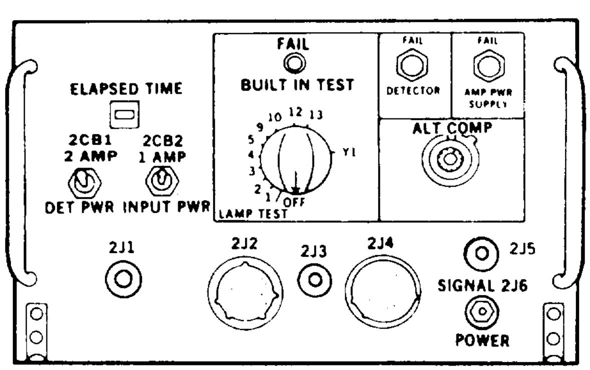


Figure 4-26.-AM-4535 amplifier-power supply.

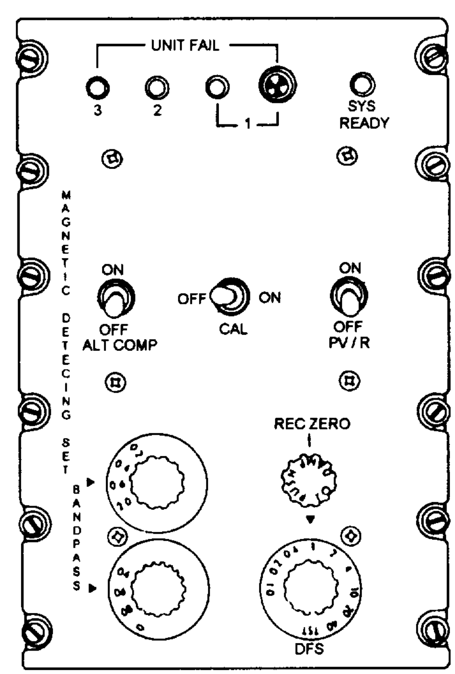


Figure 4-27.-C-6893 detecting set control.

labeled ALT COMP. This switch is used to connect the altitude compensator to the system.

The bottom portion of the control box contains four knobs. The two on the left side are labeled BANDPASS. These knobs select the high and low frequencies. The knob labeled REC ZERO is a dual-purpose knob. Turning this knob controls the pen deflection on the recorder. Depressing the knob inhibits system output. The bottom right knob is labeled **γFS,** and is used to select one of nine sensitivity ranges (from 0.1γ to 40γ full scale) or self-test. In the TST position, the self-test function will be initiated.

AN/ASA-64 SAD Group

The SAD group consists of only one unit-the ID-1559 magnetic variation indicator (MAG VAR indicator). This indicator receives the MAD signals from the ECA, along with roll attitude signals. These signals are processed and a SAD mark is generated, which is correlated with the roll input. In cases of excessive aircraft roll rate, the indicator will generate a SAD inhibit signal. This signal illuminates the SAD INHIBIT lights on the selector control panel and the pilot and copilot's navigation advisory panel, letting the operators know the SAD mark is unreliable.

AN/ASA-65 Magnetic Compensator Group

The magnetic compensator group consists of the AM-6459 electronic control amplifier (compensator ECA), C-8935 control-indicator, DT-355 magnetometer assembly, three compensating coils, CP-1390 magnetic field computer, and ID-2254 magnetic field indicator.

AM-6459 ELECTRONIC CONTROL AMPLIFIER.— The electronic control amplifier (ECA) processes standard magnetic anomaly detector signals from the MAD subsystems, operator compensation adjustments, and maneuver signals from the magnetometer. The ECA provides compensation currents, which are sent to the MAD boom compensation coils.

C-8935 COMPENSATOR CONTROL-INDICATOR.— This control-indicator (fig. 4-28) contains potentiometers for adjustment of the maneuver and correlated signals into compensating terms. The potentiometer outputs are routed back to the ECA to be amplified. From there they are sent to the compensator coil as compensation signals.

On the face of the control-indicator there are nine index counters. The top three provide the adjustment index for the potentiometers in the transverse, longitudinal, and vertical magnetometer circuits. They are labeled T (transverse), L (longitudinal), and V (vertical). The other six (labeled 1 to 6) provide compensation adjustment for the T, L, and V magnetometer circuits.

The MAG TERM knob selects the magnetic term to be compensated. This knob must be in the OFF position unless compensation is required. The RATE knob selects the speed of the servomotor with 1 being the slowest and 4 the fastest.

Across the bottom of the faceplate there are four toggle switches. The POWER-OFF switch provides power to the unit. The SERVO-OFF switch provides both ac and dc power to the servomotor system. This switch must be in the OFF position unless recompensation is required. The UP-DOWN switch provides voltage directly to the servomotor selected. The counter indication will increase or decrease depending on which way this switch is toggled. The +/OFF/– switch provides voltage to the servo system. In the OFF position, the servomotor is operated only by the UP-DOWN switch.

DT-355 MAGNETOMETER ASSEMBLY.— The magnetometer assembly contains three coils oriented to sense magnetic strength in each of the basic longitudinal, transverse, and vertical axes. This

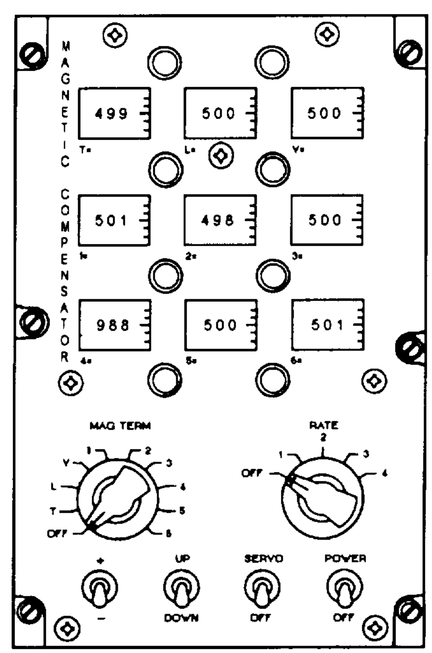


Figure 4-28.-Compensator control-indicator.

results in three output signals, which are sent to the ECA. These coils are located in the MAD boom.

COMPENSATION COILS.— There are three compensating coils located in the boom. These coils generate the magnetic field that opposes the aircraft-generated noise fields for compensation. There is one coil each for the transverse, vertical, and longitudinal fields.

CP-1390 MAGNETIC FIELD COMPUTER.— The magnetic field computer, along with the magnetic field indicator, computerizes the compensation procedure. The correlation portion of the system, the 2A5 board in the ECA, becomes redundant to the computer. The magnetic field computer receives the maneuver signals, MAD signals, and the potentiometer outputs. From these signals, it computes the adjustment values for the nine magnetic terms simultaneously.

ID-2254 MAGNETIC FIELD INDICATOR.— The magnetic field indicator (fig. 4-29) allows the operator to select various weapon loads and initiate the self-test, auto compensation, and weapon deployment programs. It also displays the most recent computer-calculated term difference value.

The PWR/OFF switch accesses aircraft power. The DISPLAY indicator is a four-digit numerical display and a polarity indicator. It shows the various BITE codes, term values, or calibration values. The EXEC push button initiates all commands. This button must be pressed after each selection of the MODE switch.

The MODE switch is a 14-position rotary switch that provides computer identification and control of fixed compensation functions. The OFF position means that there are no functions processed. The BITE position conducts a built-in test and reports the results via the digital readout. In the COMP position, pressing the EXEC button conducts the nine-term compensation program. The WD position enables the four-term weapon deployment compensation program. In the CAL position, a digital value measurement of the magnetic coils for calibration accuracy is initiated. The other nine positions report the most recent computer-calculated term difference value via the DISPLAY. Remember, after selecting any of the positions on the MODE switch, the EXEC button must be pressed.

The FAULT indicator illuminates whenever a fault condition exists. The WPN LOAD switch is a nine-position switch labeled 0-8. The number of weapons being carried is selected on this switch prior to compensation. This provides compensation for at least 80 percent of the weapons interference field.

AN/ASA-71 Selector Control Group

The selector control group consists of two units. These units are the MAD selector control panel and the selector control subassembly.

C-7693/ASA-71 SELECTOR CONTROL PANEL.— This selector control (fig. 4-30) selects the signal to be recorded on the MAD recorder and adjusts the threshold voltage for the SAD system. The two knobs labeled BLACK PEN and RED PEN

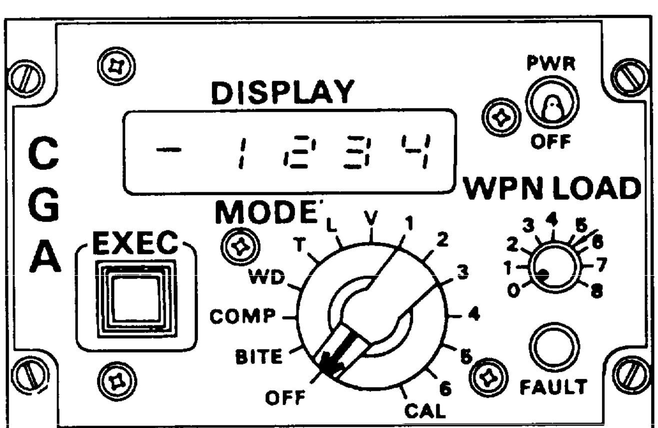


Figure 4-29.-ID-2254 magnetic field indicator.

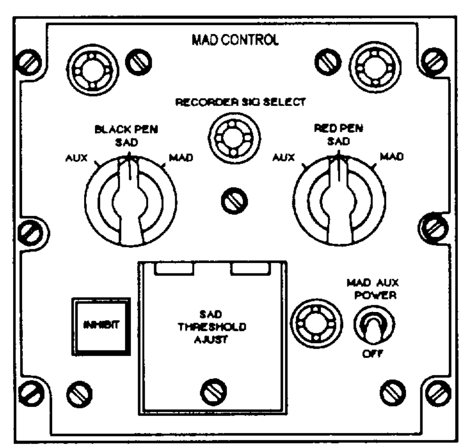


Figure 4-30.-C-7693/ASA-71 selector control panel.

select which signal goes to which pen on the recorder. The MAD AUX POWER-OFF switch supplies primary ac power to the SAD system and the selector control subassembly. The INHIBIT light indicates an inhibit signal from the SAD system.

MX-8109/ASA-71 SELECTOR CONTROL SUBASSEMBLY.— The MAD signals from the MAD control and the SAD mark from the MAG VAR indicator are routed to this subassembly. The selector control panel selects which one goes to which pen, and the subassembly routes the signal to the proper pen. A SAD mark 1-kHz tone is generated by the subassembly to be supplied to the ICS system for the SENSOR operator.

RO-32 MAD Recorder

The RO-32 recorder makes a hardcopy of MAD contacts and SAD marks. This recorder has two styluses, one black and one red, to differentiate between the two. The chart drive is removable to enable the operator to remove and replace the paper tape. here are three knobs on the faceplate. The first switch is the ON/OFF switch. The second controls the intensity of the internal lights. The third knob selects the operate mode along with the pen calibration modes.

When B is selected on the mode knob, the black pen should trace along the zero line on the paper tape. When the mode knob is switched to the +, the black pen should go to +4. When this knob is switched to the R position, the red pen traces along the zero line. When it goes to the +, the red pen should swing to the +4 line. Both pens are adjustable to these settings.

SONOBUOYS

Learning Objective: *Recognize the classifications and the operating principles of sonobuoys currently in use.*

The detection, localization, and identification of submarines is the primary mission of the Navy's airborne ASW forces. The ability of the Navy to complete this mission is dependent upon the sonobuoy. The sonobuoy has undergone a great deal of change in the past 25 years. These improvements have provided the fleet with large numbers of very reliable sonobuoys that perform various missions.

OPERATING PRINCIPLES

The sonobuoys are dropped from the aircraft into an area of the ocean thought to contain a submarine. The pattern in which the sonobuoys are dropped usually involve three or more buoys.

The sonobuoys detect underwater sounds, such as submarine noise and fish sounds. These sounds modulate an oscillator in the RF transmitter portion of the sonobuoy. The output of the transmitter is a frequency modulated VHF signal that is transmitted from the antenna. The signal is received by the aircraft, and then detected and processed by a sonobuoy receiver. By analyzing the detected sounds, the ASW operator can determine various characteristics of the detected submarine. The use of several sonobuoys operating on different VHF frequencies in a tactical pattern enables the ASW operator to localize, track, and classify a submerged submarine.

Each sonobuoy type is designed to meet a specific set of specifications that is unique to that particular sonobuoy. Even though different manufacturers, the specifications and operational performance characteristics are the same for all manufacturers. There are differences in the methods used for prelaunch selection of life and depth settings from one manufacturer to another for the same sonobuoy types. These differences are found in the *Sonobuoy Instruction Manual,* NAVAIR 28-SSQ-500-1. You should refer to this manual prior to storing, handling, or disposing of sonobuoys.

Sonobuoy Frequency Channels

Certain sonobuoy designs are equipped with an electronic function select (EFS) system. The EFS system provides each sonobuoy with a selectable 99-channel capability. EFS also provides each sonobuoy with 50 life and 50 depth setting selections. The operator must reset all three settings any time any of the three are changed.

With the older type of sonobuoy, the transmitter frequency is preset at the factory. here were 31 different channels used within the 162.25- to 173.5-MHz band. Transmitter frequency is designed to be within ±25 kHz. temperature extremes in hot or cold storage adversely affect these tolerances, especially in sonobuoys that are older.

External Markings

Each sonobuoy has marked on the sonobuoy case the following information: nomenclature or type, serial number, manufacturer's code number, RF channel number, contract lot number, weight, and prelaunch setting. Sonobuoy type and RF channel number are also stamped on each end of the buoy. Sonobuoys with EFS will have no RF channel number markings because the channel will be selected by the operator.

Deployment

The sonobuoy is aircraft deployable by any of four methods: spring, pneumatic, free-fall, or cartridge. Because descent velocities can exceed 120 feet per second, a descent-retarding device is used to increase aerodynamic stability and to reduce water-entry shock. A parachute or a rotating-blade assembly (rotochute) is used as the descent-retarding device. Because of the different descent characteristics of the parachute and rotochute, do not intermix the two. With intermixed sonobuoys, the spacing of the tactical pattern will not be right and submarines might be missed.

Water Entry and Activation

The force of water impact, or battery activation, initiates the deployment or jettison of-the various sonobuoy components. Jettisoning of the bottom plate allows the hydrophone and other internal components to descend to the preselected depth. Upon the release of the parachute or rotochute, the antenna is erected. In some sonobuoys, a seawater-activated battery fires a squib, which deploys a float containing the antenna. A termination mass and/or drogue stabilizes the hydrophone at the selected depth, while the buoyant sonobuoy section or float follows the motion of the waves. A section of elastic suspension cable isolates the hydrophone from the wave action on the buoyant section. Most of the sonobuoys in the fleet today are equipped with seawater-activated batteries, which provide the power required for the sonobuoy electronics. Data transmission from the buoys usually begins within 3 minutes after the buoy enters the water. In cold water and/or water with low salinity, the activation time might be increased. Some sonobuoys now have nonwater-activated lithium batteries.

Sonobuoy Operating Life

At the end of the preselected time, the sonobuoy transmitter is deactivated. The sonobuoy has either an electronic RF OFF timer, or, as is most common, the transmitter is deactivated when the buoy is scuttled. At the end of the sonobuoy life, or for some types of sonobuoys upon RF command, a mechanism allows seawater to flood the flotation section in the buoy. In some cases, the flotation balloon is deflated to scuttle the unit. Either way, the unit fills with seawater and sinks.

SONOBUOY CLASSIFICATION

Sonobuoys are grouped into three categories: passive, active, and special purpose. Passive sonobuoys are used in LOFAR and DIFAR systems. Active sonobuoys are used in CASS and DICASS systems. Special-purpose sonobuoys are used in missions other than ASW. These sonobuoys and acronyms, along with their meanings and relationships to each other, are discussed below.

Passive Sonobuoy

The passive sonobuoy is a listen-only buoy. The basic acoustic sensing system that uses the passive sonobuoy for detection and classification is known as the low-frequency analysis and recording (LOFAR) system.

LOFAR SYSTEM.— With this system, sounds emitted by the submarine are detected by a hydrophone that has been lowered from a passive omnidirectional sonobuoy. Data regarding the frequency and amplitude of these sounds are then transmitted by the sonobuoy antenna to the receiving station. At this station, normally on the aircraft, the sound data is analyzed, processed, displayed, and recorded. The basic LOFAR display plots the frequency of the sound waves against the intensity of their acoustic energy, and against the duration of the sound emission. This data can be displayed on a video screen and printed out. The data is also recorded on magnetic tape for storage and retrieval when desired.

DIFAR SYSTEM.— The directional low-frequency analysis and recording system (DIFAR) is an improved passive acoustic sensing system. Using the passive directional sonobuoy (fig. 4-31), DIFAR operates by detecting directional information, and then frequency multiplexing the information to the acoustic data. This signal is then transmitted to the aircraft where it is processed and the bearing is computed. Subsequent bearing information from the buoy can be used to pinpoint, by triangulation, the location of the sound or signal source.

Active Sonobuoy

The active sonobuoy is either self-timed (the sonar pulse is generated by the buoy at a fixed pulse length and interval) or command actuated. The command activated buoy is controlled by a UHF command signal from the aircraft. An active sonobuoy uses a transducer to radiate a sonar pulse that is reflected back from the target. The time interval between the ping (sound pulse) and the echo return to the sonobuoy is measured. Taking the Doppler effect on the pulse frequency into consideration, this time-measurement data is used to calculate both range and speed of the submarine relative to the sonobuoy.

RO SONOBUOYS.— Self-timed active sonobuoys, known as range-only (RO) sonobuoys, are set to ping for a limited period, starting from the time they are deployed. These buoys will provide information on range of targets only.

CASS SONOBUOYS.— The command activated sonobuoy system (CASS) allows the aircraft to deploy the sonobuoy, but the buoy will remain passive until commanded to ping. This allows the aircraft to surprise the submarine.

DICASS SONOBUOY.— The addition of a directional hydrophone turns the CASS sonobuoy into a DICASS buoy. A DICASS sonobuoy allows the aircraft acoustic analysis equipment to determine the range and bearing to the target with a single sonobuoy. DICASS sonobuoys are replacing the RO and CASS sonobuoys.

Special-Purpose Sonobuoys

There are three types of special-purpose sonobuoys in use today. These are the BT, SAR, and the ATAC sonobuoys. These sonobuoys are not designed for use in submarine detection or localization.

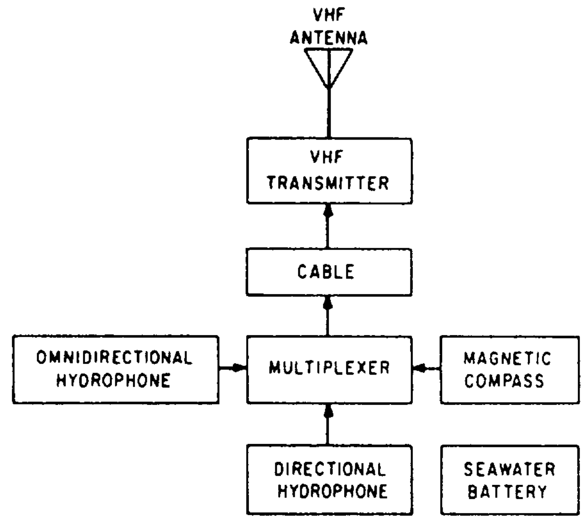


Figure 4-31.-Block diagram of the DIFAR sonobuoy.

BATHYTHERMOBUOY.— The bathythermobuoy (BT) is used to measure water temperature versus depth. The water depth is determined by timing the descent of a temperature probe. Once the BT buoy enters the water, the probe descends automatically at a constant 5 feet per second.

The probe uses a thermistor, a temperature-dependent electronic component, to measure the temperature. The electrical output of the probe is applied to a voltage-controlled oscillator. The oscillator's output signal frequency modulates the sonobuoy transmitter. The frequency of the transmitted signal is linearly proportional to the water temperature. The water temperature and depth are recorded on graph paper that is visible to the ASW operator. The sonobuoy signal is processed by the acoustic equipment on board the aircraft.

SAR BUOY.— The search and rescue (SAR) buoy is designed to operate as a floating RF beacon. As such, it is used to assist in marking the location of an aircraft crash site, a sunken ship, or survivors at sea. The buoy can be launched from aircraft equipped to launch sonobuoys or deployed over the side by hand. Nominal RF output is 1 watt for 60 hours on sonobuoy channel 15 (172.75 MHz). A floating microphone is provided for one-way voice communication. The RF beacon radiates automatically and continuously, regardless of whether the microphone is used. A flashing light and dye marker are incorporated in the buoy. The buoy also has an 8-foot tether line for attaching the buoy to a life raft or a person.

ATAC/DLC.— The air transportable communication (ATAC) and down-link communication (DLC) buoys are intended for use as a means of communication between an aircraft and a submarine. The ATAC buoy is commendable from the aircraft and provides up-link and down-link communications by a preselected code. The DLC buoy is not commandable and provides a down-link communications only by a preselected code.

SONOBUOY RECEIVERS

Learning Objective: *Recognize the operating principles and components of a typical sonobuoy receiver.*

The sonobuoy receiver set that will be discussed in this chapter is the AN/ARR-75. This set is used on the H-60 LAMPS helicopter.

The radio receiving set (RRS) receives, demodulates, and amplifies sonobuoy transmissions in the VHF bands, It provides channels A, B, C, and D acoustic data to the data link for transmission to the ship via the communications system control group. Channels E, F, G, and H acoustic data is provided direct to the data link for transmission to the ship. The acoustic data is also routed to the spectrum analyzer group for processing and display on board the aircraft. Simultaneous reception and demodulation of standard sonobuoy RF channels is possible. Any one of the received channels can be selected for aural monitoring. The RRS consists of two radio receiver groups.

The radio receiver groups each consist of four VHF radio receivers and a power supply. Each of the four receivers can operate on a separate channel, independent of the others. The RF signals received by the sonobuoy antennas are applied to each of the four receiver modules, where tuned filters select the signals for each module. The signals then pass through a series of amplifiers, filters, and mixers to produce the output audio signals. The output signals are supplied to the spectrum analyzer group and the data link system. The spectrum analyzer processes the signals to allow monitoring by the aircrew.

ACOUSTIC SYSTEM

Learning Objective: *Recognize components and operating principles of a typical acoustic system.*

The AN/UYS-1 single advanced signal processor system (SASP) processes sonobuoy acoustic audio and displays the resulting data in a format suitable for operator evaluation in the P3-C Update III aircraft.

OPERATING PRINCIPLES

The SASP processes sonobuoy audio in active and passive processing modes to provide long range search, detection, localization, and identification of submarines. The sonobuoys presently in use include the LOFAR, DIFAR, CASS, DICASS, and BT. The RF signals from the sonobuoys are received by the sonobuoy receivers and sent to the SASP. After processing, signals are sent to the displays and the recorders for operator use. The SASP also generates command tones for controlling the CASS and DICASS sonobuoys.

COMPONENTS

The major components include the TS-4008/UYS-1 spectrum analyzer (SA), PP-7467/UYS-1 power supply, and the C-11104/UYS-1 control-indicator (SASP power control).

TS-4008/UYS-1 Spectrum Analyzer

The TS-4008/UYS-1 spectrum analyzer is a high-speed signal processor designed to extract acoustic target information from both active and passive sonobuoy data. The SA determines frequency, amplitude, bearing, Doppler, range, and other characteristics for acoustic targets.

PP-7467/UYS-1 Power Supply

The PP-7467/UYS-1 power supply converts 115 volts ac into 120 volts dc operating voltages. The 120-volt dc power is then converted to low-level dc voltages for operation of individual circuits. A power interrupt unit protects the data against transient power interruptions that normally occur during airborne operations.

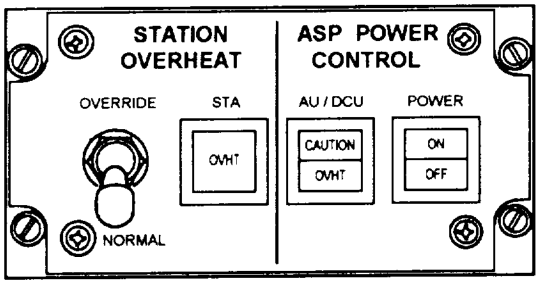


Figure 4-32.-SASP control-indicator.

C-11104/UYS-1 Control-Indicator

The C-11104/UYS-1 control-indicator (fig. 4-32) consists of one switch-indicator, two indicators, and one switch. The switch-indicator is labeled POWER ON/OFF. It controls the power to the SA, the display computer (DCU), the CASS transmitter, and the displays. The AU/DCU CAUTION/OVHT indicator indicates the temperature status in the SA and the DCU. The CAUTION section will flash on when the thermal warning is activated in either unit. The OVHT section indicates an overheat in either unit. The STA OVHT indicator indicates an overtemp condition exists at the sensor stations 1 and 2 consoles. The OVERRIDE-NORMAL switch will override the overheat warnings for the sensor stations 1 and 2 consoles.

REVIEW QUESTIONS

Q1. How was the word SONAR derived?

Q2. *In echo-ranging sonar, what is the source of the sound wave used?*

Q3. *What are the three main characteristics of seawater that affect the speed of a sound wave passing through it?*

Q4. On the azimuth and range indicator of the AN/ASQ-13E, what does the cursor intensity knob control?

Q5. What is the length of the special-purpose cable of the AN/ASQ-13E?

Q6. What are the staves of the hydrophone assembly filled with?

Q7. What is an anomaly?

Q8. What happens to the magnetic field of an aircraft as it maneuvers?

Q9. How many units are therein the ASA-64 SAD group?

Q10. With a sonobuoy equipped with EFS, how many depth settings are available?

CHAPTER 5

INDICATORS

In this chapter, we will discuss the various types of indicators in use today. These indicators range from the heading indicators to the newest heads-up display (HUD) tactical displays. Every effort was made to include as many different platforms as possible.

HEADING INDICATORS

Learning Objective: *Identify the types of heading indicators and their primary functions.*

The two heading indicators that we will be discussing are the horizontal situation indicator (HSI) and the bearing-distance-heading indicator (BDHI). Both of these indicators are used on many different types of aircraft. The information displayed by these indicators comes from the various navigational systems on the aircraft. The HSI displays more information than the BDHI.

HORIZONTAL SITUATION INDICATOR

The HSI system we will discuss is the system in use on the P3-C aircraft. The HSI group provides the pilot, copilot, and NAV/COMM operator with a visual display of aircraft course, bearing, heading, and distance to a selected point.

System Components

The HSI group consists of three ID-1540/A indicators and three control boxes. The three control boxes are the pilot's control, copilot's control, and the NAV/COMMs control. The three ID-1540/As are interchangeable between the three stations, but the control boxes are not.

ID-1540/A HORIZONTAL SITUATION INDICATOR.— The ID-1540/A indicator (fig. 5-1) is a multipurpose aircraft situation indicator. It keeps the pilot, copilot, and the NAV/COMM operator informed of the aircraft's situation at any given moment. Refer to figure 5-1 while reading the following text.

1. The lubber line is the reference line for reading the aircraft's heading on the compass card.

2. Bearing pointer 1 points to the bearing of the selected navigational point.

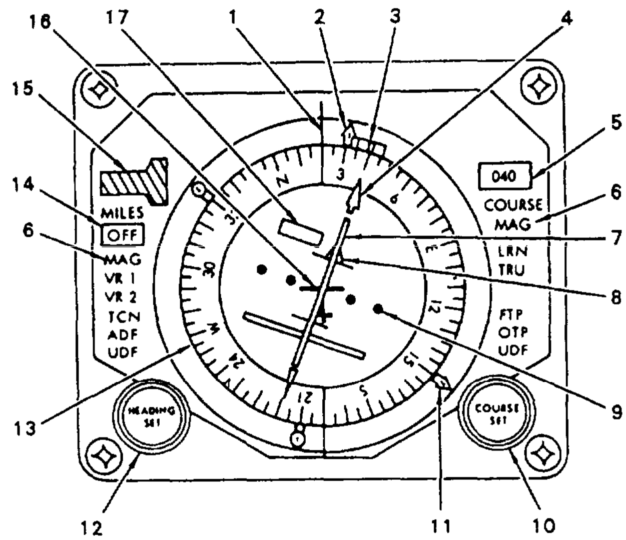
3. The heading marker indicates the desired heading as set by the HEADING SET knob.

4. The course arrow indicates the course set by the COURSE SET knob in the radio navigation mode. This arrow indicates the course set by the computer in the tactical navigational mode.

5. The COURSE indicator displays, in degrees, a digital readout of the course arrow setting.

6. The mode lights indicate the operating mode selected on the HSI control box for that station.

7. The course deviation bar indicates deviation relative to the course arrow position for VOR or



1. Lubber line
2. Bearing pointer 1
3. Heading marker
4. Course arrow
5. COURSE indicator
6. Mode lights
7. Course deviation bar
8. To-From arrows
9. Course deviation dots
10. COURSE SET knob
11. Bearing pointer 2
12. HEADING SET knob
13. Compass card
14. OFF flag
15. MILES counter
16. Aircraft symbol
17. NAV flag

Figure 5-1.-ID-1540/A horizontal situation indicator.

TACAN signals. When localizer signals are being used, the deviation is relative to the localizer.

8. The To-From arrows indicate whether the selected course is going toward or away from the selected beacon station.

9. The course deviation dots indicate course deviation in degrees relative to the course deviation bar position.

10. The COURSE SET knob allows the operator to set both the course arrow to a desired course and the COURSE indicator to the desired course readout when in any mode other than TAC NAV.

11. The bearing pointer 2 indicates the bearing to a selected navigational point.

12. The HEADING SET knob allows the operator to set the heading mark to any desired heading.

13. The compass card indicates the aircraft compass heading when read against the lubber line.

14. The OFF flag will appear whenever there is a power failure.

15. The MILES counter displays a digital readout of distance, in nautical miles, to a selected TACAN station.

16. The aircraft symbol indicates the lubber line, which, in turn, indicates aircraft heading.

17. The NAV flag will appear if the signal input from the selected TACAN or VOR becomes unreliable.

A280 PILOT HSI CONTROL.— The A280 (fig. 5-2) controls the inputs to the pilot's HSI. This unit allows the pilot to select inputs from the different navigational aids. Refer to figure 5-2 when reading the following text.

1. The HDG selector switch selects the heading signal source for display on the HSI compass card. The pilot can select either inertial navigation system 1 (INS-1) or inertial navigation system 2 (INS-2).

2. The ATTD selector switch selects the source of pitch and roll signals for the flight directory indicator (FDI) sphere. The signals will either come from the INS-1 or from the vertical gyro (STBY GYRO).

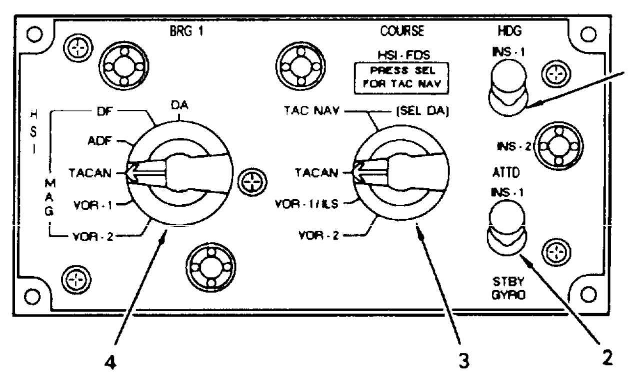
3. The COURSE HSI-FDS selector switch selects the source of course signals for display on the HSI. The signals include the course deviation and To-From signals to position the course deviation bar and the To-From arrows. They will come from the VOR-2 NAV converter (VOR-2), the VOR-1 NAV converter (VOR-1/ILS), the TACAN R/T (TACAN), and the central computer TAC NAV) when the BRG 1 switch is in the DA position.

4. The BRG 1 switch selects the source of the bearing signal to be displayed on the pilot's, copilot's, and NAV/COMM's HSIs bearing pointer 1. This switch controls all three HSIs. The bearing sources available are the VOR-2 NAV converter (VOR 2), VOR-1 NAV converter (VOR 1), TACAN R/T (TACAN), ADF receiver (ADF), or UHF direction finder group (DF). In the DA position, the drift angle supplied by the Doppler radar or the central computer is sent to the bearing pointer 1.

A279 COPILOT HSI CONTROL.— The A279 control box (fig. 5-3) controls the inputs to the copilot's HSI. It allows the copilot to select the navigational aid. Refer to figure 5-3 when reading the following text.

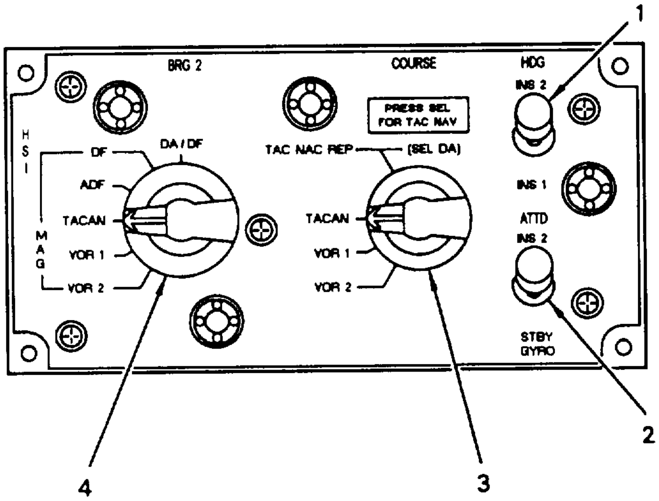
1. The HDG selector switch selects the source of heading information supplied to the HSI compass card. Either INS-2 or INS-1 is available.

2. The ATTD selector switch selects the source of pitch and roll signals for display on the FDI sphere. The source can be either the INS-2 or the vertical gyro (STBY GYRO).



1. **HDG selector switch**
2. **ATTD selector switch**
3. **COURSE HSI-FDS selector switch**
4. **BRG 1 switch**

Figure 5-2.-A280 pilot HSI control.



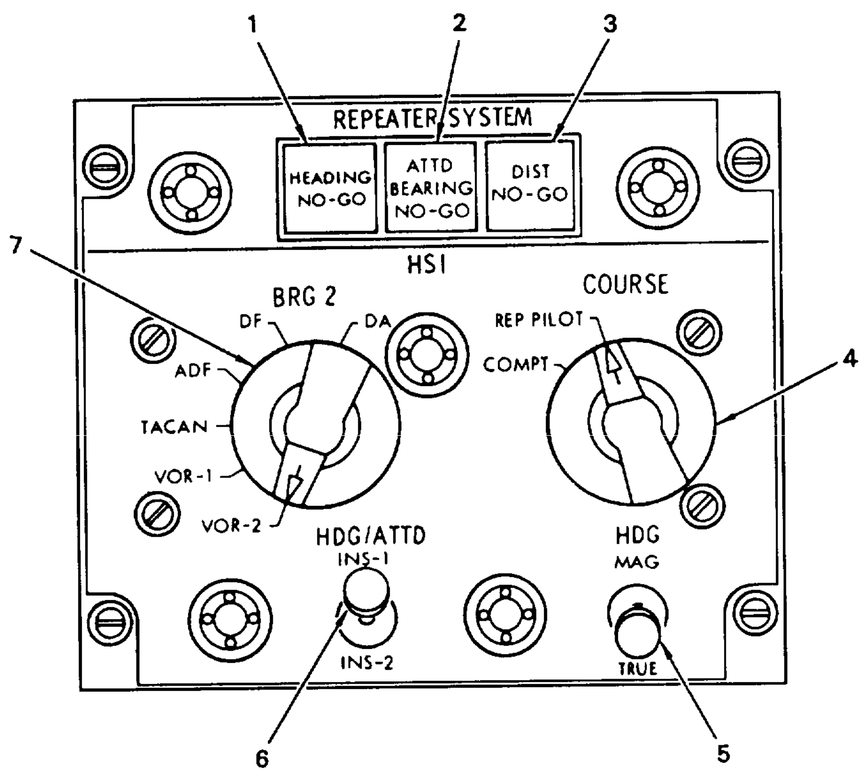
1. HDG selector switch
2. ATTD selector switch
3. COURSE selector switch
4. BRG 2 selector switch

Figure 5-3.-A279 copilot HSI control.

3. The COURSE selector switch selects the source of course signals for display on the HSI. The sources available for selection are VOR-2, VOR-1, or TACAN. Selecting the TAC NAV REP position will slave the copilot's HSI to the pilot's, provided the BRG 2 switch is in the DA/DF position.

4. The BRG 2 selector switch selects the source of the bearing signal for display on both the pilot's and copilot's bearing pointer 2. The sources available for selection are VOR-2, VOR-1, TACAN, ADF, or DF. The DA/DF position will provide drift angle information, if in radio navigation mode, or DF signals, if in the tactical navigational mode.

A309 NAV/COMM HSI CONTROL BOX.— The A309 control box (fig. 5-4) allows the NAV/COMM operator to select the inputs to the HSI at the NAV/COMM station. It also indicates certain system malfunctions. Refer to figure 5-4 when reading the following text.



1. HEADING NO-GO indicator
2. ATTD BEARING NO-GO indicator
3. DIST NO-GO indicator
4. COURSE selector switch
5. HDG switch
6. HDG/ATTD switch
7. BRG 2 selector switch

Figure 5-4.-A309 NAV/COMM HSI control box.

1. The HEADING NO-GO indicator illuminates when there is a failure with the heading function in the central repeater system (CRS).

2. The ATTD BEARING NO-GO indicator illuminates when there is a failure with the attitude bearing function in the central repeater system.

3. The DIST NO-GO indicator is not used in the P3-C.

4. The COURSE selector switch selects the course data for display on the HSI. The course data is either set by the computer (COMP) or by the pilot's control box (REP PILOT).

5. The HDG switch selects either magnetic (MAG) or true (TRUE) heading signal inputs to be displayed on the NAV/COMM HSI.

6. The HDG/ATTD switch selects either INS-1 or INS-2 to be the source for the heading data signal to be displayed.

7. The BRG 2 selector switch selects the source for the information to be displayed on the NAV/COMM HSI bearing pointer 2. The sources available for selection are VOR-2, VOR-1, TACAN, ADF, DF, or DA. In the DA position, drift angle supplied by the Doppler radar or the central computer is displayed.

System Description

The HSI system functions as a selectable display for the navigational systems on the aircraft.

When the TACAN, VOR-1, or VOR-2 system is selected, the corresponding system will provide radial bearing and bearing information, NAV flag, course deviation, and To-From signals to the HSI. The bearing signal will position the bearing pointer 1 or bearing pointer 2, as selected. The radial bearing information is resolved with the course set by the COURSE SET knob. The resultant signal is returned to the TACAN, VOR-1, or VOR-2 to be used to develop the course deviation and To-From signals. These signals are returned to the HSI, where the course deviation signal displaces the course deviation bar. The To-From signal will drive the To-From arrow in the proper direction. If the flag input signal becomes unreliable during a radio navigation mode, the NAV flag appears on the HSI. When TACAN is selected, the distance signal from the TACAN will position the dials of the distance counters to reflect the distance to or from the TACAN station.

The UHF-DF/OTPI and the ADF systems will supply bearing information when selected. This information is routed to either the bearing pointer 1 or bearing pointer 2, as selected.

Magnetic and true heading information is supplied to the HSI compass card by the INS-1 and INS-2, as selected. Magnetic heading is normally used to position the compass card. When a tactical mode is selected, magnetic heading information is switched out of the circuit, and the compass card will be driven by the true heading information.

BEARING-DISTANCE-HEADING INDICATOR

The bearing-distance-heading indicator (BDHI) (fig. 5-5) may be used with the various navigational systems, and it provides information according to the mode selected. Some aircraft may have more than one BDHI, with separate select switches for each instrument. The distance counter numerals may be in a vertical row or horizontal, as shown in figure 5-5.

Indicator Parts

This section will explain the various parts of the BDHI. Refer to figure 5-5 while reading the following text.

The lubber index is a fixed reference mark that allows the operator to read the heading from the

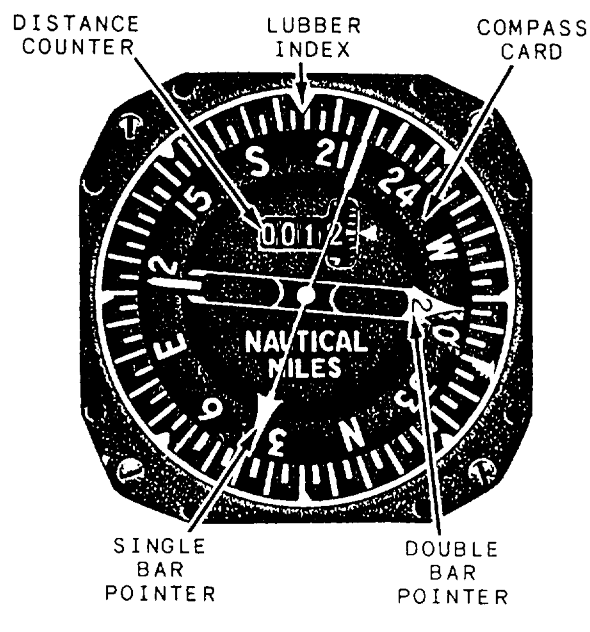


Figure 5-5.-Bearing-distance-heading indicator.

compass card. The compass card moves with the heading of the aircraft. The distance counter indicates the distance to the selected station. There are two pointers—a single bar and a double bar. These pointers or bars can indicate (1) bearing to a ground electronic station, (2) bearing to destination, (3) aircraft ground track, (4) aircraft drift angle, or (5) heading error. The available combinations of these indications are limited by the BDHI select switches used in the given aircraft configuration.

Primary Functions

Electrical signal inputs for the compass card and the pointers come from the synchro transmitters located in the various navigational systems. The compass card will follow the heading of the aircraft and is read at the lubber index. The distance counter may display distance to base, target, or ground station, depending upon the mode selected. It consists of three synchro torque receivers to position the units, tens, and hundred numerals. There is also a 1,000 flag to place the numeral 1 preceding the hundreds numeral, which enables the counter to display distance up to 1,999 nautical miles. The OFF flag covers the distance counter when distance information is not provided or is unreliable.

HEADS-UP DISPLAY (HUD)

Learning Objective: *Recognize components and functions of a typical Heads-Up Display (HUD) tactical display system.*

Modern aircraft are equipped with instruments and displays to provide the aircrew with up-to-date visual information about the performance of the aircraft. Since the advent of airborne computers, radar, and other state-of-the-art avionics equipment, the concept of visual information has taken on a new meaning. In this age of lasers, high-speed missiles, nuclear submarines, and stealth aircraft, the Navy has had to incorporate new visual display systems, and constantly improve these systems as technology advances. The visual display system, commonly called the “tactical display system” (TDS), is used by the aircrew to search for, attack, and destroy the enemy. The TDS is also used to gather information about the enemy and to allow the aircrew to defend the aircraft when attacked.

The airborne computers are used to gather information from all aircraft sensors and systems. They then perform high-speed solutions and send out continuously updated information to the various tactical display systems on the aircraft. These display systems vary from aircraft to aircraft, and the information displayed depends on the type of mission the aircraft was designed to perform.

The typical HUD TDS is an electro-optical sight system for use only by the pilot. The purpose of the electro-optical display unit is to display attack and flight information directly to the pilot’s field of view. The electro-optical display uses a light source (fig. 5-6) to display

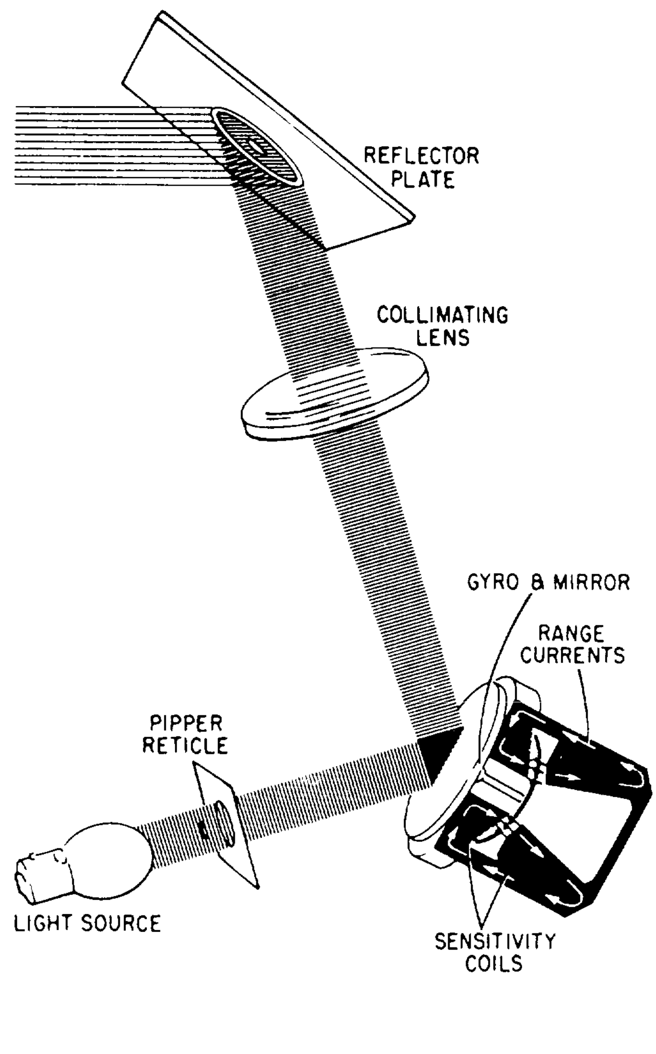


Figure 5-6.-Basic principle of a sight unit.

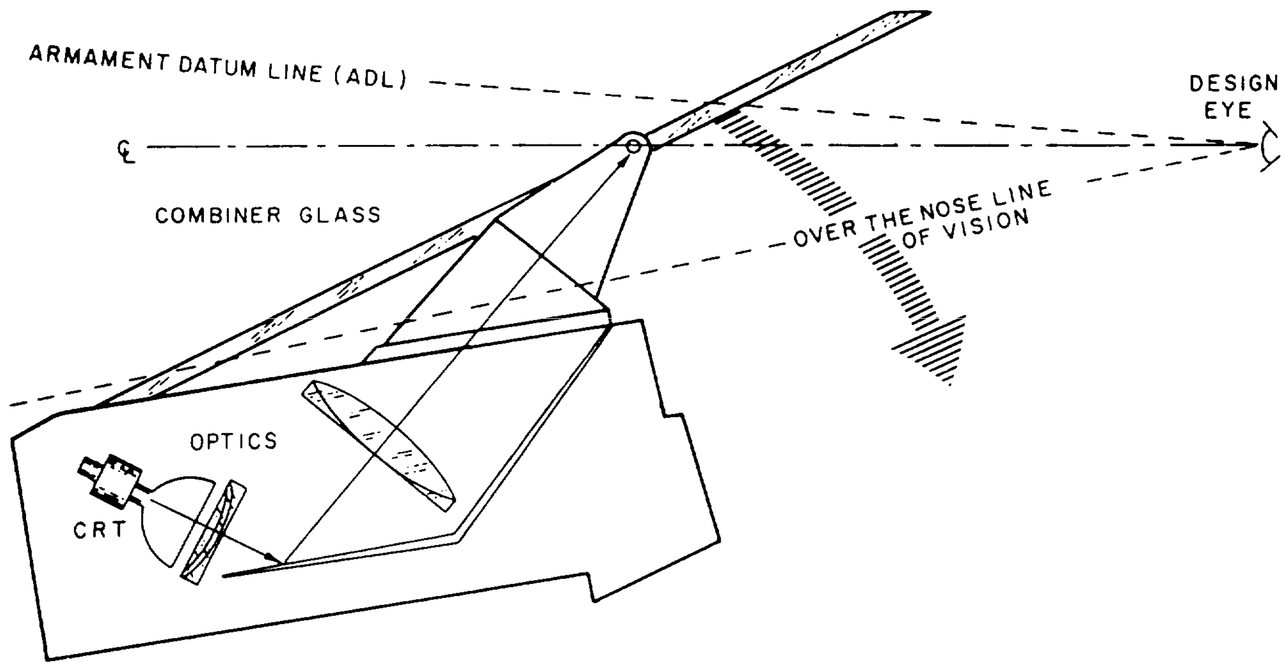


Figure 5-7.-New optical sight with CRT.

the information. Figure 5-7 shows an example of a modern electro-optical sight. This unit or system is known as a heads-up display (HUD).

The HUD receives computed attack and navigational input signals from a tactical computer, aircraft performance data from aircraft flight sensors, and discrete signals from various aircraft systems (fig. 5-8). Information received from these sources is displayed on a transparent mirror (combiner) located directly in front of the pilot at eye level. The HUD processes these signals in the signal data processor. These signals are then applied to the display unit as X (horizontal), Y (vertical), and Z (bright-up) signals that provide the symbols that appear on the combiner. The symbols are focused to infinity and are superimposed over real world objects in line with the aircraft flight path. Certain symbols are positioned on the combiner to correspond with real world object positions relative to the aircraft, even though the real world object may not be visible.

COMPONENTS

This section will discuss the two major components of a HUD set—the signal data processor and the heads-up display unit.

Signal Data Processor

Three-phase ac power is applied to six different rectifiers contained in the low-voltage power supply. The ac voltage is rectified by each rectifier, and then regulated to a precise value. Each value of dc supply voltage is distributed for circuit operation through the signal data processor.

INPUT RECEIVERS.— Digital data signals are applied to the input receivers on four channels. Data transfer is in serial form, and all four channels are in operation at the same time. Each channel consists of a signal and a signal-return line. Specific input data is applied to each channel as follows:

1. Channel one receives a data word signal and a data word signal return.

2. Channel two receives the data identity signal and a data identity signal return.

3. Channel three receives a data ready signal and a data ready return signal.

4. Channel four receives a data clock signal and a data clock return signal.

Data identity signals are transmitted simultaneously with each data word signal. They identify the data word. The identity signal consists of 20 bits of data, which include the control bit, data identity, and parity bit.

DIGITAL COMPUTER.— The digital computer processes the applied digital data in three phases. After the three phases are completed, the entire cycle is repeated. All steps of each phase are performed sequentially according to a prewired program of instruction contained in the program. When electrical power is applied to the digital computer, clock pulses are generated within the clock generator of the program. The clock pulses are distributed by the control logic to the sequence control, input receivers, symbol generator, and processor counter. The processor counter is used to record a specific number of clock pulses so that the demand-next instruction (DNI) pulse is not arbitrarily initiated. However, if a jump signal is received by the function decode, a DNI pulse is initiated. The jump signal may be repeated until the correct instruction is selected. When the DNI pulse is initiated and is in coincidence with a specific clock pulse in the sequence control, a data request signal is applied to the program of instructions.

SYMBOL GENERATOR.— The symbol generator operates in three major modes. The three modes of operation are the line, circle, and analog-to-digital conversion (ADC). Each mode is independently and completely performed before repeating or starting a different mode. The mode to be performed is initiated by the function decode in the digital computer. Correct sequencing of each mode of operation is provided by the timing pulses from the control logic section of the digital computer. The

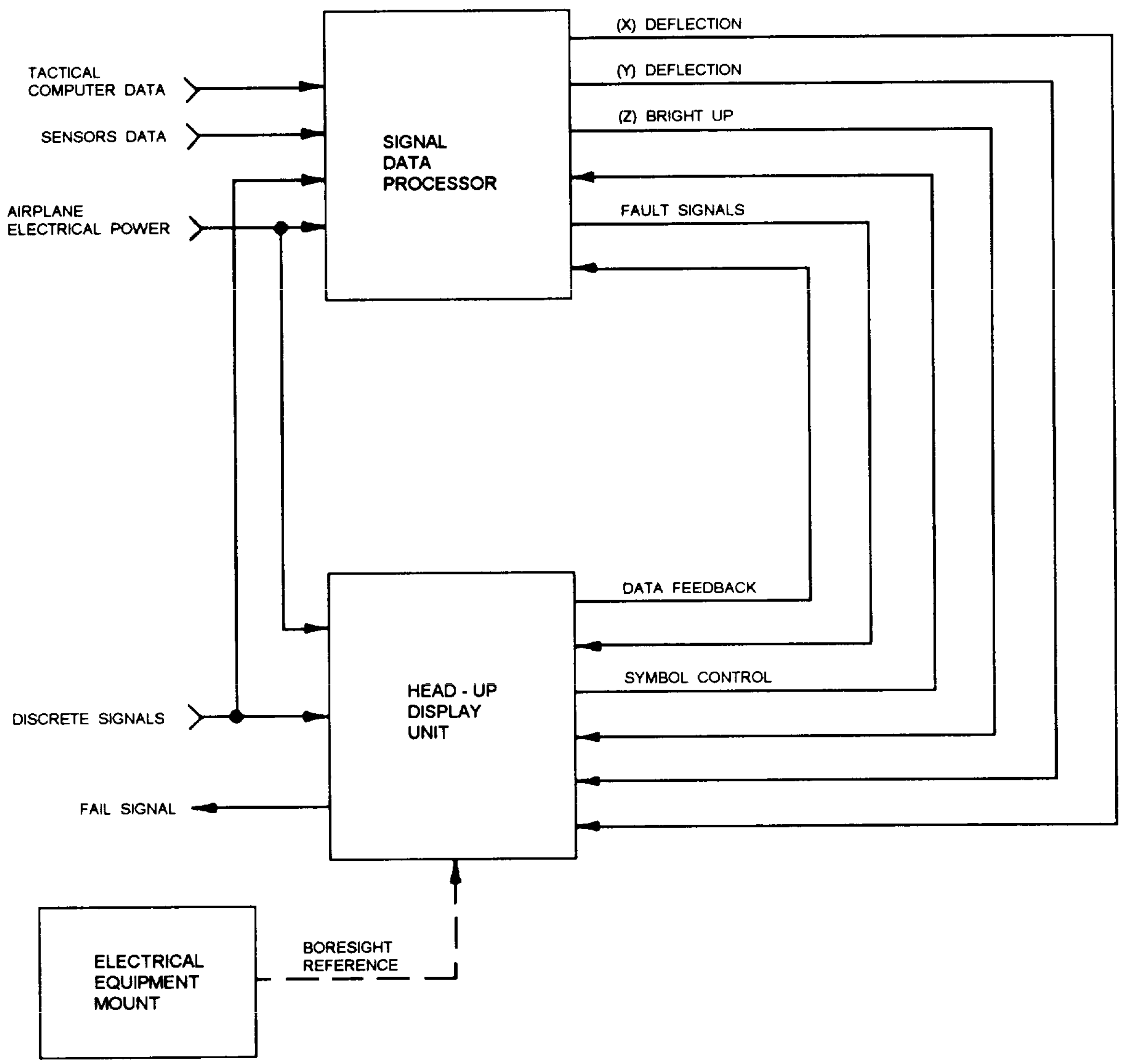


Figure 5-8.-Heads-up display set block diagram.

computer's program determines which mode is initiated in the symbol generator.

Line Mode.— When a line is to be drawn on the CRT, the line mode signal goes to the input/output buffer of the symbol generator. This signal starts a counter that controls all operations of the generator.

The first operation is to transfer the X 1 data from memory to the X channel deflection register. It is transported through the adder and input/output buffer and control. The X 1 data is the digital equivalent of the analog voltage that drives the beam to the start point (in the horizontal axis) of the line draw.

The second operation is to transfer the Y1 data from memory to the Y channel deflection register. The Y1 data is the digital equivalent of the analog voltage that drives the beam to the start point (in the vertical axis) of the line draw. The digital data in each of the deflection registers immediately converts to an equivalent analog voltage. This conversion takes place in the X and Y channel digital-to-analog converters (DACs). Each DAC holds the X and Y deflection voltage until the input/output buffer and control gates them to the HUD.

The third operation transfers the X2 data from memory to the parameter register. The X2 data is a digital quantity representing the line slope angle cosine.

In the first half of the fourth operation, the X2 data shifts from the parameter register to the X channel rate register. In the second half of this operation, the Y2 data transfers to the parameter register from memory. The Y2 data is the digital quantity representing the line slope angle sine.

In the first half to the fifth operation, the Y2 data shifts from the parameter register to the Y channel rate register. In the second half of this operation, the T data transfers from memory to the parameter register. The T data is a digital quantity representing the length of the line draw (bright-up pulsewidth).

During the sixth and seventh operations, the BITE circuits check all data in the X and Y channel rate registers for correctness. All the data required to draw a specific line is now within the symbol generator. The specific line to be drawn could be a symbol in itself or just part of a symbol.

When all the data to draw a specific line is in the symbol generator (after the seventh operation), the busy signal from the HUD is sampled. If the busy signal is high, the operations stop until the busy signal is low. The low signal signifies that the HUD is ready to accept the data. At this time, the input/output buffer and control sends a start pulse to the parameter register. This causes it to start down counting. The down counting controls the length of time the bright-up pulse is applied to the HUD. At the same instant, a gating pulse goes to each DAC. This allows an analog voltage to go to the deflection circuits of the HUD. At the same time, the contents of the rate registers either add to or subtract from the respective residue register. This causes generation of either a positive or negative overflow. The overflow drives the deflection register up or down. This causes the start point of the line to move in the direction of the line slope angle. After a preset time delay, a bright-up pulse goes to the HUD. The time delay compensates for the slower response time of the deflection circuits in the HUD. The bright-up pulse continues until the parameter register has down counted to zero. When the parameter register stops counting, the bright-up pulse turns off. At this time the end of the line mode is indicated to the digital computer. The line mode may be repeated as many times as necessary to complete the required symbol.

Circle Mode.— When drawing a circle on the CRT, a circle mode signal goes to the input/output buffer and control. The signal starts the operation counter as in the line mode. The data required to draw a circle in a specific location transfers to the symbol generator in the same manner as in the line mode. However, the X2 data is equal to negative one, and the Y2 data is all zeros. The T data set into the parameter register is the digital equivalent of one over the circle radius. Circles are drawn in a counterclockwise direction, starting from the top. The overflow from the residue registers controls the direction and amount of change in each deflection register. However, in the circle mode, the overflow also controls the circle logic to the opposite channel. The circle logic is such that a positive X channel overflow causes the contents of the parameter register to add to the contents of the Y channel rate register. If the X channel overflow is negative, then the contents of the parameter register subtract from the Y channel rate register. The opposite occurs if the overflow from the Y channel residue register is positive. This will cause the contents of the parameter register to subtract from the X channel rate register. If the Y channel overflow is negative, the contents of the parameter register add to the X channel rate register.

This cross-coupling causes the two channels to be interdependent on each other. As the rate of change in one channel increases, the rate of change in the other decreases. If the circle is large, the rate of change in the analog defection voltage output is large. If the circle is small, the analog voltage will be small. The rate of change is inversely proportional to the contents of the parameter register, which contains the inverse of the circle radius. This causes the generator to produce a circle with the desired radius.

The bright-up pulse control is from a quadrant counter in the input/output buffer and control. This turns on the bright-up pulse after the electron beam travels halfway around the circle. This delay compensates for the slow response time of the deflection circuits in the HUD. The bright-up pulse stays on until the quadrant counter counts four times. A short time after the fourth count, the bright-up pulse turns off, and the symbol generator busy signal terminates. This completes the circle mode.

Analog-to-Digital Conversion (ADC) Mode.— The third mode of symbol generator operation is the analog-to-digital conversion mode. In this mode, the operation of both the X and the Y channels are the same. Therefore, only the X channel operation is described. At the start of the ADC mode, the most significant bit in the parameter register becomes preset to the one level.

The rate and deflection registers are preset to zero and coupled directly to each other. The direct coupling of the two registers provides for duplication of the contents of either register.

The third step gates a specific analog voltage from the X channel input selector to one side of the X channel comparator.

The fourth step gates the digital-to-analog converter (DAC) voltage from the X channel DAC to the other side of the X channel comparator. The DAC voltage represents the contents of the X channel deflection register. If a difference in voltage level exists between the two applied voltages, the comparator has an output applied to the deflection register. The output of the comparator represents the sign of the difference. This output causes the contents of the parameter register to add to or subtract from the contents of the rate register.

On the next operation, the one in the parameter register shifts to the next lower bit location, and the voltage comparison phase repeats. This process continues until the parameter register reaches zero. When at zero, the contents of the rate register (in digital form) are equal to the input selector analog voltage at the comparator. The next operation transfers the contents of the rate register to memory by way of the data feedback (DFB) lines. In later operations, the remaining analog voltages go to the comparator, and the entire process repeats. The ADC mode continues until all analog voltages are converted to digital data and stored in memory.

Heads-Up Display Unit

Aircraft ac power applied to the low-voltage power supply is rectified, and then divided into seven different dc levels for distribution throughout the display. A transistorized oscillator in the high-voltage power supply receives 24 volts of dc excitation from the low-voltage power supply. The oscillator output is applied to a voltage multiplier and rectifier circuit, which increases the input voltage to 15,000 volts. The 15,000 volts are applied to the CRT anode and a voltage divider within the high-voltage power supply. Outputs from the voltage divider are used to control the oscillator frequency and a comparator output. The comparator senses any differences that may exist between the voltage divider output and a fixed reference voltage. If the high voltage drops below a prescribed level, a fail signal is generated by the comparator and applied to the BITE circuit.

OPTICAL MODULE.— The optical module contains the standby reticle, in-range indicator, control panel, autobrilliance sensor, and lens unit. The standby reticle is used only when the HUD is inoperative, and is controlled electrically and mechanically from the control panel. Electrical power used for the operation of the standby reticle is obtained from outside the HUD.

Light emitted from the standby reticle is transmitted through the lens unit to the combiner. The in-range indicator indicates when a range discrete signal is received from the forward-looking radar set. Symbols are represented by light emitted from a CRT located in the video module. As symbols are drawn on the CRT face, the emitted light is received by the lens unit and applied to the combiner. The desired level of brightness is selected from the control panel by adjustment of the voltage level applied to the cathode bias circuit. The autobrilliance sensor is used to detect ambient light changes. Any change in ambient light proportionally changes the output voltage level of the autobrilliance sensor.

VIDEO MODULE.— The video module contains the bright-up and autobrilliance amplifiers, cathode bias circuit, horizontal and vertical deflection coils, and CRT. Symbols are drawn at the rate of 50 times a second on the CRT. The rapidly moving electron beam is generated by the bright-up pulse from the signal data processor. The bright-up pulse is amplified by the bright-up amplifier, and then applied to the CRT grid. The CRT, which is normally biased into cutoff, is turned on, and an electron beam is emitted. The electron beam strikes the CRT face at a position determined by the amount of current flowing in the horizontal and vertical deflection coils. The amount of light (symbol brightness) emitted from the CRT is controlled by the cathode bias circuit. A control voltage from the control panel is applied to the cathode bias circuit, which serves as a reference voltage for the autobrilliance sensor and the CRT cathode. The voltage output from the autobrilliance sensor is amplified by the autobrilliance amplifier. The output is applied to the cathode bias circuit, which changes the amount of bias (brightness) on the CRT. Thus, an optimum CRT contrast is constantly maintained under varying ambient light.

DEFLECTION MODULE.— The deflection module contains the X and Y deflection amplifiers, X and Y low amplifiers, X and Y comparators, and one OR gate. The type and location of each symbol on the combiner is determined by X and Y analog voltages applied to the deflection circuits. As the need for a symbol arises, the busy signal from the HUD is sampled by the symbol generator. The busy signal is generated any time current is flowing in either deflection coil. Comparators, connected across each coil, are used to detect when the deflection coil current is equal to zero. As the current in either deflection coil reaches zero, the output from the comparator, connected across the coil, goes low. When both comparator outputs are low, the OR gate output goes low, and the busy signal is removed from the symbol generator input. At the same instant, the symbol generator applies a precise analog voltage to the X and Y deflection amplifiers. The output from the deflection amplifiers causes current to flow in the deflection coils. The current amplitude is precalculated to drive the CRT electron beam to the start point of the symbol to be drawn. A bright-up pulse is then applied to the bright-up amplifier in the video module. At the same instant, the deflection voltage is modulated at a predetermined rate and amplitude by the symbol generator. The modulation is detected by the deflection amplifiers and applied to each deflection coil. A specific part (or all) of a symbol is then drawn on the CRT face in a precise location. The bright-up pulse continues long enough to draw the prescribed line or circle that makes up the symbol. When the bright-up pulse is removed, the CRT is driven into cutoff until the next bright-up pulse is applied. This process is repeated until all symbols have been displayed on the CRT.

BITE Functions

Both the signal data processor and the heads-up display unit contain built-in test equipment (BITE).

SIGNAL DATA PROCESSOR.— The built-in test equipment contained in the signal data processor consists of a clock pulse monitor, data test equipment, raw data test equipment, six low-voltage comparators, a signal data processor fail indicator, and a thermal overload sensor.

HEADS-UP DISPLAY UNIT.— The built-in test equipment contained in the HUD unit consists of a high-voltage comparator, seven low-voltage comparators, a bright-up parity circuit, a HUD fail indicator, and a thermal overload sensor.

SYMBOLOGY

The symbols that are used with the various modes of operation in the F-14 are listed and described in figure 5-9. These symbols give the pilot important information, such as aircraft attitude, heading, altitude, angle-of-attack, and ground track during flight. Attack information, such as closure rate, range to target, maximum range for weapon launch, minimum range for weapon launch, and boresight reference, is available during air-to-air and air-to-ground operations. Ordnance information, such as number of rounds remaining, the type of weapon selected, and the number of weapons ready for launch, is also available.

DECLUTTER

The system used in the F-14 (AVA-12) has a feature known as declutter. It is used to remove preselected, unwanted symbols from the display during certain modes of operation. This feature is especially important during an air-to-air situation. When the pilot is trying to locate and engage an enemy target, the declutter feature will clear the unnecessary symbols from his/her view.

SYMBOLOGY

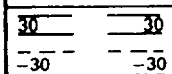
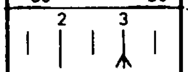
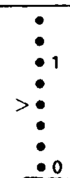
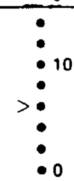
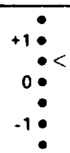
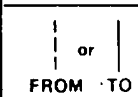
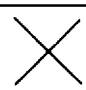
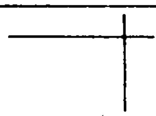
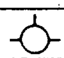
HUD SYMBOL	NAME	FUNCTION
	Aircraft reticle	Depicts own aircraft wings and when lined up with the horizon, the aircraft is in straight and level flight.
	Horizon	This is a demarcation point between ground and sky textures on the VDI. It represents the horizon with respect to the aircraft, and changes orientation with any change in aircraft pitch or roll.
	Pitch lines	Indicates with respect to aircraft reticle pitch attitude. In cruise and A/A mode, HUD pitch lines have a 4:1 compression ratio. Dotted lines indicate a negative pitch. Solid lines indicate positive pitch. Pitch lines above the magnetic heading scale are blanked.
	Magnetic heading (AHRS or WCS via CSDC)	Indicates magnetic heading with respect to index mark.
	Radar Altimter Scale	Indicates altitude derived from radar altimeter. Scale is from 0 to 1400 feet in 200-foot increments and has a movable pointer. This symbol is only available in the takeoff and landing modes.
	Barometric Altimeter Scale	Indicates altitude derived from the pressure altitude via the CADC. Scale is from 0 to 14,000 feet in 2000-foot increments. This scale is available in A/G and TARPS modes. The altitude is referenced to 29.92 inches Hg.
	Vertical Speed Indicator	Indicates rate of altitude change. Scale is from -1500 to +1500 ft/min in 500-foot increments. This scale appears on the left side of the HUD in takeoff and landing modes.
	TACAN Deviation Bar (TACAN via CSDC)	Indicates difference between bearing to TACAN and selected TACAN radial. Deviation is limited to ±5.625° TACAN deviation on the VDI, and ±3° TACAN deviation on the HUD. The symbol never leaves field of view. It will limit at edge nearest selected TACAN radial.
	Breakaway	Appears as a flashing symbol at a 3-cycle per second rate in the center of field-of-view when range-to-go-to minimum or safe pullup point is zero. Symbol is commanded by the WCS computer or by D/L, depending on mode of operation.
	Precision course Vector	This symbol consists of two independent vectors (vertical and horizontal), which form a cross pointer. Elevation glide slope information positions the horizontal vectors, whereas the vertical vector is positioned by azimuth glide slope information. This symbol is also used in D/L bombing modes.
	Velocity Vector	Indicates direction of ground track velocity vector (where the aircraft is going, not where it's pointed).
	Angle of attack error (CADC via CSDC)	Its position in relation to aircraft reticle indicates angle-of-attack error. Symbol is position by true AOA. Small center horizontal bar indicates zero error. When this symbol is in line with the aircraft reticle, the AOA is 15 units (10.31°). If symbol is below aircraft reticle, AOA is too high; above the aircraft reticle indicates AOA is too low. Symbol is displayed in landing mode only.
ORD, G, SW, SP, or PH 0,1,2,3,4,5,6	Armament Ready Legends	ORD – indicates bombs or rockets selected, or bombs and gun selected (A/G GUN switch on ACP set to MIXED) G – indicates gun is selected or gun and bombs are selected (A/G GUN switch on ACP 6 set to OFF). Number under G indicates rounds remaining in hundreds (6, 5, 4, 3, 2, 1, 0). SW, SP or PH – indicates missile type selected (Sidewinder, Sparrow or Phoenix) and the numbers (0 to 6) indicates number of missiles ready for launch.

Figure 5-9.-Symbology.

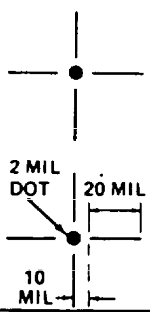
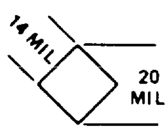
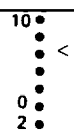
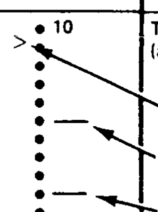
HUD SYMBOL	NAME	FUNCTION
	MASTER ARM switch off	An X symbol through armament ready legend indicates MASTER ARM switch on ACM panel is OFF. Disappears when MASTER ARM switch is set to ON.
	Steering Tee	Provides elevation and azimuth steering in the air-to-air modes when a single target track exists. Type of steering (pursuit, collision, etc.) is dependent on weapon selection and the mode selected on the TID by the RIO. May also provide azimuth steering only on the VDI in TWS. Aircraft steering is accomplished by aligning and maintaining the vertical and horizontal bar of the inverted T with the aircraft reticle center dot. Steering sensitivity on the HUD is 26.5° per inch; on the VDI 25° per inch.
	Boresight Reference	Symbol is a set of crosshairs which is fixed on the HUD and is used to represent the armament data line (ADL) of the aircraft. The reference is located 5.03° above aircraft reticle.
	Moveable Reticle (Impact Point)	Symbol serves as an optical sight for A/A gunnery and for A/G weapons delivery. In A/A gunnery, the symbol is used for lead angle determination. It can be positioned manually using the elevation lead control or automatically by the computer when the pilot selects the gun solution mode. The symbol is so designed that stadiametric ranging techniques can be employed during manual gun firing mode. This symbol in A/G modes indicates instantaneous weapon impact point. This symbol is positioned by the computer in all modes except manual. In the manual mode, it is positioned by the elevation lead control. The computer positions the symbol based on the ballistics of the bomb, wind conditions, and various aircraft parameters. This symbol must overlay the target at the moment of release.
	Target Designator	Indicates radar pointing angle. This symbol is used in all computer A/G modes. It is positioned in this case by the pilot using the TARGET DESIGNATE switch. Once the symbol is over the target, the switch is depressed and the computer knows the slant range to the target. In real-time gunsight mode of air-to-air gun, the target designator is positioned at the 1000-foot bullet solution. In all other weapon modes or with OFF selected, and with a valid sensor angle track on the target, the target designator symbol represents the approximate line of sight to the target. If the target is not within the HUD field of view (FOV) the symbol is positioned at the edge of the FOV in the direction of the target. Limits of designator are 10° in horizontal and vertical.
	Closure Rate	Indicates closing velocity from -200 to +1000 knots between aircraft and target.
	Target Range Scale (azimuth range bar)	Appears on right side of HUD during A/A modes. Scaling is determined by RIO selecting RANGE pushbuttons on the DDD panel. On the VDI, the range scaling is indicated in the lower left corner of the display. Limits are ±35° in horizontal. The symbol appears on the left side of the VDI during A/A modes, except in STT when it will be located at target azimuth.
	Target Range Mark	Indicates range to target.
	Maximum Range Mark	Indicates maximum range for weapon launch.
	Minimum Range Mark	Indicates minimum range for weapon launch.
	Upper Solution Cue	Cue is a measure of instantaneous weapon range. It is constrained to motion on the bomb fall line. Displayed with respect to velocity vector to indicate range-to-go to weapon release. When it crosses the velocity vector symbol the computer commands a weapon release.
	Lower Solution Cue	Cue is a measure of maximum range of weapon calculated from instantaneous aircraft position, constrained to motion on the bomb fall line and is used in conjunction with velocity vector to indicate range-to-go-to in range. In range when cue crosses velocity vector and indicates weapon can reach target if pilot executes a pullup. Cue appears after designate.
	Pullup Cue	Cue is a measure of range at which a 4 g pullup is required to clear weapon fragmentation pattern or ground. Positioned directly below velocity vector. Used in conjunction with velocity vector to indicate range to go to minimum safe pullup point, when one crosses the other.

Figure 5-9.-Symbology—Continued.

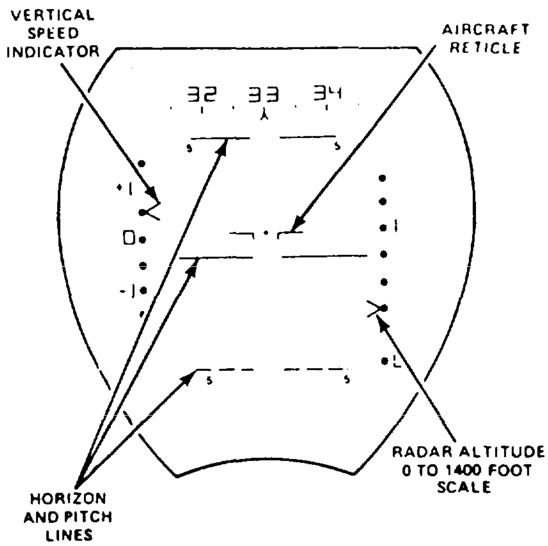


Figure 5-10.-Takeoff mode.

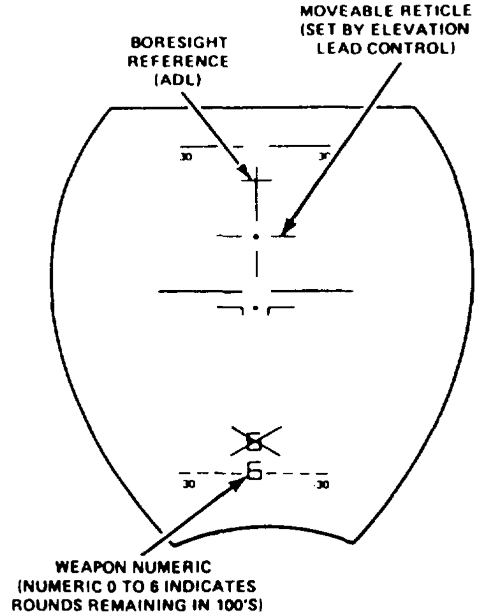


Figure 5-12.-Gun mode.

MODES OF OPERATION

There are five basic modes of operation. These modes are takeoff, cruise, air-to-air (A/A), air-to-ground (A/G), and landing.

Takeoff

The takeoff mode is shown in figure 5-10. This mode is used during takeoff and displays vertical speed, altitude, and aircraft attitude.

Cruise

The cruise mode is shown in figure 5-11. This another. The display gives the pilot attitude reference, magnetic heading, and various weapon information.

Air-to-Air

Figures 5-12, 5-13, 5-14, and 5-15 are examples of the air-to-air mode. These displays give the pilot attack data with the various types of A/A weapons selected. In addition to attitude reference, the weapon

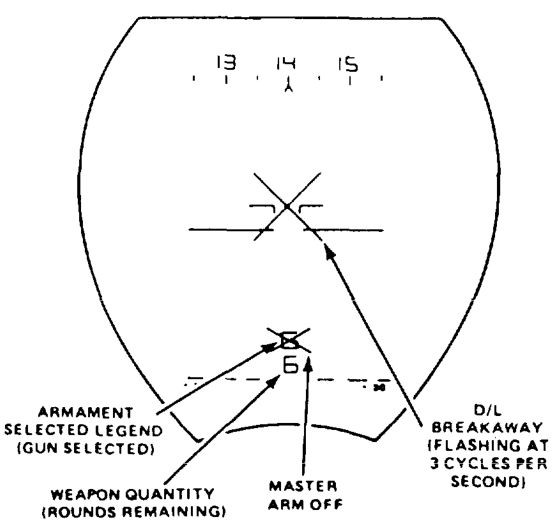


Figure 5-11.-Cruise mode.

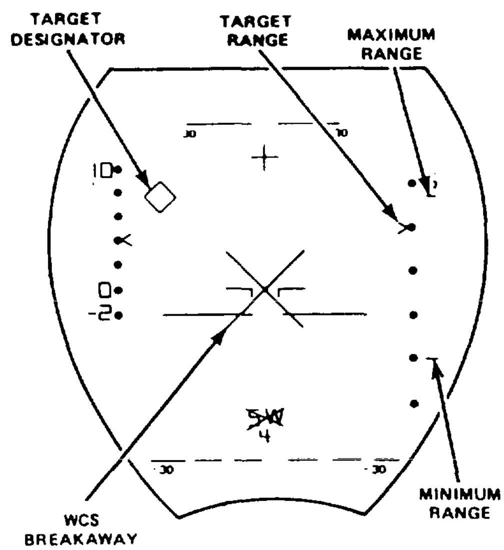


Figure 5-13.-Sidewinder mode.

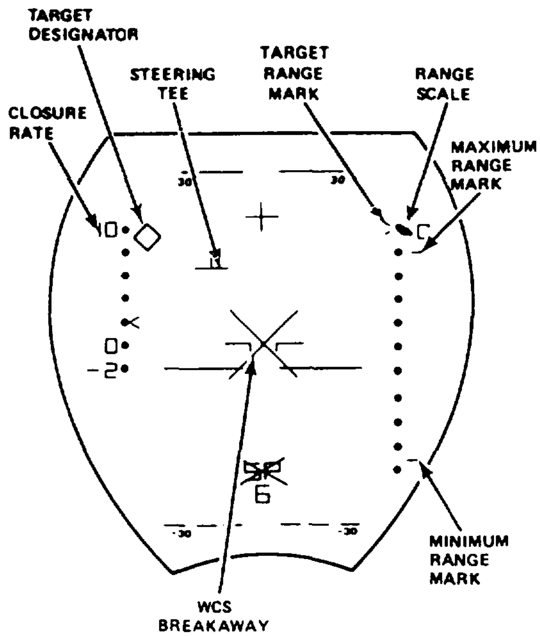


Figure 5-14.-Sparrow mode.

along with various types of target information.

Air-to-Ground

The air-to-ground mode is shown in figure 5-16. This mode is used primarily for the delivery of bombs or other types of A/G weapons. Along with the navigational information, it shows bomb ballistic and target information.

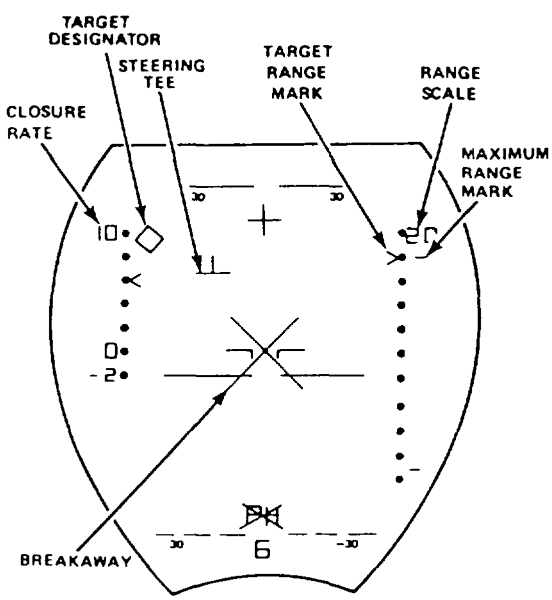


Figure 5-15.-Phoenix mode.

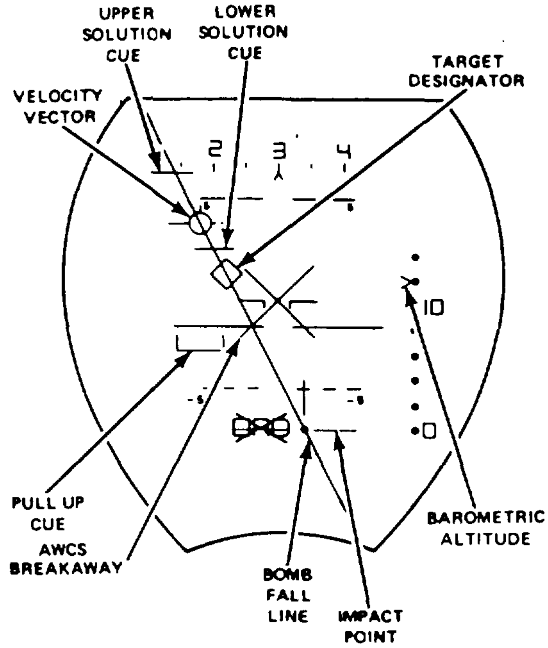


Figure 5-16.-Air-to-ground mode.

Landing

The landing mode is shown in figure 5-17. This display shows the pilot radar altitude, vertical-descent, angle-of-attack, and velocity

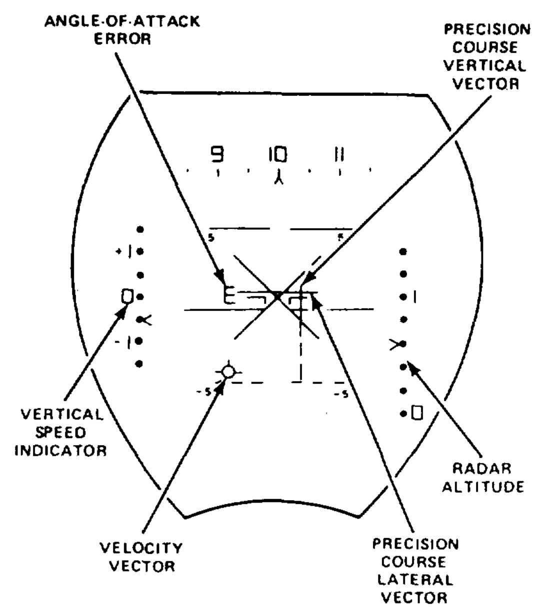


Figure 5-17.-Landing mode.

information. This mode is used when the aircraft is making an approach to an airfield or a carrier until the pilot has visual contact with the field.

TACTICAL DISPLAY SYSTEM (NON-HUD)

Learning Objective: *Recognize components and functions of a non-HUD tactical display system.*

The AN/ASA-82 TDS is installed on the S-3 aircraft. This system is representative of ASW tactical display systems in use by the Navy.

The AN/ASA-82 consists of five indicators and a digital-to-analog converter. The digital-to-analog converter is commonly called a "display generator unit" (DGU). Three of the indicators are multipurpose displays (MPDs), which, with a few exceptions, can display all pertinent mission data developed within the aircraft. These MPDs are located at the TACCO (tactical coordinator), SENSO (sensor operator), and copilot stations. Because the copilot assists the TACCO during an ASW mission, the copilot station is referred to as the COTAC station. At the SENSO station, there is an additional indicator used to display acoustical data. This is the auxiliary readout unit (ARU). The fifth indicator in the system is located at the pilot's station. This indicator displays tactical plot data required to maintain aircraft position while the aircrew is searching for or prosecuting a submarine.

DISPLAY GENERATOR UNIT

The display generator unit generates alphanumeric characters, conics (curved lines), and vectors (straight lines). These graphic symbols are sent to all MPDs and to the pilot's display. However, the DGU does not send all data types to all displays. The data capabilities of each display will be discussed later in this chapter. The DGU also positions all video data in the proper place on the display. Display data is processed through four processing channels, which are interchangeable, to supply the data for the four crew stations. When a processor channel fails, it is identified and reported to the general-purpose digital computer (GPDC) by the operation of the built-in test equipment at each station.

PILOT DISPLAY

The pilot display presents the key elements of the TAC (tactical) plot, selected alerts, and peripheral information. The data presented on the display is produced by the GPDC, and is controlled by aircrew members through their integrated control system (INCOS) panels. The basic pilot display format is shown in figure 5-18.

COPILOT/COTAC DISPLAY

The copilot/COTAC display provides the video presentations listed below:

- Alerts and cues for the GPDC
- Tableaus containing GPDC-stored data
- Tactical plot (TAC plot) composed of symbols, vectors, and conics
- FLIR (Forward-looking infrared)
- MAD
- BT
- Scan-converted radar
- Test patterns

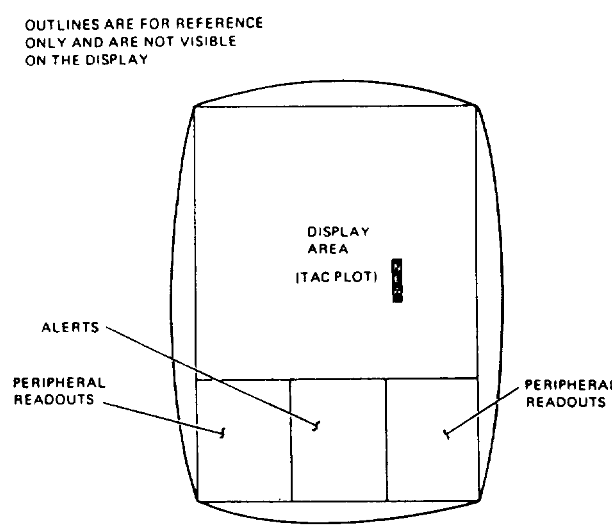


Figure 5-18.-Pilot display format.

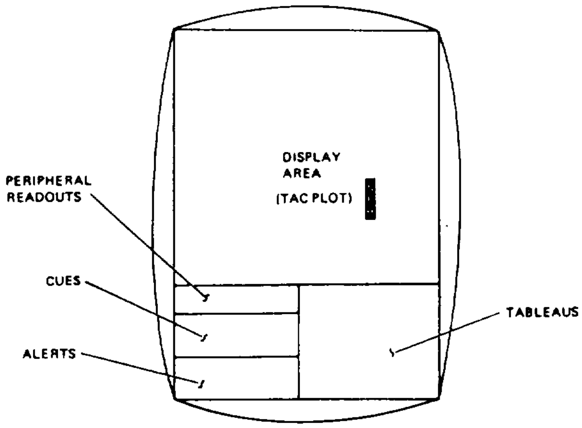


Figure 5-19.-Copilot/COTAC display format.

The basic copilot/COTAC display format is shown in figure 5-19.

TACCO AND SENSO DISPLAYS

The TACCO display provides the video presentations listed below:

- Alerts and cues from the GPDC
- Tableaus containing GPDC-stored data
- TAC plot composed of symbols, vectors, and conics
- Analog acoustic data from the acoustic data processor (ADP) in the form of frequency, bearing, and range information from active sonobuoys (pingers) and signal strength from passive sonobuoys
- FLIR
- MAD
- BT
- Scan-converted radar
- Raw radar
- Test patterns

The TACCO and SENSO display formats are identical, and are shown in figure 5-20.

SENSO ARU DISPLAY

The SENSO ARU displays analog acoustic data from passive sonobuoys. This data includes frequency, bearing, and signal strength.

TACTICAL DISPLAY SYSTEM INTERFACE

As was previously mentioned, the TDS is the primary means used by the GPDC to present information to the operators. As shown in figure 5-21, the GPDC sends commands to the DGU. The DGU interprets them, determines the operating mode, and generates the requested symbols or displays. The DGU also regulates the data flow rates from the FLIR, radar, and the ADP to allow direct interface between these systems and the TACCO, SENSO, and COTAC stations. The pilot's display receives video data from the DGU only. The SENSO ARU interfaces with the ADP only.

TELEVISION

Learning Objective: *Recognize components and operating fundamentals of a television system.*

Television can be defined as the transmission and reception of visual images by means of electrical signals from one point to another. There are three basic elements in all television systems. These elements are as follows:

- A pickup device to convert an optical image into an electrical signal.
- A means of transmitting that signal from one point to another.
- A reproducing device to convert the eleclrical signal into an optical image.

Pickup devices, or camera tubes, include image orthicons, image isocons, vidicons, plumbicons, and secondary electron conduction (SEC) tubes.

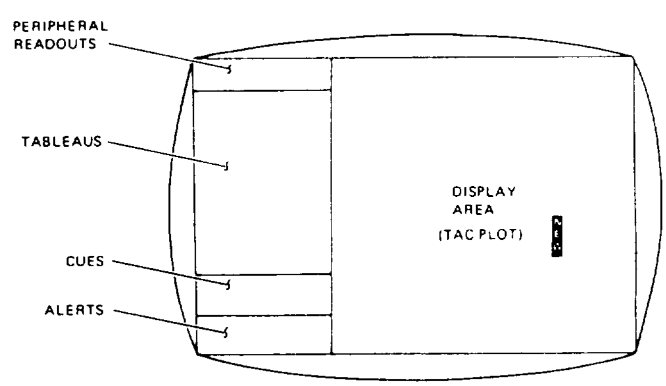


Figure 5-20.-TACCO and SENSO display format.

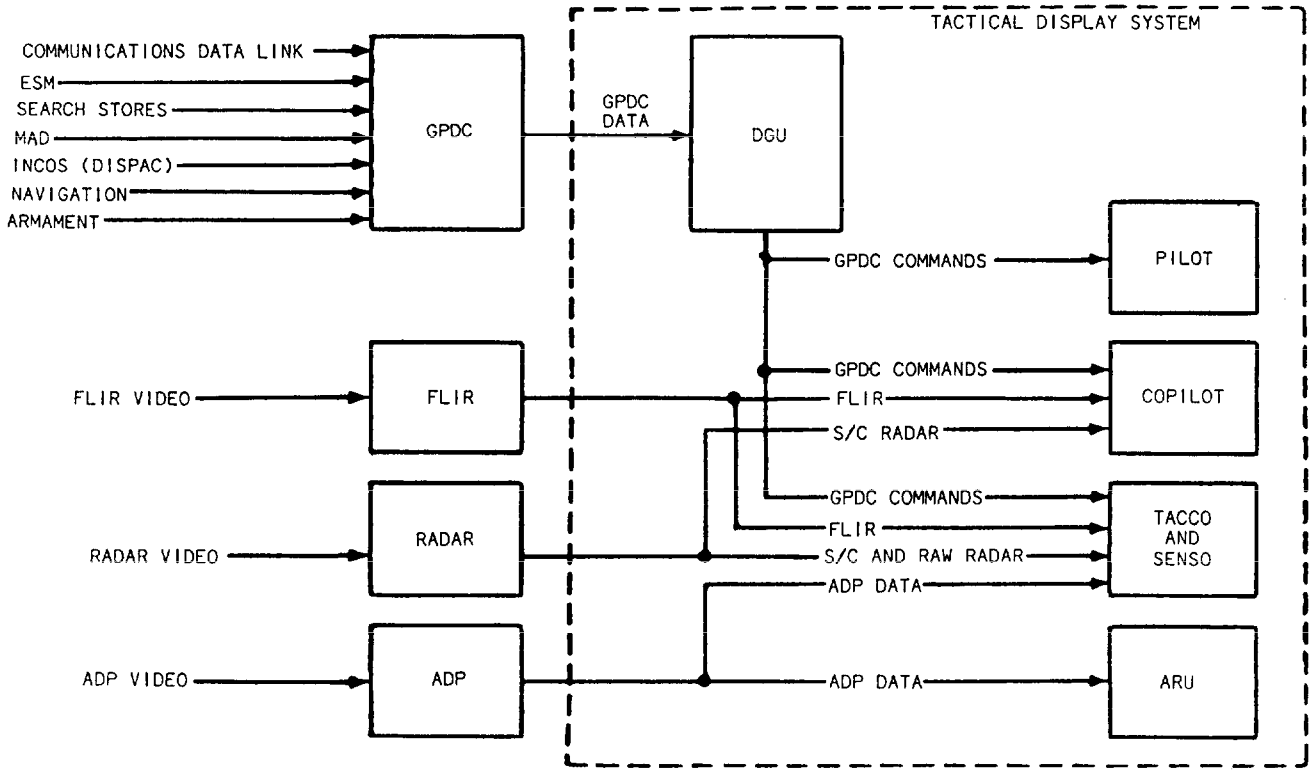


Figure 5-21.-TDS Interface block diagram.

Transmitting devices include coaxial lines, low- or high-power transmitters, or microwave relay links. The reproducing device is a television receiver, a television monitor, or some form of electro-optical projection system.

This chapter will discuss the camera tubes (pickup devices) and picture tubes (reproducing devices). For most uses in aircraft, coaxial cables provide the means for transmitting the video signals from the pickup to reproducing devices.

TELEVISION FUNDAMENTALS

Television transmission of a picture from one point to another involves a process in which light, reflected from an object or scene, is converted into electrical impulses of varying magnitude. This process is accomplished by means of synchronized scanning. In synchronized scanning, the picture is examined by the camera and reproduced by the viewing monitor. This is done point-to-point and in a regular pattern. The process is carried out so rapidly that the entire picture is scanned many times each second, and the eye sees it as a single complete image.

The basic television system is shown in figure 5-22. Notice that it consists of a transmitter and a monitor. An image of the scene is focused on the camera pickup device. An electron beam in the device scans the optical image and produces an

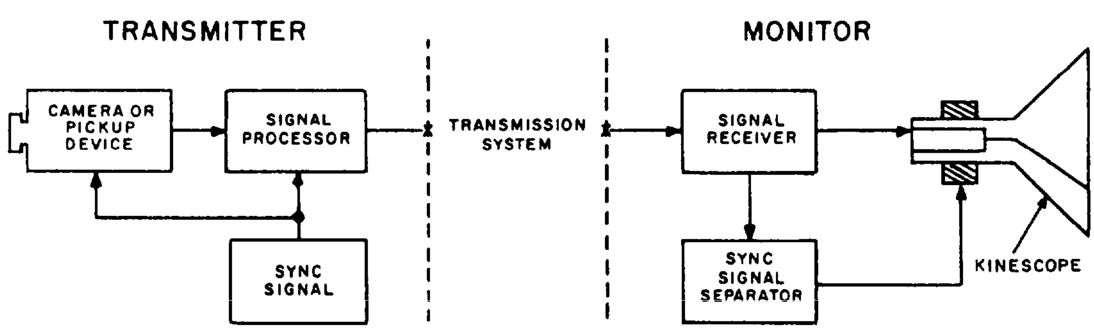


Figure 5-22.-Basic television system.

electrical signal, which varies in amplitude with the amount of light that falls on each point of the image. A synchronizing signal is added to the electrical signal from the camera. The resultant composite video signal is then transmitted to the monitor.

In the monitor, the synchronizing signal causes the beam to scan the picture tube (kinescope) faceplate in synchronism with the camera scanning beam. The intensity of the beam is varied in accordance with the picture signal. The varying beam causes the image to appear on the face of the picture tube.

The time required for one vertical scan of the picture in broadcast television systems in the United States is 1/60 of a second (60 Hz) or a multiple or submultiple thereof. The rate of 60 Hz was chosen because most commercial electrical power sources in the United States operate at a frequency of 60 Hz. Synchronization with the 60-Hz power frequency reduces the visible effects of hum and simplifies the problem of synchronizing film projectors with scanning.

Scanning

Scanning is the process of breaking up the scene into minute elements, and using these elements in an orderly sequence. Reading a printed page is similar to scanning. You start at the beginning of one line and move to the right, word by word, until you reach the end of the line. Then you jump back to the beginning of the next line and repeat the process until you reach the end of the page. In television, this process is done to the picture.

Scanning Methods

The number of scanning lines determines the maximum ability of the system to resolve fine detail in the vertical direction. Also, the number of scanning lines is related to the resolution ability in the horizontal direction. Resolution is determined by the number of scanning lines. For a given video bandwidth and frame time, horizontal resolution is inversely proportional to the number of lines. Therefore, as the scanning lines are increased in number, the bandwidth of the system must also be increased in the same ratio to maintain the same resolution in the horizontal direction.

Maintaining approximately equal values of horizontal and vertical resolution is ideal. The bandwidth requirements increase as the square of the number of lines. The present system of 525 lines was chosen for broadcast television as the most suitable compromise between channel width and picture resolution. This system is also used in many closed-circuit televisions (CCTV).

NONINTERLACED SCANNING.— This is the simplest method of scanning. It is also known as sequential or progressive scanning. Noninterlaced scanning uses an electron beam that moves very rapidly from left to right on an essentially horizontal line. It travels slowly from the top to the bottom of the picture. When the electron beam reaches the end of a line, a blanking voltage is applied, which shuts off the beam. The period of time the beam is shut off is known as the horizontal retrace period or flyback time. Similarly, when the beam reaches the bottom of the picture, the beam is again blanked, and returns to the top of the picture. This period of time is known as vertical retrace or flyback time.

INTERLACED SCANNING.— An important variation of the scanning method is known as interlaced scanning. It is the method used by broadcast television and most CCTV equipment. With interlaced scanning, it is possible to reduce the video bandwidth by a factor of two without reducing the resolution or seriously increasing flicker.

In the standard two-to-one method of interlacing, alternate lines are seamed consecutively from top to bottom. Then, the remaining alternate lines are seamed. This principle is shown in figure 5-23. In

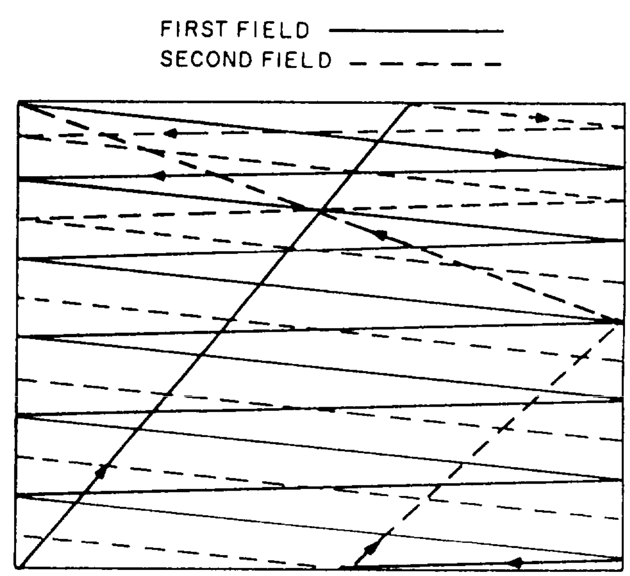


Figure 5-23.-Interlaced scanning.

this type of scanning, each of the two groups of alternate lines is called a field, and the frame is made up of two fields. Interlacing is accomplished by making the total number of lines in a frame an odd integer. Thus, the number of lines in each of the fields is an even number plus one-half line. This results in consecutive fields that are displaced in space with respect to each other by one-half of a line. The total number of lines is 525, the total lines per field is 262 1/2, the vertical scanning frequency is 60 Hz, the number of frames per second is 30, and the horizontal scanning frequency is 15,750 Hz (60 x 262 1/2).

Television Signals

The standard television signal consists of the following four elements:

1. The picture information
2. The picture blanking pulses
3. The picture average dc component
4. The picture synchronizing pulses

These four elements are discussed in the following text.

PICTURE INFORMATION.— The picture information is the basic part of the signal. It is a series of waves and pulses generated during active scanning of the camera tube. As the scanning line travels across the tube, it is amplitude modulated in proportion to the brightness variation in the scene it is scanning. For commercial television, the amplitude variations are such that the maximum video amplitude produces black, and the minimum amplitude produces white. Ordinarily, the maximum and minimum video amplitude values represent 75 and 15 percent of the maximum carrier voltage, respectively.

PICTURE BLANKING PULSES.— To prevent undesirable signals from entering the picture during retrace time, blanking pulses are applied to the scanning beams in both the camera tube and the receiver picture tube (kinescope). Camera blanking pulses are used only in the pickup device. They serve only to close the scanning aperture on the camera tube during retrace periods, and never actually appear in the final signal sent to the receiver. In some systems, the same pulse that triggers the seaming circuit and blanks the kinescope also closes the camera aperture.

The function of the kinescope blanking pulses is to suppress the scanning beam in the kinescope during both vertical and horizontal flyback times. The kinescope blanking pulses are simple rectangular pulses, somewhat wider than the corresponding camera blanking pulses. They have a duration slightly longer than the actual retrace time. The reason for the slightly longer blanking time is to trim up the edges of the picture and to provide a clean, noise-free period during flyback. Figure 5-24 shows a complete video signal that contains pulses for the removal of visible lines during horizontal retrace periods only. The horizontal pulses recur at intervals of 1/15,750 of a second. At the bottom of the picture, they are replaced by vertical blanking pulses. These are similar to the horizontal pulses, except they are of much longer duration (approximately 15 scanning lines) and have a recurrence of 1/60 of a second.

Note that the blanking pulses (and synchronizing pulses) are added at a relatively high-level point in the transmitter because they are considered to be

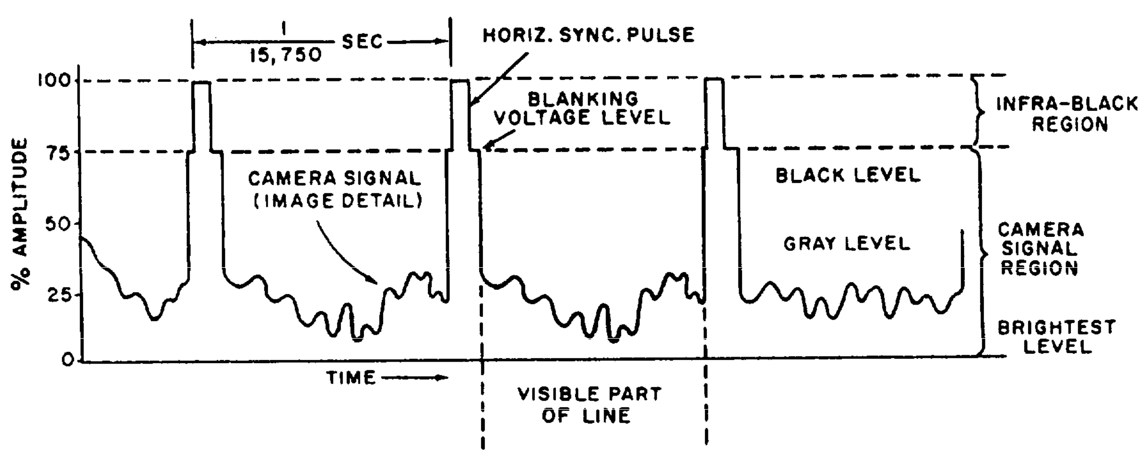


Figure 5-24.-The complete video signal for three scanned lines.

noise-free at that level. The importance of noise-free blanking and synchronizing pulses should be emphasized. They determine the stability of the viewed picture or the degree to which a picture remains locked-in on the picture tube, even under the most adverse transmission conditions. This is important when considering the use of television signals for close-circuit applications. The extreme environmental conditions that may be encountered can seriously degrade the picture signal. This makes it difficult to synchronize or lock-in a picture unless the original blanking-to-picture and signal-to-noise ratios are high.

PICTURE AVERAGE DC COMPONENT.— If a television picture is to be transmitted successfully with the necessary fidelity, it needs the dc component of the picture signal. This component is a result of slow changes in light intensity. The loss of the dc component occurs in ac or capacitive coupling circuits. The loss is evidenced by the picture signal tending to adjust itself about its own ac axis. The dc component is returned to the video signal by means of a dc restorer or inserter circuit.

PICTURE SYNCHRONIZING PULSES.— Synchronizing the scanning beams in the camera and the receiver must be exact at all times to provide a viewable picture. To accomplish this, synchronizing information is provided by electrical pulses in the retrace intervals between successive lines and between successive pictures (fig. 5-24). The retrace periods should be as short as circuit considerations will allow. These periods are in areas where synchronization pulses may be inserted without interfering with the picture.

Synchronizing pulses are generated in the equipment that controls the timing of the scanning beam in the pickup device. They become a part of the complete signal that is transmitted to the receiver. In this manner, scanning operations at both ends of the system are always in step with each other. In general, synchronizing signals should provide positive synchronization of both horizontial and vertical sweep circuits. They should be separable by simple electronic circuits to recover the vertical and horizontal components of the composite sync signal. They should be able to be combined with the picture and blanking signals to produce a standard composite television signal.

Most television systems produce synchronizing information that conforms to the basic requirements of synchronization. Figure 5-24 shows how the synchronizing signal waveform is added to the picture information and blanking signals to form a complete composite picture signal ready to be transmitted. Note that the duration of the horizontal sync pulses is considerably shorter than that of the blanking pulses. Vertical sync pulses are rectangular, but they are of much shorter duration than the horizontal pulses. Thus, they provide the necessary means for frequency discrimination.

Synchronization presents a difficult problem as more failures occur from the loss of proper interlacing. Discrepancies in either timing or amplitude of the vertical scanning of alternate fields cause displacement in space of the interlaced fields. The result is nonuniform spacing of the scanning lines. This reduces the vertical resolution and makes the line structure of the picture visible at normal viewing distance. The effect is usually known as "pairing."

Another series of pulses is added before and after the vertical sync pulses to prevent the pairing problem and to maintain continuous horizontal synchronizing information throughout the vertical synchronization and blanking interval. These are equalizing pulses (fig. 5-25). The time between the last horizontal sync pulse and the first equalizing pulse changes from a full horizontal line interval to one-half of a horizontal line interval every other field. This is caused by the ratio between 15,750 Hz and 60 Hz. The ratio produces the necessary difference between fields to provide interlaced scanning. Since the horizontal oscillator is adjusted to the frequency of the horizontal sync pulses, it is triggered only by every other equalizing pulse or serration of the vertical sync pulse.

Other Systems

Commercial broadcasting and many closed-circuit installations adhere closely to the synchronization signal specifications just discussed. There are some noncommercial and closed-circuit installations that use less rigorous sync signal specifications. We will now discuss four categories of these signals.

RANDOM INTERLACE, NO SPECIAL SYNC PULSES.— The random interlace is the simplest television method. It provides no special sync pulses and no fixed relationship between the horizontal and vertical scanning raster. Synchronization information at the monitor is obtained from the horizontal and vertical blanking pulses contained in the video signal. Figure 5-26, view A, shows this type of video signal. Usually at the camera control

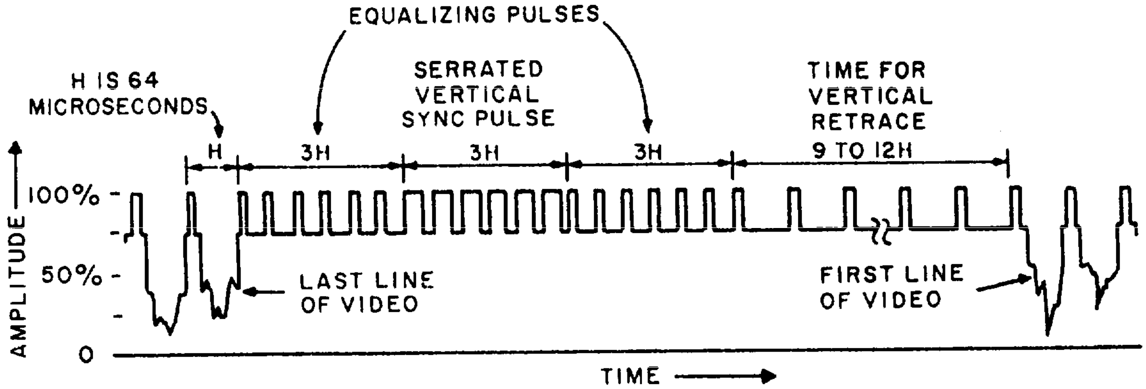


Figure 5-25.-Vertical synchronizing and equalizing pulses.

location, sufficient blanking signal is added to the video signal to provide an adequately long and steep transition at both vertical and horizontal frequencies to provide lock-in.

Some monitors may have problems synchronizing with this information. Electrical noise is a possible condition when the camera and monitor are separated by a great distance. The lock-in of such a signal becomes extremely difficult. Note in figure 5-26, view A, that there are no horizontal sync signals during vertical blanking time. The horizontal frequency circuit in the monitor is essentially free-running during this time. This circuit has the tendency to keep on the proper frequency, but it could get off frequency. This is not a problem during the blanking time. However, when the horizontal sync signals return, it may have trouble synchronizing to the new information.

The most undesirable characteristic of this system is insufficient resolution caused by the lack of interlace. Good interlace is not possible because an absolute frequency relationship between the horizontal and vertical frequencies is lacking. The nominal vertical frequency is usually 60 Hz. The horizontal frequency (usually established by a free-running oscillator) is nominally 15.75 kHz. There is no direct relationship between the two frequencies as required for good interlace. The advantages of this system are reduced costs and greater simplicity of circuits. However, marginal resolution capabilities, incompatibility, marginal stability, and general reduction of system performance limit its application and use.

ODD-LINE INTERLACE, NO SPECIAL SYNC PULSES.— The odd-line interlace system with no special sync pulses has a distinct advantage over the previous system. A definite relationship exists between the horizontal scan frequency and the vertical field rate. This system (waveform seen in figure 5-26, view B) can effectively use the 2:1 odd-line interlace technique. Therefore, it provides a considerable improvement in the resolution capabilities of the system. In theory, the vertical resolution should be double that of the previous system. However, the improvement in resolution is somewhat less since it is difficult to obtain perfect interlace.

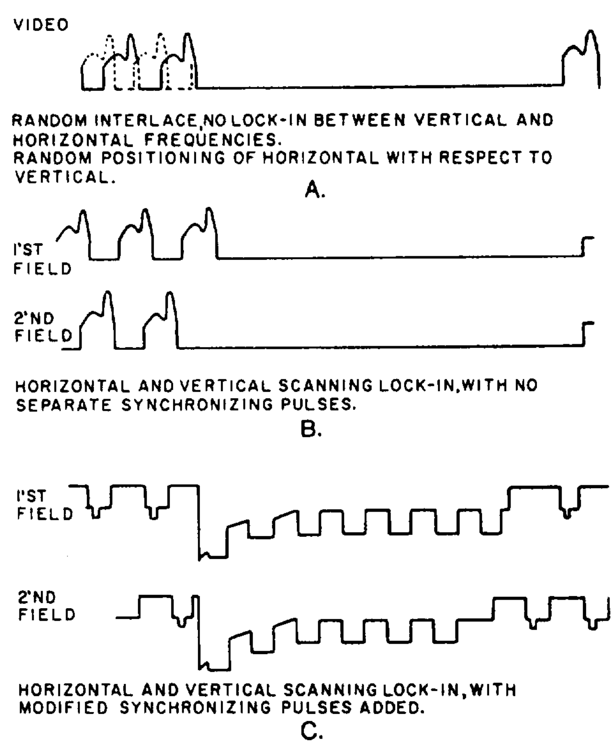


Figure 5-26.-Nonstandardized television waveforms.

Like the random interlace, this system does not provide a special synchronizing signal; therefore, it is subject to the same synchronizing limitations discussed previously. These limitations become an important problem in the more elaborate installations where a series of cameras and monitors might be separated by wide distances. For this reason, installations using these systems are usually the smaller, less complex applications, where stability and reliability may not be an important factor.

ODD-LINE INTERLACE, MODIFIED SYNC PtILSES.— The odd-line interlace method with modified sync pulses provides further advantages over the previous two systems. However, it has a considerable number of limitations. In this system, special synchronizing pulses have been added to the video waveform (fig.5-26, view C).

Note that the synchronizing signal has been added to the tip of each horizontal blanking pulse. The sync pulses also continue through the vertical blanking interval. They provide synchronizing information for the monitor horizontal frequency-locking circuits at all times. These circuits are no longer free-running during the vertical blanking interval. Addition of these special sync pulses greatly improves the lock-in ability of the composite video signal under adverse conditions of noise and spurious signals.

SLOW-SPEED SCAN.— A television system that is being used frequently has a slow-speed scan technique. This technique represents a radical departure from the nominal scanning standards. It permits a scene to be picked up and transmitted successfully from one location to another, if the scene contains a limited amount of action or movement and a great deal of redundancy. It affords fair resolution and fidelity in signals transmitted over relatively economical narrow-band transmission facilities. For example, a slow-speed camera located in a bank, a message center, or a newspaper office can scan printed information and transmit it to a distant location over ordinary telephone line facilities. Some methods are able to transmit pictures having more action, such as a person talking, with reasonable clarity. Such methods, however, require a somewhat greater bandwidth.

Most slow-speed scan systems use a much slower scanning rate, with a correspondingly narrower bandwidth, than present telecasting standards. Broadcasting systems transmit a picture every 1/30 of a second, with a 4-MHz bandwidth. Slow-scan systems transmit a picture in 1/10 of a second to 2 seconds, with a video bandwidth ranging from approximately 250 kHz to as low as 500 Hz.

Most slow-speed scan systems are practical where time is available for transmission. For example, the information contained in a 5-minute commercial television program requires several hours of time to be transmitted with comparable detail by the average slow-speed scanning system. The advantages of the slow-speed system are greatly simplified equipment and relatively inexpensive transmission facilities. The disadvantages are that the scene content is limited to relatively immobile objects, resolution is marginal, and the system is incompatible with standard television systems. Rather complex scan conversion equipment is required to make the two systems compatible. Except for certain special applications, slow-speed scan systems are inferior in performance and cannot be used successfully where a high degree of resolution and detail is required.

COMPONENTS

The pickup devices and picture tube basics are discussed in the following text.

Camera Tubes

To assure high-quality images at the picture tube, the camera must resolve the scene into as many picture elements as practical. The quality of the picture increases as the number of elements increase. The pickup tube must produce signals that accurately represent each element. The optical-electrical conversion must have a signal-to-noise ratio high enough to assure effective pickup sensitivity at the lowest light level that may be transmitted. Ideally, when there is no light present, there should be no output signal.

The type of camera tube used is determined by the intended use of the camera and the amount of available light. The amount of light required by a camera tube is rated in candelas. The minimum number of candelas required by a camera tube is a measure of the tube's sensitivity. The following types of tubes are in use today.

IMAGE ORTHICON.— The image orthicon (fig. 5-27) is an ultrasensitive television camera pickup tube. The tube requires only 8 to 40 candelas for light, and is used in modern conventional and CCTV systems. When this tube is used, a light image for the subject (arrow at extreme left in figure) is picked up by the camera lens and focused on the light-sensitive face of the tube. This causes electrons to be released from each of the thousands of tiny globules in proportion to the intensity of the light striking it.

These electrons are directed on parallel courses from the back of the tube face to the target, from which

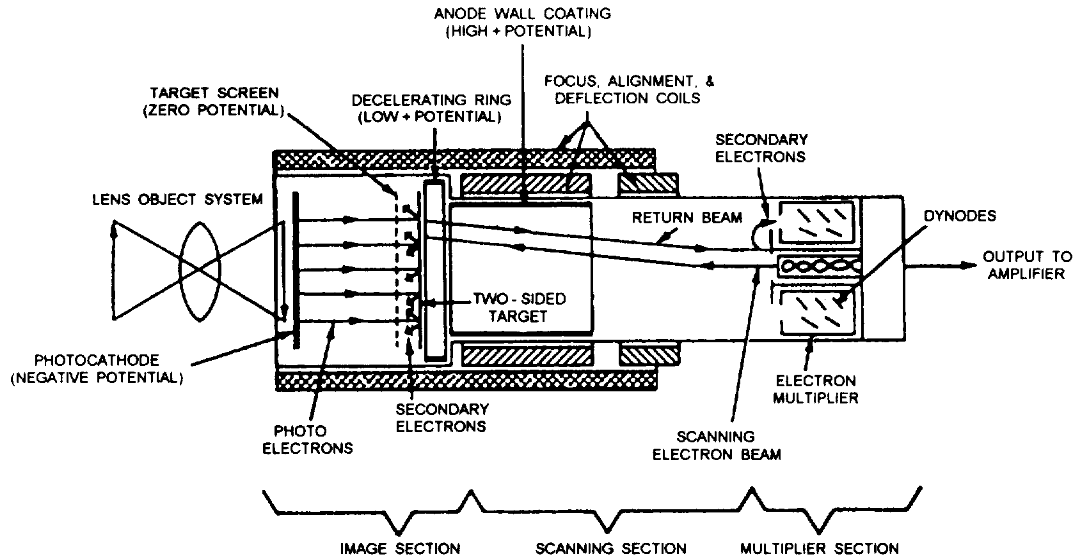


Figure 5-27.-Image orthicon tube.

each striking electron liberates several more electrons, leaving a pattern of propottionate positive charges on the front of the target. When the back of the target is scanned by the beam from the electron gun in the base of the tube, enough electrons are deposited at each point to neutralize the positive charge. The rest of the beam returns to a series of electron multiplier stages or dynodes surrounding the gun.

Each dynode is a metallic disk with openings similar to a pinwheel, and operates at a positive potential of 200 to 300 volts greater than the preceding dynode. Multiplication occurs through secondary emission at each dynode. If five dynode stages are used, each having a gain of 4, a gain of 1,000 (4 x 4 x 4 x 4 x 4) is realized in the multiplier section. Now, consider dynodes with a gain of 5. The overall gain would be 5,000. This setup would allow the pickup tube to operate with relatively less light than the plumbicon or vidicon (to be discussed later). The electrons from the last dynode are routed through a signal-developing resistor to an extremely high B+ voltage. The output signal is then coupled to the first stage of video amplification in the camera.

IMAGE ISOCON.— The image isocon tube (fig. 5-28) is similar to the image orthicon in construction and operation. The main difference is

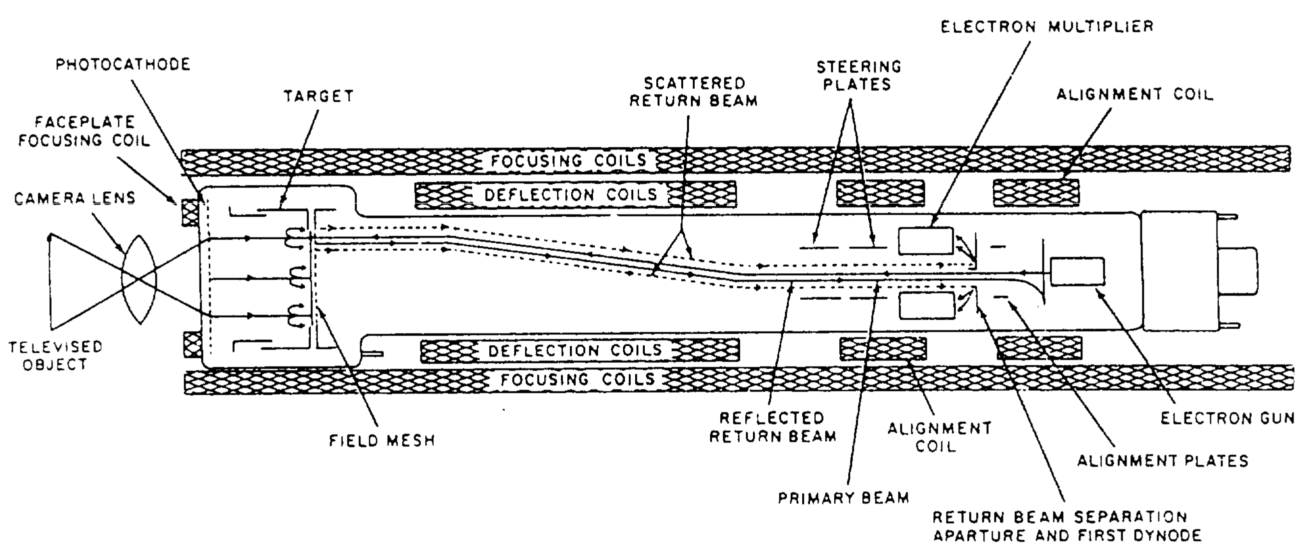


Figure 5-28.-Image isocon tube.

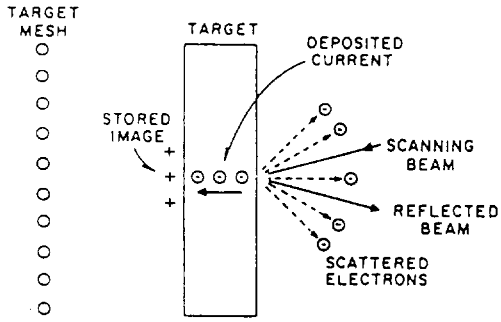


Figure 5-29.-Image isocon target.

the method of extracting the video information from the returned electron beam. The image isocon uses scanning beam electrons scattered by the positive-stored charges on the target. Figure 5-29 shows this method of signal generation.

When the primary scanning electron beam hits the target, three events occur. Some of the electrons neutralize the target, some electrons reflect back to the gun, and some electrons scatter as they hit the target. Instead of using the reflected electrons, the image isocon uses the scattered electrons. These electrons, as well as the reflected electrons, return toward the electron gun. At the gun end of the tube, the reflected electrons are separated from the scattered electrons. The scattered electrons go to an electron multiplier that amplifies the signals before they are taken out of the tube.

The polarity of the signal developed by the isocon is opposite to the polarity of the signal of the orthicon. In the isocon, the maximum number of scattered electrons occurs at the highlights of the picture, while virtually no scattered electrons occur in the dark. This produces a signal that has much less noise in the lower lights. It also improves the ability of the tube to handle a very wide range of light levels without requiring additional camera adjustments.

The image isocon is useful in very low-light applications where there is a wide range of scene contrast. It is also useful where a low-noise signal is important in low-light areas.

VIDICON.— The vidicon camera tube (fig. 5-30) has a transparent conductive coating on the inner surface of the faceplate. This coating is known as the signal electrode. The signal electrode has a layer of photoconductive material deposited on it. When light from the scene being televised passes through the faceplate and is focused on the photoconductive layer, the resistivity of this material (which has been extremely high) is reduced in proportion to the amount of light reaching it. Because the potential gradient between adjacent elements in the photoconductive layer is much less than the potential gradient between opposite sides of the layer, electrons from the beam side of the layer leak by conduction to the other side between scans of the electron beam.

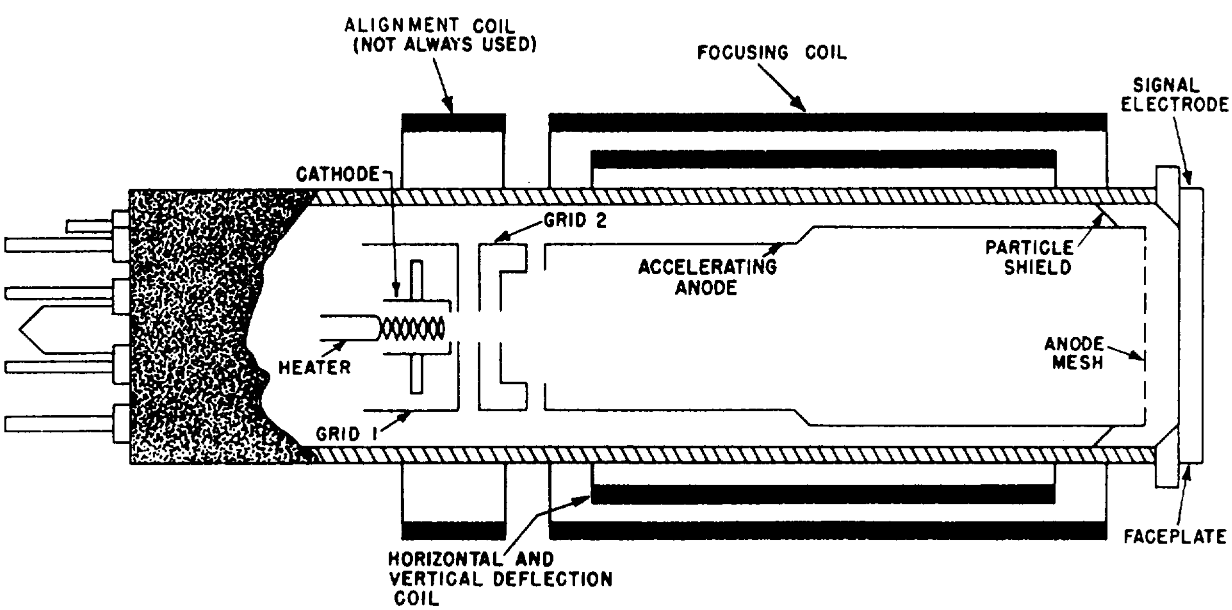


Figure 5-30.-Structure of a vidicon tube.

Consequently, the potential of each element on the beam side approaches the potential of the signal electrode side. It will reach a value that varies with the amount of light falling on the element. On the next scan, the electron stream replaces a number of electrons on each element, just sufficient to return it to the potential of the cathode. Because each element is effectively a small capacitor, a capacitive current is produced in the signal electrode circuit that corresponds to the electrons deposited as the element is scanned. When these electrons flow through the load resistor in the signal electrode circuit, a voltage, which becomes the video signal, is produced.

PLUMBICON.— The plumbicon is similar in appearance and operation to the vidicon. It has several advantages over the vidicon. The plumbicon has a more rapid response and produces high-quality pictures at lower light levels. Because of its small size and low power consumption, the plumbicon is well suited for use in transistorized TV cameras. Its simplicity and spectral response to primary colors make it particularly useful in color cameras.

A unique feature of the plumbicon is that its color response can be varied by the manufacturer. It is, therefore, available with spectral responses for each of the primary colors. The color response of each tube is identified by the letter *R* (red), *G* (green), or *B* (blue) following the basic number. For example, a plumbicon for a green channel may be designated 55875G.

A simplified diagram of a plumbicon target is shown in figure 5-31. The faceplate (view A) has its inner surface coated with tin dioxide. This thin, transparent layer is the signal plate of the target. The tin dioxide itself is a strong N-type semiconductor. Two layers of lead oxide are deposited on the scanning side of the target. The first of these two is almost pure lead oxide. Lead oxide is an intrinsic semiconductor. The second layer of lead oxide is doped to form a P-type semiconductor. As shown in view B of figure 5-31, the three layers form a P-I-N junction.

Light from the televised scene passes through the layer of tin dioxide and is focused on the photoconductive lead oxide. Notice in view C of figure 5-31 that each picture element charge acts like a capacitor whose positive plate faces the scanning beam. The target signal plate forms the negative plate. As the low-velocity scanning beam strikes each charged element, it releases electrons that neutralize the capacitors.

SECONDARY ELECTRON CONDUCTION (SEC).— This is a vidicon-like tube with a special target that uses secondary electron conduction. In this tube, light is focused on the photocathode that emits electrons into the tube. These electrons are focused to form an image of electron streams that strike the SEC target. The electrons are accelerated to approximately 10,000 electron volts by the time they strike the target. The SEC target intercepts these streams of electrons. A great number of secondary electrons from each

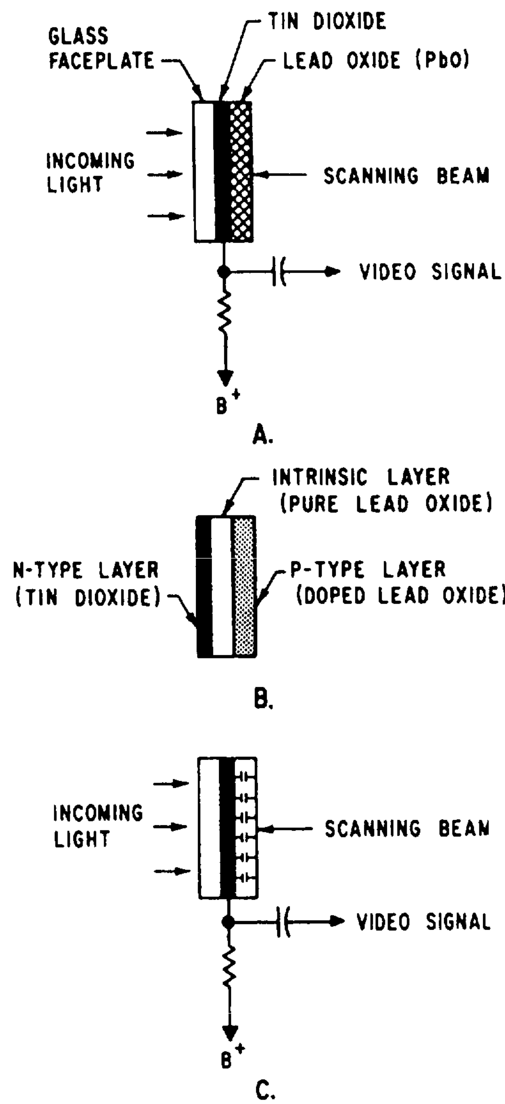


Figure 5-31.-Plumbicon target.

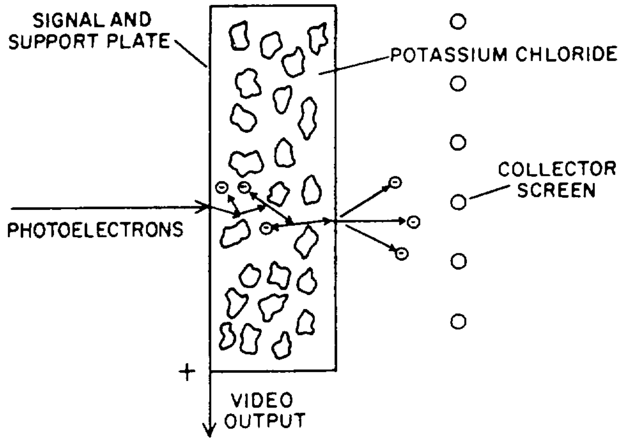


Figure 5-32.-SEC camera tube target operation.

electron striking the target are emitted and stored (fig. 5-32).

The photoelectrons possess sufficient energy to penetrate the thin, metallic signal and support plate. As they travel through the porous potassium-chloride layer, many secondary electrons are emitted as the beam strikes the interlined particles. These secondary electrons either escape to the positive collector screen or they travel through the spaces of the porous layer to the positive collector plate. This loss of electrons produces a positive charge on the scanned side of the target. Several hundred secondary electrons are emitted for each incident electron, producing a substantial gain at the target.

The video signal is developed from the target by the scanning beam discharging the positively charged areas of the target in the same manner as in a vidicon tube. This charging current, flowing out of the signal plate connection, is then amplified by an external amplifier.

The SEC tube has applications in extremely low-light, nighttime military TV systems where a high internal amplification and a fast speed or response to moving images are important.

Picture Tubes

A monochrome picture tube is a specialized form of the cathode-ray tube. An electron gun in the tube directs a beam of electrons toward a fluorescent material on the screen. The screen glows when struck by the electrons. Between the gun and the screen are deflection coils that deflect the beam horizontally and vertically to form a raster. The brightness of the picture is controlled by varying the grid-bias voltage with respect to the cathode voltage. This bias can be changed by varying either the cathode voltage or the grid voltage.

Color picture tubes operate on the same basic principle as monochrome picture tubes. The difference between the two systems is the types of phosphors that coat the screen. The different types of phosphors produce colors when struck with the electron beam. Three basic or primary colors are used in combination to produce all the other desired colors. These primary colors are red, green, and blue. In a three-gun color picture tube (fig. 5-33), there is a separate gun for each of the color phosphors. The tube's screen consists of small, closely spaced phosphor dots of red, green, and blue. The dots are arranged so a red, green, and blue dot form a small triangle. The shadow mask provides a centering hole in the middle of the triangle of dots. The convergence electrode causes the three separate electron beams to meet and cross at the hole in the shadow mask.

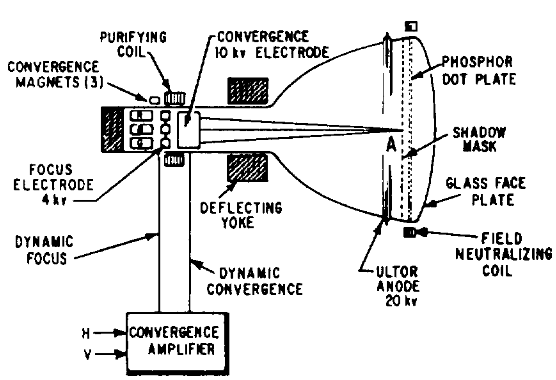


Figure 5-33.-Color picture tube.

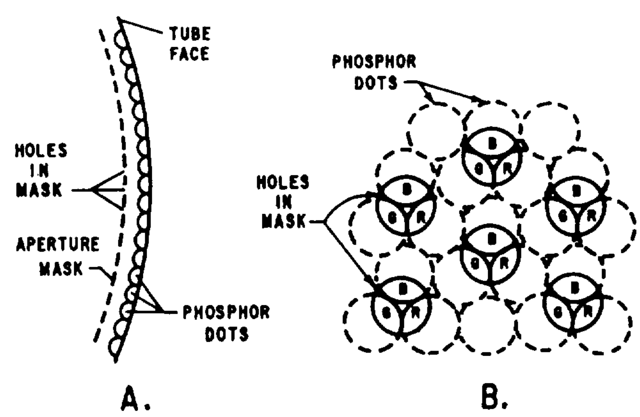


Figure 5-34.-Color picture tube. A. Side view. B. Front view.

Each electron gun is electrostatically focused by a common grid voltage. In other words, each gun has its own electrode, but all three are connected together requiring only one grid voltage. The three electron beams scan the screen and are controlled by the deflection yoke mounted externally around the neck of the tube. As the three beams scan the phosphor screen horizontally and vertically in the standard scanning pattern, the dot triads light up according to the video input signals (fig. 5-34).

The purifying coil produces a magnetic field within the tube that aligns the electron beams parallel to the neck of the tube. Rotating the purifying coil adjusts the electron beams so they strike their respective color dots without striking neighboring dots. When this adjustment is made for the red dots, the other two electron beams are aligned as well.

The high-voltage anode is a metallic ring around the tube. The field neutralizing coil aids color purity at the outer edges of the picture tube. A metal shield, called a mu-metal shield, is placed around the bell of the tube to prevent stray magnetic fields from affecting the electron beams.

REVIEW QUESTIONS

Q1. Which heading indicator displays the most information?

Q2. Are the three control boxes in the HSI group interchangeable between the stations?

Q3. On the BDHI, what is the lubber index?

Q4. What does HUD stand for?

Q5. What does TDS stand for?

Q6. What is a combiner, as used with the HUD system?

Q7. How many different dc voltages are used in the HUD unit?

Q8. In the HUD system how many basic modes of operation are there?

Q9. The SENSO ARU receives inputs from what source?

Q10. What is another term for a camera tube?

Q11. What process is referred to as scanning?

Q12. *How many elements are contained in a standard television signal?*

CHAPTER 6

INFRARED

The term *infrared is* a Latin word meaning *beyond the red.* Infrared is commonly shortened to IR. The process of detecting or sensing infrared radiation from a target without being in physical contact with that target is known as *remote sensing.* Active and passive systems are used for remote sensing.

Active systems send a signal to the target and receive a return signal. Radar sets are examples of active systems. Passive systems detect a signal or disturbance originating at the target. The signal may be emitted either by the target or another source. Photography using natural light is an example of a passive system.

Humans can see only a small part of the entire electromagnetic spectrum. However, even though we cannot see them, other parts of the spectrum contain useful information. The infrared spectrum is a small portion of the entire electromagnetic spectrum. IR radiation is a form of electromagnetic energy. IR waves have certain characteristics similar to those of light and RF waves. These characteristics include reflection, refraction, absorption, and speed of transmission. IR waves differ from light, RF, and other electromagnetic waves only in wavelengths and frequency of oscillation.

The IR frequency range is from about 300 gigahertz to 400 terahertz. Its place in the electromagnetic spectrum (fig. 6-1) is between visible

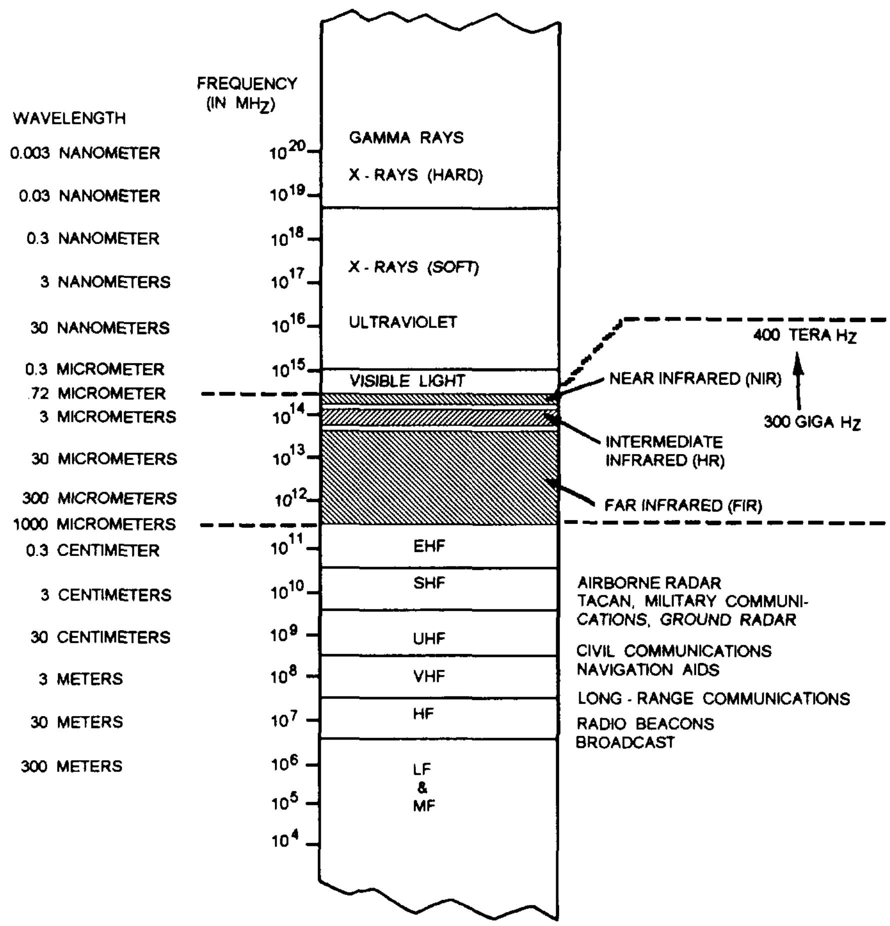


Figure 6-1.-Electromagnetic spectrum.

light and the microwave region used for high-definition radar. The IR region of the electromagnetic spectrum lies between wavelengths of 0.72 and 1,000 micrometers. Discussion of the IR region is usually in terms of wavelength rather than frequency.

NOTE: A basic knowledge of IR detection principles is essential to understanding thermal imaging and the FLIR system as discussed in this chapter. If needed, you should review IR detection principles in *Aviation Electronics Technician 3*, NAVEDTRA 12329, before reading this chapter.

THERMAL IMAGING

Learning Objective: *Recognize functions, characteristics, components, and operating principles of thermal or infrared imaging.*

Infrared radiation is also known as *thermal* or *heat* radiation. Most materials emit, absorb, and/or reflect radiation in the IR region of the electromagnetic spectrum. For example, an aircraft parked on a sunlit runway absorbs and radiates varying amounts of IR radiation. After the sun sets, the aircraft continues to radiate the absorbed heat, making detection at night possible. Even if the aircraft is moved, detection of the aircraft is possible because the runway surface, which was directly below the aircraft, will be cooler than the surrounding runway.

Thermal imaging is referenced in terms of temperature instead of reflectivity (radar) or color (visible light). Variations of the temperature in a scene tend to correspond to details that can be visually detected. The IR imaging system processes this information and converts it into information that the system operator can use. Currently, the types of imaging systems generally used are mechanical-scanning, fast-framing devices. They use the frame rate (information update rate) that is similar to television. They are known as forward-looking infrared (FLIR) devices.

Before a target can be detected, it must exchange energy with its environment, be self-heating, have emissivity differences, and reflect other sources. Look at figure 6-2. Notice the atmosphere between

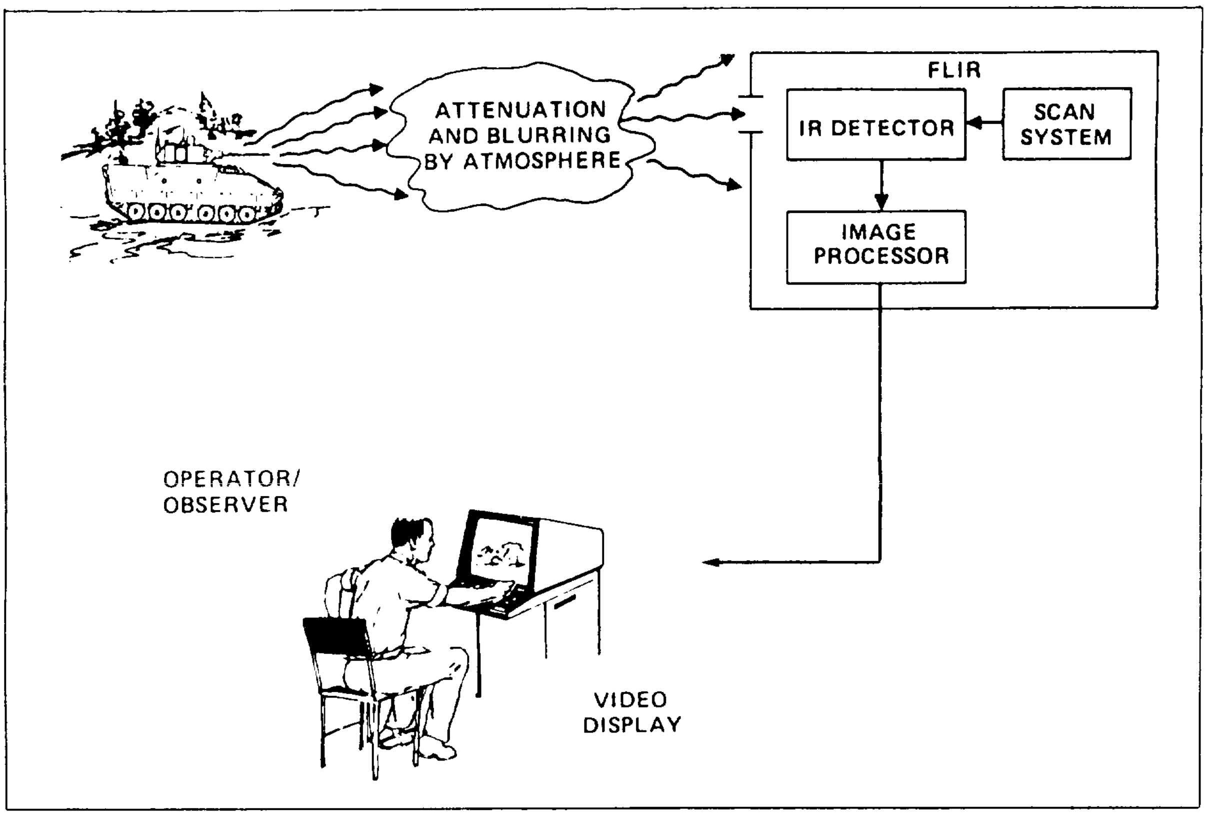


Figure 6-2.-Thermal imaging.

Table 6-1.-Characteristics of IR Radiation

NAME		WAVELENGTH (µM)	FREQUENCY (HZ)
NEAR INFRARED	NIR	0.72 µM – 3 µM	4.3 ö 10^{15} – 1 × 10^{14}
MIDDLE INFRARED	MIR	3 µM – 6 µM	3.0 ö 10^{14} – 5 × 10^{13}
FAR INFRARED	FIR	6 µM – 15 µM	5.0 ö 10^{13} – 2 × 10^{13}
EXTREME INFRARED	XIR	15 µM – 1000 µM	2.0 ö 10^{13} – 3 × 10^{11}

the target and the FLIR attenuates and blurs the target signal. The FLIR operator aims the limited field of view FLIR to search the scene for targets, using a search pattern and clues, such as radar targets or laser designators.

The FLIR system uses thermal sensitivity, image sharpness, spectral response, contrast, and magnification to produce a visual image of the thermal scene. The operator uses training, experience, and image interpretation skills to detect and identify targets.

INFRARED RADIATION

The atmosphere is a poor transmitter of infrared radiation because of the absorption properties of CO_2 (carbon dioxide), H_2O (water), and O_3 (ozone). Infrared radiation is broken into four regions, as can be seen in table 6-1. Only the first three are used with this system. Figure 6-3 shows the transmission spectrum of the atmosphere. You can see that the best transmission is between 3 µm and 5 pm, and between 8 µm and 14 µm. The range between these wavelengths is known as a window. Infrared imaging devices are designed to operate in one of these two windows, usually the 8 µm to 14 µm window.

Infrared Radiation Sources

All matter whose temperature is above -273°C (absolute zero) emits IR radiation. The amount of the radiation emitted is a function of heat. Theoretically, a perfect emitter is a black body with an emissivity of 1. Realistically, the best emissivity is somewhere around 0.98. The emissivity of various objects is measured on a scale of 0 to 1.

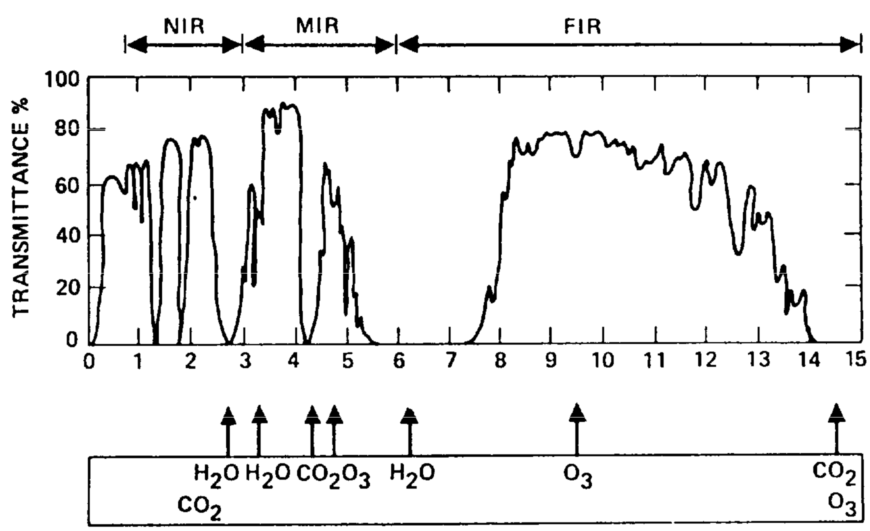


Figure 6-3.-Transmission spectrum of the atmosphere.

The total energy emitted by an object at all wavelengths is directly dependent upon its temperature. If the temperature of a body is increased 10 times, the IR radiation emitted by the body is increased 10,000 times. If the energy emitted by a black body and its wavelengths is plotted on a graph, a hill-shaped curve results (fig. 6-4). By looking at this graph, you can see that the energy emitted by short wavelengths is low. As the wavelengths get longer, the amount of energy increases up to a peak amount. After the peak is reached, the energy emitted by the body drops off sharply with a further increase in wavelength.

Infrared Optics

Many of the materials commonly used in visible light optics are opaque at IR frequencies. For this reason, they cannot be used in IR imaging systems. The optical material used in IR imaging systems should have a majority of the following qualities:

- Be transparent at the wavelengths on which the system is operating
- Be opaque to other wavelengths
- Have a zero coefficient of thermal expansion to prevent deformation and stress problems in optical components

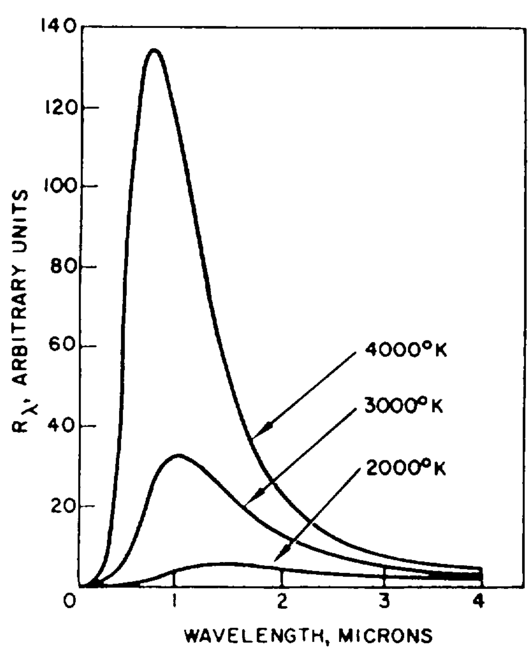


Figure 6-4.-Black body radiation.

- Have high surface hardness to prevent scratching the optical surfaces
- Have high mechanical strength to allow the use of thin lenses (high-ratio diameter to thickness)
- Have low volubility with water to prevent damage to optical components by atmospheric moisture
- Be compatible with antireflection coatings to prevent separation of the coating from the optical component

None of the materials currently used for IR optics have all of these qualities. However, silicon, germanium, zinc selenide, and zinc sulfide have many of them.

Infrared Detectors

The detector is the most important component of the IR imaging system. There are many types of detectors, each having a distinct set of operating characteristics. Bolometers, Golay cells, mercury-doped germanium, lead sulfide, and phototubes are the most commonly used types of detectors. Detectors can be characterized by their optical configuration or by the energy-matter interaction process. There are two types of optical configurations—elemental and imaging.

ELEMENTAL DETECTORS.— Elemental detectors average the portion of the image of the outside scene falling on the detector into a single signal. To detect the existence of a signal in the field of view, the detector builds up the picture by sequentially scanning the scene. The elemental detector requires time to develop the image because the entire scene must be scanned.

IMAGING DETECTORS.— Imaging detectors yield the image directly. An imaging detector is considered a myriad of point detectors. Each of the detectors responds to a discrete point on the image. Therefore, the imaging detector produces the entire image instantaneously. A good example of an imaging detector is photographic film.

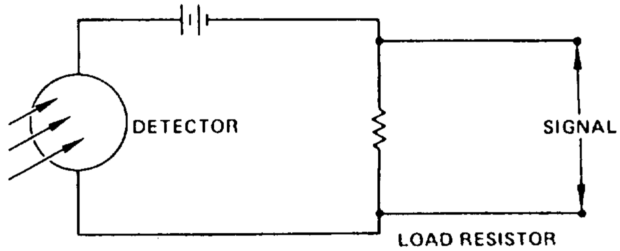


Figure 6-5.-Photoconductive detector circuit.

Energy-Matter Interaction

There are two basic types of energy-matter interaction. They are the *thermal effect* and the *photon effect.*

THERMAL EFFECT.— The thermal effect type of energy-matter interaction involves the absorption of radiant energy in the detector. This results in a temperature increase in the detector element. The radiation is detected by monitoring the temperature increase in the detector. Both the elemental and imaging forms of detectors use the thermal effect.

PHOTON EFFECT.— In the photon effect type of energy-matter interaction, the photons of the radiant energy interact directly with the electrons in the detector material. Usually, detectors using the photon effect use semiconductor material. There are three specific types of photon effect detection. They are *photoconductivity, photoelectric,* and *photo-emissive.*

1. Photoconductivity. Photoconductivity is the most widely used photon effect. (See figure 6-5.) Radiant energy changes the electrical conductivity of the detector material. An electrical circuit is used to measure the change in the conductivity.

2. Photoelectric (also referred to as photo-voltaic). In the photoelectric effect (fig. 6-6), a potential difference across a PN junction is caused by the radiant signal. The photocurrent (current generated by light) is added to the dark current (current that flows with no radiant input). The total current is proportional to the amount of light that falls on the detector.

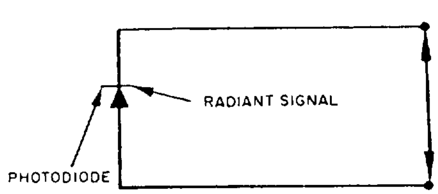


Figure 6-6.-Photoelectric effect.

3. Photoemissive. The photoemissive effect (fig. 6-7) is also known as the *external photo effect.* The action of the radiation causes the emission of an electron from the surface of the photocathode to the surrounding space. The electron is photoexcited from the Fermi level above the potential barrier at the surface of the metal.

INFRARED IMAGING SYSTEMS

An infrared imaging system has the following components: detectors, a scene dissection system, front end optics, a refrigeration system, and an image processing system.

Detectors

Detectors convert the IR radiation signal into an electrical signal that is processed into information used by the operator. Detectors can be arranged in many different configurations for their use in an IR imaging system.

DETECTOR ARRAY.— Only a small portion of the image scene is taken by a detector (or detectors) to

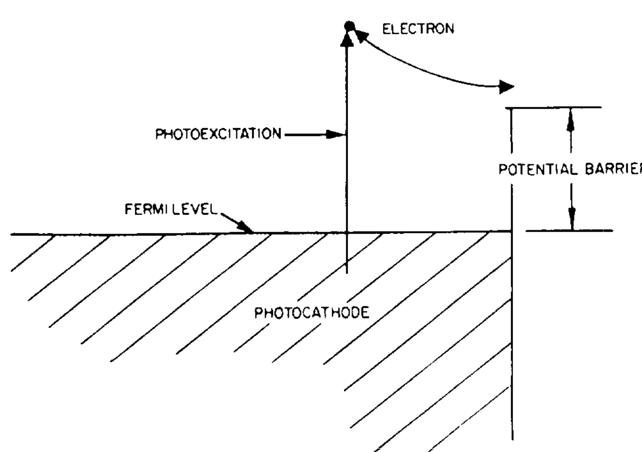


Figure 6-7.-Photoemessive effect.

achieve maximum resolution. A large number of detector elements can be grouped together to form an array (fig. 6-8, view A). The elements of this array are packed closely together in a regular pattern. Thus, the image of the scene is spread across the array like a picture or a mosaic. Each detector element views a small portion of the total scene. The disadvantage of this type of system is that each detector element requires a supporting electronic circuit to process the information that it provides. Also, each detector element requires a preamplifier to boost the signal to a usable level.

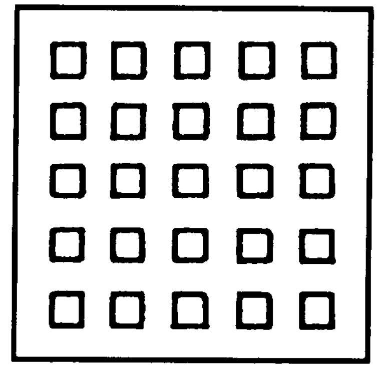
SINGLE DETECTOR.— Another method that is used to provide the operator with information is the single detector (fig. 6-8, view B). Here, there is one detector requiring one set of supporting circuitry. In this type of system, the detector is scanned across the image so that the detector can see the whole image. An optical system is required that can supply the scanning. This type of system is adequate if real-time information is not needed, or if the object of interest is stationary or not moving quickly.

Scene Dissection System

The scene dissection system is used to scan the scene image. There are many types of scanning-one associated with each type of detector array. When a single detector with one axis of fast scan and one axis of slow scan is used, the scene is scanned rapidly in the horizontal direction and slowly in the vertical direction. As a result, the line is scanned horizontally; then the next line is scanned horizontally, etc.

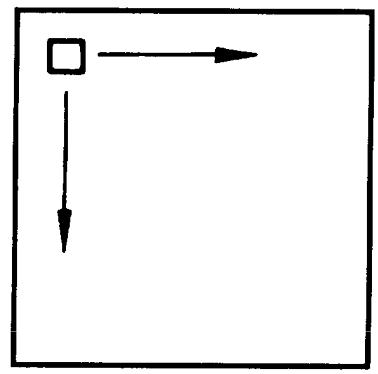
A vertical linear array is scanned rapidly in the horizontal direction (fig. 6-8, view C). One detector element scans one line of the image. In the linear array, there is a space, one element wide, between each element. The scan is one axis with an interlace being used. A vertical linear array is scanned rapidly in the horizontal direction. After each horizontal scan, the mechanism shifts the image upward or downward one detector element width so that on the next scan, the lines that were missed are covered.

Each system has an optimum configuration of detector array and image dissection. If the number of elements in the detector increases, the system becomes more complicated. Also, the cost of the



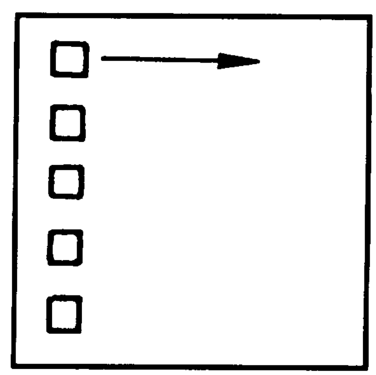
MOSAIC ARRAY WITH NO SCAN

A



SINGLE DETECTOR WITH VERTICAL SLOW SCAN AND HORIZONTAL FAST SCAN

B



PARALLEL ARRAY WITH SLOW SCAN HORIZONTALLY INTERLACE, VERTICALLY

C

Figure 6-8.-Detector arrays.

system increases, and the reliability of the system decreases. If the number of detectors decreases, the amount of information that can be processed is reduced. A compromise between a large number of elements (increased cost) and a smaller number of elements (reduced information) is the linear array that scans in one direction only. Each detector scans one line of the scene image. The complexity of the electronics is reduced, and the amount of information that is processed is increased. Thus, the size of the scene to be viewed and the detail of the scene is increased.

There are many types of mechanisms that can be used to scan the scene. When you scan with two axes, the two scanning motions must be synchronized. The electronic signal that controls the sampling of the detectors must also be synchronized with the scanning motions.

Front End Optics

The front end optics collect the incoming radiant energy and focus the image at the detectors. The optics may be reflective or refractive, or a combination of both. Many systems offer a zoom capability, allowing a continuous change in magnification of the image without changing the focus. Spectral filters are used to restrict the wavelength of light entering the system. This prevents unwanted wavelengths of light from reaching the detector and interfering with the imaging process.

Refrigeration System

A refrigeration system is needed in imaging systems because many types of infrared detectors require low temperatures if they are to operate properly. The two types of detector cooling that are used are the *open-cycle* and the *closed-cycle* types.

In the open-cycle type of cooling, a reservoir of liquified cryogenic gas is provided. The liquid is forced to travel to the detector, where it is allowed to revert to a gas. As it changes from a liquid to a gas, it absorbs a great deal of heat from the surrounding area and the detector.

In the closed-cycle type of cooling, the gas is compressed, and the heat generated by the compression is radiated away by the use of a heat exchanger. The gas is then returned to the compressor and the cycle repeats itself.

Image Processing Systems

The image processing system is used to convert the data collected by the detectors into a video display. Data from the detectors is multiplexed so that it can be handled by one set of electronics. Then it is processed so that the information coming from the detectors is in the correct order of serial transference to the video display. At this point, any other information that is to be displayed is added.

In other image processing systems, the signals from the detectors are amplified and sent to an LED display, or they are optically amplified by photomultiplier tubes and projected on a phosphorescent screen.

FORWARD-LOOKING INFRARED SYSTEM

Learning Objective: *Recognize components and operating principles of a typical FLIR system.*

A forward-looking infrared system is an infrared detecting set (IRDS). The IRDS is a passive device that operates on the IR principles of emissivity. The terms *FLIR* and *IRDS* are synonymous so far as system operation is concerned. Only the azimuth coverage differs. The FLIR system scans an operator-selected portion of the terrain along the aircraft's flight path and displays a televised image of the IR patterns of the terrain. The primary function of the FLIR system is to give the operator an improved capability to detect, identify, and classify targets of interest that would otherwise be concealed from either visual observation or radar detection. The visual concealment could be due to darkness or camouflage. The radar concealment could be due to extreme scope clutter caused by inclement weather, rough seas, or electronic jamming. Additionally, the FLIR system emits no transmission for detection by an enemy. Although there are various types of FLIR systems

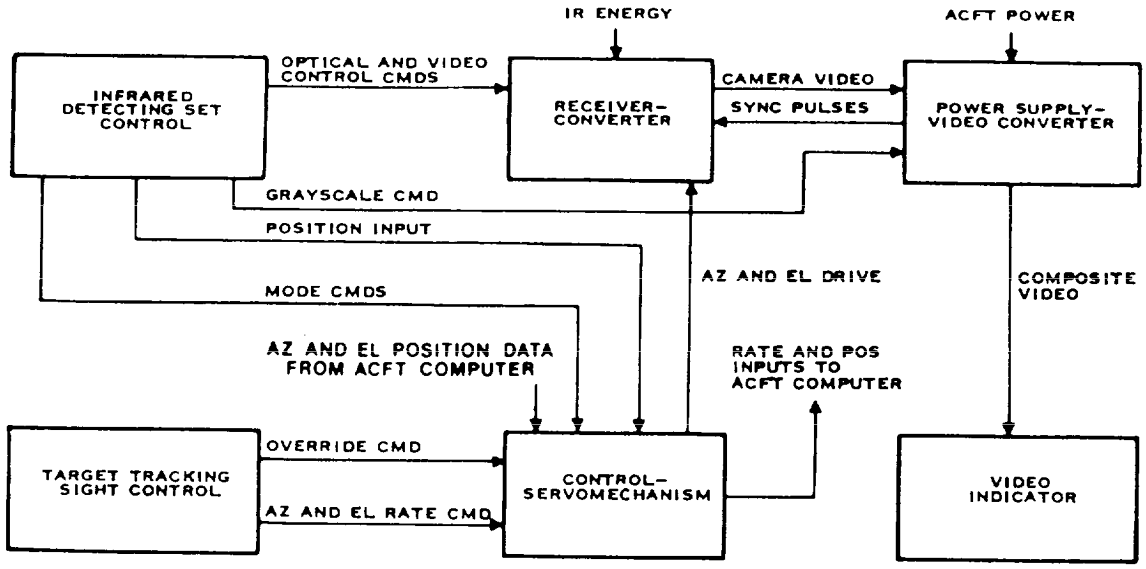


Figure 6-9.-FLIR system block diagram.

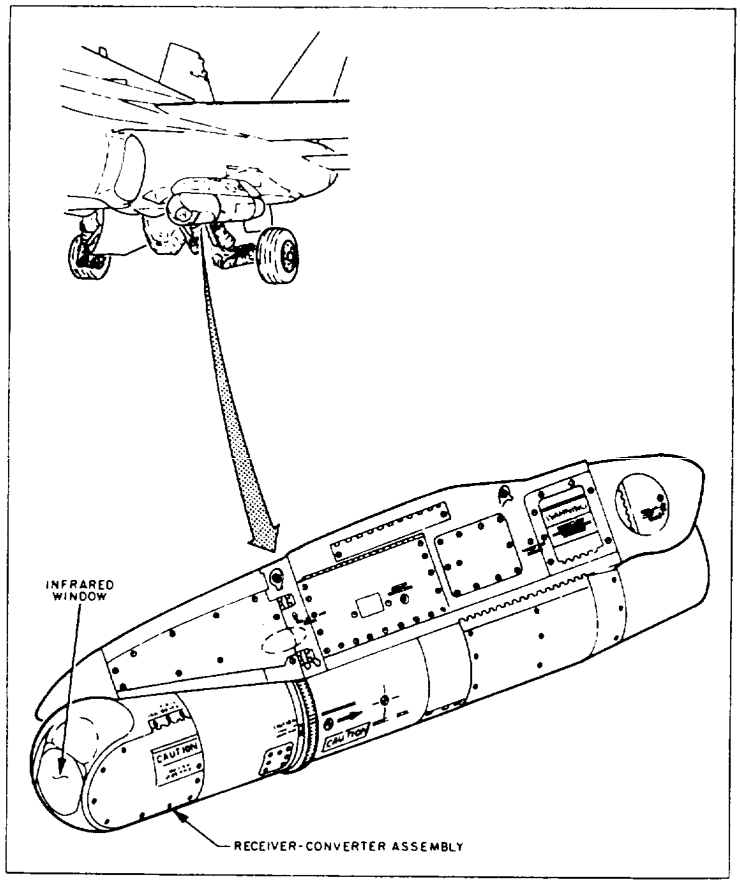


Figure 6-10.-Station-mounted FLIR pod.

used in the Navy, their principles of operation are basically the same.

A typical FLIR system contains several weapons replaceable assemblies (WRAs). These WRAs are as follows: receiver-converter, power supply-video converter, control servomechanism, target tracking sight control, infrared detecting set control, and video indicator. Figure 6-9 shows the block diagram of a typical FLIR system. You should refer to the block diagram as you read about the FLIR system components.

RECEIVER-CONVERTER ASSEMBLY

The receiver-converter assembly contains all of the optics and electronics used to detect and convert IR energy into a single-channel video output to be processed by the power supply-video converter assembly. The processed video output is applied to the video indicator. The receiver-converter assembly contains gyros, gimbals, and drive motors to aim and stabilize the receiver section in azimuth and elevation. It also contains a heat exchanger to circulate conditioned air throughout the assembly and a refrigerator unit to keep the IR detectors cooled to cryogenic temperatures. The receiver-converter assembly is housed in either the forward section of a station-mounted FLIR pod (fig. 6-10) or in its own pod, mounted on the forward lower part of the aircraft's fuselage (fig. 6-11). The housing used is dependent on the aircraft model.

Functionally, the receiver-converter breaks down into four subsystems as follows:

- IR to composite video conversion
- Temperature control
- Positioning and stabilization
- BITE (built-in test equipment)

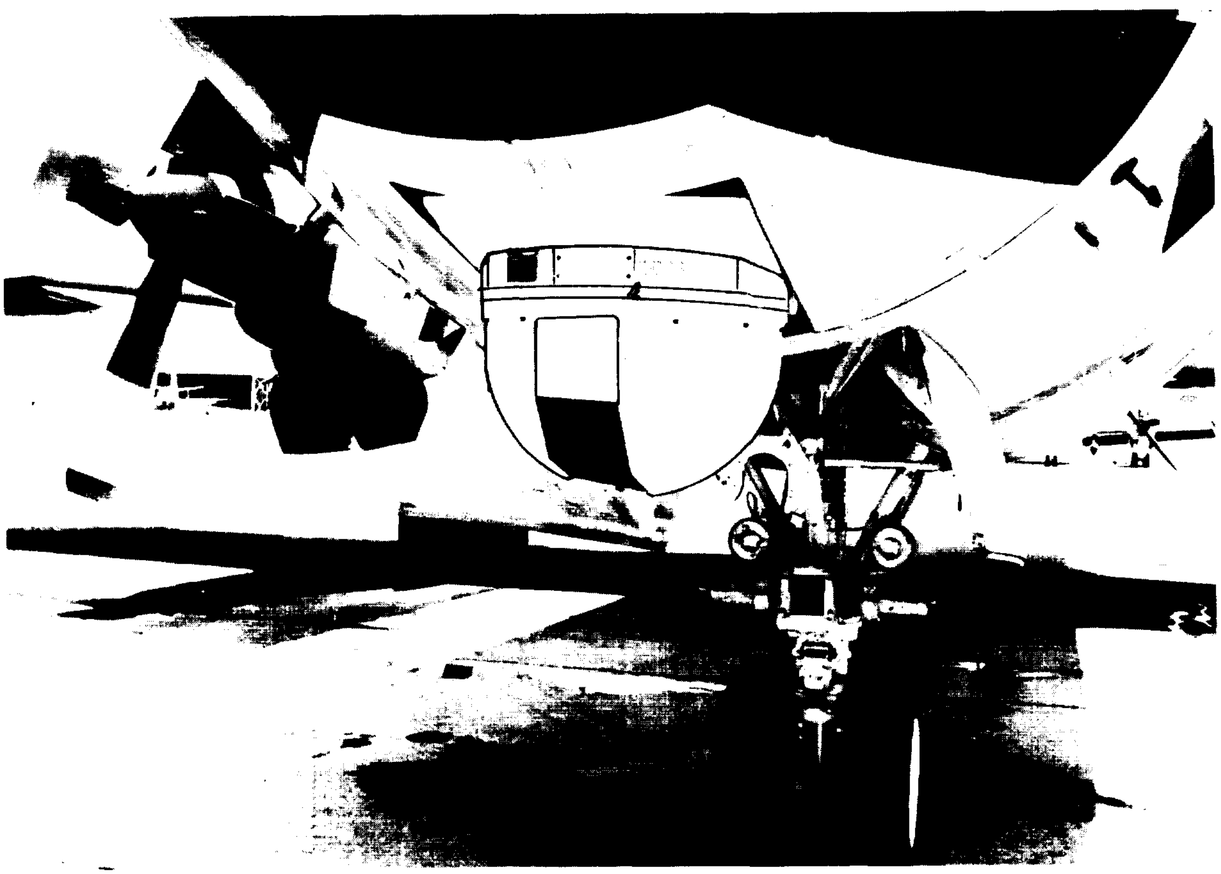


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Figure 6-11.-Receiver-converter pod shown in operating position.

IR to Composite Video Conversion

Figure 6-12 is a diagram showing the optics and electronic components of a typical receiver-converter required to perform IR detection and conversion into a useable video signal. Although the signal optical path and conversion coincide, each path is discussed separately for simplicity. You should refer to figure 6-12 as you read the following paragraphs.

SIGNAL OPTICAL PATH.— Incoming IR energy from a target enters the receiver through a window and strikes one side of a double-sided scan mirror. This mirror is controlled by a seamer module. The IR signal either strikes the mirror directly or is focused onto the mirror by optical lenses contained in what is called an afocal optics unit. The operation of the afocal unit is governed by a field of view (FOV) switch on the operator's infrared detecting set control (IRDSC). In the wide FOV mode of operation, the afocal optic lenses are not in the signal optical path. In the narrow FOV mode of operation, the lenses are in the path shown in figure 6-12. The lenses are focused by a motor that is controlled by a focusing module in the receiver-converter assembly. The focusing module has two inputs to control the operation of the focusing motor. One input is a target range scale set by the operator on the IRDSC. The other input is a feedback signal from a temperature-sensing circuit in the afocal optics unit. Because the index of refraction of an optical lens changes with changes in temperature, the focusing module monitors the temperature of the lens and maintains proper focusing of the IR signal onto the scan mirror.

The scan mirror is controlled by a scanner module. It is also positioned in line-of-sight (LOS) position, along with the entire receiving head, by

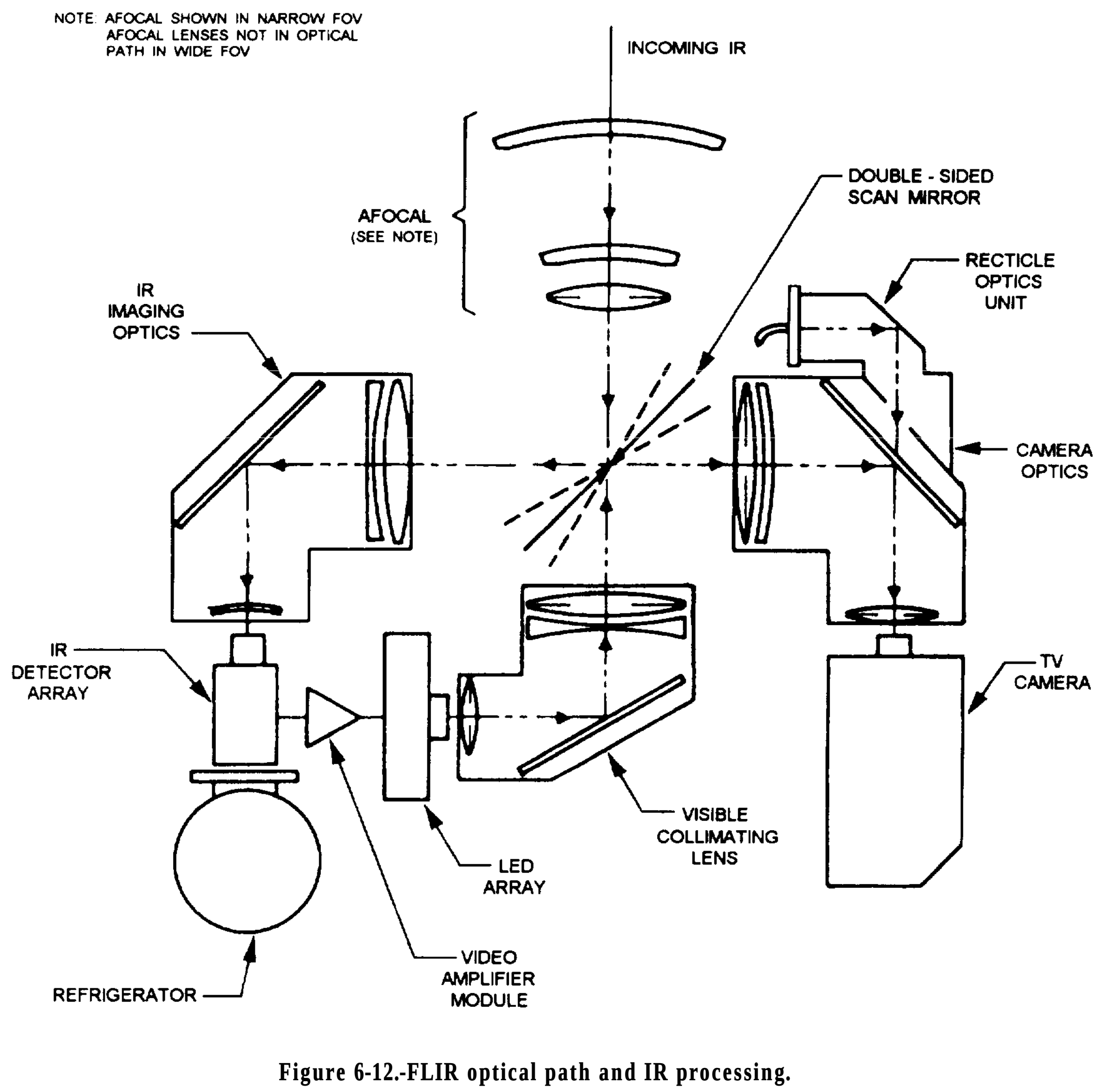


Figure 6-12.-FLIR optical path and IR processing.

signals from the control servomechanism. As shown at the top of figure 6-12, one side scans the incoming IR energy and reflects the signals into the IR imaging optics, while the bottom side simultaneously scans visible light signals from the collimating lens and reflects the signal into the TV camera optics. The mirror scans the horizontal axis, and is indexed in the vertical axis to provide a 2:1 ratio interlace scan. The mirror scan is synchronized to the TV camera by sync signals.

IR TO VIDEO PROCESSING.— The IR signals reflected from the scan mirror into the imaging optics are focused onto an IR detector array located behind an imaging lens. The lens is kept in focus much the same as the afocal lenses. The IR detector array consists of approximately 180 individual detectors arranged in a linear array with a space between each to allow for 2:1 interlacing. The scan mirror scans the image across the detectors, and each detector produces a single horizontal line of IR video. The scan mirror is indexed one line width in the vertical direction, making a total of 360 lines of video with only 180 detectors and amplifier channels. Because of the 2:1 interlacing, two full scans of the mirror are required to reproduce the entire image. Each detector conducts according to the amount of IR energy impressed on it from the scan mirror. The resultant output of the IR detector array is 180 parallel signals representing 360 video lines of IR energy scanned by the scan mirror.

The IR detectors are kept at cryogenic temperatures by the refrigerator unit. The detectors are biased to process the incoming IR energy into a useable multichannel IR video signal. The low-level output of the detector array is fed to a video amplifier module. The module consists of one preamplifier and three postamplifiers for each of the IR detectors in the array. This is required to increase the IR signal to a useable level. The output of the postamplifiers is controlled by a dc level (+ or –) whose polarity is controlled by a polarity switch on the IRDSC. The purpose of the dc polarity is to have "hot" targets appear either white or black on the video indicator. Also, the outputs of the video amplifiers are gated on or off in synchronization with the scan mirror and the TV camera sweep.

Each video amplifier feeds a light-emitting diode (LED) of the LED array. The LED array duplicates the IR detector array. The visible light intensity output of one LED is proportional to the IR output of the corresponding IR detector in the detector array. The resultant output of the LED array comprises 180 parallel visible light beams (signals) representative of the IR energy scanned by the scan mirror. In other words, the resultant output of the LED array represents the terrain or targets scanned.

The output of the LED array is applied to the collimating lens unit. This unit focuses the visible light while maintaining the light beams parallel to each other rather than converging them to a focal point, as shown in figure 6-13, views A and B.

The output of the collimating lens unit is scanned by the back side of the scan mirror and is reflected into the camera optics unit that focuses the light for the TV vidicon camera. Also, a reticle light signal from the reticle optics unit is applied simultaneously to the TV camera to give an indication of the position of the receiving head. The TV vidicon camera processes the visible light signals into a single channel video signal. The video output of the camera is fed to the power supply-video converter assembly for further processing.

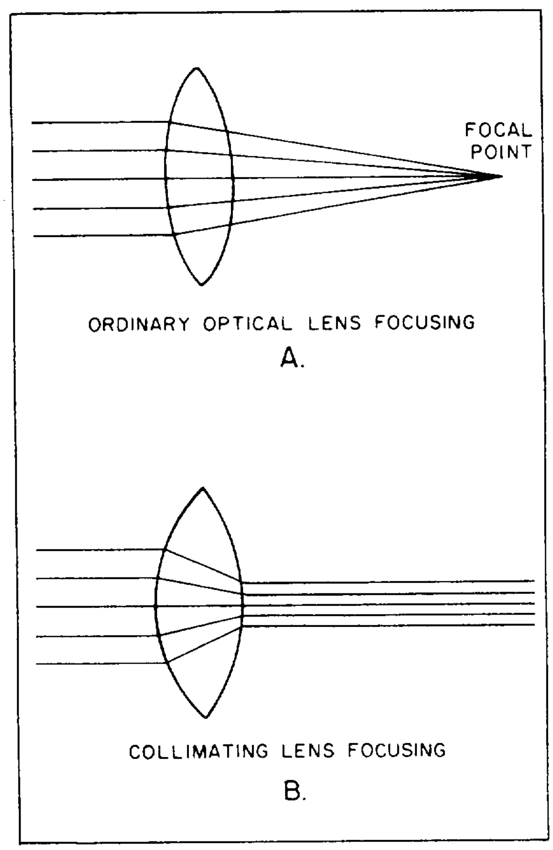


Figure 6-13.-Lens focusing patterns.

Temperature Control

Figure 6-14 is a block diagram of a receiver-converter heat exchanger. The heat exchanger supplies conditioned air to the receiver-converter assembly for environmental control. The exchanger shown consists of two blowers, six heaters, three temperature-sensitive switches, and an air-to-air heat exchanger. Three of the heaters are connected in a wye conflguration, and the other three are connected in a delta configuration. The three temperature-sensitive switches are usually mounted on the receiver casting. Blowers B1 and B2 circulate cooling air and heating air within the receiver-converter. Internal blower B1 operates whenever the FLIR system is turned on. If the temperature of the assembly compartment goes above approximately 77°F (25°C), thermal switch RT3 operates relay K3, applying power to external blower B2. Blower B2 draws cool external air through the air-to-air heat exchanger. Internal blower B1 circulates the cool air and cools the compartment. If the temperature in the compartment goes below 68°F (20°C), thermal switch RT2 operates relay K1, applying power to the wye-configured heaters. The heaters operate at approximately 365 watts. If the compartment temperature drops below 50°F (10°C), thermal switch RT1 operates K2, applying power to the delta-cordigured heaters. This increases the wattage used by the heaters to approximately 1,200 watts. Thus, the heat exchanger is able to maintain the receiver-converter compartment at a temperature between 68°F and 77°F at all times.

Positioning and Stabilization

The function of the stabilized gimbal subsystem of the receiver-converter is to allow the operator to select the line-of-sight (LOS) desired to the receiver unit. Another function is to maintain a steady image of the IR patterns of the areas viewed regardless of aircraft movement. This critical stability is obtained by means of gyros mounted on the receiver assembly. There is one azimuth and one elevation gyro. Figure 6-15 is a simplified block diagram of a typical FLIR positioning and stabilization subsystem.

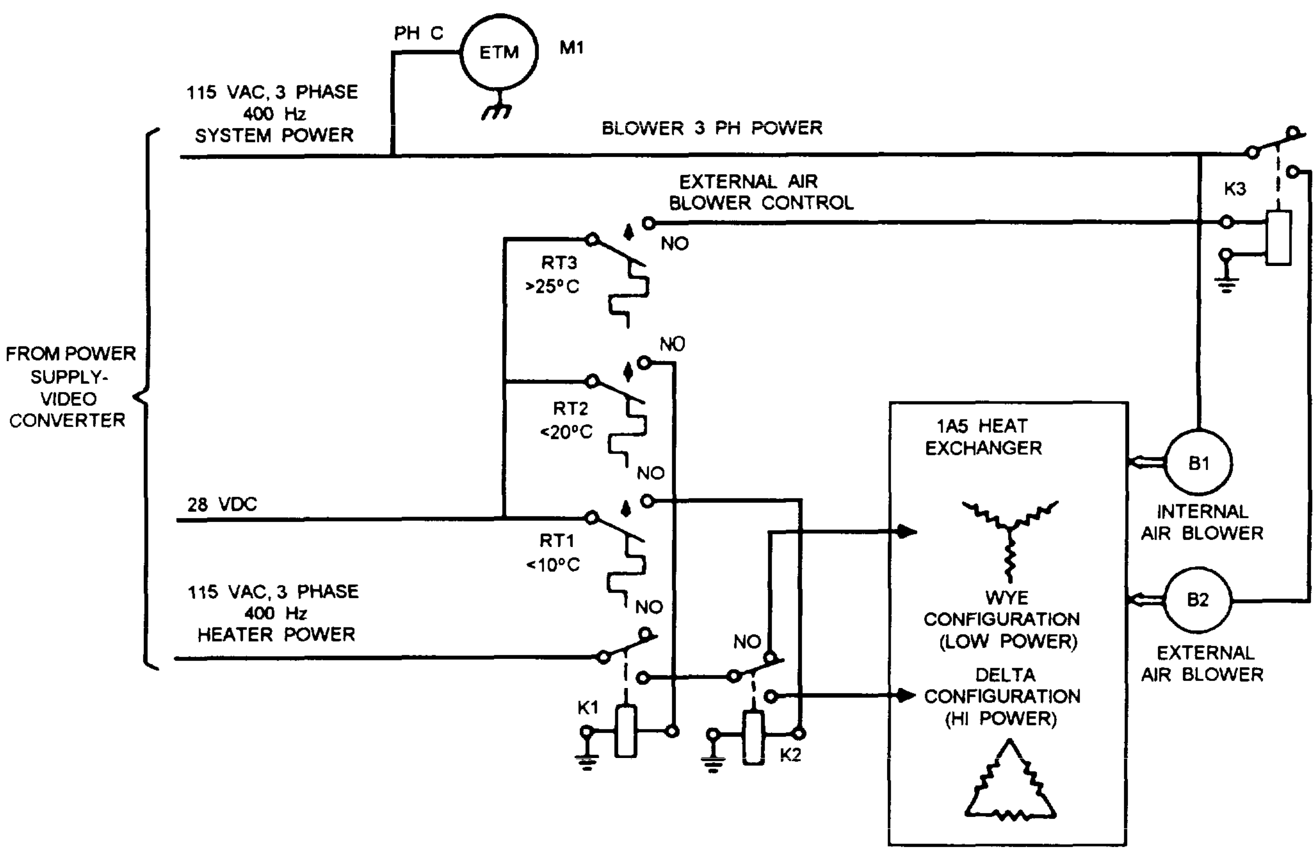


Figure 6-14.-Receiver-converter heat exchanger block diagram.

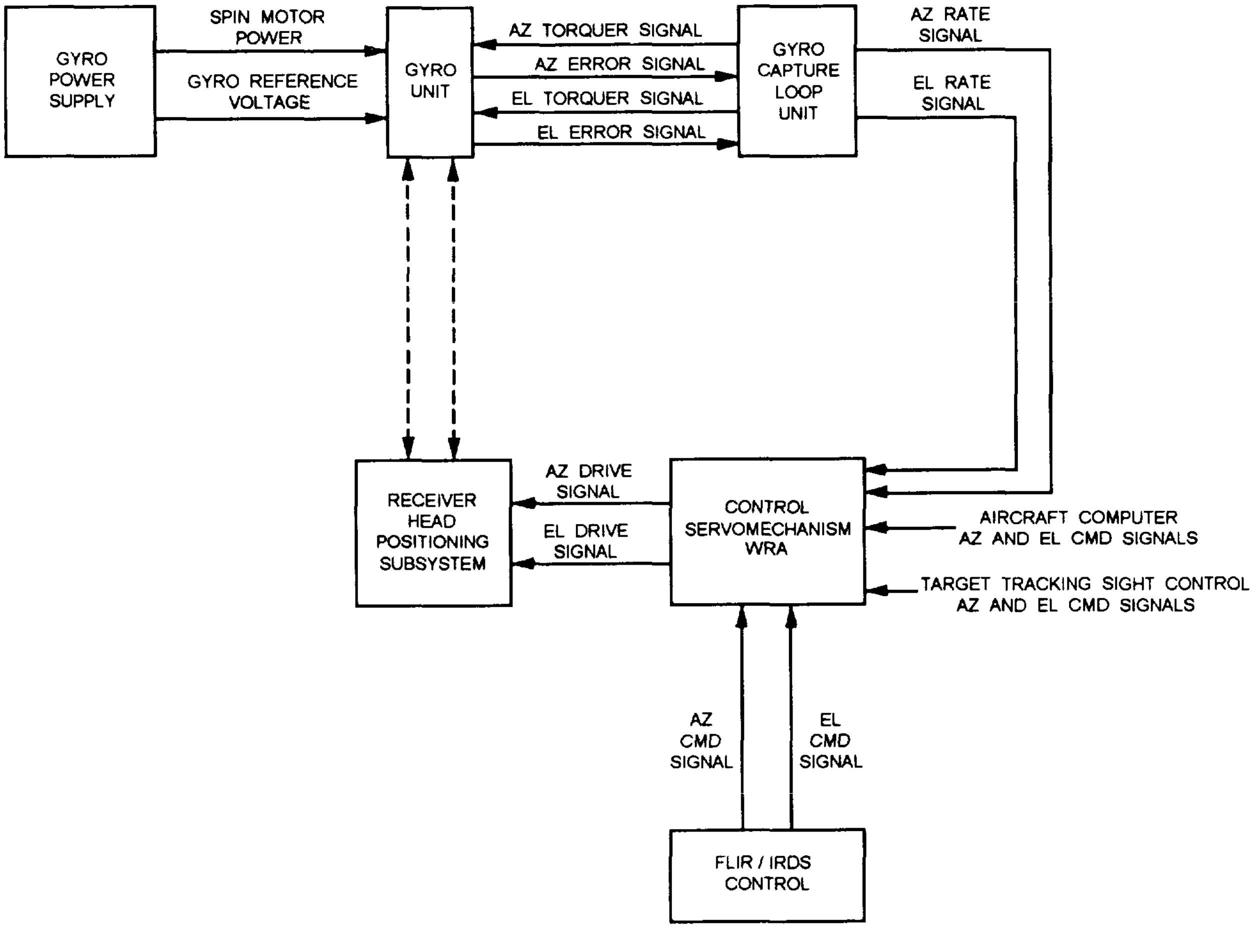


Figure 6-15.-FLIR positioning/stabilization block diagram.

The LOS of the receiver is selected in one of three ways:

- By a program in the aircraft's computer (or a video tracking computer when the system is used with a laser system)
- By inputs from the target tracking sight control
- By operator adjustment of the azimuth and elevation controls on the control box

The control servomechanism WRA processes these azimuth and elevation commands, no matter from which source they come. This WRA will then apply drive signals to the receiver head positioning motors and gimbals. The receiving head is aligned to the desired LOS. If the aircraft should pitch or roll, the gyros (mounted on the receiver head) initiate error signals to a capture loop. This loop creates azimuth and elevation rate signals. The rate signals are fed back to the control servomechanism (CS). The CS will then process these rate signals and apply them to the receiver head as drive signals to maintain the correct LOS. In the manual mode (which uses the target tracking sight control), the stabilization system is inhibited in the control servomechanism assembly.

BITE System

Most FLIR systems are equipped with a built-in test equipment (BITE) system. The receiver-converter BITE subsystem monitors status signals from the following subassemblies:

- Camera video
- Refrigerator unit
- Gimbals from the control servomechanism assembly
- Scan mirror and TV camera scan
- Focus drive of the lenses
- Heat exchanger

- Afocal optics assembly

- IR detectors

Figure 6-16 is a simplified block diagram of a receiver-converter BITE system. The BITE signals go to a BITE logic module in the power supply-video converter WRA. In this WRA, they are combined and sent to the IRDSC to light the various indicators.

POWER SUPPLY-VIDEO CONVERTER ASSEMBLY

Functionally, the power supply-video converter assembly breaks down into three subsystems. These subsystems are the power supply, the video processing, and the BITE system.

Power Supply

The power supply subsystem is a typical power supply. It filters aircraft power for use by the receiver-converter assembly. It also develops all the operating voltages for both the receiver-converter and the power supply-video converter circuits.

Video Processing

The video processing subsystem generates the synchronizing drive and timing signals for the receiver-converter. It also converts the TV camera video from the receiver-converter assembly into a composite video format. This format consists of camera video and receiver position information for presentation on the video indicator.

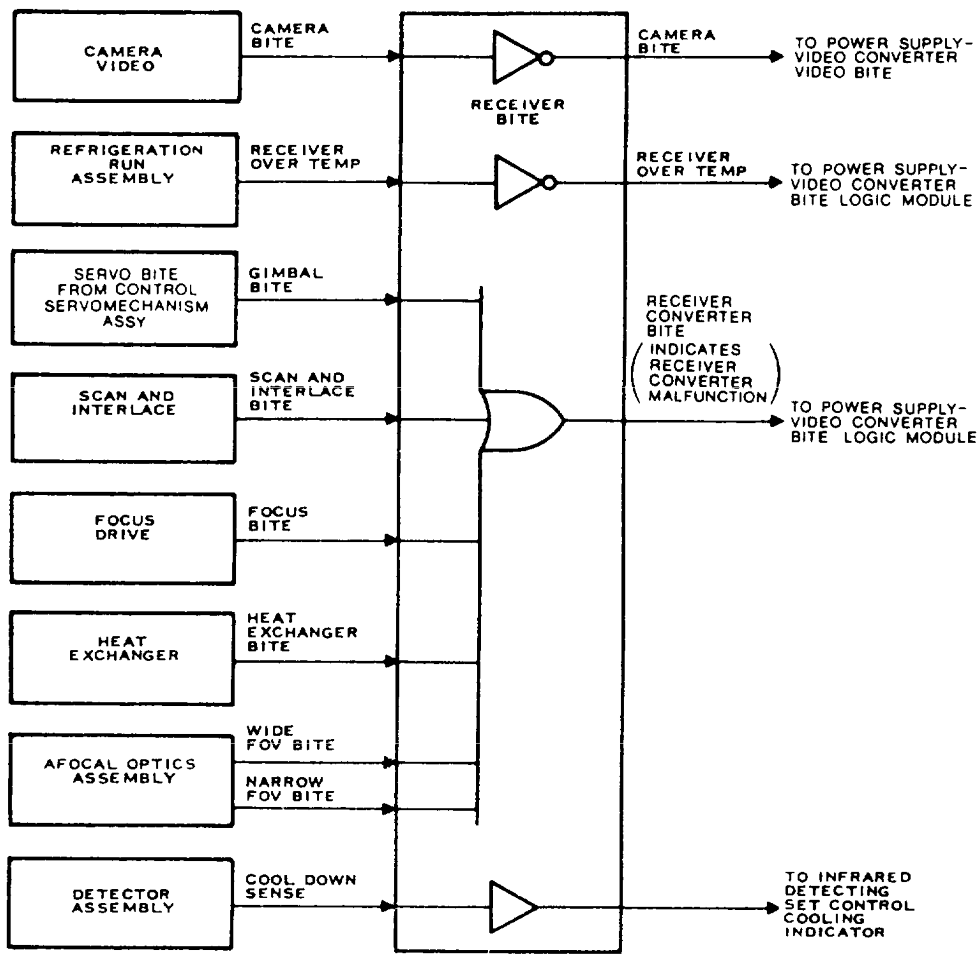


Figure 6-16.-Receiver-converter BITE block diagram.

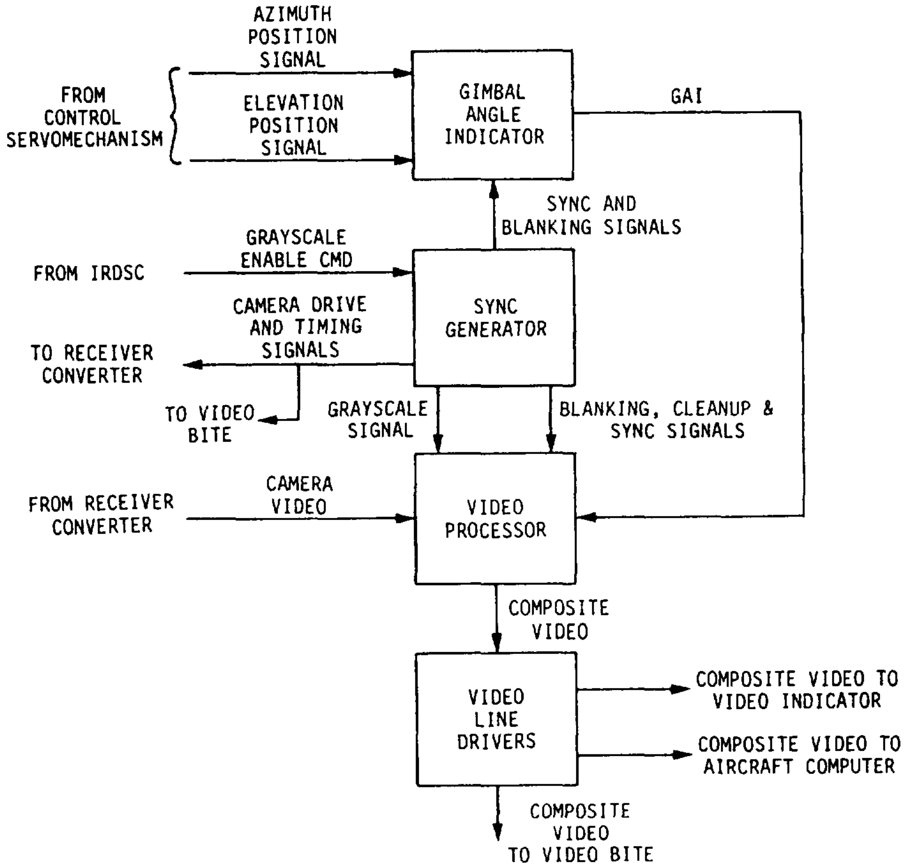


Figure 6-17.-Video converter video processing block diagram.

Figure 6-17 is a simplified block diagram of the video processing sections found in a typical FLIR power supply-video converter WRA. The gimbal angle indicator unit receives linear signals from the control servomechanism azimuth and elevation gimbal potentiometers. These potentiometers receive inputs from the gimbals in the receiver-converter. The potentiometers then generate synthetic video signals. The signals present short, bright-line segments along the calibrated scales on the video indicator to show receiver head position. An example of this is shown in figure 6-18.

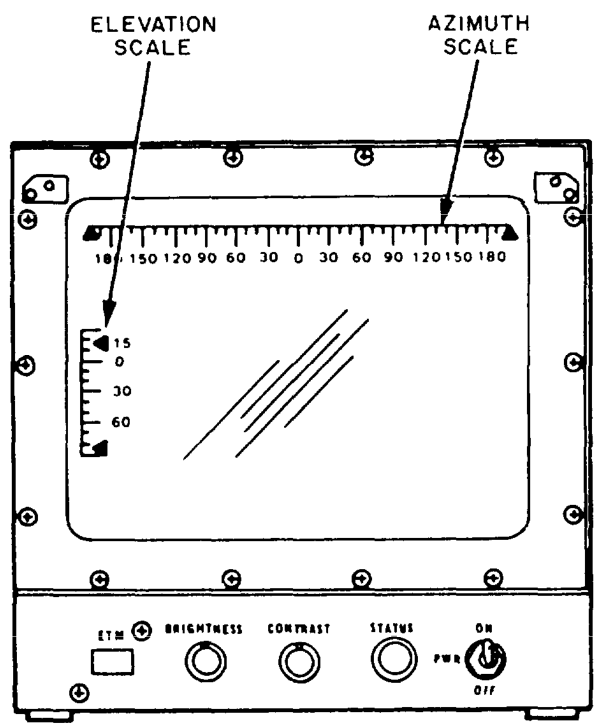


Figure 6-18.-Azimuth/elevation scale on a video indicator.

The sync generator module contains a crystal-controlled clock. The module generates all timing (sync), clamping, and drive signals for the receiver-converter and the TV camera. It also generates all timing, gating, clamping, and blanking signals for the video processor and gimbal angle

Table 6-2-Sync Generator Outputs

SYNC GEN OUTPUT	UNIT SUPPLIED
Beam gate only	TV camera
Cathode drive	TV camera
Dark current drive	TV camera
Horizontal current drive	TV camera
Vertical deflection drive	TV camera
Composite clamping	TV camera
Scanner sync	Scanning optic unit
Horizontal sync	Gimbal angle indicator (GAI)
Composite blanking	GAI, video processor
Vertical blanking	Gimbal angle indicator
Composite sync	Video processor
Gray scale signal	Video processor
Horizontal clamping	Video processor

indicator (GAI) modules. These signals are listed in table 6-2.

The sync generator module also generates a gray scale signal upon receipt of a gray scale command signal from the IRDSC. The IRDSC generates this command whenever the gray scale switch is turned on. The gray scale signal presents a gray scale pattern (fig. 6-19) on the video indicator. The pattern serves to aid the operator in adjusting the level and gain controls on the IRDSC. There is a total of ten different shades. Each shade represents a different IR temperature range to which the operator can compare the target intensity and estimate the temperature of the target. The temperature is an indication of the type of target material.

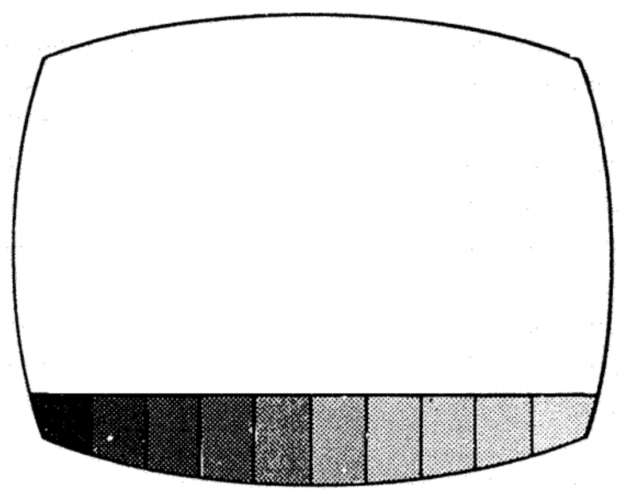


Figure 6-19.-Gray scale video indicator presentation.

The video processor receives raw video signals from the TV camera. It also receives gimbal angle Indicator synthetic video, gray scale signals, composite sync, composite blanking, and horizontal clamping signals from the sync generator. The video processor combines all of these signals into a composite video signal, which is fed to the video line drivers. The video line drivers amplify the composite video and provide three separate outputs. One output goes to the video indicator, one goes to the aircraft computer, and one goes to the video BITE module.

BITE Subsystem

Figure 6-20 shows a simplified block diagram of the BITE subsystem of the power supply-video converter. The BITE logic module receives an initiation command signal from the IRDSC. This command is generated whenever BITE is selected on the IRDSC. The signal causes the BITE logic module to generate and send a gray scale enable signal to the sync generator. This signal overrides the gray scale switch on the IRDSC, and causes the sync generator to output a gray scale signal in addition to the sync, blanking, clamping, and drive signals. BITE logic also sends a BITE initiate signal to the control servomechanism to initiate servo BITE. A BITE ON signal is sent to the IRDSC from the BITE logic module to light the BITE ON indicator. This indicator shows that the BITE mode is operating.

The TV video BITE module monitors the output of the sync generator, the video line drivers, and the camera BITE from the receiver-converter. If a failure occurs in any of these circuits, the video BITE module generates and sends a TV fail signal to the power supply BITE module.

The power supply BITE module monitors all of the power supply voltages. If any voltage is not correct, a power supply malfunction signal is generated and sent to the BITE logic module. This signal causes the logic module to send a power supply fail signal to the IRDSC to light the power supply fail light. If the power supply receives a TV fail signal

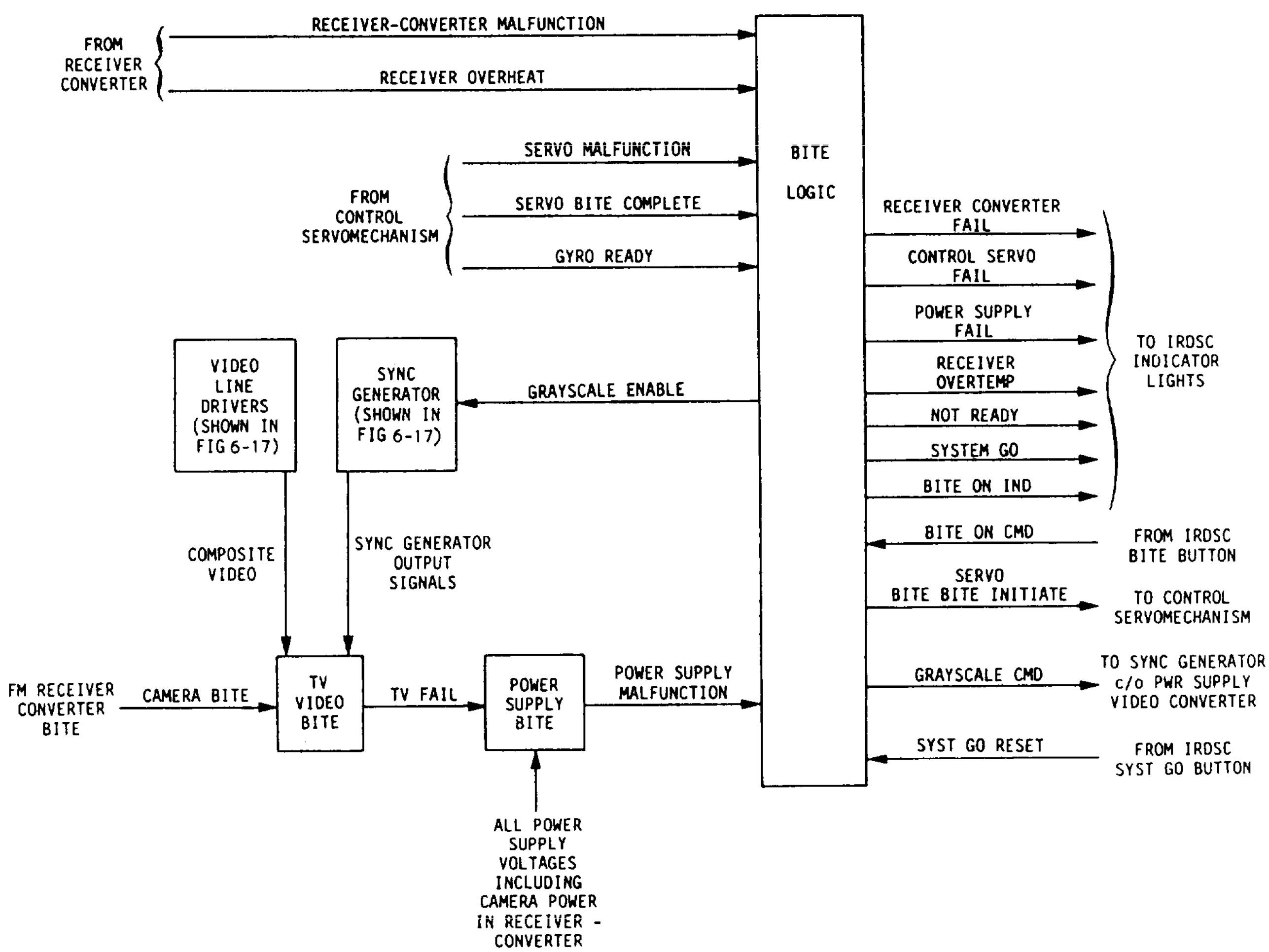


Figure 6-20.-Power supply-video converter BITE block diagram.

from the video BITE, it will send a power supply malfunction signal to the IRDSC to light the power supply fail light.

BITE logic also monitors incoming signals from the receiver-converter and control servomechanism. The logic module will initiate signals to the IRDSC to operate the various indicator lights based on these signals.

CONTROL SERVOMECHANISM ASSEMBLY

The control servomechanism assembly processes line-of-sight (LOS) position and rate commands from the IRDSC, the target tracking sight control (TTSC), or the aircraft computer. The source of these commands depends upon which operational mode the system is operating in. These commands are processed as analog drive signals for slewing (steering) the receiver-converter drive motors and gimbals to position the receiver head. Functionally, the control servomechanism assembly breaks down into four subsystems. These are the power supply, azimuth drive, elevation drive, and the BITE subsystems.

The azimuth and elevation drive signals are processed simultaneously in a given module. For simplicity, we will discuss each subsystem separately. Notice the modules are labeled in their respective block diagrams as azimuth (fig. 6-21) or elevation (fig. 6-22) as appropriate. Keep in mind that, in actual practice, a module (such as mode logic) is

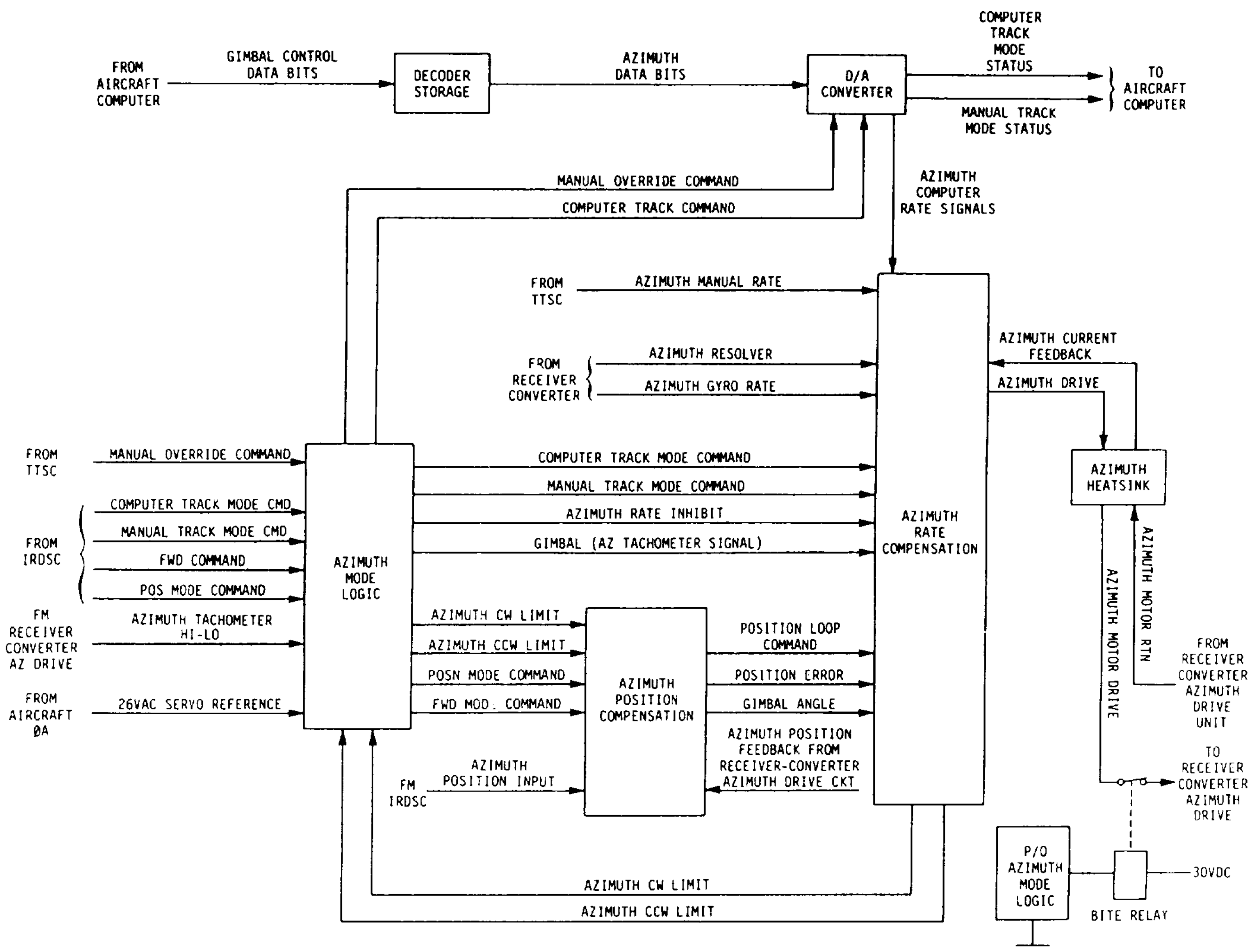


Figure 6-21.-Azimuth drive subsystem block diagram.

shared by both azimuth and elevation drive signals. The following discussion will refer to that module as the azimuth mode logic module or the elevation mode logic module, as appropriate.

Power Supply

The power supply is a typical power supply. It filters aircraft power and develops all of the operating voltages for the control servomechanism assembly and the TTSC assembly circuits.

Azimuth Drive Subsystem

Figure 6-21 is a simplified block diagram of a typical azimuth drive subsystem used in a control servomechanism assembly. The azimuth mode logic module receives one of four operational commands from the IRDSC. These mode commands are for either the position, the forward (FWD), the manual track, or the computer track modes. The operator selects the mode on the IRDSC.

POSITION MODE.— The position mode command signal is processed by the mode logic module, which sends a position (POS) command signal to the azimuth position compensation module. This module processes the signal, enabling it to receive azimuth position (LOS) information from the IRDSC azimuth control. It outputs position loop command and gimbal angle signals to the azimuth rate compensation module. The azimuth rate compensation module sends an azimuth drive signal to the azimuth heat sink module. This module

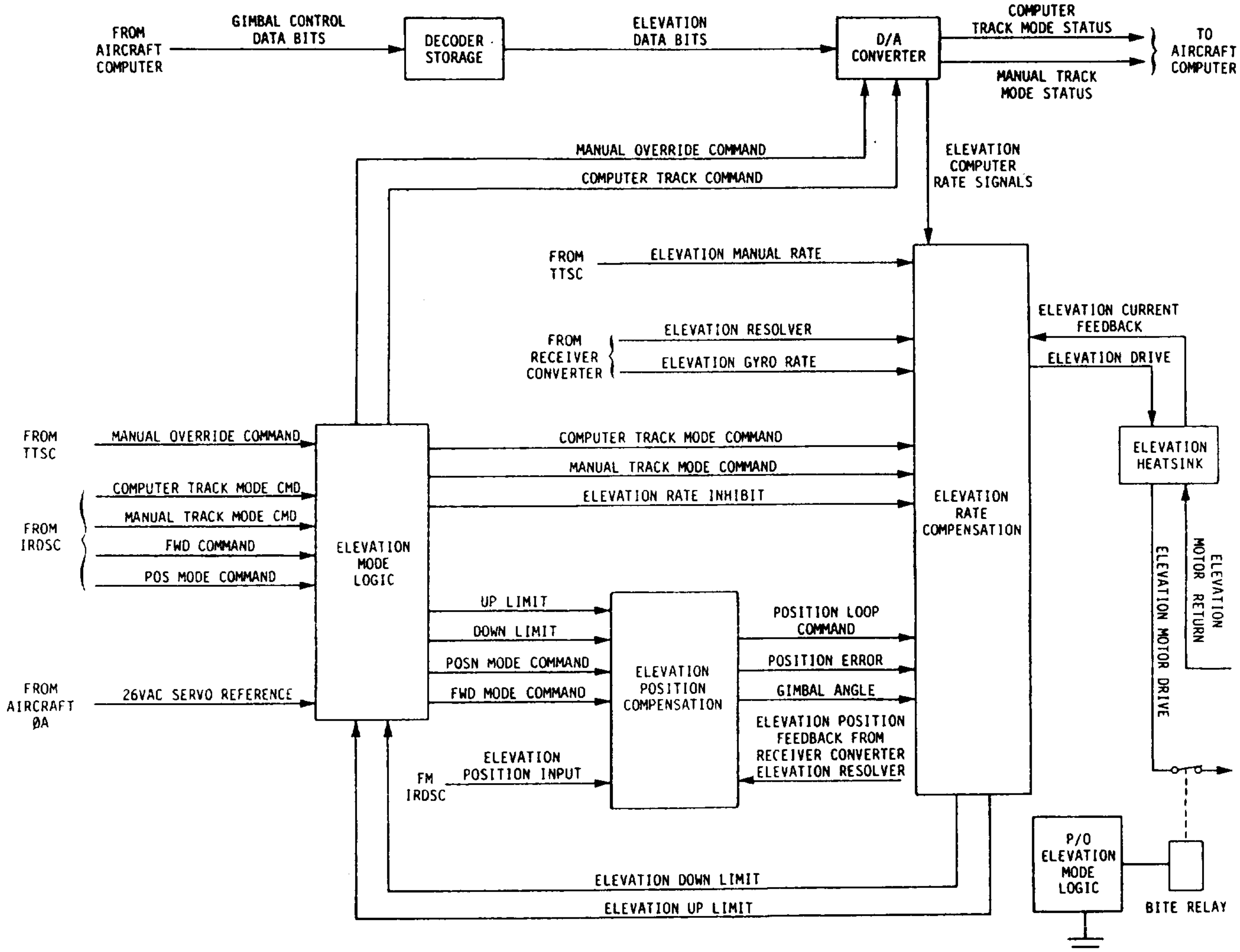


Figure 6-22.-Elevation drive subsystem block diagram.

amplifies the signal to develop enough motor drive power to steer the receiver head to the azimuth bearing selected on the IRDSC by the operator.

Four feedback signals are involved in ensuring the receiver head maintains the correct LOS. An azimuth tachometer signal from the receiver-converter azimuth drive unit is fed back to the mode logic module. The mode logic module produces a gimbal rate signal for the azimuth rate compensation module. An azimuth position signal from the same azimuth drive unit is fed back to the azimuth position compensation module. The mode logic module compares the azimuth position signals with the IRDSC azimuth input and, as applicable, outputs a position error signal to the azimuth rate compensation module. An azimuth gyro rate signal from the receiver-converter's gyro unit is fed to the azimuth rate compensation module. Also, an azimuth current drive signal is fed back to the rate compensation module. The rate compensation module processes all of the feedback signals (position error, gimbal rate, gyro rate, and current drive signals) and develops an output signal. This output signal, if necessary, maintains the receiver head at the correct selected heading.

FORWARD MODE (FWD).— The FWD mode command is processed by the azimuth mode logic module. This module outputs a FWD mode command signal to the azimuth position compensation module. This module will process the command signal. It then outputs a position loop command and a gimbal angle signal to the azimuth rate compensation module. This module then sends an azimuth drive signal to steer the receiver head to 0° azimuth. The azimuth drive signal is amplified by the azimuth heat sink module to produce the motor power to drive the motors in the receiver-converter. The stabilization/positioning feedback circuits work the same as the circuits in the position mode previously explained.

MANUAL TRACK MODE.— The manual track mode command signal is processed by the mode logic circuit. This circuit sends a manual track command signal and an azimuth rate inhibit signal to the azimuth rate compensation module. These signals cause the circuits to accept only azimuth rate signals from the target tracking sight control assembly. The TTSC assembly is a pistol grip unit. The operator uses the thumb control on the pistol grip unit to aim the receiver head to the desired LOS. The azimuth drive output signal from the circuit is controlled by the TTSC, and no feedback is used for stabilization.

Action of a comparator circuit in the azimuth rate compensation module determines when the receiver-converter gimbals reach their electrical limits and produce limit signals (CW and CCW). These limit signals prevent the manual track mode and computer track mode commands from developing the azimuth drive signal. The limit signals are fed back to the mode logic module that outputs a CW or CCW signal to the azimuth position compensation module. This signal causes the module to develop an error signal that, in turn, develops appropriate azimuth drive.

COMPUTER TRACK MODE.— The aircraft computer supplies gimbal control data bits (azimuth and elevation position rate commands) from its program to the decoder storage module. This module demultiplexes and stores 12-bit azimuth and elevation rate commands. It also provides azimuth and elevation data outputs to the digital-to-analog (D/A) converter module. The purpose of storage is to allow the decoder to output data bits to the D/A converter, while the computer updates itself from feedback information before issuing new gimbal control signals to keep the receiver head at the programmed LOS.

When the computer track mode is selected on the IRDSC, the computer track command is processed by the mode logic module. This module will send a computer track mode command to the D/A converter and to the azimuth rate compensation module. The signal enables the D/A converter to process azimuth data bits into analog azimuth position rate signals, which are fed to the azimuth rate compensation module. The D/A converter also sends a computer track mode status signal to inform the aircraft computer that the D/A converter is operating in the computer mode. The computer track command signal enables the azimuth rate compensation module to accept azimuth position rate signals from the D/A converter only. The azimuth rate compensation module disables inputs from the azimuth position compensation module. This means no feedback information can be processed in the computer mode. The rate compensation circuit processes the azimuth position rate signal from the D/A converter and outputs an azimuth drive signal. This signal goes through the azimuth heat sink circuit to slew the receiver head to the azimuth position programmed into the computer.

An azimuth resolver in the receiver-converter feeds back four-wire resolver position information signals to the azimuth rate compensation module where they are converted into three-wire syncro information signals. These signals are fed back to the aircraft computer logic circuits to update the computer and develop gimbal control data bits to maintain the receiver head at the correct LOS.

If the system is operating in the position mode, FWD mode, or computer track mode, and the operator wants to quickly shift to the manual track mode, the operator is able to do so by use of a manual override function on the TTSC. When manual override is initiated, a manual override command signal from the TTSC is processed by the azimuth mode logic module. This module sends a manual override signal to the D/A converter. It also sends out manual track command signals, as explained previously for manual track mode. The FLIR system functions in the manual track mode regardless of the position of the control box mode select switch.

The manual track override signal disables the D/A converter. It also sends a manual track mode status to the aircraft computer logic to prevent the computer from operating should the control box have computer track selected.

Elevation Drive Subsystem

Figure 6-22 is the simplified block diagram of an elevation drive subsystem. Compare figures 6-21 and 6-22. Notice they are the same except for the elevation and azimuth labels on the modules. The subsystems are the same because the servomechanism elevation drive circuits operate the same and process the same signals and develop the same drive signal as the azimuth drive subsystem. The only difference is that no tachometer feedback is used in the elevation circuits, and all signals come from or go to elevation circuits vice azimuth circuits.

In the FWD mode of operation, the elevation circuits slew the receiver head to –4° (down tilt) elevation. The azimuth circuits slew the receive head to 0° azimuth. All other modes operate the same except the receiver head is slewed in elevation instead of in azimuth.

CS BITE Subsystem

The control servomechanism BITE subsystem automatically determines whether a servo-system failure is in the CS WRA or in the receiver-converter WRA. Figure 6-23 is a simplified block diagram of the CS BITE subsystem. For ease of signal tracing, some of the modules have been duplicated at various locations on the diagram. These modules, such as the mode logic, have alphanumeric designators (A1, A2, A3, etc.). However, the modules are all part of one logic module. The alphanumeric numbers are used to show where signals enter/leave a particular module.

A temperature sensor in the receiver-converter monitors the gyro operating temperature. When the gyros are operating properly, the sensor develops a temp ready signal, regardless of which operational mode is selected on the control box. The temp ready signal is fed to the mode logic module (A1) of the CS. The mode logic circuit outputs a rcvr ready signal to the servo BITE module (B1). The rcvr ready signal enables servo BITE (B1). When BITE is initiated on the control box, a BITE initiate signal is received by the servo BITE (B1) module from the power supply-video converter BITE logic module. The BITE initiate signal initiates a series of four test sequenced as follows: fault isolate, BITE 1, BITE 2, and BITE 3. All tests are controlled by a 10-HZ clock in the servo BITE module. Each test sequence takes 10 to 12 seconds to complete.

FAULT ISOLATE TEST.— Initially (when rcvr ready and BITE initiate are received), the servo BITE module (B1) generates a BITE fault isolate signal and a digital computer interface (DCI) fault isolate signal. The BITE fault isolate signal goes to the following modules: azimuth position compensation (C1), elevation position compensation (D1), mode logic (A3), azimuth rate compensation (E1), and elevation rate compensation (F1). The signal enables all of these modules and causes the azimuth position compensation module (C2) and elevation position compensation module (D2) to generate BITE motor drive signals.

The DCI fault isolate signal goes to the decoder storage module (for use in the BITE 3 test) and to mode logic (A2). The DCI signal causes mode logic to open the BITE relay drive line, de-energizing the BITE relay (shown in the de-energized position). Opening the relay removes azimuth and elevation motor drive from the motors in the receiver-converter. Instead, the azimuth and elevation heat sink motor drive output is routed to the azimuth position compensation module (C1) and the elevation position compensation module (D1). The BITE motor drive signals generated by the azimuth position compensation (C2) and elevation position compensation (D2) are routed by way of AZ POSN and EL POSN lines to the azimuth rate compensation (E1) and elevation rate compensation (F1), respectively. The drive signals out of these modules

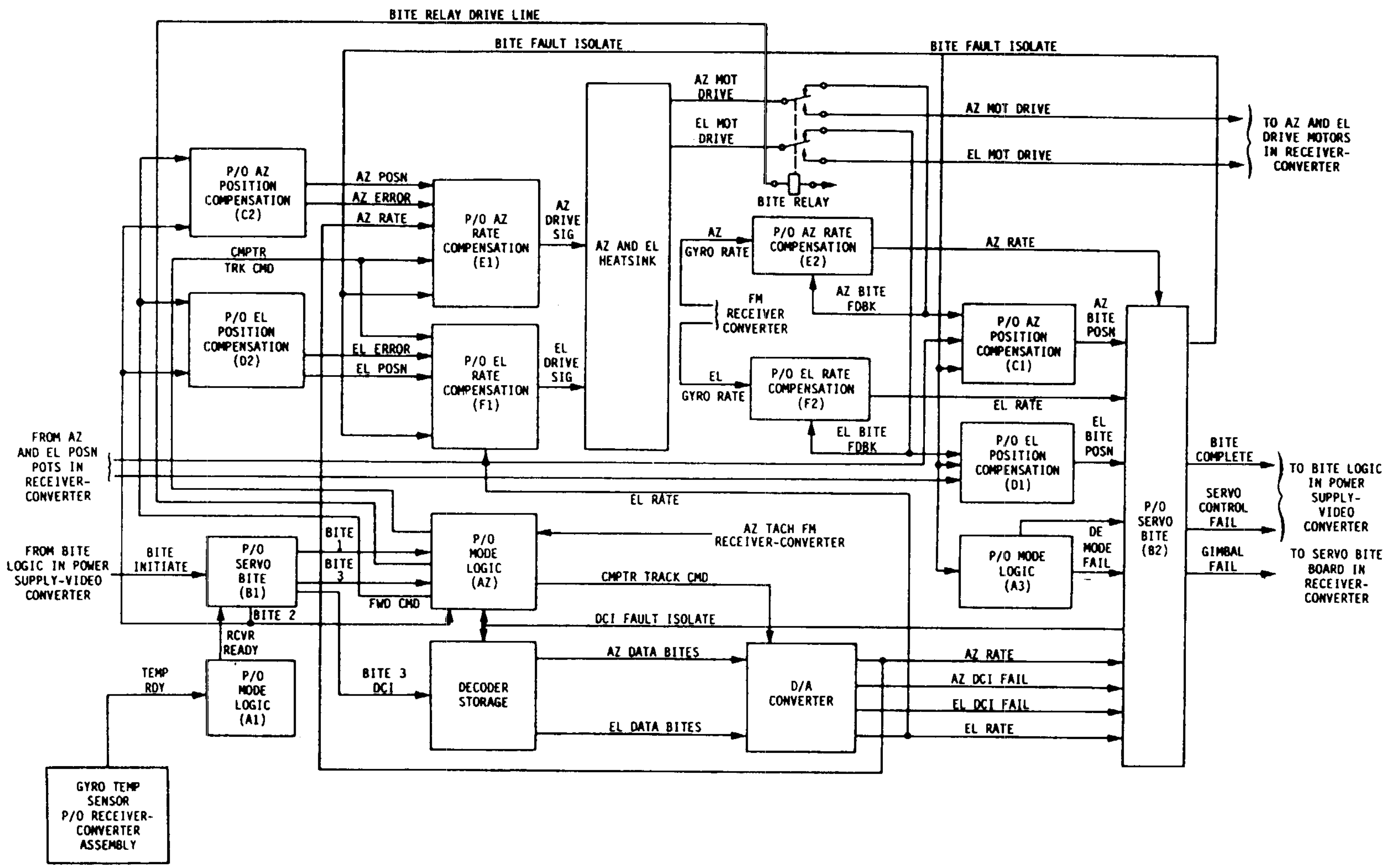


Figure 6-23.—Control servomechanism BITE block diagram.

go to the azimuth/elevation heat sink module. From this module, the signals go through the BITE relay and back into azimuth position compensation module (C1) and elevation position compensation module (D1). Modules C1 and D1 output azimuth and elevation BITE position signals to servo BITE (B2). The servo BITE module (B2) outputs a servo control fail signal to the power supply-video converter BITE logic circuit, which is labeled a servo malfunction in figure 6-20. This logic circuit, in turn, outputs a not ready signal to light the NOT READY light on the control box.

With the BITE relay de-energized (as shown), an azimuth loop is formed. This loop consists of the azimuth position compensation (C2), azimuth rate compensation (E1), a heat sink module and BITE relay, azimuth rate compensation (E2), and azimuth position compensation (C1). Likewise, an elevation loop is formed. This elevation loop consists of elevation position compensation (D2), elevation rate compensation (F1), a heat sink module and BITE relay, elevation rate compensation (F2), and elevation position compensation (D1). This allows the BITE motor drive signals (developed in C2 and D2) to continue around the loop. The BITE motor drive signals are monitored by frequency and amplitude detectors in servo BITE (B2). The inputs to these detectors are the azimuth and elevation BITE position signals from C1 and D1, which represent the signals in the loops. If an error or failure occurs, servo BITE (B2) generates a servo control fail signal. This signal is sent to the power supply-video converter BITE logic, labeled servo malfunction in figure 6-20. From here a control servo fail signal is sent to the control box to light the CONTROL SERVO FAIL light.

If no errors or failures are present during the fault isolation test, which takes approximately 10 to 12 seconds, a BITE 1 signal is generated by servo BITE (B1). This signal terminates the fault isolation test and initiates the BITE 1 test.

BITE 1 TEST.— When servo BITE (B1) generates a BITE 1 signal, the signal is fed to mode logic (A2). This causes module A2 to energize the BITE relay (via the BITE relay drive line), reconnecting the heat sink module output to the drive motors in the receiver-converter WRA. This also opens up the azimuth and elevation loops. Mode logic (A2) also generates a FWD command signal. This signal is fed to the azimuth position compensation module (C2) and elevation position compensation module (D2). These two modules generate BITE motor drive signals. These signals are fed through the azimuth and elevation rate compensation modules (E1 and F1) to the heat sink module and the now energized BITE relay. This positions the receiver head in the receiver-converter to 0° azimuth and -4° elevation. Position feedback signals from the receiver-converter are fed to the servo BITE (B2) module where they are monitored. If there is an error/failure, a gimbal fail signal is generated and fed to the servo BITE board in the receiver-converter. This action causes the receiver BITE circuit to generate and send a receiver-converter malfunction signal to the control box to light the RCVR CONV FAIL light.

If the feedback signals to B2 are correct (for 10 to 12 seconds), a BITE 2 signal is generated by servo BITE (B1). The BITE 2 signal terminates the BITE 1 test and initiates the BITE 2 test.

BITE 2 TEST.— When servo BITE (B2) generates a BITE 2 signal, the signal is fed to the mode logic module (A2) to cancel the FWD command signal. The BITE 2 signal is also fed to the azimuth position compensation module (C2) and the elevation position compensation module (D2). The BITE 2 signal causes these modules to develop and send error motor drive signals to the receiver head by way of the same signal path as the BITE 1 signal. These signals drive the receiver head to 130° azimuth and -60° elevation. Feedback signals are monitored by servo BITE (B2). If an error is present, B2 generates a gimbal fail signal to light the RCVR CONV FAIL light on the control box. This fail signal uses the same path as in BITE 1 testing. If the feedback signals are correct, servo BITE (B1) generates a BITE 3 signal. This signal terminates BITE 2 testing and initiates the BITE 3 test.

BITE 3 TEST.— When servo BITE (B1) generates a BITE 3 signal, the module B1 also generates a BITE 3 DCI signal (simulated computer data bit). This signal is sent to the decoder storage module. Simultaneously, a BITE 3 signal is sent to mode logic (A2). This module initiates a computer track command signal and sends it to the azimuth position compensation module (C2), the elevation position compensation module (D2), and the D/A converter module. The computer track command signal enables these modules for the computer track mode.

The BITE 3 DCI signals from the decoder storage module are processed by the D/A converter. The D/A converter outputs azimuth and elevation rate signals. A circuit in the D/A converter monitors the amplitude and frequency of these rate signals. If the amplitude and frequency are incorrect, the D/A converter generates a DCI fail (either azimuth or elevation) signal to the servo BITE (B2). This module outputs a servo control fail signal, which, in turn, lights the

CONTROL SERVO FAIL light on the control box. If the signals are correct, they are fed to the azimuth and elevation rate compensation modules (E1 and F1) to develop motor drive signals to slew the receiver head gimbals maximum CW and up. The rate feedback signals (gyro rate to E2 and F2 and azimuth tachometer to mode logic A2 and A3) are fed to servo BITE (B2). These signals are compared to the signals (azimuth/elevation rate) from the D/A converter. Should an error exist, a DCI fault isolate signal is generated by servo BITE (B2) and fed to mode logic (A2). Mode logic (A2) sends a known tachometer signal to the tachometer demodulator. If the demodulator is bad, a DEMOD fail signal is generated and sent to B2 that causes a control servo fail output. If the demodulator is good, but a rate error still exist, B2 outputs a gimbal fail signal that signifies the receiver-converter is bad. If the rate comparison shows no error, a BITE complete signal is generated by servo BITE (B2) and sent to the power supply-video converter. If no error has occurred during BITE, the BITE logic module initiates a system go signal. This signal is sent to the control box to light the SYS GO light.

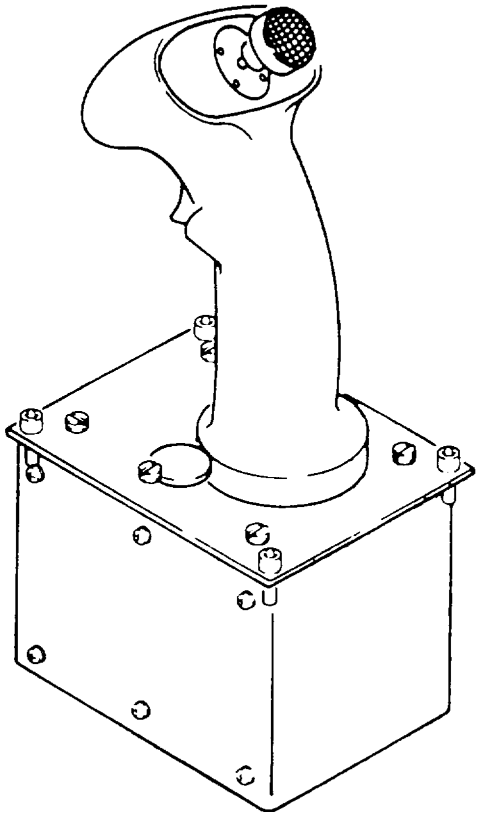


Figure 6-24.-Target tracking sight control.

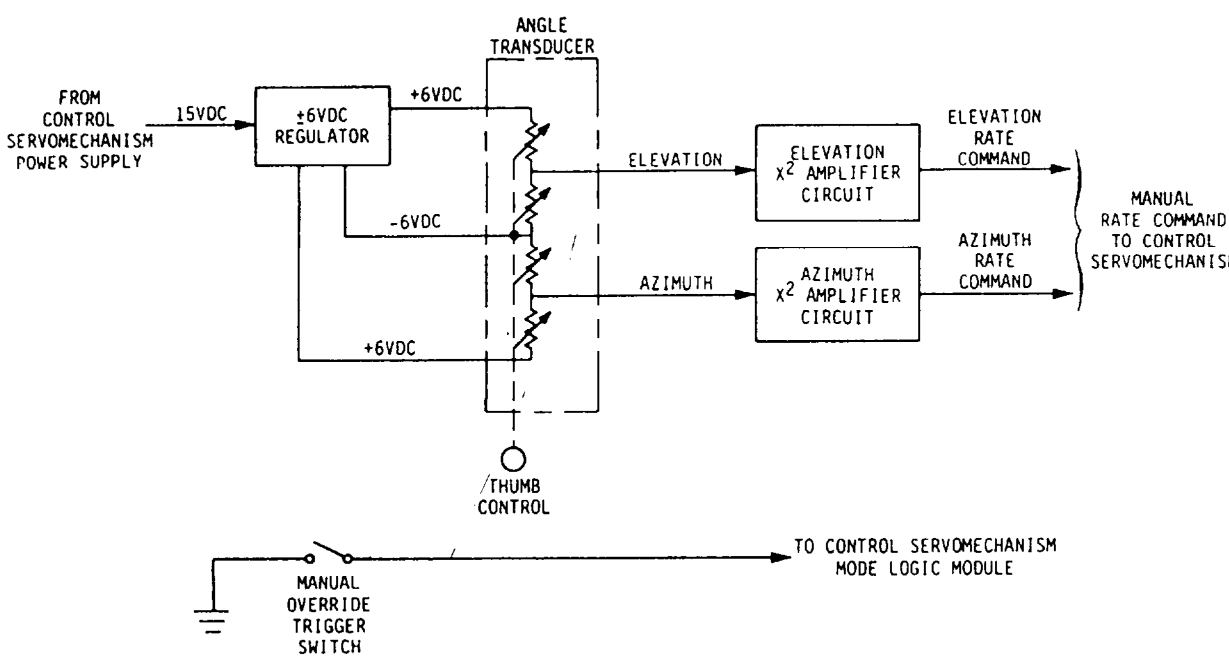


Figure 6-25.-TTSC block diagram.

TARGET TRACKING SIGHT CONTROL

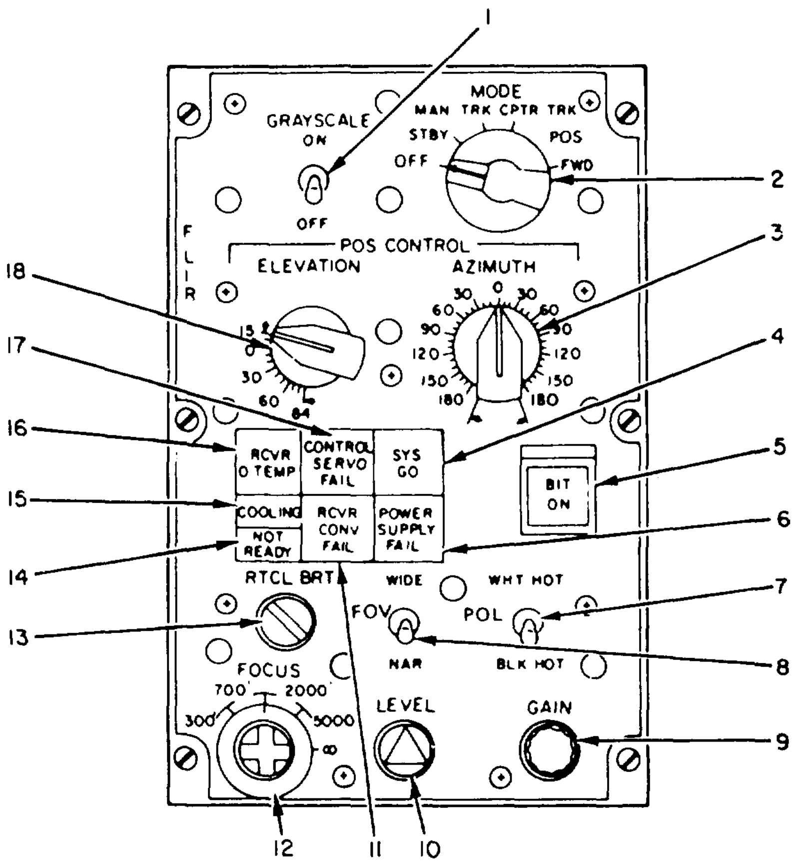
As mentioned earlier in this chapter, TTSC is the manual control used in the manual mode of operation to position the receiver-converter to the desired LOS. Figure 6-24 is a drawing of the TTSC. The TTSC consists of a stationary control stick (A) and the electronics for producing azimuth and elevation dc rate command signals. A thumb control (B) is used in conjunction with an angle transducer to steer the receiver head. A trigger-type switch (C) is used to provide manual override.

Figure 6-25 is a simplified block diagram of a TTSC. A voltage regulator regulates the 15-volt dc input from the control servomechanism WRA and provides +6 volts dc and –6 volts dc to an angle transducer. Adjustment of the thumb control produce voltage outputs from the elevation and azimuth angle transducers. These outputs are amplified and sent to the control servomechanism. Here they are processed to position the receiver head to the desired LOS.

Should you select the computer tracking mode, the FWD mode, or the position mode on the control box, depressing the trigger switch initiates a manual override command signal. This signal goes to the mode logic and D/A converter modules. This places the system in the manual track mode of operation.

INFRARED DETECTING SET CONTROL (IRDSC)

Figure 6-26 is a drawing of an IRDSC/FLIR control box. Notice that each control has been



1. GRAY SCALE switch
2. MODE switch
3. AZIMUTH knob
4. SYS GO push button
5. BIT ON push button
6. POWER SUPPLY FAIL indicator
7. POL switch
8. FOV switch
9. GAIN knob
10. LEVEL knob
11. RCVR CONV FAIL indicator
12. FOCUS switch
13. RTCL BRT knob
14. NOT READY indicator
15. COOLING indicator
16. RCVR O TEMP indicator
17. SERVO FAIL indicator
18. ELEVATION knob

Figure 6-26.-IRDSC/FLIR control box.

numbered. Refer to these numbers while you read the following section.

1. The GRAY SCALE switch energizes the circuit in the power supply-video converter WRA, which presents ten shades of gray across the bottom of the video indicator.

2. The MODE switch is a 6-position rotary switch that selects the mode of operation. In the STBY position, the system is maintained in the operational readiness state. The air conditioning and cryogenic cooling of detectors is activated. The receiver head is in the stow position (CCW and up limits).

3. The AZIMUTH knob controls the receiver slew signals (azimuth) in the position mode of operation.

4. The SYS GO push button illuminates to indicate a good system at the completion of BITE. The light can be extinguished by pressing the indicator.

5. The BIT ON push button initiates the BITE test sequence. The push button is lit while BITE is in progress. The light goes out upon completion of BITE.

6. The POWER SUPPLY FAIL indicator illuminates if the power supply-video converter fails BITE.

7. The POL switch is a two-position switch that selects the polarity of video signals from the postamplifiers of the receiver-converter detector array video amplifier circuits. In the WHT HOT position, the hot targets appear white on the video indicator. In the BLK HOT position, the hot targets appear black on the indicator.

8. The FOV switch selects either wide (WIDE) or narrow (NAR) field of view. It does this by switching an afocal lens assembly in or out of the optical path of the receiver.

9. The GAIN knob adjusts the dc level of the video output to the video indicator. This affects the contrast of targets on the indicator.

10. The LEVEL knob adjusts the dc level of the video output of the receiver-converter. This affects the brightness of the background on the video indicator.

11. The RCVR CONV FAIL indicator illuminates if the receiver-converter fails BITE test.

12. The FOCUS switch is a four position rotary switch that selects target range for focusing the afocal lenses in the narrow FOV.

13. The RTCL BRT knob controls the brightness of the reticle that is superimposed on the video signal applied to the video indicator.

14. The NOT READY indicator illuminates when the receiver-converter is not at operating temperature, when gyro spin-up is not complete, or when BITE is in the fault isolation mode.

15. The COOLING indicator illuminates to indicate the IR detectors in the receiver-converter have not reached operating temperature.

16. The RCVR O TEMP indicator shows excessive temperature within the receiver-converter.

17. The SERVO FAIL indicator illuminates if the control servomechanism fails the BITE test.

18. The ELEVATION knob controls the receiver slew signals (elevation) in the position mode of operation.

VIDEO INDICATOR

The typical video indicator (fig. 6-18) is an 875-line, 30 frames-per-second, closed-circuit TV monitor. On the front of the WRA is an ON-OFF power switch, an elapsed time meter, brightness and contrast controls, and a status indicator. Operation of the indicator is similar to that of a TV monitor. Figure 6-27 is a simplified block diagram of a video indicator's signal processing circuits.

Composite video from the video line driver module of the power supply-video converter is applied to the video amplifier/sync stripper module. This module separates the video signals (IR, RETICLE, GAI, and gray scale) from the sync signals (blanking, clamping, and sync). The module amplifies the video signals and provides the video output to the CRT for display. The contrast control is also injected in the video amplifier/sync stripper module. The module also sends the composite sync signals to the vertical, sync, CRT protect, and brightness control module.

The video amplifier/sync stripper module processes the composite sync signal. It provides vertical and horizontal sync signals to the vertical and horizontal sweep module. It also provides blanking and clamping signals to the CRT. The brightness control is injected in this module. The module also monitors the vertical sweep and horizontal flyback signals, removes the 300-volt dc operating voltage from the CRT, and extinguishes the STATUS light when a failure occurs.

The vertical and horizontal sweep module generates the vertical and horizontal sweeps used to drive the CRT yoke. It provides these drive outputs to the sweep heat sink module. The sweep module receives feedback signals from the sweep heat sink module to update and maintain the proper drive outputs.

The sweep heat sink module receives the vertical and horizontal drive signals and provides the proper level of yoke drive to the CRT. The sweep heat sink module also sends feedback signals to the monitor circuits in the vertical, sync, CRT protect, and brightness control module.

The image presented on the video indicator is a TV picture of the IR energy scanned by the receiver. The video indicator is independent of the BITE subsystems of the other WRAs. Only the STATUS light and picture are indicative of a properly operating video indicator.

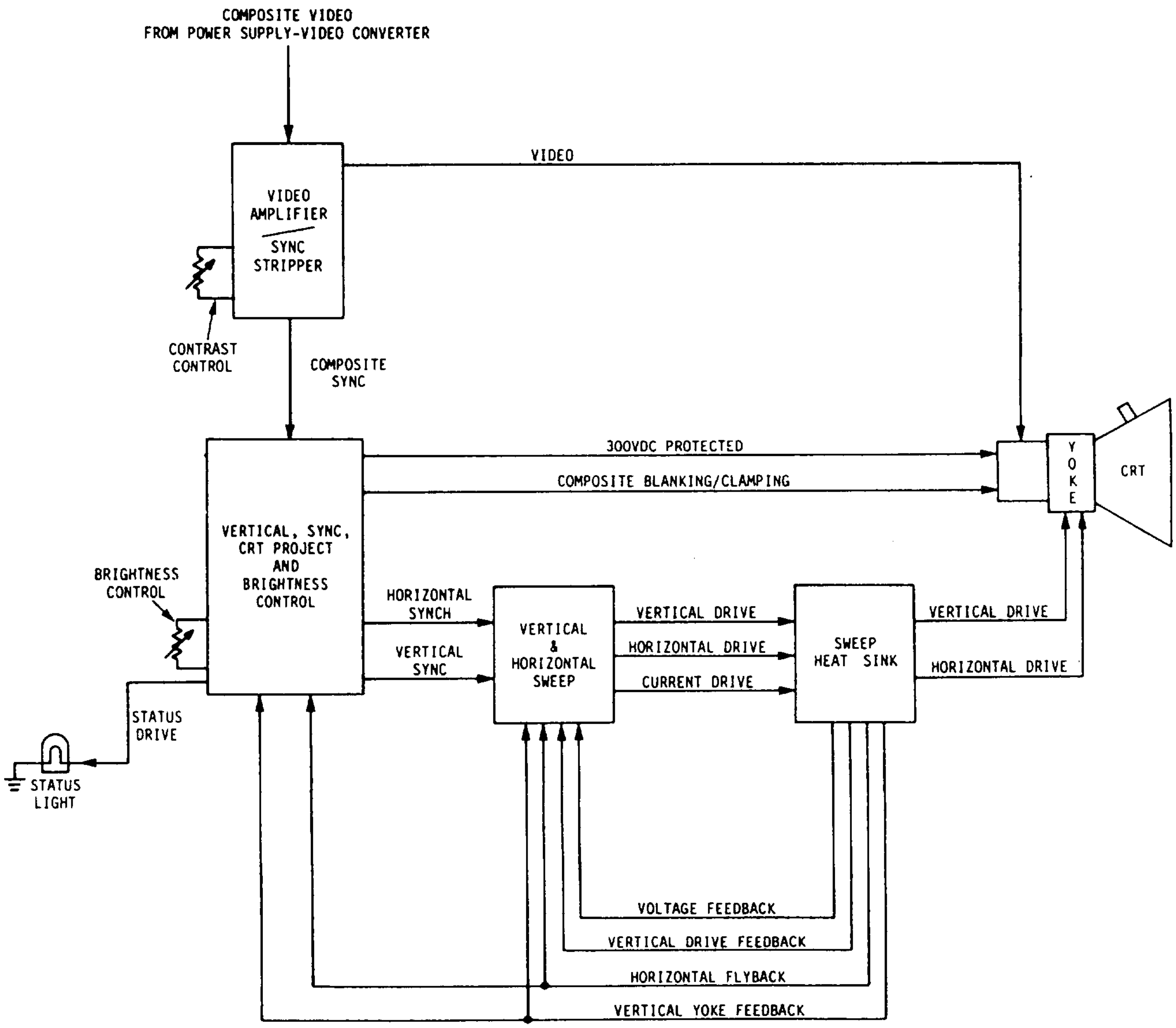


Figure 6-27.-Video Indicator block diagram.

REVIEW QUESTIONS

Q1. Where does the IR frequency range fall in the electromagnetic spectrum?

Q2. How do the IR waves differ from any other wave in the electromagnetic spectrum?

Q3. Realistically, what is the best emissivity of an object?

Q4. What is a good example of an imaging detector?

Q5. What is the major disadvantage of a detector array?

Q6. How wide is the space between the detector elements in a linear array?

Q7. Is a typical IRDS an active or passive system?

Q8. In a typical infrared system, how many detector elements are used to get the 360 lines of video?

Q9. How are the six heaters connected in the heat exchanger?

Q10. What are the four operational modes of operation in the IRDS system?

Q11. True or False. The BITE testing of the system will indicate a video indicator fault.

CHAPTER 7

WEAPONS SYSTEMS

As a result of major developments in current aircraft design and computer technology, modern aircraft are able to deliver sophisticated weapons to a target automatically and with unprecedented accuracy. These aircraft are designed and built as a completely integrated weapons system. The weapons subsystems are interconnected and dependent, to some extent, on each other or on other aircraft systems. For example, the bomb release system in some modes of operation is dependent upon the aircraft's flight control system. In another example, the missile system is interconnected with the aircraft's radar system for missile guidance. In addition to delivering weapons more accurately, the computer-controlled weapons systems provide a higher degree of safety by significantly reducing the degree of human error.

When avionics technicians are testing, trouble-shooting, or performing maintenance on an avionics system, they must be aware of the effects the system can have on ordnance, either loaded or to be loaded on the aircraft. To complicate matters, most aircraft in the Navy's inventory are multimission aircraft. The F/A-18 is used as a fighter and an attack aircraft. The P-3C is an antisubmarine warfare (ASW) and a patrol aircraft. The aircraft discussed in this chapter are the fighter, fighter/attack, and the ASW aircraft.

FIGHTER AIRCRAFT WEAPONS SYSTEMS

Learning Objective: *Recognize various fighter aircraft weapons systems and their operating functions.*

The following discussion of the F-14 and the F/A- 18 aircraft will provide you with information on the available aircraft armament systems and the basic controls and components for both the fighter and the fighter/attack aircraft.

F-14 AIRCRAFT WEAPONS SYSTEMS

The F-14 aircraft is a two seat, supersonic fighter aircraft. The aircraft's armament system consists of the following systems and subsystems: armament basic controls and components, missile control system, multiple weapons release system, M61A1 20-mm automatic gunfire control system, AN/AWW-4 fuze function control system, AN/ALE-29A or AN/ALE-39 decoy dispensing system, and a jettison system.

Armament Basic Controls and Components

The F-14 armament system consists of the following basic controls and components that are common to all systems: the air combat maneuver (ACM) panel, the armament control panel, the display control panel, the control stick, the master light control panel, the landing gear handle, and the armament safety override switch.

AIR COMBAT MANEUVER (ACM) PANEL.— The ACM panel (fig. 7-1) is located on the forward cockpit center console. It contains switches for missile preparation, missile operating mode selection, and for arming the systems. Indicators are provided to inform the pilot of weapon status, when the missile is locked on to the target, and when the missile is ready to be launched. The ACM panel switches are discussed in the following paragraphs.

Master Arm Switch.— This switch is important to the avionics technician who must be aware that when the guard switch is raised and the switch is set to ON, a master arm signal is sent to the armament panel to enable the master arm logic circuitry.

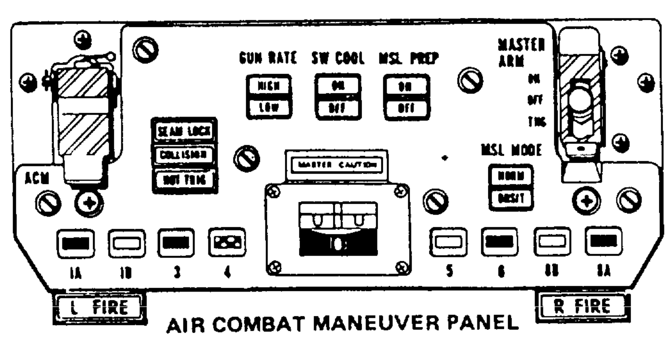


Figure 7-1.-Air combat maneuver (ACM) panel.

CAUTION

Before applying external power, the technician must ensure that all armament switches are in their proper position. If they are not, the technician must notify the appropriate person(s). Failure to do so could result in injury or death to personnel or damage to the aircraft/weapon systems.

ACM Switch.— This switch is a cam-type switch that is activated when the switch guard is moved up to select the ACM encounter mode. The normal missile mode is automatically selected.

ACM JETT Switch.— This switch is a push-button switch located under the ACM switch guard. When the switch is pressed, the stores on the stations that are selected on the armament panel are jettisoned.

HOT TRIG (Trigger) Warning Indicator Light.— This warning indicator lamp lights to notify the pilot that missiles are ready for launching, the gun is ready to fire, or the weapons selected are ready for release or firing.

Weapon Status Indicators.— These indicators indicate weapon status when the landing gear handle is in the UP position. These indicators are labeled 1A, 1B, 3, 4, 5, 6, 8B, and 8A. They correspond to the weapon stations on the aircraft. There are three indications possible:

1. White indication—Weapon station is ready and weapon is loaded.

2. Checkerboard indication—Weapon station is loaded, ready, and selected. Only one weapon status indicator is checkerboard at any one time.

3. Black indication—Weapon station has no weapon loaded, or the weapon is not ready.

ARMAMENT CONTROL INDICATOR PANEL.— The armament control indicator panel (fig. 7-2) is located in the aft cockpit console and contains the following selector switches: attack mode; weapon type; electric fuze; delivery mode and options; station select; missile options; missile speed gate; and select jettison, tank jettison, and jettison options.

DISPLAYS CONTROL PANEL.— The displays control panel (fig. 7-3) is located in the forward cockpit right vertical console. This panel contains

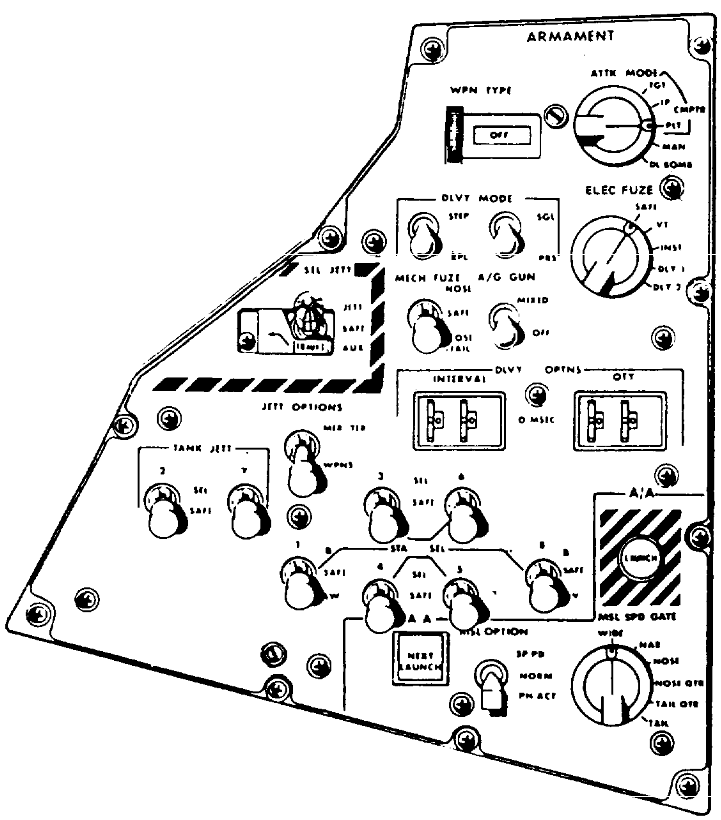


Figure 7-2.-Armament control indicator panel.

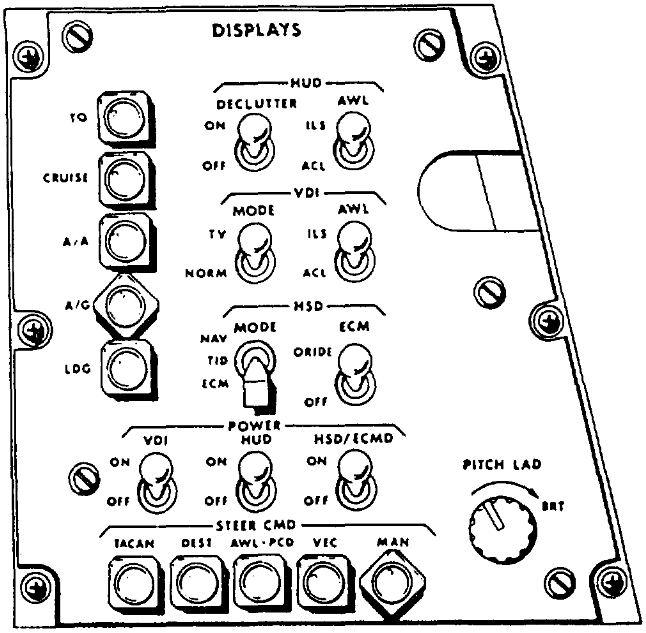


Figure 7-3.-Displays control panel.

push-button mode selection switches for air-to-ground or air-to-air selection. The panel also contains the all-weather landing/precision course direction push-button switch for air-to-air mode selection. The all-weather landing/precision course direction switch is used when weapons are to be released using the data link system.

CONTROL STICK.— The control stick (fig. 7-4) is located in the forward cockpit and contains the weapons selector button, weapon trigger, bomb release push button, and the DLC/CHAFF DISPENSE push button.

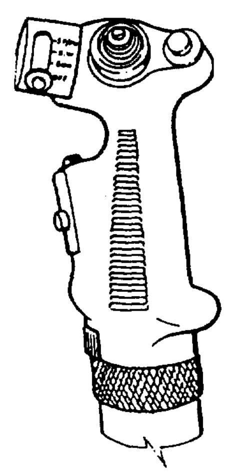


Figure 7-4.-Control stick.

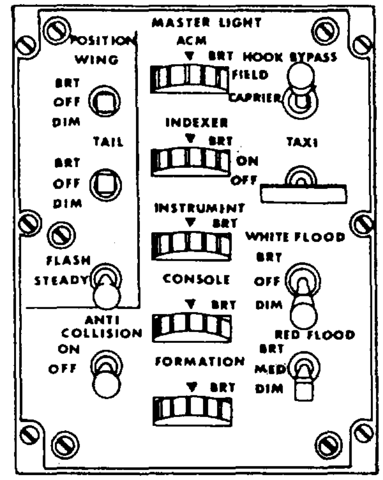


Figure 7-5.-Master light control pannel.

MASTER LIGHT CONTROL PANEL.— The master light control panel (fig. 7-5) is located on the right side console of the forward cockpit and contains the ACM thumb-wheel control. This thumb-wheel controls the 26-volt ac to the ACM panel indicator lights.

LANDING GEAR HANDLE.— The landing gear (LDG GEAR) handle (fig. 7-6) is located on the left vertical console of the forward cockpit. Movement of the LDG GEAR handle operates a switch assembly that functions as an armament safety device. This assembly prevents inadvertent missile launching, bomb release, rocket firing, and ACM encounter jettison of external weapons/stores when the aircraft

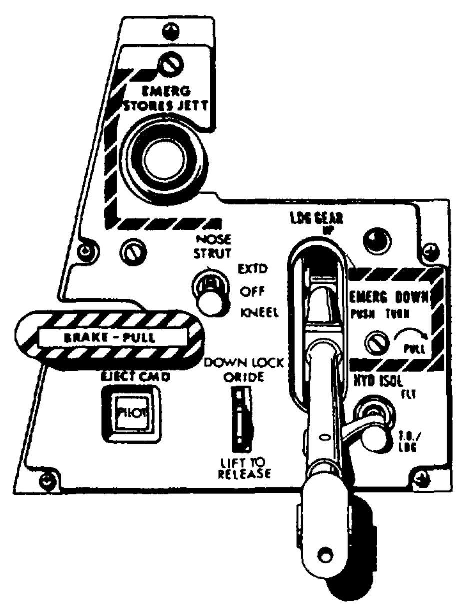


Figure 7-6.-Landing gear handle.

is on the ground. Master arm power is removed when the handle is in the DOWN position, but is available when the handle is in the UP position.

ARMAMENT SAFETY OVERRIDE SWITCH.— The armament safety override (ARMT SAFETY ORIDE) switch (fig. 7-7) is located in the nosewheel well. This switch is a magnetically held closed switch. The switch is used as an armament safety override to bypass the open landing gear safety circuit when the LDG GEAR handle is in the DOWN position. This switch enables technicians to perform functional checks while the aircraft is on the ground.

Missile Control System

The missile control system consists of the basic controls and components previously discussed, and the following controls and components: the weapons status indicators, the liquid (LIQ) cooling control panel, and the aft cockpit caution advisory panel.

Multiple Weapons Release System

The multiple weapons release system comprises the basic controls and components, as well as the multiple weapons systems controls and components.

M61A1 20-mm Automatic Gunfire Control system

The M61A1 20-mm automatic gunfire control system enables selecting, arming, and firing of the gun. Depending upon the mission objective, the gunfire control system can be operated in an air-to-air (A/A), air-to-ground (A/G), or air-combat maneuver (ACM encounter) mode.

AN/AWW-4 Fuze Function Control System

This system is used to provide a high dc voltage for the charging and arming of electrical bomb fuzes. It also provides voltage for the electrical initiation of the VT or proximity fuze. The faze is called a VT fuze because the original device contained vacuum tubes.

Decoy Dispensing Systems

The F-14 aircraft uses the AN/ALE-29A or the AN/ALE-39 decoy dispensing system to eject decoy rounds into the air. These rounds consist of chaff packages or flares. Releasing these rounds allows the aircraft to evade air-to-air and surface-to-air attacks. The location of the decoy dispenser is shown in figure 7-8.

Jettison System

The jettison system enables the jettisoning of certain external stores. There are four jettison modes:

1. Emergency—Pilot controlled.

2. ACM encounter—NFO selected, pilot controlled.

3. Selective—NFO controlled.

4. Auxiliary—NFO controlled.

The NFO is the person in the back seat of the aircraft. The NFO selects and controls the jettison by using the armament control indicator located in the aft cockpit (fig. 7-2). In all modes, arming and fuzing are

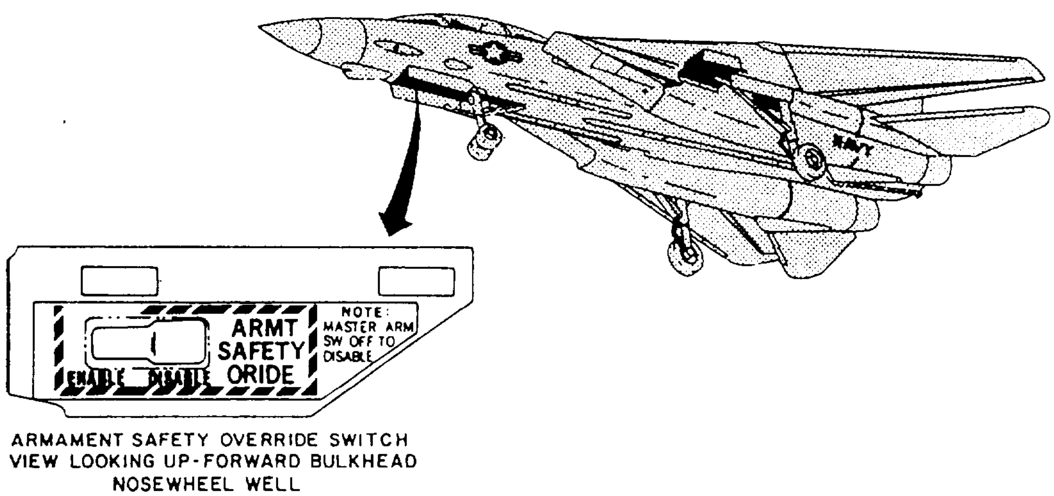


Figure 7-7.-Armament safety override switch.

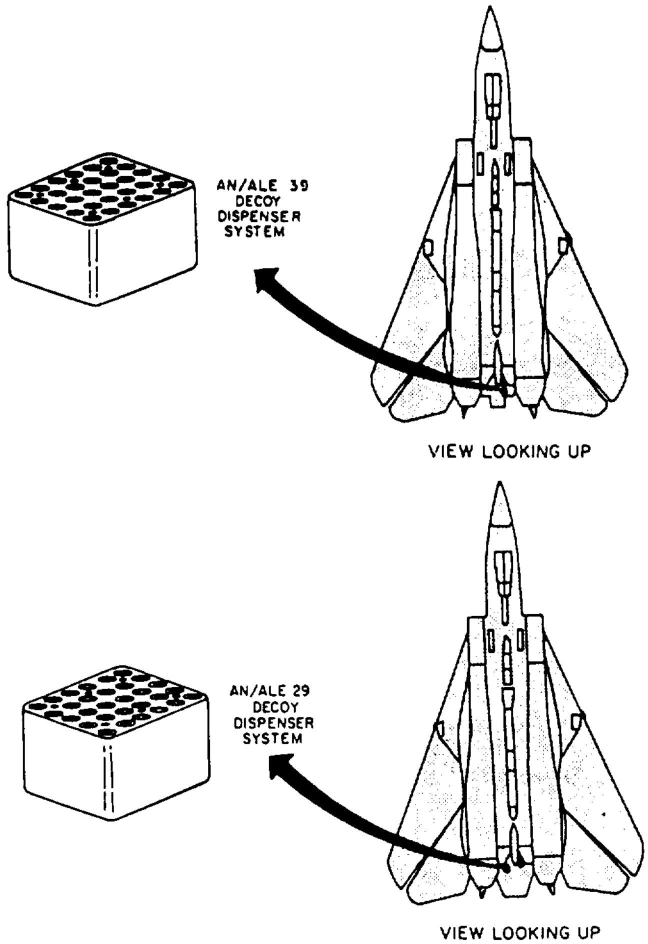


Figure 7-8.-Decoy dispenser configuration on aircraft.

disabled during jettisoning. The landing gear handle must be in the UP position for all modes except emergency.

F/A-18 AIRCRAFT WEAPONS SYSTEMS

The F/A-18 aircraft is a single seat, dual role (fighter/bomber), supersonic aircraft. Provisions are available in the aircraft for the application of external power. The external power connector connects 115/200 volt, three-phase, 400-Hz ac power to the ac bus. When external power is not available, there is an auxiliary power unit (APU) to drive either of the aircraft generators for functional checkout of the aircraft systems.

The F/A-18 armament system consists of the following systems and subsystems:

- F/A-18 armament basic controls and components
- AN/AWW-4 fuze function control system
- Rocket firing system
- Walleye system
- AN/AWW-7 data link system
- AGM-65 Maverick fire control system
- AGM-88 HARM fire control system
- AIM-7 Sparrow fire control system
- AIM-9 Sidewinder fire control system
- M61A1 20-mm gun system
- AN/ALE-39A decoy dispensing system

F/A-18 Armament Basic Controls and Components

The F/A-18 armament system consists of the following basic controls and components that are common to all systems: the ground power control panel assembly, the landing gear control handle, the armament safety override switch, the master arm control panel assembly, the aircraft controller grip assembly, and the two digital display indicators.

GROUND POWER CONTROL PANEL ASSEMBLY.— A ground power control panel assembly provides four toggle switches, three of which control the application of external power to avionic and instrument systems. This prevents excessive equipment operation time because of other unassociated ground operations.

The EXT PWR switch is a three-position switch that applies electrical power to the aircraft. In the NORM position, electrical power is supplied to the aircraft. In the OFF position, no power is supplied to the aircraft. The RESET position resets power for the external monitoring circuit when there is a temporary overload. Switch 1 is a three-position switch with B ON to provide enabling power to the mission computers. Switch 2 is a three-position switch with B ON to provide enabling power to the digital display indicators (DDIs) and the radar. Switch 3 is three-position switch with B ON to provide enabling power to the armament computer, the AN/AWW-4 system, the HARM system, and the AN/ALE-39A system.

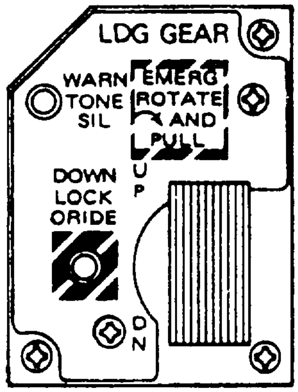


Figure 7-9.-Landing gear control handle.

LANDING GEAR CONTROL HANDLE.— The LDG GEAR control (fig. 7-9) in the DN position disables normal weapon release, launch, and fire signals. In the UP position, 28-volt dc power is applied from the main landing gear weight-off-wheels relay to the master arm circuit breaker.

ARMAMENT SAFETY OVERRIDE SWITCH.— The armament safety override switch (fig. 7-10) is on the maintenance panel that is located in the nosewheel well. In the override position, it overrides the landing gear handle DN position to enable weapons systems for ground operational maintenance.

MASTER ARM CONTROL PANEL ASSEMBLY.— The master arm control panel assembly (fig. 7-11) is located in the cockpit. It contains the A/A, A/G, and the MASTER switches. The A/A and A/G switches are push-button switches that provide a ground to the stores management processor (SMP). They select the air-to-air or air-to-ground computer modes, respectively. The MASTER switch is used in conjunction with the LDG GEAR handle or the armament safety override switch. In the SAFE position, weapons cannot be released or fired. Emergency jettison can be initiated while this switch is in the SAFE position. The ARM position provides an input to the SMP and power for weapns release, fire, or jettison. The switch position (SAFE/ARM) will be displayed on the DDIs in the wing-form display.

Figure 7-10.-Armament safety override switch.

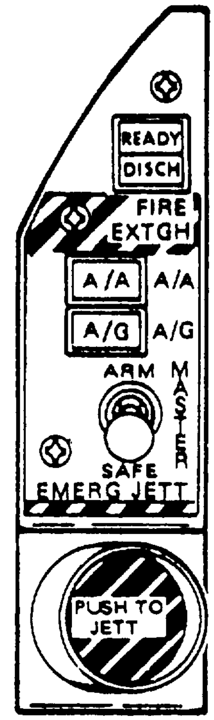


Figure 7-11.-Master arm control panel assembly.

AIRCRAFT CONTROLLER GRIP ASSEMBLY.— The aircraft controller grip assembly (fig. 7-12) contains the A/G weapons release switch (bomb release switch). The switch is spring-loaded to the OFF position. When the switch is pressed, it completes a circuit from the SMP and provides an input back to the SMP. The aircraft controller grip assembly also contains an A/A switch and the trigger switch.

DIGITAL DISPLAY INDICATORS DDIs).— The digital display indicators (fig. 7-13) are located on the main instrument panel vertical consoles. The DDIs monitor the SMP and display that information. The DDIs always have a wing-form display, and when in the air-to-ground mode, a program list. The wing-form display, program list, and switches/controls on the DDIs are discussed in the following paragraphs.

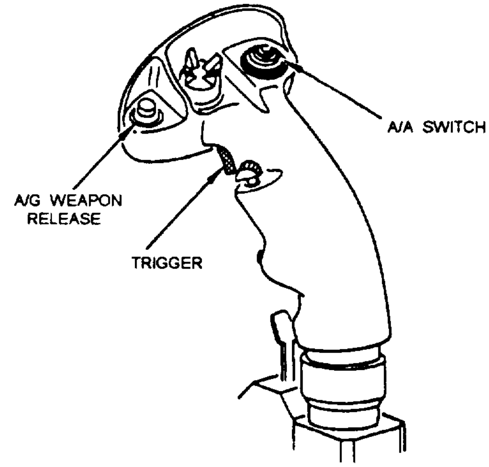


Figure 7-12.-Aircraft controller grip assembly.

The wing-form display is displayed in the air-to-air and the air-to-ground computer modes. It identifies what is loaded on all stations except the wing tip AIM-9 stations, which are always displayed. The weapon loaded is displayed on the DDI by the appropriate acronym. When weapons are loaded on the stations, the type of weapon is coded into the SMP during loading procedures. Thus, when selected, the DDIs display the appropriate acronym. An acronym is an abbreviated number and letter, such as 1 82B, which indicates that one Mk 82 blunt-nose bomb is loaded.

The push-button switches around the DDIs are used to select weapons, various functions, and mode options of a function (if any). For example, mechanical fuzing (MFUZ) is one function and nose

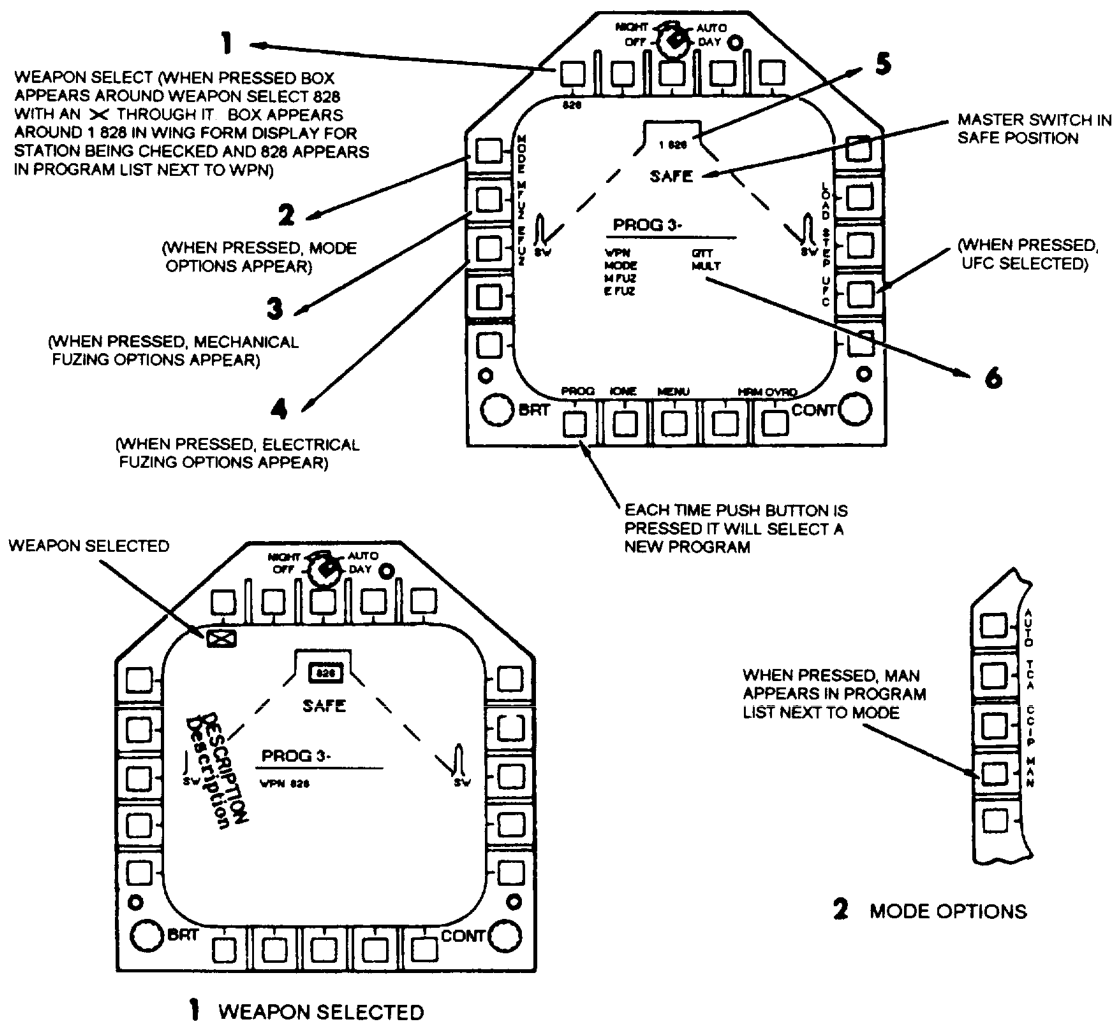


Figure 7-13.-Digital display indicators.

(NOSE), nose/tail fuzing (N/T), and long-delay fuzing (LDLY) are the selectable options.

Weapon selection for air-to-ground weapons is accomplished by pressing the push-button switch located next to the acronym of the weapon desired. When the weapon is selected, a box lights around the acronym. When the MASTER switch is in the SAFE position, an X appears superimposed through the acronym. When the MASTER switch is in the ARM position, the X is removed and RDY is displayed under the box light around the acronym. A box also appears around the acronym of the weapon in the wing-form display for the first priority (first station in firing sequence) station that has this particular weapon loaded. Also, this weapon acronym is displayed next to WPN in the program list.

Armament Computer

The armament computer (SMP) is shown in figure 7-14. The computer is interfaced with and controlled by the digital computers in the aircraft. The SNIP is also interfaced with and controls the weapons station command encoders/decoders. The SMP has a weapon insertion panel with code wheels. These code wheels are used to enter the code into the weapon-type (ARMAMENT) and nose/tail fuzes (FUZING). The weapon-type code must match the weapon loaded. The nose/tail fuze codes must be compatible with the weapon, or the SMP will not

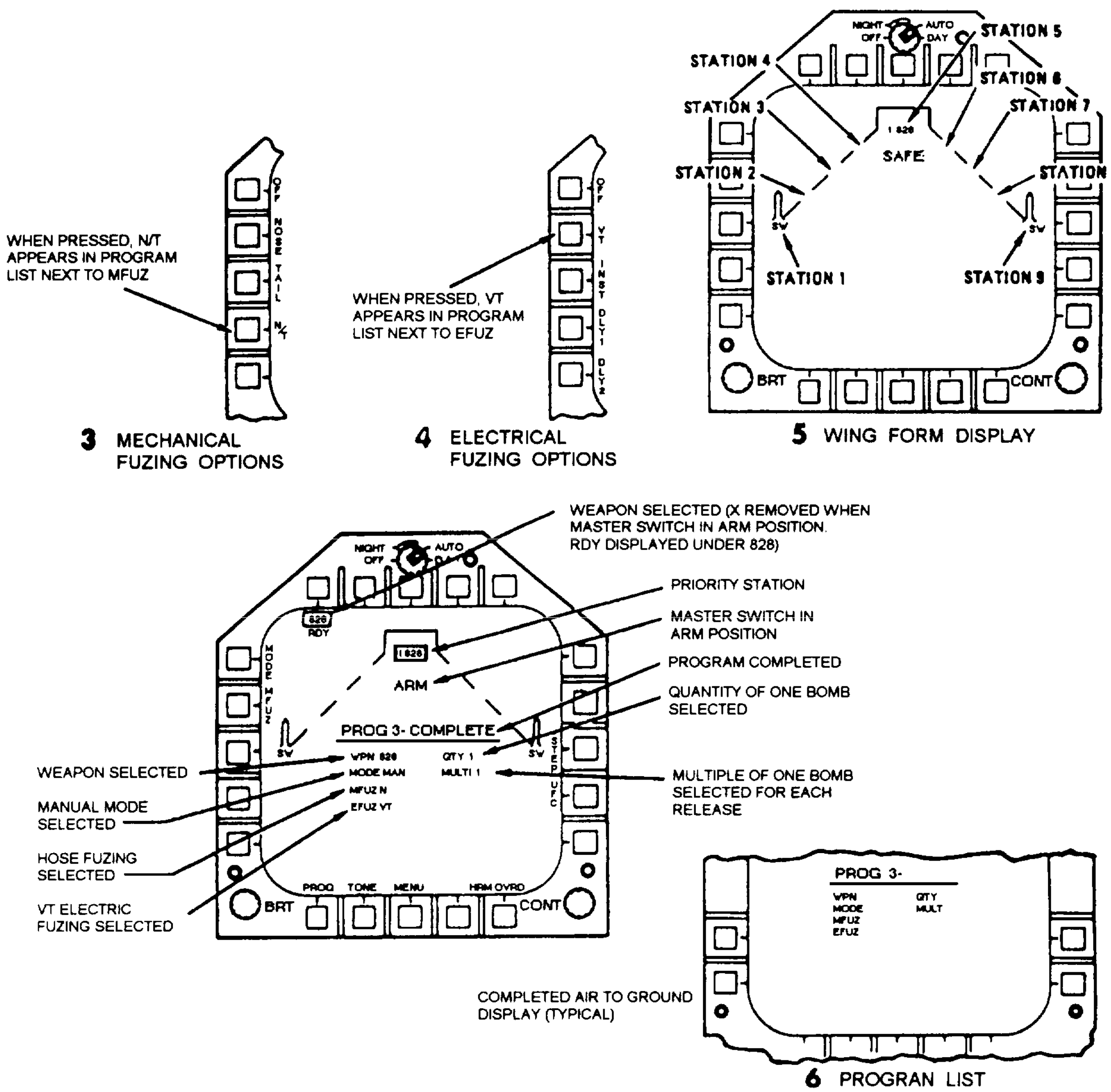


Figure 7-13.-Digital display indicators—Continued.

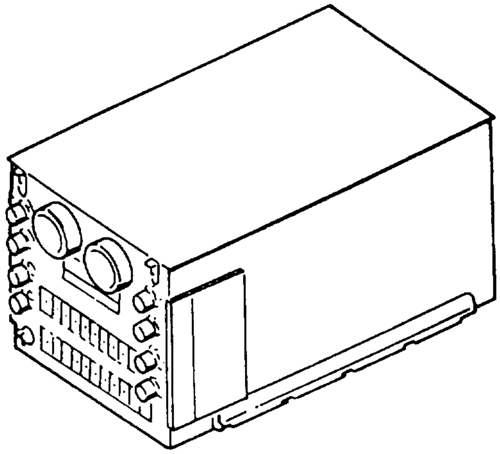


Figure 7-14.-Armament computer (stores management processor) (SMP).

allow it to release normally. For weapons without nose/tail fuzes, the codes must still match the weapon loaded. AIM-7 missiles loaded on fuselage stations 4 and 6 do not require a weapon code.

Digital Computers

Digital computers make up the mission computer system and control the avionics systems. They interface with the SMP and allow the SMP to route power to the encoders/decoders for weapons release. The digital computers are controlled by the MC switch on the MC/HYD ISOL panel. When the MC switch is in the 1 OFF position, power is removed from mission computer No. 1. When in the NORM position, power is applied to mission computers Nos. 1 and 2. When in the 2 OFF position, power is removed from mission computer No. 2.

The command encoders/decoders provide an interface with the SMP and the weapons loaded. When the SMP supplies power to the encoders/decoders, they allow the weapon release.

Jettison System

The jettison system provides a method of jettisoning weapons, stores, launchers, and fuel tanks. The jettison system has three modes of release—emergency, selective, and auxiliary.

The emergency jettison mode jettisons all weapons from the five pylon stations. Conditions for jettisoning are weight-off-wheels or landing gear control handle in the UP position and the EMERG JETT PUSH TO JETT switch pressed. The PUSH TO

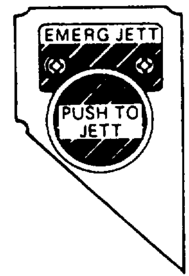


Figure 7-15.-Emergency jettison control panel assembly.

JETT switch (fig. 7-15) is on the emergency jettison control panel assembly.

The JETT STATION SELECT switches (fig. 7-16) are on the flaps, landing gear, and stores indicator panel. When the switches are pressed, a ground is provided to the SMP and the station is selected. The SELECT JETT switch is located on the left-hand vertical control panel assembly. The rotary portion of the switch selects the fuselage missile stations (L FUS MSL/ R FUS MSL/ RACK LCHR/ STORES) to be jettisoned.

The auxiliary jettison is a gravity mode of jettisoning used on the five pylon stations when emergency and selective jettison fails. Conditions for jettisoning are as follows: the landing gear handle in the UP position, all gear up and locked, MASTER switch to ARM, stations selected by the JETT STATION SELECT switches, AUX REL switch to ENABLE, and the bomb-release switch pressed. The AUX REL switch is located on the ECM control panel assembly. When it is positioned to ENABLE, it provides a ground to the SMP and allows the auxiliary cartridge to fire when the bomb-release switch is pressed.

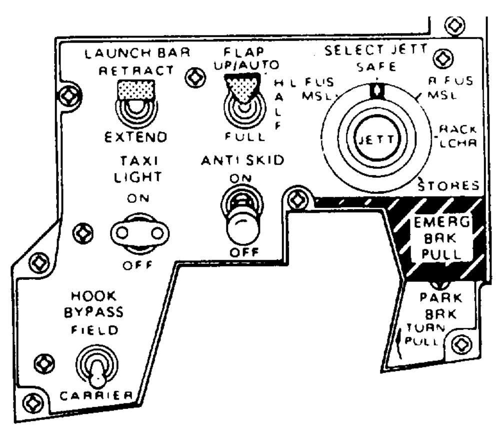


Figure 7-16.-Jettison station select stitches.

Bomb Release System

The bomb release system provides the aircraft with capabilities for release of conventional weapons. Normal release is provided in four electrically controlled modes of operation. Release is accomplished by electrically firing two gas-generating cartridges in the breech housing unit in the bomb rack. The system consists of the armament basic controls and components.

AN/AWW-4 Fuze Function Control System

The AN/AWW-4 fuze function control system provides the aircraft with capabilities for the use of electric fuzes. Voltage is supplied by the PP-6419 power supply to the bomb arming unit through the aircraft wiring. There are four voltages selected on the DDIs. When release is initiated, a voltage is supplied through an interconnecting cable to the weapon during the first few inches of fall of the weapon. No voltage is supplied to the bomb rack until the bomb-release switch is pressed. The system consists of the power supply and the armament basic controls and components.

Rocket Firing System

The rocket firing system provides the aircraft with the capability for firing rockets. When the bomb release switch is pressed, voltage is supplied through the aircraft wiring to the vertical ejector rack (VER). Wiring within the VER allows the rocket to fire. The system consists of the armament basic controls and components.

Walleye Guided Weapon System

The Walleye guided weapon system provides the aircraft with the capability for the release and guidance of a Walleye weapon. Video is supplied from the weapon through the aircraft wiring to the DDIs. No voltage is supplied to the bomb rack until the bomb release is pressed. The system consists of the CAGE/UNCAGE switch and the armament basic controls and components. The CAGE/UNCAGE switch is located on the throttle. When the switch is pressed, the selected weapon is either caged or uncaged.

AN/AWW-7B Data Link System

The AN/AWW-7B data link system is used with the Mk 21 and Mk 27 Walleye weapons. The data link system provides control and guidance to these weapons with a data pod externally mounted to the aircraft. The system consists of the armament basic controls and components.

AGM-65 Maverick System

The AGM-65 Maverick system provides the aircraft with the capability for firing the Maverick missile. Control of the missile is supplied through the missile control system while the AN/AWW-4 fuze function control provides fuze arming. Video is supplied from the weapon to the DDIs. No voltage is supplied to the missile until the trigger switch is pulled. The system consists of the trigger switch and the armament basic controls and components. The trigger switch is located on the aircraft controller grip assembly. The switch is a two-position detent switch, with the first detent initiating the camera operation and the second initiating missile launch.

AGM-88 HARM System

The AGM-88 HARM system provides the aircraft with the capability for firing a HARM missile. Control of the missile is provide through the SMP. No voltage is supplied to fire the missile until the trigger switch is pulled. The system consists of the trigger switch and the armament basic controls and components.

AIM-7 Sparrow Fire Control System

The AIM-7 Sparrow fire control system provides the aircraft with the capability for firing an AIM-7 missile. Control of the missile is supplied through the SMP and the radar system. No voltage is supplied to fire the missile until the trigger switch is pulled. Weapon selection is accomplished by the A/A weapon select switch on the aircraft controller grip assembly. The system consists of the RADAR switch, CAGE/UNCAGE switch, and the armament basic controls and components.

The A/A weapon select switch selects the Sparrow missile on the priority station when the switch is in the FWD position. Each time the switch is depressed, the priority station changes. SEL is displayed on the DDI underneath the SP acronym of the station selected. An X is superimposed through the SP when the missile is not tuned. The X disappears when the missile tunes. The RADAR switch is located on the sensor control panel.

AIM-9 Sidewinder Fire Control System

The Sidewinder fire control system provides the aircraft with the capability for firing a Sidewinder missile. Control of the missile is provided through the SMP. No voltage is supplied to fire the missile until the trigger switch is pulled. Weapon selection is made by the A/A weapon select switch on the aircraft controller grip assembly. Tone volume is controlled by the WPN VOL switch. The system consists of the IR COOL switch, trigger switch, and the armament basic controls and components.

The A/A weapon select switch selects the Sidewinder missile on the priority station when the switch is in the DOWN position. Each time the switch is depressed, the priority station changes. SEL is displayed on the DDI underneath the SW acronym of the station selected. The WPN VOL switch is on the intercommunication amplifier control panel assembly.

The IR COOL switch is a three-position switch on the map gain control panel assembly. When the switch is in the OFF position, coolant is disabled to the seeker heads unless weight is off the wheels, the MASTER switch is in the ARM position, and the station is selected. In the NORM position, coolant is enabled to all seeker heads when the weight is off the wheels. In the ORIDE position, coolant is enabled to all seeker heads when power is applied to the aircraft.

M61A1 20-mm Gun System

The M61A1 20-mm gun system provides the aircraft with the capability for firing the gun. The system enables selecting, arming, and firing. Depending upon the mission objective, the gun can be operated in the A/A or the A/G computer modes. In the A/G mode there are two submodes. The two submodes are the continuously computer impact point (CCIP) and the manual (MAN) modes. There are three A/A modes. These are the director, disturbed, and the cage modes. Control of the gun is supplied through the SMP. No voltage is supplied to the gun until the trigger switch is pulled.

AN/ALE-39 Decoy Dispensing System

The AN/ALE-39 decoy dispensing system provides the aircraft with the capability for dispensing chaff and flares. The decoy rounds are contained in two dispensers at the fuselage underside area. Control is supplied through the SMP. The system consists of the dispenser/ECM control panel, engine throttle lever grip assembly, left console DISP switch, the ALE-39 programmer, two AN/ALE-29A dispensers, and the armament system basic controls and components.

ANTISUBMARINE WARFARE WEAPONS SYSTEMS

Learning Objective: *Recognize various weapons systems on ASW type aircraft.*

Antisubmarine warfare (ASW) is becoming an ever broadening field. Our ASW capabilities have been improving constantly. As a senior avionics technician, you must play the key role in maintaining the ASW platform used for in-flight launching of search and kill stores. When launched at precise intervals and locations and in conjunction with the aircraft's electronic data processing equipment, these stores provide accurate information for detecting enemy submarines. The kill stores consist mainly of torpedoes, mines, bombs, rockets, and guided missiles.

The remainder of this chapter discusses the basic ASW system, the P-3C and S-3A search store systems, the helicopter search store systems, the P-3C and S-3A kill store systems, and the helicopter kill store systems. Finally, the control systems for release and control of search and kill stores are discussed.

BASIC ASW WEAPONS SYSTEMS

The basic ASW weapons systems consist of the equipment and accessories necessary for carrying and releasing the search and kill stores.

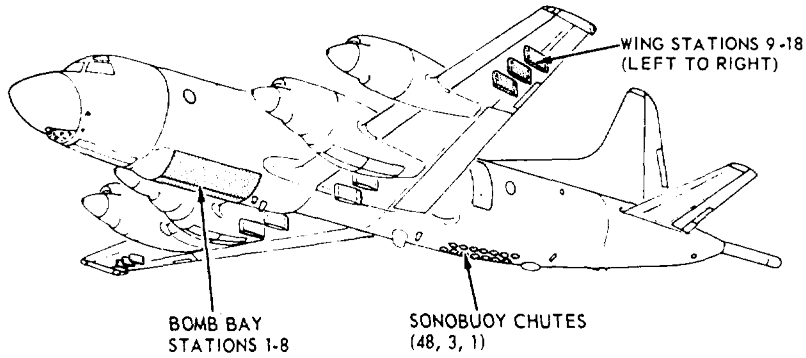


Figure 7-17.-P-3C ordnance stations.

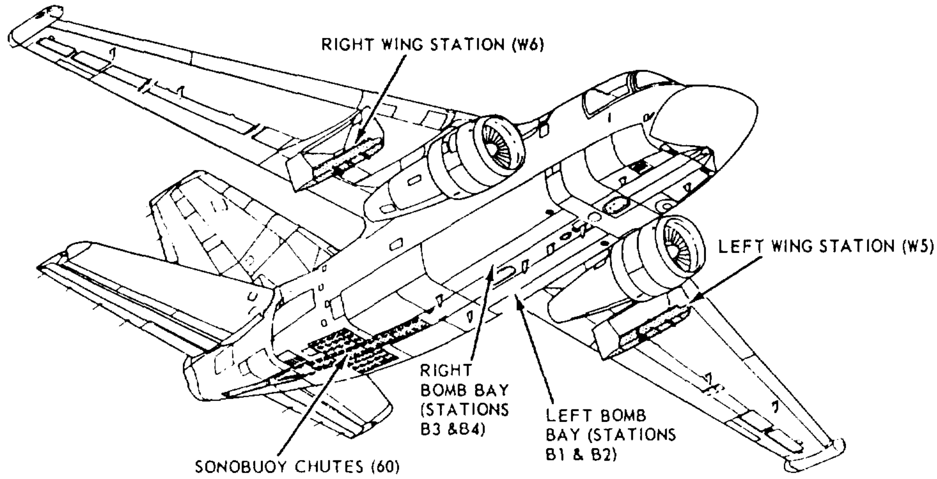


Figure 7-18.-S-3A ordnance stations.

In the P-3C, in addition to the eight bomb bay stations, ten wing stations are available for the carriage of a variety of stores. Forty-eight unpressurized, three pressurized, and one free-fall launch chutes are used in the search store system (fig. 7-17).

In the S-3A, two bomb bays with two stations each and two wing stations are available for store carriage. Sixty unpressurized launch chutes are used in the search store system (fig. 7-18).

The weapons control system of each aircraft has the units, panels, switches, logic circuits, interfaces, computer, and controls necessary for selecting, arming, and releasing the kill or search stores. Additionally, status lights indicate store selection errors and store go or no-go status. Electrical jettison release systems are incorporated to release or eject all kill stores of the P-3C aircraft, and the wing stations and all search stores of the S-3A aircraft.

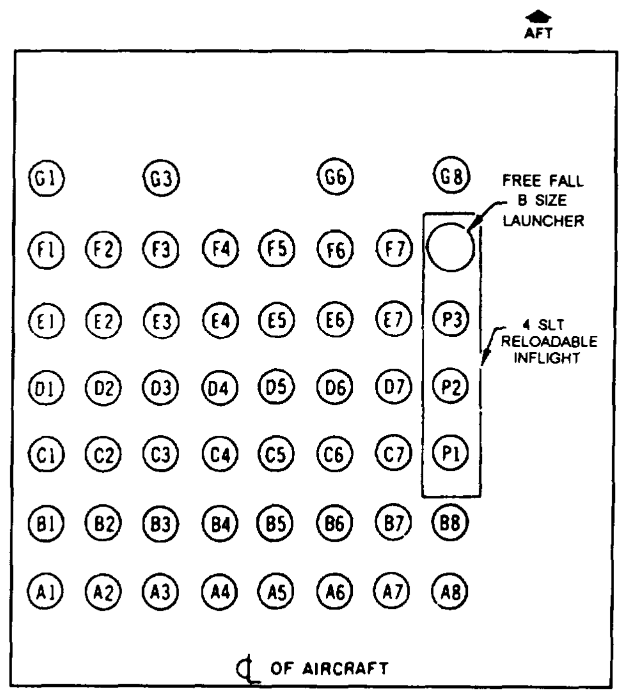


Figure 7-19.-P-3C SLT arrangement.

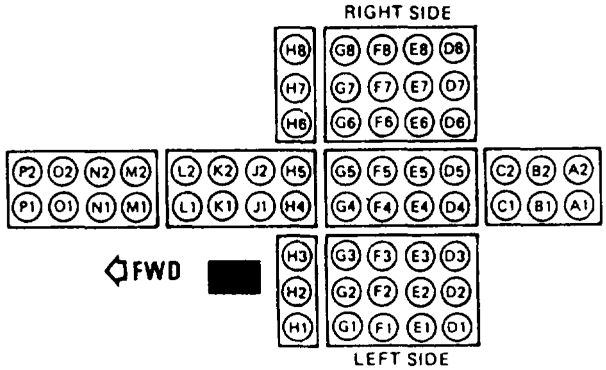


Figure 7-20.-S-3A SLT arrangement.

FIXED-WING SEARCH STORE SYSTEMS

The search store systems of the P-3C and the S-3A aircraft consist mainly of the equipment and accessories necessary to carry and release sonobuoys. The sono systems also have the capability for carriage and release of several other search related stores.

Part of the system consists of unpressurized, size A sonobuoy launch tubes (SLTs) installed in the underside of the aircraft fuselage. Forty-eight of the SLTs on the P-3C and all of the S-3A SLTs (60) are of this type. These SLTs are not accessible from inside the pressurized aircraft. Figure 7-19 shows the arrangement of the P-3C SLTs (as you lookup at the lower fuselage), while figure 7-20 shows the S-3A arrangement.

The P-3C also has three pressurized size A SLTs (fig. 7-21) and one unpressurized size B free-fall chute. These are accessible from inside the aircraft, and are reloadable in flight. Size A chutes are approximately 5 inches in diameter, and the size B chute is approximately 7 inches in diameter.

The size B chute is a tube with a pressure-sealing cover at the top end. If it is pressurized, the cabin of the aircraft must be depressurized before you open the

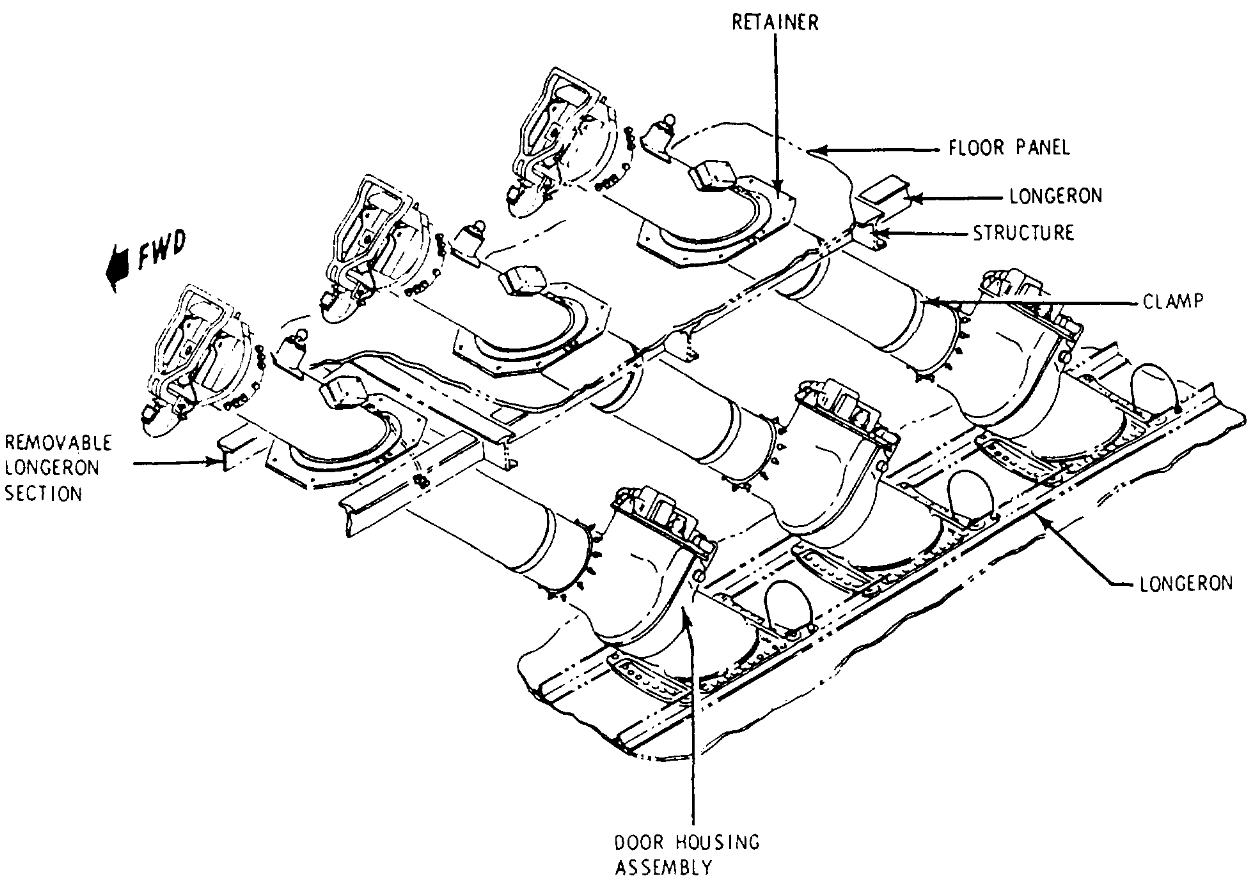


Figure 7-21.-Pressxurized size A sonobuoy launch tubes.

sealing door of the chute. The chute may then be used for manually expending miscellaneous items less than 7 inches in diameter. The size B chute has no connecting electrical circuits.

All of the size A SLTs in both aircraft have electrical connections that interface with the aircraft computer. There are also connections for the manual mode control circuits for sono inventory and launching.

Sonobuoys, Mk 58 and/or Mk 25 marine location markers (MLMs), and signal underwater sounds (SUSs) can be loaded into sonobuoy launch containers (SLCs). The Mk 25 MLMs and SUSs may be dropped from the size B chute of the P-3C. After a store is loaded into the SLC, with the appropriate pads and spacers, an end cap is installed at the open end and marked with information of the enclosed store. The end cap has two protruding pin lugs, which mate with slots on the SLC to Iock the store in place. The lugs shear when the cartridge-activated device (CAD) is fired. When the CAD fires, everything in the SLC is ejected.

NOTE: Some sonobuoys may be received prepackaged in disposable SLCs. This deletes the need for loading SLCs at the organizational maintenance level.

Before you load the SLCs into the SLTs, you should perform a no-voltage and stray-voltage check on the sono circuits at the sonobuoy safety switch for the S-3A, and on the sono launch circuit tester in the P-3C. The safety switch on both aircraft is located adjacent to the SLTs and is actuated to the safe position when the switch access door is open.

CAUTION

When either type of aircraft is on the deck, the switch access door should be open to prevent inadvertent firing of the SLT stores. Inadvertent firing may cause injury or death to personnel, and will cause damage to the equipment.

The SLC, with CAD installed, is loaded into a designated SLT according to the load plan. The locking lugs at the CAD cap mate with the locking lugs of the SLT. The CAD is pressed against the electrical firing pin in the SLT breech assembly. In the S-3A, tube P2 is always loaded with an SLC containing a search and rescue (S AR) sonobuoy. The P-3C also has a stowage rack inside the aircraft for 36 SLCs for use in the four SLTs inside the cabin.

When the SLCs are loaded, the area beneath the loaded SLTs is cleared, and the safety switch door is closed. When the door is closed, the cockpit sono disabled indication will be extinguished. A continuity check is performed by the aircraft circuits on the CADs, and the load status verified by using the sono select switches of the particular aircraft. The switch door is opened again, and the system is disabled until just before takeoff. The load plan is given to the tactical coordinator (TACCO) for computer programming of the specific store in each SLT, and in the case of the P-3C, the stowage rack.

Release of the SLT stores in flight is normally activated by the aircraft computer. The computer is programmed by the TACCO and controlled by the pilot's or TACCO's keyset in the P-3C. In the S-3A, the TACCO's keyset programs and controls the computer. The manual release mode is normally used only during maintenance testing and system checks, and as an emergency backup for the auto mode. Emergency jettison of the SLTs is not included in the P-3C system. In the S-3A, it is part of the jettison circuit, and when activated, will jettison 59 of the 60 SLCs in less than 10 seconds. Until the pilot initiates circuit activation, the SAR buoy will remain in the P2 chute.

HELICOPTER SEARCH STORE SYSTEM

The search store system of helicopters is less complex than that of the fixed-wing aircraft just discussed, but it serves the same purpose. Figure 7-22 shows some of the basic search store equipments

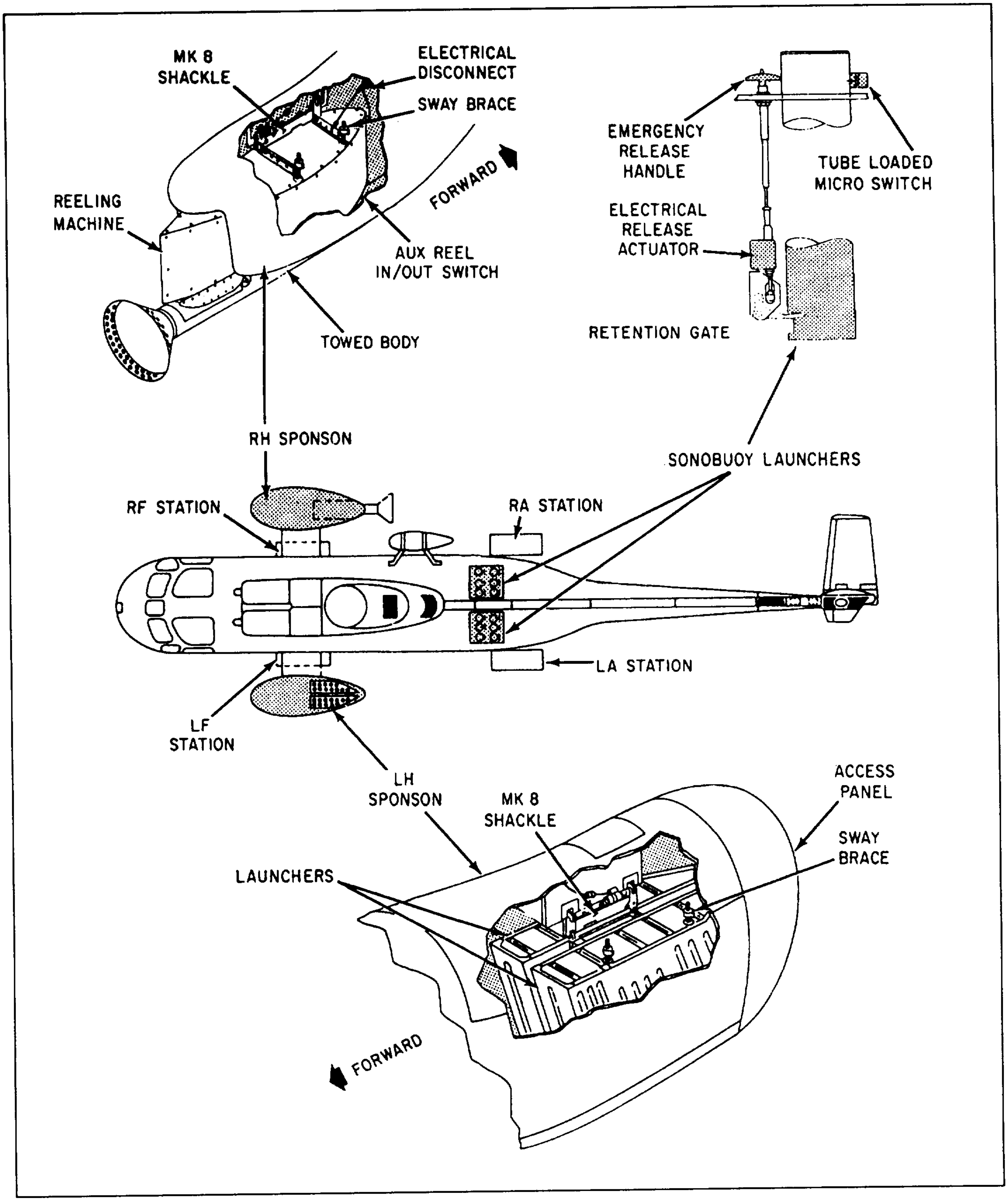


Figure 7-22.-SH-3 (series) search and kill stores.

of the SH-3 series helicopter, and figure 7-23 shows the basic equipments of the SH-60 series helicopter. Both types of helicopters have various models with different configurations. In this chapter, no specific model is discussed.

SH-3 Series Helicopter Sonobuoy Launcher

The launcher used in the SH-3 series helicopter provides a means for free-fall launching of sonobuoys. The system consists of a control panel and 12 launcher tubes (size A), which are incorporated as an integral part of the airframe. Each tube contains a retention gate that can be electrically or manually released to launch the individual sonobuoy. A tube-loaded microswitch operates a panel light when the selected tube is loaded.

SH-60 Series Helicopter Sonobuoy Launcher

The SH-60 series sonobuoy launcher is designed to pneumatically launch up to 25 sonobuoys. The buoys exit from the launcher on the left-hand side of the aircraft. The system consists of a launcher assembly, a distributor valve, a high-pressure air bottle, and an electrical control unit (ECU). The air

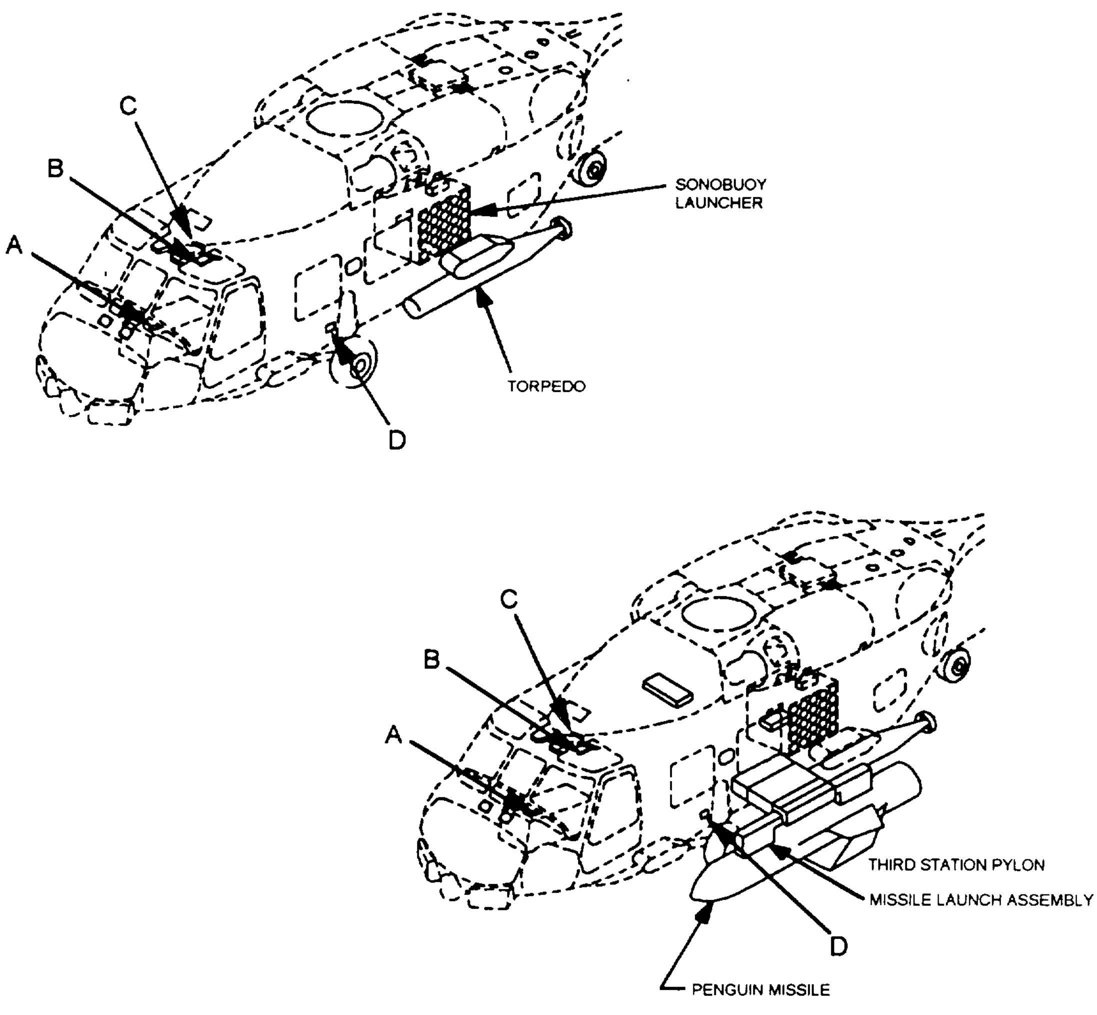


Figure 7-23.-SH-60 (series) search and kill stores.

bottle and the ECU are mounted on top of the launcher assembly. A servicing valve is provided, on the left-hand side of the helicopter, for servicing the air bottle. The air bottle should be serviced to 1200-1250 psi. This ensures that the system will be able to launch all 25 sonobuoys.

The distributor valve assembly uses a stepping motor to route air pressure to the selected launch tube. A manual selection knob, distribution lock, and tube-selected indicator window are located on the valve. The manual selection knob can be hand rotated to move the rotary valve to vent or to any desired launcher tube position. The valve lock allows the rotary valve to be manually secured to any desired launcher tube position or vent. The tube-selected indicator window displays the position of the rotary valve at any one of 25 tubes or vent.

The ECU front panel contains three controls and one indicator. The controls are a AUTO/MANUAL switch, a SELF TEST switch, and a SAFE switch. The indicator is a STATUS display. When the AUTO/MANUAL switch is in the AUTO position, the ECU controls the rotary valve. In the MANUAL position, the rotary valve is controlled by manually turning the manual selection knob. Depressing the SELF TEST switch initiates the BITE testing for the ECU and the launcher. The STATUS indicator displays any faults found during self-test. If more than one fault is found, the failure codes will cycle at 3-second intervals. The SAFE switch causes the rotary valve to move to the vent position.

FIXED-WING KILL STORE SYSTEMS

The kill store system consists of all equipment necessary to select, arm, and release weapons from the bomb bay(s) and wing stations of the aircraft. The system is divided into two subsystems—the bomb bay and the wing store systems.

Bomb Bay System

The bomb bay system consists of the units and components necessary for the carrying, arming, and releasing of stores. On the P-3C, these stores are installed on bomb racks suspended from removable pylon assemblies, which are mounted across the center of the bomb bay. On the S-3A, the racks are attached to brackets mounted to the aircraft in a cruciform pattern. Each of these basic installations is assigned a station number. Numbers followed by letters (such as A or B) designate these stations for special capacities or types of stores. In addition, these stations are arranged in pairs: stations 1 and 2, stations 3 and 4, etc. As a further identification feature on the P-3C, the stations are grouped into two layers. Odd numbered stations in the upper layer and even numbered stations in the lower layer. When the bomb bay is loaded with mixed stores, each pair of stations must be loaded with the same type of store to ensure proper clearance between the stores. The S-3A has only one layer of stations because of its much smaller bomb bays.

The bomb bay doors are electrically controlled and hydraulically operated. For ground maintenance without power, the doors may be opened or closed internally on the P-3C by a manual control valve and hand pump. On the S-3A, the doors can be operated externally with a 3/8-inch drive crank. Both aircraft have a ground safety pin that is used to disable the door mechanism in the open position. The door safety pin must be inserted when personnel are working in the bays.

The release of bomb bay stores is normally accomplished by the computer. In the P-3C, the TACCO performs programming, and the pilot or TACCO controls the release. In the S-3A, the TACCO does both, with the copilot acting as backup. The pilots in both aircraft have final control because they must activate the master arm switch.

Wing Store System

The wing store system consists of the units and components necessary for carrying, arming, and releasing external stores. On the P-3C, these stores are suspended from 10 wing stations, numbered 9 through 18. On the S-3A, the stores are suspended from two wing stations, W5 (left) and W6 (right).

P-3C WING LAUNCHER ASSEMBLY.— The P-3C wing launcher assembly universal pylon is shown in figure 7-24. It consists of a pylon assembly supporting an Aero 65A-1 bomb rack with two Aero 1A adapters, four sway braces, and an emergency release jettison mechanism. Three hoist positions are identified by decals, and are labeled A, B, and C. Their use is determined by the relationship of the store suspension lugs to the center of gravity (CG) of the weapon. The rear sway braces are positioned at a forward or aft mounting position, depending upon weapon length and contour. The forward position is used with 500- and 1,000-pound mines, and the aft position is used with the 2,000-pound mines. The wing launcher fairing is trimmed to fit the wing contour at one station, and is not interchangeable between stations after trimming. Jettison operation of weapons occurs when the jettison solenoid in the wing launcher is energized. The solenoid-actuated linkage connects to the Aero 65A-1 manual release cable. The jettison solenoid and linkage must be cocked before loading.

S-3A PYLON/RACK ASSEMBLY.— The S-3A pylon/rack assembly (fig. 7-25) consists of a pylon supporting a BRU-11A/A ejector rack. The rack is a self-contained unit that performs all the functions of carrying, arming, and releasing the stores. It is controlled by the aircraft armament circuits. The pylon provides structural attachment between the aircraft wing and rack. It also contains the necessary wiring and components to connect the rack to release and status indicating circuits.

HELICOPTER KILL STORE SYSTEM

The kill store system of the SH-3 series helicopter consists of control panels, interconnecting electrical units, and four launchers. The SH-60 series helicopter has either two or three launchers. On the SH-3 series helicopter, the launcher consists of an Mk 8 Mod bomb shackle, an Aero 7 series release unit, mechanical arming units, and accessories varied by location for a particular model. The SH-60 series helicopter uses the BRU-14/A bomb rack attached to the pylons. Each type of helicopter is designed to release and jettison electrically through normal and jettison-release circuits.

FIXED-WING RELEASE AND CONTROL SYSTEM

The functions of the fixed-wing release and control systems are to provide necessary controls and

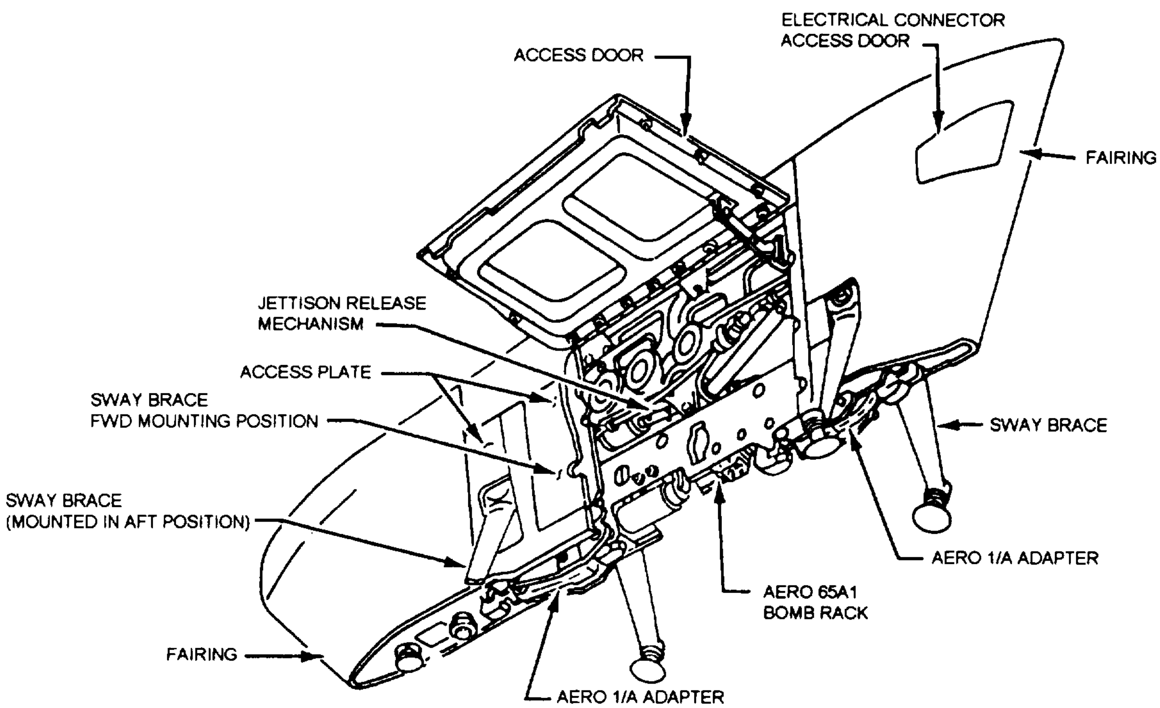


Figure 7-24.-Wing launcher assembly universal pylon.

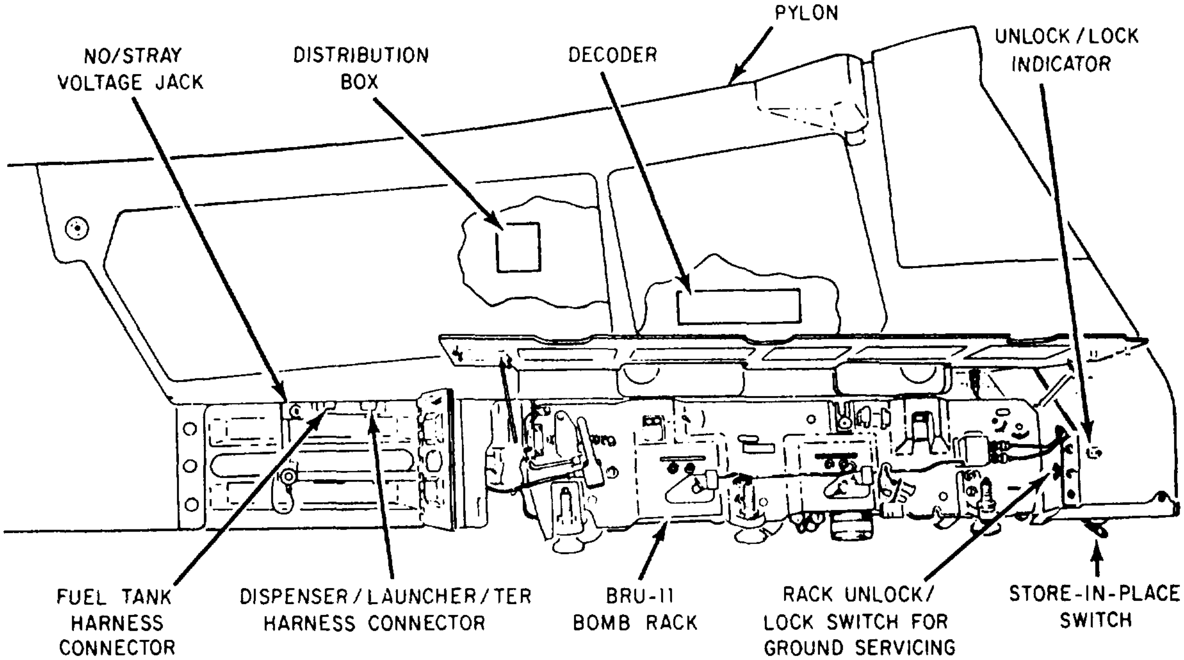


Figure 7-25.-Pylon/rack assembly.

circuitry for control and release of search and kill stores from the aircraft.

In the P-3C aircraft, system control is concentrated between the pilot and TACCO, with the copilot and other crew members having minor control functions. In the S-3A aircraft, the control is concentrated between the TACCO and copilot. The pilot and SENSO also have control functions available. In both aircraft, the pilot has final control over the release of stores through the master arm and search power switches.

The basic operation of the release and control systems of both aircraft are discussed in the following text. Remember, this information is of a general nature. For more detailed information, refer to the aircraft's MIMs.

Operation

The system's primary mode of operation is the automatic (on-line) mode. This mode uses the computer, logic units, crew member's keysets, bomb bay rack lock panel (P-3C), multipurpose data displays, pilot's armament control panel (ACP), and other displays and panels to control and monitor the system. The manual mode uses the same components, less the computer and logic units, through the TACCO's manual weapon control box (P-3C) and the main auto key select on the pilot's ACP (S-3A).

AUTOMATIC MODE.— The automatic mode permits a method of search and kill store management that allows maximum flexibility and control of the system while minimizing the amount of necessary manual action required by the aircrew. In the automatic mode, the system is designed to have the computer and its subsystems perform the following functions:

1. Maintain an up-to-date inventory of all stores on the aircraft and provide weapon inventory that can be called up for display on the TACCO's auxiliary readout (P-3C) or any crew member's MPD (S-3A).

2. Determine the availability of a selected weapon and select the weapon station from which the weapon is to be released (station priority).

3. Energize the armament system relays at the proper time, in the proper sequence, and for the proper time duration to accomplish a store release under joint computer and operator control.

4. Instruct the operator, by cuing via a light display or readout on the MPD, to perform a manual

operation. For example, the computer may cue the operator to turn on the bomb bay door switch and the master arm switch. The P-C3 computer also uses the ordnance panel to instruct the ordnance crew member on how to perform certain pressurized SLT loading or unloading operations (exchange between storage rack and SLTs). This enables the ordnance crew member to make available the search store requested by the TACCO.

5. Present the operator with alternatives for which decisions are required; for example, arming has three selections (nose, tail, or both). The computer also furnishes alerts, such as components or circuit failures and selections errors, to bring important developments to the operator's attention.

6. Calculate and initiate fly-to-point store releases, intervals between releases for train releases, and furnish system release commands in response to crew member release commands.

7. Secure the system following each weapon release, check store-in-place status, update the inventory, and prepare the system for the next store selection.

MANUAL MODE.— In the P-C3, the manual mode provides the TACCO with management control of all kill and search stores. In the S-3A, each crew member controls kill and search stores under the management of the pilot and TACCO conjunctival y.

In the manual mode, the P-C3 TACCO/S-3A pilot selects the bomb bay or wing station for release, along with the arming and release mode of the selected store. These actions are executed by the control on the weapons control panel. If required, the pilot is cued to turn on the master arm switch and open the bomb bay doors.

When the station, arming, and release modes in the P-C3 have been selected, the master arm power will be on, the bomb bay doors will open (if required), and the kill ready lights on the ACP and TACCO manual weapons control panel will illuminate. If the selected station is loaded, the station select keys on the ACP will light amber (S-3A). The store may then be released by the pilot, copilot, or TACCO (also the SENSO in the S-3A) by use of their release switches.

The P-C3 search store release and control in the manual mode is completed by the ordnance crew member using the controls on the search stores interconnection box. The desired SLT is selected by using the letter and number switches. This cues the pilot to turn on the search power switch. When the SLT has been selected and search power is on, a launch is effected by actuating the sono launch switch on the search stores interconnection box.

Jettison

Store jettison of both aircraft is somewhat similar in operation and control. Manual actuation of the jettison or the external jettison switch by the pilot disables the arming circuit and initiates jettison.

In the P-C3, the jettison programmer is energized and sends sequential release and bomb bay door open/close signals. Wing stations are released in pairs (one from each wing) from outboard stations to inboard stations at 2-second intervals. At this same time, the bomb bay doors are opening. Then, the lower stations are released, the upper stations release after the lower stations, and then the doors are closed.

A separate switch on the pilot's console initiates the jettison function for wing stations only. Selective jettison from any station may be accomplished through normal manual release with the arming select (TACCO weapons panel) set on safe.

In the S-3A, the wings and SLTs receive jettison commands from the wing and search store decoders to release all wing stores and 59 SLTs. The SAR chute remains loaded.

Bomb bay stores, wing stores only, and wing stores from auxiliary devices (such as flare launchers) are released by using the ACP AUX rotary switch. This is done according to the load to be jettisoned. In this situation, the mechanical arm thumb-wheel selector must be set to safe, and the arm set switch depressed. Armed store releases may also be initiated in the above reamer.

When the aircraft is on the ground, the jettison circuits of both aircraft are disabled by the weight-on-wheels switches. These switches are located on the right and left main landing gear (main mounts).

REVIEW QUESTIONS

Q1. True or False. The weapons systems in modern aircraft are completely independent of any other systems.

Q2. What should an avionics technician do if the armament switches are in the wrong position?

Q3. What does the checkerboard symbolize on the weapon status indicators?

Q4. What switch is used to enable ground technicians to perform functional checks while the aircraft is on the ground?

Q5. What weapon does not require a weapon code when loaded on stations 4 and 6 on the F-18 aircraft?

Q6. How many bomb bay stations are available on the P-C3 aircraft?

Q7. How many launch chutes are available on the P-C3 aircraft? (Include all pressurized, unpressurized and free-fall chutes.)

Q8. How many sonobuoys can the SH-60 helicopter launch?

CHAPTER 8

COMPUTERS

As late as the middle 1970's, the phrase "kick the tires and light the fires" was the main theme in launching an aircraft sortie. This meant that as long as there was an airframe with nothing falling off, an engine that would start and achieve takeoff speed, and air in the tires, the aircraft would be launched. This was done so the pilots would get their flight time every month. Now the *mission* has become the prime objective of the aircraft. This is not meant to belittle the importance of the engine and airframe. Obviously, they are important, but the aircraft and pilots are designated to perform certain missions. The performance of these missions is dependent upon the status of the various avionics packages. If one or more of these packages are degraded or not working at all, the aircraft is considered to be partial mission capable or not mission capable.

This lack of mission capability has thrust many an avionics work center supervisor into the spotlight. If you are one of the supervisors who has been there, then you know how *pleasant* the maintenance chief is to you. It is then that you realize that aircraft maintenance is not a game. As we head toward the 21st century, newer and more sophisticated aircraft are being designed and built. The avionics systems are becoming more complex, thus allowing the aircraft to perform more difficult missions. The increased complexity forces the solutions to problems in microseconds. The only system capable of performing these solutions is the computer. In turn, each associated avionics system will act as a sensor that feeds continuously updated information to the computer. The computer processes the data and sends out information to where it is needed.

Because computers are used so extensively in Navy aircraft, the avionics supervisor must have a basic understanding and working knowledge of computers.

COMPUTER MAKEUP

Learning Objective: *Identify computer hardware and software.*

The electronic components of a computer are commonly called *hardware*. Examples of computer hardware are cathode-ray tubes, transistors, microchips, printed circuit cards, etc. *Software,* on the other hand, is a term that is applied to a set of computer programs, procedures, and possibly associated documentation concerned with the operation of a data processing system. Software includes compilers, assemblers, executional routines, and input/output libraries. The advances in computer software provide the industry with the greatest realm of application possibilities. The problem of attempting to communicate with a computer has led to the development of symbolic languages that approach human language. The fact that a person can tell a computer what to do, just as one directs the actions of another person, has been made possible by the advances in software.

Software is also used to overcome design deficiencies in computers. Programming around design deficiencies is a common practice in the computer industry. Software is, in fact, often used to determine design feasibility. The practice of designing a computer with a computer is a common practice of design engineers.

Perhaps the best software application has been in the area of real-time processing. Real-time processing is a situation where the data is submitted to a computer, and an immediate response is obtained. The capability of a computer to perform real-time processing could determine the success or failure of an aircraft's mission.

Programming in a universal language has led to the development and refinement of a number of computer languages. Many of these languages are for a special area or purpose. For example, FORTRAN (FORmula Translator) for business and scientific programs, COBOL (COmmon Business Oriented Language) for business, and Jovial for large scale, computer-based, command and control systems. PL/1 (Programming Language/one) is a language for real-time systems. Each of the languages fulfills a specific need for a specific problem, but lacks the universal ideal application.

COMPUTER APPLICATIONS

Learning Objective: *Identify computer applications.*

Computer applications fall into a variety of broad categories. Information retrieval is one such application, or in a narrower sense, indexing or cataloging. Information is stored under a variety of key words or index headings. By calling up one of these headings, a listing of all or part of the information will be outputted by the computer.

Another application is simulation. This involves simulating the operation of a new computer by using an older computer model. In this way, design deficiencies can be identified without going through the time-consuming and expensive process of building the newer unit.

Real-time control of a production process is another application. For example, the petroleum and chemical industries put this process to good use. The computer can detect minute changes in the production process and initiate immediate corrective action.

The advent of personal (home) computers has greatly expanded the computer-use horizon from the routine upkeep of a checkbook balance to the more complex functions of financial planning, home security, and computer video games.

The application of the computer and its functions is virtually endless. For this reason, there are some people who believe that the computer will soon control everything and everyone. This is not necessarily the case, however, as computers can do only what their creators have intended them to do. The computer enables people to do more than they have been able to do in the past. For example, computations that required years to calculate by human methods can now be accomplished in a matter of moments by modern computers. This has become particularly evident in our space program. The ability to put a man on the moon and send *Voyager I* and *Voyager II* on their journeys would have been impossible without the use of computers. Fears over job losses are, for the most part, needless. While some jobs may be eliminated, new ones are created. Thus, a worker may have to learn a new skill. For example, a laborer may have to be retrained as a computer programmer or operator. Rather than destroying jobs, the computer creates opportunities where none existed before.

TYPES OF COMPUTERS

Learning Objective: *Identify the types of computers and the analytical processes used by each type.*

In general, there are two basic types of computers— *analog* and *digital.*

ANALOG COMPUTERS

The term *analog,* as applied to computers, pertains to representation by means of continuously variable physical quantities. For example, an analog computer can be a device that solves problems by setting up electrical circuits that represent the physical equivalents of certain phenomena. Then, measurements are made as these circuits are varied in accordance with changes in the phenomena. The analog computer is by no means restricted to electrical circuits as equivalents. The physical equivalents may be gear trains, gases, fluids, etc.

Analog computers, because of their nature, have some inherent limitations. The use of physical equivalents limits their versatility. They are limited to performing only the tasks for which they were designed or, in certain instances, closely related tasks.

DIGITAL COMPUTERS

A digital computer is a device that solves problems by manipulating the numerical equivalents of phenomena in accordance with mathematical and logical processes. These numerical equivalents may be expressed as binary numbers, octal numbers, decimal numbers, etc. In an electronic digital computer, the numerical equivalents are generally expressed as binary numbers 1 or 0. Values of voltage and current are used to represent the 1s and 0s.

The versatility of digital computers is based on the fact that they use numerical equivalents not only to represent the data to be processed, but also the instructions for processing the data. In other words, digital computers are generally provided with a wide variety of instructions. They are designed to respond in certain ways to the numerical equivalent of these instructions. Programming is merely a matter of modifying and/or arranging these instructions so that the computer will respond in a predictable manner to a given situation. While much more versatile than an analog system, digital systems are still limited as to the variety of tasks they can perform by the following factors:

- The design of their central processors

- The variety of input/output devices used

- The programmer's capability to develop a numerical method for representing and solving the problem

There are two basic types of digital computers—the special-purpose and the general-purpose computer.

Special-Purpose Digital Computers

Special-purpose digital computers are designed to follow a specific set of instruction sequences that are fixed at the time they are manufactured. To change the operation of this type of computer, the actual construction of the machine has to be altered.

General-Purpose Digital Computers

General-purpose digital computers follow instruction sequences that are read into and stored in memory prior to the calculation performance. This type of computer operation can be altered by inputting a different set of instructions. Since the operation of general-purpose digital computers can be changed with relative ease, as compared to special-purpose computers, they provide a far greater usage flexibility.

DIGITAL COMPUTER OPERATION

Learning Objective: *Recognize the operating principles of a digital computer.*

Each major section of the digital computer is comprised of various electrical circuits. These circuits include flip-flops (bistable devices), amplifiers, gates (such as AND and OR gates), and passive memory elements. These elements are organized into registers, counters, and gates. Registers are a series of electronic devices for temporary storage of a binary word. Counters are a series of electronic devices that progress through a specific binary sequence. The gates are used to set a flip-flop or generate a times condition signal. The computer manipulates binary numbers representing numerical values or conditions. Devices to retain these binary figures comprise the majority of the computer registers, and each register has a distinct purpose or function. Many operations require that the binary word or data be transferred from one register to another. It is possible for several different words to be transferred simultaneously.

Gates are used to control the transfer of data words from one register to another. These gates consist of diode and resistor networks. The gate circuit generates a signal to transfer the contents of one register to another at a particular time if certain conditions are met. For example, if the instruction being executed is an add, and if one of the numbers being added is a negative number, then the gate will generate a command signal. If these conditions are not met, the gate will not generate the command signal.

Several gates in the computer are active only during specific instructions, such as divide or multiply, and then only during that particular instruction. On the other hand, some gates are active during several instructions, generating command signals. In the design of a computer, each instruction that the computer is to perform is very methodically analyzed, and for each signal required, a gate is designated to generate the signal.

The size of the registers determines the general size of the computer. Not all registers in the computer have the same word length. Some are determined by the accuracy required, while others are determined by the instruction word, number of addresses in the memory, and various other parameters.

DIGITAL DATA PROCESSOR

Learning Objective: *Referring to various schematic and block diagrams, recognize the components of a digital data processor and the function(s) of each.*

Figure 8-1 is a functional block diagram of a digital data processing set. Of the processes that take place within a computer, the manipulation of data is

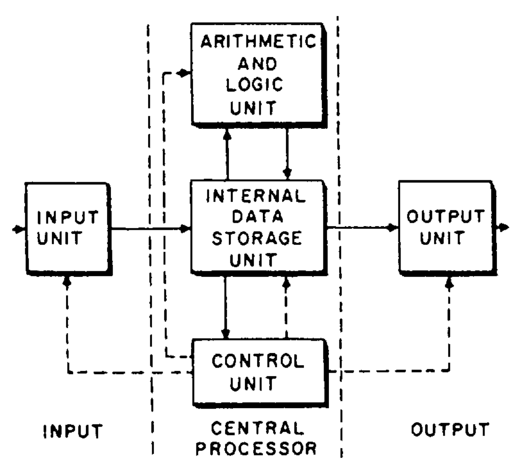


Figure 8-1.-Digital data processor block diagram.

the most important. This data manipulation takes place within the central processor (CP) (area encompassed by vertically dashed lines). The CP consists of three basic units. These units are as follows:

- Control unit—This unit directs the overall operation of the computer in accordance with a prescribed plan.

- Arithmetic-logic unit-This unit performs the actual processing.

- Internal data storage unit-This unit stores the data to be processed and the prescribed plan (program).

CONTROL UNIT

In a typical digital computer, the control section includes the instruction register, the P register, the general register(s), and the SC register. A brief explanation of each type of register follows:

- Instruction register—This register holds the instruction code during execution. The size of the register is dependent upon the instruction word and makeup of the computer. The instruction code usually has more than one part or field.

- P register—This register contains the address of the next sequential instruction to be executed. The contents of the P register are automatically advanced by one by the P + 1 adder.

- General register—This register stores the quantity used for address modification. In addition, it usually has the properties of automatic increment or decrement. Most computers have more than one general register.

- SC register—This register consists of one or two registers to accomplish the holding of a shift count. Its size is dependent on the maximum number of places that a word can be shifted.

An easy way to comprehend the operation of the control unit is to draw a comparison to a telephone exchange. The act of dialing a phone number energizes certain switches and control lines in a telephone exchange. In a similar manner, each program instruction, when executed, causes the control section to energize certain “switches” and “control lines.” This enables the computer to perform the function or operation indicated by the instruction.

A computer program can be stored in the internal circuits of the computer, or it may be read instruction-by-instruction from external media. The internally stored program type of computer is the most practical type to use when speed and fully automatic operation are desired. This type of computer is known as a stored-program computer.

In addition to the command that tells the computer what to do, the control unit also dictates how and when each specific operation is to be performed. It is also active in initiating circuits that locate information stored in the computer and in moving this information to the point where the actual manipulation or modification is to be accomplished.

In the stored-program computer, the control unit reads an instruction from the memory section. The information read into the control unit from memory is in the form of varying voltage levels that make up the binary word. This word represents a specific operation that is to be performed. The location of the data to be operated on is generally a part of the instruction and energizes circuitry that causes the specified operation (add, subtract, compare, etc.) to be executed. Subsequently, the control unit reads the next instruction or jumps as directed to find the next instruction to execute.

Computer instructions are broken down into four general categories. The instructions are transfer, arithmetic, logic, and control.

Transfer commands transfer data from one location to another. One of the instructions is usually an address in memory, and the other is either a register or an input/output device.

Arithmetic instructions combine two pieces of data to forma single piece of data by using one of the arithmetic operations. In some computers, one of the pieces of data is in a location specified by an address contained in an instruction. The other piece of data is already in a register (usually the accumulator). The results are usually left in the accumulator.

Logic instructions make the digital computer much more than an expensive adding machine. The use of logic instructions enables the programmer to construct a program capable of a number of tasks. These instructions enable a computer used for inventory maintenance to follow one set of procedures if an inventory item count is too high, and another if the count is too low. The choice of which set of procedures to use is made by the control unit under the influence of the logic instructions. Logic instructions provide the computer with the ability to make decisions based on the results of previously generated data.

Control instructions send commands to devices not under direct control of the control unit, such as input and output units. The address portion of the control instruction does not specify a location in memory, but is usually a coded group that specifies an action be required of a particular piece of equipment.

In a single-address computer, where each instruction refers to only one address or operand, the instructions are normally taken from the memory in sequential order. If one instruction comes from a certain location, such as X, the next instruction is usually taken from location X + 1. However, the execution of a logic instruction may produce a result that dictates that the next instruction is to be taken from an address as specified in a portion of the logic instruction. For example, the logic instruction may initiate certain operations in the computer to determine if the content of a given register in the arithmetic section is negative. If the answer is yes, the location of the next instruction is specified in an address section of the logic instruction. If the answer is no, the next instruction would be taken from the next sequential location in the memory.

Every computer provides circuitry for a variety of logic instructions, thus providing the capability of selecting alternate instruction sequences if certain desirable or undesirable conditions exist. The ability to branch at key points is the special feature of the computer that makes it able to perform such diverse tasks as missile control, accounting, and tactical air plotting.

ARITHMETIC-LOGIC UNIT

The arithmetic-logic unit (ALU) is the section in which arithmetic and logic operations are performed on the input or stored data. The operations performed in this unit include adding, subtracting, multiplying, dividing, counting, shifting, complementing, and comparing.

Generally, information delivered to the control unit represents instructions, while information routed to the arithmetic unit represents data. Frequently, it is necessary to modify an instruction. This instruction may have been used in one form in one step of the program, but must be altered for a subsequent step. In such cases, the instruction is delivered to the arithmetic unit where it is altered by addition to or subtraction from another number in the accumulator. The resultant modified instruction is again stored in the memory unit for use later in the program.

All arithmetic operations can be reduced to one of four processes: addition, subtraction, multiplication, or division. In most computers, multiplication involves a series of additions, and division is a series of subtractions.

The arithmetic unit contains several registers. Each register is a unit that can store one “word” of computer data. These registers generally include the D, X, and Q register, and a unit called the accumulator (A register). The registers are so named for identification purposes only. During an arithmetic process, the D, X, and Q registers temporarily hold or store the numbers being used in the operation. These numbers are called the operands. The accumulator stores the result of the operation. The control unit instructs the arithmetic unit to perform the specified arithmetic operation as requested by the program. The control unit transfers the necessary information into the D, X, and Q registers from memory and controls the storage of the results in the accumulator or in some specific location in memory.

The arithmetic unit also makes comparisons and produces yes or no or GO/NO-GO outputs as a result. The computer can be programmed so that ayes or GO result causes the computer to perform the next step in the program, while a no or NO-GO result causes the computer to jump several steps in the program. A computer can also be programmed so that a no result at a certain point in the program will cause the computer to stop and await instructions from a keyboard or other input device.

INTERNAL DATA STORAGE UNIT

In some digital computers, the internal data storage unit, or memory section, is constructed of small, magnetic cores, each capable of representing anon or off condition. An on condition is represented by a 1 and an off condition is represented by a 0. A system of these cores arranged in a matrix can store any computer word that is represented in binary form.

All computers must contain facilities to store computer words or instructions until these instructions or words are needed in the performance of the computer calculations. Before the stored-program type of computer can begin to operate on its input data, it is first necessary to store, in memory, a sequence of instructions and all numbers and other data that are to be used in the calculations. The process by which these instructions and data are read into the computer is called *loading.*

The first step in loading instructions and data into a computer is to manually place enough instructions into memory by using the console or keyboard. These instructions are then used to bring in more instructions as desired. In this manner, a few instructions are used to “bootstrap” more instructions. Some computers use an auxiliary (wired) memory, which permanently stores the bootstrap program, thereby making the manual loading unnecessary. These instructions may be stored in chips. These chips are referred to as “read only memories” or ROMs.

The memory section of a computer is essentially an electronically operated file cabinet. It is actually a large number of storage locations. There are generally between 1 and 40,000 locations. Each one is referred to as a storage address or register. Every computer word that is read into the computer during the loading process is stored or filed in a specific storage address and is almost instantly accessible.

The types of memory storage devices used most frequently in present-day computer technology are magnetic cores, semiconductor, thin film, magnetic drum, magnetic tape, and magnetic disks.

Magnetic Cores

One of the methods for storing internal data in a computer is realized by using magnetic cores. Cores are generally constructed by two methods. The first type of core, called a tape wound core, is fabricated by wrapping a tape of magnetic material around a nonmagnetic toroidal form. A *toroid* is a term used to describe a doughnut-shaped solid object. The second type of core is called a ferrite core, and it is made by molding finely ground ferrite into a toroidal form. The ferrite used in this application is a ceramic iron oxide possessing magnetic properties. The ferrite particles are then heat-fused or “sintered” by the application of heat and pressure.

In magnetic core memories, each data bit is stored in the magnetic field of a small, ring-shaped magnetic core (fig. 8-2). Magnetic cores generally have four wires running through them. Two wires are used for READ selection. These same two wires are used for WRITE by reversing the direction of current flow. An inhibit wire prevents writing a 1 when a 0 is to written. The sense wire picks up the signal voltage generated by the shifting of core from 1 to 0 in a READ cycle.

Since a single core stores only one bit of a word, a large number of cores are required to handle all the bits in every word to be stored. These cores are arranged in arrays to assign memory address locations and quickly write data and locate data for read-out purposes. The technique used most frequently for writing and reading data in magnetic core arrays is known as the coincident-current technique.

In computer memory applications, the ferrite core is magnetized by a flux field produced when a current flows in a wire (drive line) that is threaded through the core. The core retains a large amount of this flux when the current is removed. Flux lines can be established clockwise or counterclockwise around the core, depending on the direction of the magnetizing current. A current in one direction establishes a magnetization in a given direction. Reversing the direction of the current flow reverses the direction of the flux field and the core magnetization. These two unique states represents 0 and 1, respectively.

Semiconductor Memories

Semiconductor memories are used in many modern computers. Most of the semiconductor memories are of the MOS LSI type, which may be

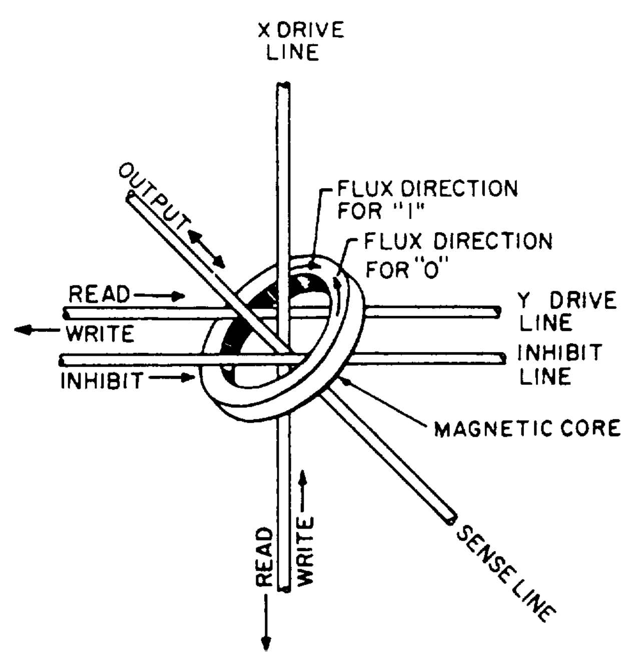


Figure 8-2.-Magnetic core showing X, Y, inhibit, and sense lines.

static or dynamic. MOS means metal oxide semiconductor, and LSI means large scale integration.

Thin Film

Thin film memory consists of Permalloy, a ferromagnetic material, deposited on a supporting material (substrate) of thin glass. This is done under controlled conditions in a vacuum chamber. When all air has been removed from the chamber, a shutter arrangement is opened, and vapors from molten Permalloy pass through a mask and are deposited on the supporting material. The pattern thus formed is determined by the shape of the mask. The thickness of each spot (magnetized area) is controlled by the amount of time the shutter is open.

A magnetic field is applied parallel to the surface of the substrate during deposition. The film spots become easier to magnetize in the direction parallel to that in which the magnetic field was applied during the deposition process. This direction is known as the preferred direction; likewise, the axis of this magnetism is called the preferred axis.

Magnetic Drums

The magnetic drum storage device is a cylinder that rotates at a constant velocity. Information is written on or read from the drum when its magnetic surface passes under magnetic heads, which are similar to the magnetic heads found on commercial tape recorders.

Magnetic drums provide a relatively inexpensive method of storing large amounts of data. A magnetic drum (fig. 8-3) is made from either a hollow cylinder (thus the name drum) or a solid cylinder. The cylinder may consist entirely of a magnetic alloy, or it may have such an alloy plated upon its surface. Many drums are made by spraying on magnetite, an iron oxide. The surface is then coated with a thin coat of lacquer, and buffed.

Representative drums have diameters ranging from 12.7 to 50.8 centimeters (about 5 to 20 inches respectively). The surface of the drum is divided into tracks or channels that encircle the drum. A number of READ and WRITE heads are used for recording and reading. There is at least one head per track. The drum is rotated so that the heads are near, but not touching, the drum surface at all times.

As the drum rotates, the tracks are continuously passing under their respective head. Each track is subdivided into cells, each of which can store one binary bit. All the cells that are positioned under the heads of a multitrack drum at the same time are called a "slot." With some drums, each head reads or writes one bit of a word. Thus, when a word is written into or read from a slot, each track contains one bit of that word. The number of heads used depends on the size of the word that the computer is designed to handle.

One of the tracks provides timing signals for the drum rotation. The timing track determines the location of each set of storage cells around the drum. Each timing signal denotes a unit of time of drum rotation. For example, if the timing track is 80 inches long and timing signals are recorded at 120 pulses per inch, there are 9,600 locations for bit storage on the track. If the drum has 32 tracks in addition to the timing track, the drum has the capacity to store a total of 307,200 bits.

Some drums use two or even three timing tracks. The timing tracks are used for synchronization purposes and are sometimes called "control" or "clock" tracks. The timing pulses establish the time scale to which all circuits through the computer are synchronized.

The retrieval of data from a rotating drum can be a rather involved process, as can be realized by drawing a comparison to the core memory of a computer. When core memory is used, all the data is stored in the cores in a static condition. The data can be located at a given place at any instant, and can be easily read from that location in serial or parallel form

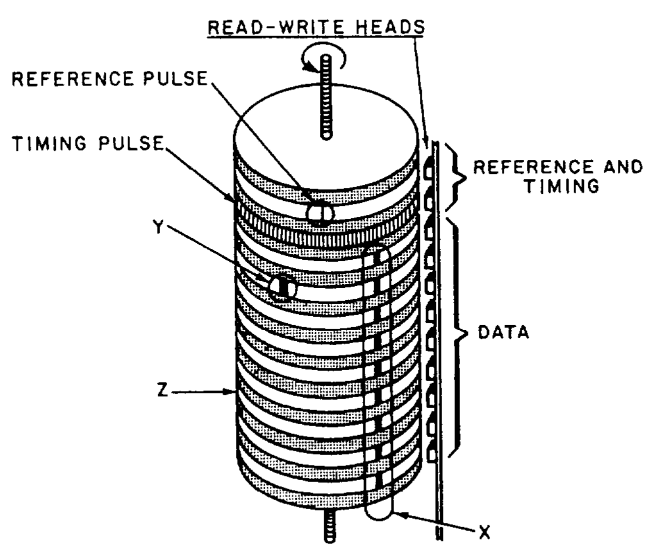


Figure 8-3.-Magnetic drum.

to represent the same data that was stored in that location.

Transfer of the data from constantly rotating magnetic drums, on the other hand, is complicated. Timing pulses are not used to synchronize the drum speed, which may vary slightly from time to time. Thus, some method must be used to ensure that data read into the drum memory in a given bit position will be read from the memory with the same time reference. The probability y of an incompatible time relationship between the drum speed and synchronizing pulses makes it necessary to establish some means of compensating for variations in drum speeds.

In practice, the drum contains a control point and a number of sectors in a specific format. The control point is a magnetic mark that specifies a starting location on the drum. All data stored on the drum is referenced to this indexing point or reference pulse, as shown in figure 8-3.

Magnetic Tapes

Magnetic tape is widely used as a storage medium for large amounts of data, or it may be used as a main storage backup. However, it is normally not used as an internal (main) storage medium because of its long access time. This is readily realized if you consider that needed information is widely, and sometimes randomly, distributed along the tape. Magnetic tape has two main advantages—its large storage capacity and its low cost.

Magnetic Disks

The magnetic disk is a convenient medium for semipermanent storage of mass volumes of production programs. For many applications, disks

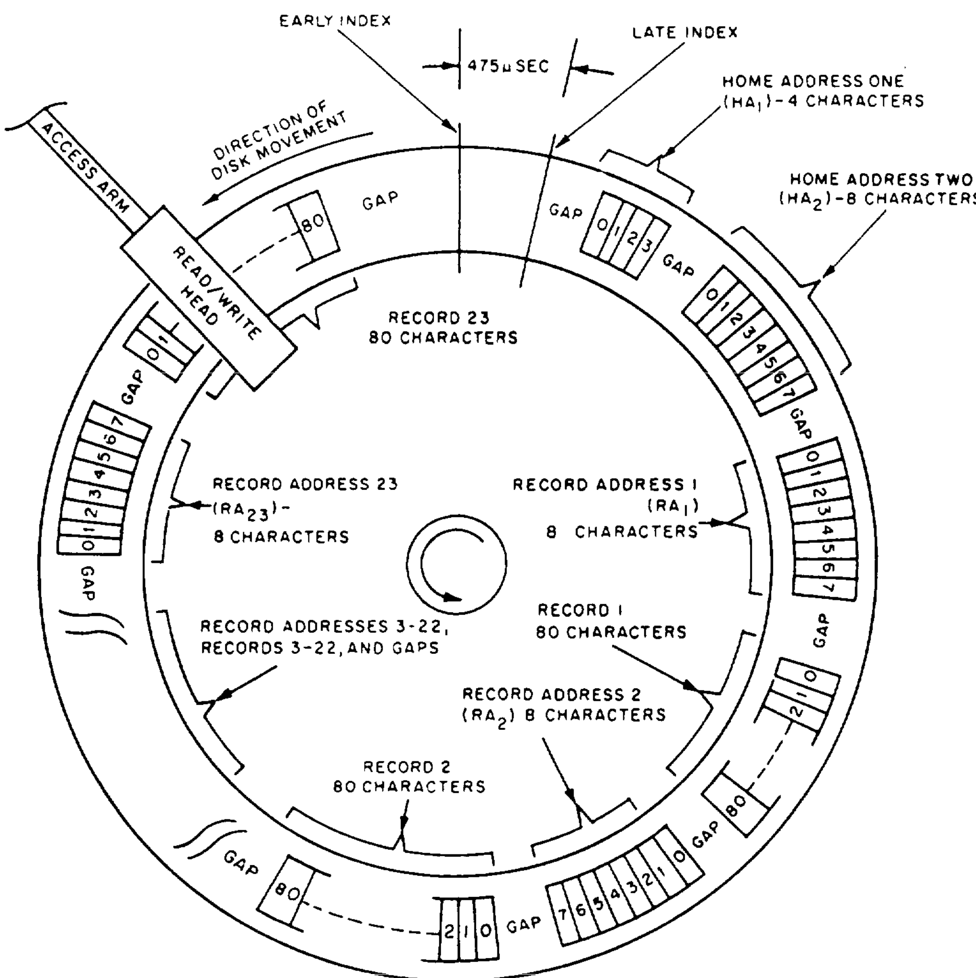


Figure 8-4.-Circular data track.

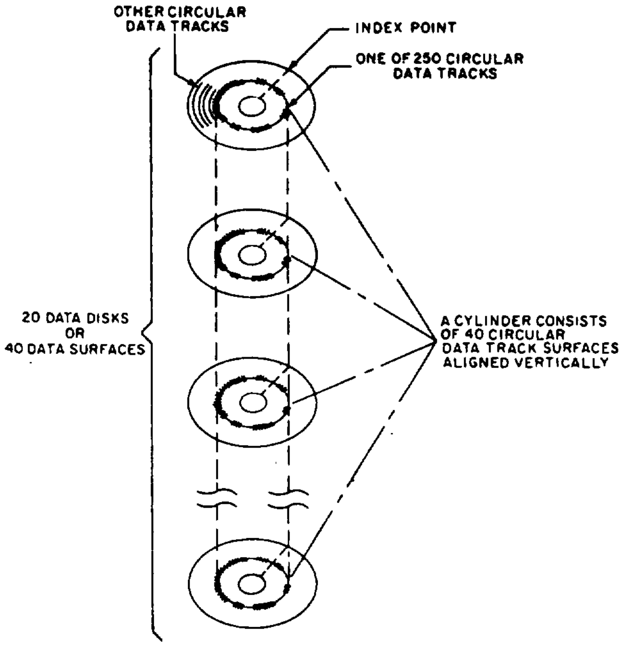


Figure 8-5.-Data storage disk assembly.

are superior to magnetic tapes for rapid acquisition and storage of mass volumes of system programs and data.

Magnetic disks resemble phonograph records that have been coated with iron oxide. The disks are arranged in stacks in much the same way as a record stack in a jukebox. All the disks are continuously revolving and spaced apart so that a record head driven by an access mechanism can be positioned between the disks.

Data is recorded at a certain address on a specified disk. When readout of a particular bit of data is desired, the recording head is automatically positioned, and the data is read serially from the surface of the selected disk.

The basic unit of information on the disk is called a character. By design, each character contains a given number of bits for fixed-word applications. One or more of these characters in a group form a record. A circular data track (fig. 8-4) consists of one or more records, associated record addressees, gaps, and data track identification. A number of data tracks aligned on vertically arranged disks (fig. 8-5) form a cylinder of information. A magnetic disk file system may contain one or more bands (modules). Each module contains a specified number of disks with their associated cylinders and data tracks. The flow chart in figure 8-6 illustrates the procedures necessary to retrieve or store information.

INPUT/OUTPUT (I/O) SECTION

Learning Objective: *Describe how a digital computer communicates with external peripheral devices.*

The I/O section is that portion of the digital computer through which the CPU communicates with the external peripheral devices. In a useful computer function, data is read into the computer, processed, and then transferred to the output. The peripheral units handle the data input and output display functions. The I/O section controls the transfer of data between the computer and the peripherals.

The I/O section is the interface between the computer and any extenal devices. An interface is an assembly of electronic circuits that make the computer compatible with the peripheral units. This

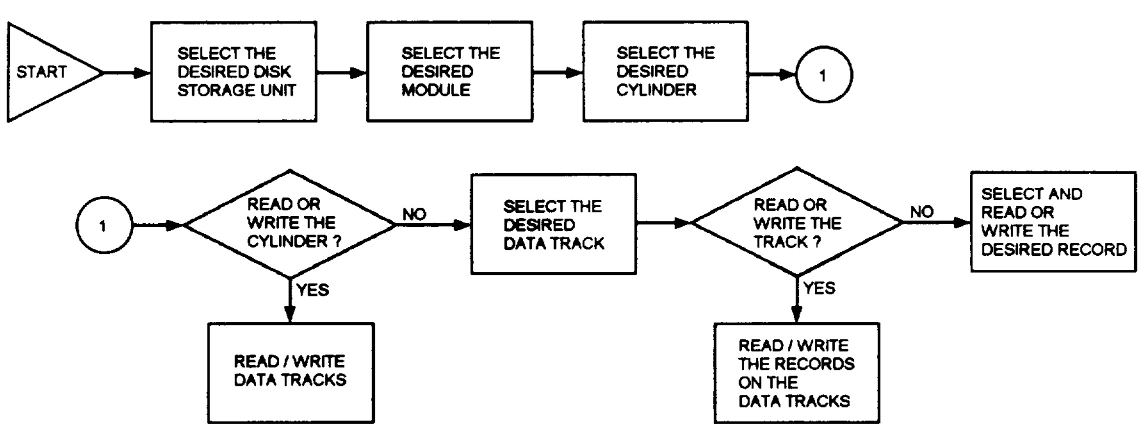


Figure 8-6.-Flow chart for storage and retrieval of data from disks.

compatibility permits the computer and the peripheral units to communicate intelligently. The compatibility involves logic levels, timing or speed, and control.

When digital data is transmitted between two units, the binary voltage or current levels must be compatible. Logic-level conversion is often required to properly interface different types of logic circuits. For example, logic-level shifting is often required to properly interface bipolar and MOS circuits. The speed of the data transmission must also be compatible. Some type of temporary storage between the two units may be required as a buffer to match the high-speed CPU to a low-speed peripheral unit.

Control is another function of the interface. There are status lines that tell when the computer or peripheral unit is ready or busy, and strobe lines that actually initiate the data transfers. This process is often referred to as "handshaking."

The type of information exchanged between the I/O unit and the peripheral devices includes data, addressing, and control signals. Since multiple I/O units can usually be connected to a computer, some coding scheme is required to select the desired unit. This is usually done with a binary word used as an address. The address is transmitted to all the peripheral devices. The unit recognizing the address is connected to the I/O section. Data can then be transmitted to or from the device over the interconnecting data lines. The actual data transfers are controlled by control signals between the two devices.

Programmed data transfers that take place as the result of executing an I/O instruction usually cause the data to be transferred between the peripheral unit and the accumulator register in the CPU. Other CPU registers may also be used, depending upon the computer architecture and the instruction. In some computers, peripheral units are addressed as storage locations, and all memory reference instructions can be used in performing I/O operations. No special I/O instructions are used in these computers.

PARALLEL VERSUS SERIAL DATA TRANSMISSIONS

There are two methods of transmitting digital data. These methods are parallel and serial transmissions. In parallel data transmission, all bits of the binary data are transmitted simultaneously. For example, to transmit an 8-bit binary number in parallel from one unit to another, eight transmission lines are required. Each bit requires its own separate data path. All bits of a word are transmitted at the same time. This method of transmission can move a significant amount of data in a given period of time. Its disadvantage is the large number of interconnecting cables between the two units. For large binary words, cabling becomes complex and expensive. This is particularly true if the distance between the two units is great. Long multiwire cables are not only expensive, but also require special interfacing to minimize noise and distortion problems.

Serial data transmission is the process of transmitting binary words a bit at a time. Since the bits time-share the transmission medium, only one interconnecting lead is required.

While serial data transmission is much simpler and less expensive because of the use of a single interconnecting line, it is a very slow method of data transmission. Serial data transmission is useful in systems where high speed is not a requirement. Serial data transmission techniques are widely used in transmitting data between a computer and its peripheral units. While the computer operates at very high speeds, most peripheral units are slow because of their electromechanical nature. Slower serial data transmission is more compatible with such devices. Since the speed of serial transmission is more than adequate in such units, the advantages of low cost and simplicity of the signal interconnecting line can be obtained.

PARALLEL DATA TRANSMISSION

In a parallel data transmission system, each bit of the binary word to be transmitted must have its own data path. There are a variety of ways to implement this data path. The two basic classifications of transmission line circuits are single-ended and balanced. Single-ended transmission systems use a single-wire data path for each bit. When combined with a ground or return reference, the electrical circuit between the sending circuit and the receiving circuit is complete. In a balanced transmission line system, two conductor cables are used to send the data. The data on the dual-transmission line is complementary. The dual-transmission lines also use a ground return reference. While a single-ended transmission line is simpler and less expensive, it is subject to more noise problems than the balanced or dual-transmission line system.

SERIAL DATA TRANSMISSION

The simplest, most economical, and easiest to use method of transferring digital information from one point to another is serial data transmission. In a serial system, the digital data is sent one bit at a time. This means only one pair of transmission wires is required. The serial transmission of data is far slower than parallel transmission. In most computer systems, the low speed is not a disadvantage. Data rates achievable in serial data systems are sufficiently high to make them very practical.

Serial data transmission is preferred because it is inexpensive. It is especially beneficial in transferring data over long distances. For long distances, you can see that multiple parallel lines are far more expensive than a single cable.

Low-speed serial data transmission also offers another benefit. The data rate is slow enough to permit the transmission of data over telephone lines. In this case the digital data is converted into a pair of audio tones representing binary 1s and 0s. These can be transmitted economically for long distances over standard telephone lines. In addition, low cost tape recorders can be used to record the serial data. This provides a low cost means of mass data storage and retrieval. Standard audio cassette recorders are widely used in this application.

Serial data transmission also permits transmission of data by radio. A radio communications path represents only a single interconnecting link similar to a transmission line pair. Therefore, for data to be transmitted by radio, it must be in serial format. Serial digital data is used to modulate a radio carrier in various ways.

In digital computer systems, you will find that both serial and parallel data transmission methods are used. Where high speeds and short distances are required, the parallel method is used. The serial method is used where low cost, simplicity, low speed, and long distances are necessary.

INPUT/OUTPUT (I/O) DEVICES

I/O devices are similar in operation but perform opposite functions. It is through the use of these devices that the computer can communicate with devices external to the computer itself (peripheral devices).

The I/O section of a computer provides the necessary lines of communication and generates such signals necessary for the computer to communicate with, and when necessary, control the operation of the I/O devices. The I/O section, once it has been initiated by the control section, usually operates independently of the control section, except when it must time-share memory with the control section.

Input Devices

Input data may be in any one of three forms:

- Manual inputs from a man-machine interface (MMI), such as a keyboard or console
- Analog and/or digital inputs from instruments or sensors
- Inputs from a source on or in which data has been previously stored in a form intelligible to the computer

Computers can process hundreds of thousands of computer words per second. Thus, a study of the first method (manual input) reflects the inability of human-operated keyboards or keypunches to supply data at a speed that matches the speed of digital computers. A high average speed for keyboard operation is two or three characters per second. This actually translates to a data input rate of less than one computer word per second due to coding time. Since the computer can read several thousand times this amount of information per second, it is clear that manual inputs should be minimized to make more efficient use of computer time.

Instruments used as input sensors are capable of supplying several thousand samples regarding pressure, temperature, speed, and other measurements per second. This is equivalent to 10,000 to 20,000 bits or binary digits per second. Digital computers that use these devices must be equipped with analog-to-digital (A/D) converters (assuming the input is in an analog format) to convert physical change to specific increments.

Input data that has been previously recorded on punched cards, perforated tapes, magnetic tapes, or magnetic drums or disks in a form understood by the program may also be entered into the computer. This method is much faster than entering data manually from a keyboard. The most commonly used input devices in this category are magnetic tape readers and paper tape (perforated tape) readers.

One of the main features of computers is their ability to process large amounts of data quickly. In most cases, the processing speed far exceeds the ability of input devices to supply information. One common limitation of most input devices is that each involves some mechanical operation. For example, the movement of a tape drive or card feeder. Because a mechanical movement of some part of these devices cannot take place fast enough to match electronic speeds with the computer, these input devices limit the speed of operation of the associated computer. This is particularly evident in cases where successive operations are dependent upon the receipt of new data from the input medium.

Several methods of speeding up mechanical operation have been devised, all of which are designed to move a smaller mass a shorter distance and with greater driving force. Many of these designs have been directed toward increasing the drive speed of magnetic tapes. For example, present-day tape drives can pass up to 400 inches of tape per second of a tape reading head. Card readers can read up to 2,000 cards per minute. Present-day disk systems operate at speeds up to 3,600 RPM.

The comparative rates of data for these systems are as follows:

- Card systems—2,700 characters per second
- Tape systems—350,000 characters per second
- Disk systems—15,000,000 characters per second

Another method of entering data into a computer, which we have not previously mentioned, is to link two or more computers together and program them to communicate with each other. This is perhaps the fastest method of entering or extracting data from a computer. An example of this method is the data link.

Output Devices

Output information is also made available in three forms:

- Displayed information, such as codes or symbols presented on a monitor screen, that is used by the operator to answer questions or make decisions.

- Control signals, which is information that operates a control device, such as a lever, aileron, or actuator.

- Recordings, which is information stored in a machine language or human language on tapes or printed media.

Devices that store or read output information include magnetic tapes, punched cards, punched paper tapes, monitors, electric typewriters, and high-speed printers.

INTEGRATED CIRCUIT (IC) TECHNOLOGY

Learning Objective: *Identify integrated circuit classifications and various types of integrated circuits.*

Modern digital computers are made with ICs. ICs provide the most economical and practical method of implementing the circuits required to carry out the functions of a digital computer.

IC CLASSIFICATIONS

ICs fall into four basic levels of complexity. These are small scale integration (SSI), medium scale integration (MSI), large scale integration (LSI), and very large scale integration (VLSI). The designations define the size and complexity of individual ICs.

Small Scale Integration (SSI)

SSI circuits contain very little circuitry, generally fewer than 10 circuits no more complex than a typical logic gate. Typical SSI circuits include multiple logic gates, flip-flops, and simple combinational logic circuits.

Medium Scale Integration (MSI)

MSI circuits are more complex and sophisticated than SSI circuits. Most MSI circuits contain 12 or more circuits equivalent in complexity to a typical logic gate. MSI circuits are functional in nature in that the y perform a specific logic operation with no further interconnection. Typical MSI circuits include counters, shift registers, arithmetic-logic circuits, decoders, multiplexer, and other combinational and sequential logic circuits. MSI circuits are highly beneficial because they significantly cut design time. They also reduce the number of ICs in design, minimize circuit wiring, and reduce size and power consumption. Most digital equipment can be implemented by simply combining the proper MSI circuits.

Large Scale Integration (LSI)

LSI circuits are large and complex, and generally contain circuitry equivalent to 100 or more typical logic gates. LSI circuits are also functional in nature. Typical LSI ICs include memories and microprocessors.

Very Large Scale Integration (VLSI)

VLSI circuits are large, complex circuits that contain the equivalent of 1,000 or more logic gates.

Early digital computers use a mix of SSI MSI, and LSI circuits. Over the years, the trend has been toward the greater use of MSI, LSI, and VLSI circuits. Today, most computers are predominately MSI, LSI, and VLSI circuits. The SSI circuits are used only in interfacing the other three larger and more sophisticated types.

DIGITAL CIRCUIT CHARACTERISTICS

Many factors influence the choice of logic circuits used to implement a digital computer. The most important of these are speed, power dissipation, and the availability of MSI, LSI, and VLSI circuits. Other factors include the cost, noise immunity, and interface capabilities.

The most important choice of a type of logic involves speed and power dissipation. Speed refers to the frequency of operation or propagation delay of the logic circuits. The higher the speed of operation, the greater the amount of data that can be processed in a given time. Therefore, computer designers try to achieve as much speed as possible in their designs.

Many high-speed circuits and techniques are available. Besides choosing circuits with low propagation delay times, circuit reduction techniques are used to minimize propagation delay through proper physical layout as well as logic simplification. However, speed is always obtained at the expense of increased power dissipation and cost. Invariably, the designer faces a speed-power tradeoff, and attempts to optimize the design for maximum speed within realistic power consumption and cost guidelines.

Choosing ICs for use in a digital computer involves not only choosing a specific logic family, but also in choosing the correct mix of the various IC technologies available. By being flexible in the circuit choice of mix, a designer can more easily optimize the design. This means freely mixing different families of bipolar and MOS, as well as VLSI, LSI, MSI, and SSI circuits.

For a detailed look at bipolar and MOS theory, as well as more information on VLSI, LSI, MSI, and SSI circuits, refer to *Aviation Electronics Technician 2 (Intermediate)*, NAVEDTRA 12334, chapter 2.

PROGRAMMING FUNDAMENTALS

Learning Objective: *Recognize concepts and procedures used in the construction of a computer program.*

Computer programming is the process of planning a solution to a problem. You can derive a general outline for calculating total resistance of a parallel resistance circuit by using the following steps:

1. Take the reciprocal of the resistance in ohms of all resistors in a circuit.
2. Calculate the sum of the values from step 1.
3. Compute the reciprocal of the value from step 2.

The process of preparing a program from this explanation is not difficult. One basic charcteristic of the computer must be considered-it cannot think. It can only follow certain commands, which must be correctly expressed and must cover all possibilities. If a program is to be useful, it must be broken down into specifically defined operations or steps. These operations or steps, along with other data, must be communicated to the computer in a language that it can understand.

NOTE: The instructions are read sequentially unless otherwise stated.

Generally, the steps that a computer follows in the execution of a program are as follows:

1. Locates parameters (constants) and such data as necessary for problem solving
2. Transfers the parameter and data to the point of manipulation
3. Performs the manipulation according to certain rules of logic

4. Stores the results of manipulation in a specific location

5. Provides the user with an useful output

Even with a simple program, such as the resistance program, each step must be broken down into a series of machine operations. These instructions, along with the parameters and data, must be translated into a language or code that the computer can understand.

Programming is a complex problem that may involve writing a large number of instructions. It may also involve keeping track of a great many memory cells that are used for instruction and data storage, which is time-consuming and can lead to errors.

To reduce time and the possibility of errors for complex program preparation, the compiler has been developed. The compiler is a program that takes certain commands and then writes, in a form the machine understands, the instructions necessary for a computer to execute these commands. Compilers can bring many instructions into the final program when called upon or signaled by a single source statement. The compiler is problem oriented because the operations produced are those needed to work the problem as set out by the problem statement. Compilers are built at various levels or degrees of complexity. The simplest form of compiler takes one mnemonic phrase and writes one machine instruction. A mnemonic code is an abbreviated term describing something to assist the human memory. For example, to shift the contents of the A-register right nine places, the mnemonic code RSH.A9 is used. This causes the compiler to write an instruction that shifts the contents of the A-register right 11_8 places. A compiler written on this level is commonly called an assembler. Note the advantages as follows:

1. No opportunity to use the wrong function code

2. No necessity to convert the shift count to octal

A more sophisticated compiler may take a statement, such as “multiply principal by rate,” and generate all the instructions necessary for the computer to do the following:

1. Locate the factors involved (in this case the principal and rate)

2. Transfer these factors to the arithmetic unit

3. Perform the indicated arithmetic operation (in this case multiplication)

4. Store the resultant (which, in this case, will be the interest or the principal)

The compiler also keeps track of all memory allocations, whether being used for data or instructions.

Depending on the complexity of the problem to be solved, programs may vary in length from a few instructions to many thousands of instructions. Ultimately, the program could occupy a significant, perhaps even an excessive, portion of computer memory. One method used to preclude this possibility is to segment the program, storing seldom used portions in auxiliary storage, and reading these portions into the main memory only when they are required. An important method of developing this ability is through the use of subroutines.

SUBROUTINES

As a program grows larger, certain functions must be repeated. The instructions necessary to perform each of these repeated functions are grouped together to form subroutines. These subroutines may then be referenced by a relatively few instructions in the main program. This eliminates repeating certain groups of instructions throughout the program.

EXECUTIVE ROUTINES

The instructions that control access to the various subroutines are called the executive routine of the main program. Depending upon the complexity of the program, there may also be subexecutive routines within the executive routines.

Housekeeping is a term used frequently with subroutines. At the time of entry into a subroutine, the contents of the various addressable registers may or may not be of value. An addressable register is defined as any register whose contents can be altered under program control. The programmer must take steps to preserve the contents of these registers unless they are of no value.

JUMP AND RETURN JUMP INSTRUCTIONS

The jump and return jump instructions are used to assist in the construction of executive routines. These instructions provide the computer with the ability to leave the sequential execution of the main program, execute any of the subroutines, and then return to the main program.

Execution of a return jump instruction causes the address of the next instruction to be executed in the main program to be stored (usually in the entry cell of the subroutine). It then causes the instruction of the second cell of the subroutine to be executed. The last instruction to be executed will usually be a straight jump to the address contained in the entry cell. Since a jump instruction specifies the address of the next instruction to be executed, the computer is provided with a means of returning to the main program once the subroutine has been executed.

PROGRAM CONSTRUCTION

The process of writing a program is broken down into six basic steps.

1. Statement. A statement forms a clear comprehensive statement of the problem.

2. Analysis. Analysis consists of laying out the problem in a form that will lend itself to arithmetical and/or logical analysis, determining what logical decision must be made, and if data manipulation is required.

3. Flow diagram. A flow diagram, or chart, is an expansion of the steps in which special symbols are used to represent the various operations to be performed and the sequence in which they are to fall.

4. Encoding. The process of converting the operations listed in the flow chart into language the computer will use, either machine instructions, words, or compiler statements.

5. Debugging. The process of locating errors in the program is called "debugging." Various techniques are available for this purpose. A program may be written to include some aids for itself, or a separate debugging program may be run to test the operation of a malfunctioning program. For a simple program, a trial solution may be done on paper, and the computed results compared with those actually obtained at each step.

6. Documentation. Documentation is very important because later changes may be warranted in a program, or it may be desirable to use subroutines from another program. Proper documentation will ensure that this can be accomplished. Documentation should include the following:

- Program title
- Problem statement
- Programmer's name
- Date
- Memory area used and/or number of cells used
- Registers used
- I/O devices required
- Flow diagram(s)
- Hard copy (program listings, especially a listing of the coded instructions)
- Program tapes

FLOW CHARTING

The programmer constructs a program "map" in determining a solution to a problem. This map is commonly called a flow chart and serves a multitude of important functions. The flow chart maps the logical steps required, decisions to be reached, and paths to be followed as a result of the decisions. When properly annotated, it defines input/output requirements, address allocations, data accuracy considerations, and register usage. A flow chart is valuable when debugging a program and when making future changes.

Flow charting can be constructed at various levels of complexity. A high-level flow chart consists of a few symbols and presents a broad overview of the problem. A low-level flow chart may approach a one-to-one correspondence between flow chart symbol and program instruction. Usually, there will be several flow charts for a program area. These may be compared to the prints found in a maintenance manual. These prints include a block diagram to show the relationship of major units (high-level), functional block diagrams showing the major circuits in a unit (intermediate-level), and the schematics of the circuits (low-level). Flow charts should beat such a level that they will implement all the uses previously discussed.

MAINTENANCE PROGRAMS

As we have previously stated, a routine or program is a series of instructions that control the operations of a computer. Each instruction is used to cause some action that is part of the overall task the computer must perform. Therefore, an instruction may be considered as the basic building block of a computer program.

An overall check of a computer can be done by the use of a maintenance program. The maintenance program provides a thorough and rapid method for the detection of failures in a specific portion of the computer. This type of overall maintenance check is flexible and efficient. The programs may use the same type of tape, memory, computing, and external storage media as operational programs. The maintenance program can be altered when the computer or auxiliary components are changed. The program can also be constantly improved. Generally, no extra test equipment is required since the computer circuits are used to perform the test. Testing by means of maintenance programs results in the computer circuits being used in a more comprehensive manner than during normal program execution. When a program has been checked and accepted as a good maintenance tool, it is not subject to deterioration. In contrast, test equipment may be checked and accepted only to become unreliable shortly after being placed in use.

Maintenance programs are divided into two main classes: reliability and diagnostic. Maintenance programs that are used to detect the existence of errors are called reliability programs. Reliability programs should be arranged to check as many computer circuits as possible.

Maintenance programs that are used to locate the circuits in which computer malfunctions originate are called diagnostic programs. An effective diagnostic program should locate the source of trouble as closely as possible. Actually, in many cases, reliability programs have some diagnostic features, just as diagnostic programs have some reliability features. For convenience, a program is called either a reliability or diagnostic program, depending on its intended emphasis. In general, programs that check rather than diagnose are shorter and simpler.

PERIPHERAL AVIONICS SYSTEMS

Learning Objective: *Identify peripheral avionics systems and describe their interaction with the computer.*

The aircraft computer is considered the most important avionics system in achieving the mission of the aircraft. However, the success of the computer depends upon its external sensors or other avionics systems. The quality of data fed to the computer determines the quality of data fed out of the computer. The following avionics systems provide inputs to and receive outputs from the computer: navigation, radar, ordnance/weapons, and data link. These are only a few of the major aircraft avionics systems that interface with the airborne computer.

NAVIGATION

Navigation systems are designed to tell pilots where they are, where they have been, and where they are going. The TACAN/DME system provides known station reference points, while an inertial navigation system provides continuous updating of such information as latitude and longitude. This information is fed to the computer where it is compared, updated, and sent out to other systems.

SEARCH/TRACK RADAR

A search radar system is designed to give visual indications of what is around the aircraft. Some of the present-day aircraft have a 150-mile or greater range. Depending upon the size and/or speed of the radar indications, a computer can determine whether the target is stationary or moving, a land mass or an aircraft, friendly or unfriendly, and many other items of information. If a target is determined to be unfriendly, a tracking radar can be used to tell the pilot what to do to eliminate the target.

ORDNANCE/WEAPONS

The design characteristics and ballistics of the many types of ordnance, weapons, and missiles require the use of a computer to store the information. The airborne computer aids the pilot by telling him/her when to release the weapons. The computer greatly increases the pilot's chances of destroying designated targets.

DATA LINK

Combat aircraft have to have the most up-to-date information available to successfully complete combat missions. On an aircraft carrier, the combat information center, CIC, is normally in constant contact with an airborne CIC. The airborne CIC is usually an E-2 or P-3 aircraft. These two CICs will crosstalk by use of the data link system. Basically, data link involves a series of transmitted pulses that represent information. The pulsed information is sent to the computers of all combat aircraft to enhance their chances of success.

REVIEW QUESTIONS

Q1. What are some examples of computer hardware?

Q2. True or False. An analog computer designed to measure fuel quantity can be used to measure elapsed time in flight?

Q2. In a digital compute, how are some of the numerical equivalents expressed?

Q4. What are the three basic units of a central processor?

Q5. What is the most frequently used technique for writing and reading data in a magnetic core array memory?

Q6. Representative magnetic drums have diameters in what size range?

Q7. What method of inputting or outputting data is considered the fastest?

Q8. Computer designers must face a tradeoff between what two choices when using ICs?

Q9. What method is used to preclude the possibility of a computer program from using an excessive amount of memory?

Q10. What are the six steps of writing a computer program?

CHAPTER 9

AUTOMATIC CARRIER LANDING SYSTEM

The most demanding task facing a pilot is the landing of the aircraft on an aircraft carrier in rough seas. Landing an aircraft on a stationary land airstrip is hard enough. Add to that task the motion of the carrier in the water, the wave action, and the vortex of air caused by the island, and you can see the problems facing the pilot.

With the electronic technology of today, the carrier landing is made easier for the pilot. The automatic carrier landing system (ACLS) is a great aid to the pilot. This system, once engaged, provides the aircraft with the following capabilities:

- Data link roll commands are used to intercept and lock onto the landing pattern.

- Data link pitch commands establish the proper glide path.

- The autopilot provides warnings if the automatic carrier landing mode becomes uncoupled or is degraded.

This system does not guarantee a perfect landing, nothing can do that. What this system does do is to ensure that the pilot and aircraft have the best and safest possible approach and descent to the carrier deck and touchdown.

AUTOMATIC CARRIER LANDING SYSTEM COMPONENTS

Learning Objective: *Recognize systems, subsystems, and components used in the automatic carrier landing system.*

Although this system is used on the aircraft, some of the subsystems are located on the aircraft carrier. There is no ACLS "box" on the aircraft. This system uses parts of other systems already onboard the aircraft. Figure 9-1 shows how the ACLS components interface and the signal data.

AUTOMATIC FLIGHT CONTROL SYSTEM AN/ASW-42

The automatic flight control system (AFCS or autopilot) is located on the aircraft. This system provides the interface between the data link and the aircraft flight control surfaces. It is the system the pilot uses to select ACLS. The AFCS provides switching and signal conditioning, engage logic, command signal limiting, and failsafe interlocks. The failsafe interlocks are required to couple and process data link signals to the pitch and bank channels of the AFCS. Automatic synchronization is provided in all three axes.

DIGITAL DATA COMMUNICATION SET AN/ASW-25B

The digital data communication set (DDCS) receives the data link messages and signals, screens out invalid messages, and then sends the signals to the AFCS. The DDCS is located in the aircraft.

RECEIVING-DECODING GROUP AN/ARA-63

The receiving-decoding group (R-DG) determines the glide-path errors from the carrier's instrument landing system radar. It also converts the data into signals for the pilot's flight path cross pointers. The R-DG is used for airborne monitoring of Mode I approaches and for Mode II. All three modes (Mode I, Mode II, and Mode III) will be discussed later in this chapter.

INSTRUMENT LANDING SYSTEM AN/SPN-41

The instrument landing system (ILS radar) transmits the glide path pulse-coded Ku-band information from the carrier to the aircraft. This system is located on the carrier and uses two antennas. One antenna is used to transmit azimuth information, and the other transmits elevation information. Both signals are processed by the R-DG on the aircraft.

LANDING CONTROL CENTRAL SYSTEM AN/SPN-42

The landing control central system (tracking and comparison radar) (LCCS) transmits Ka-band signals from the carrier to the aircraft. The LCCS uses a conical scan antenna. This radar system tracks aircraft, and compares the aircraft position to the desired glide path. There are five shipboard subsystems included in this system. These subsystems are as follows:

1. Tracking pulse radar set (Ka band). This radar set locks on aircraft when the aircraft enters the acquisition gate. The system then tracks the aircraft in range, azimuth, and elevation until touchdown or waveoff.

2. Stabilization group. This group translates the actual radar-derived position vector of the aircraft to a

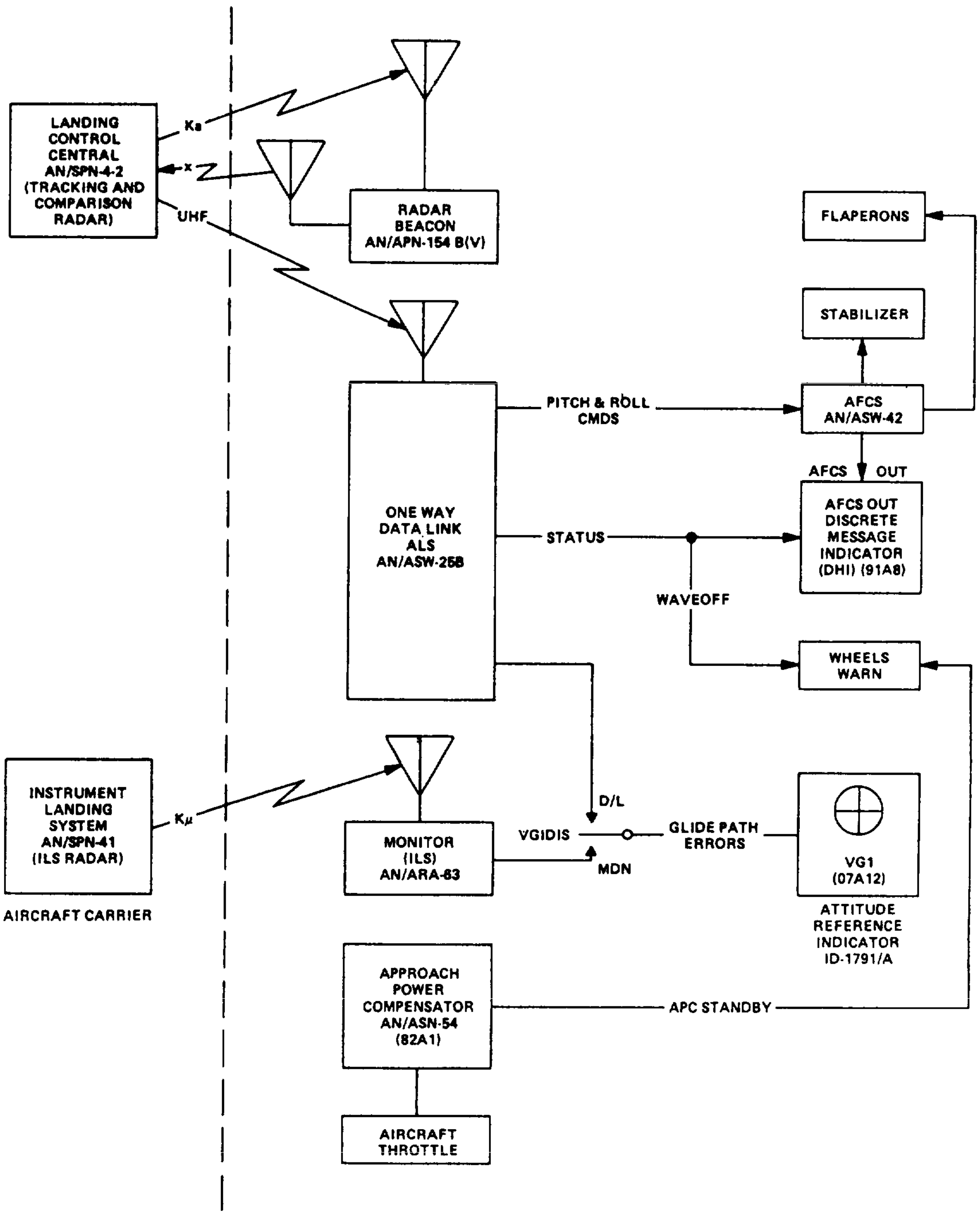


Figure 9-1.-Simplified block diagram of the ACLS system.

stabilized deck-coordinated system referenced to the touchdown point on the flight deck.

3. Digital computer. This is a general-purpose computer used to provide functions for radar data stabilization, data filtering, and computations required for control of the aircraft.

4. Data link monitor. This subsystem continuously checks data link transmissions for errors. If the messages do no check properly, the monitor will switch the system to either Mode II or Mode III, or will generate a waveoff signal.

5. Control console. This console monitors and controls the various functions of the landing system.

RADAR BEACON AN/APN-154B

The radar beacon is located on the aircraft and is used to receive the Ka-band signal interrogations from the LCC radar. The radar beacon then transmits X-band replies to the carrier to provide precise aircraft position data.

APPROACH POWER COMPENSATOR AN/ASN-54

The approach power compensator (APC) automatically adjusts throttles to maintain the angle-of-attack, and thus, the airspeed during aircraft landing approach. It can be used for all carrier landings and is required for Mode I approaches. For Mode II and Mode III approaches, the APC is optional. Data from the angle-of-attack transducer, normal accelerometer, and the stick/stabilizer position are used to control an electromechanical servo actuator. This servo actuator is coupled to the throttle linkage on the engine fuel control.

ATTITUDE REFERENCE INDICATOR ID-1791/A

The ID- 1791/A (VGI) is used to display the glide path errors from either the data link or monitor link on cross pointer needles. This indicator also determines and displays backup pitch and roll attitude, as well as displaying side-slip and turn rate.

DISCRETE MESSAGE INDICATOR 128AV66836

This indicator is located on the aircraft. It displays nine status indications from the one-way link system, autopilot, and the beacon radar.

WARNING INDEXER PANEL

Three warning lights on the warning indexer panel informs the pilot of the status of the approach power compensator, the status of the AFCS, and whether a waveoff has been initiated. The three indicators are the APC STBY, AFCS OUT, and the WAVEOFF indicators. The APC STBY will illuminate when the APC is in standby. The AFCS OUT will illuminate when the autopilot system is not operating properly. The WAVEOFF indicator will illuminate when a wave-off has been initiated. When either the AFCS OUT or the WAVEOFF indicators illuminate while in Mode I approach, the pilot is required to immediately take over control of the aircraft.

APPROACH INDEXER 1284V653-1

This unit is located on the aircraft. It provides an additional angle-of-attack in the pilot's field of view. This unit is used when flying cross pointers on a Mode II approach or when monitoring display on a Mode I approach.

PRINCIPLES OF OPERATION

Learning Objective: *Recognize the operating principles of the automatic carrier landing system.*

The all-weather combination AFCS/ACLS provides automatic, semiautomatic, or manual operation for aircraft carrier operations with minimum use of airborne electronic subsystems. The aircraft control commands are generated by shipboard computers so that the necessary pitch and bank signals can be received by the AFCS via the one-way data link system. This closed-loop operation between aircraft and carrier provides automatic control to touchdown. This system provides a final approach and landing for carrier-based aircraft during daylight or darkness, with minimum interference for conditions of severe weather and sea state, and no limitation due to low ceiling and visibility.

There are three modes of operation of the ACLS that can be selected by the pilot—Mode I, Mode II, and Mode III. Mode I is a fully automatic approach from entry point to touchdown on the flight deck. Mode II requires manual control of the aircraft. In this mode, the pilot controls the aircraft by observing cockpit displays. Mode III is manual pilot control with talkdown guidance by a shipboard controller that provides verbal information for pilot control to visual minimums. The pilot can use full Mode I capability with Mode II and Mode III as backups.

LANDING SEQUENCE

The landing sequence begins when the aircraft is at the marshaling point (fig. 9-2) under control of the carrier air traffic control center (CATCC). The sequence is in two phases: approach and descent. Flight from the marshaling point to the radar acquisition window is the approach phase. Flight from the radar window to touchdown is the descent phase. Transition from the approach phase to the descent phase is done with a minimum of switching operations to reduce pilot task loading.

MODE I LANDING OPERATION

Figure 9-3 shows the Mode I landing sequence. The sequence begins when the aircraft is at the marshaling point. Here the aircraft is held according

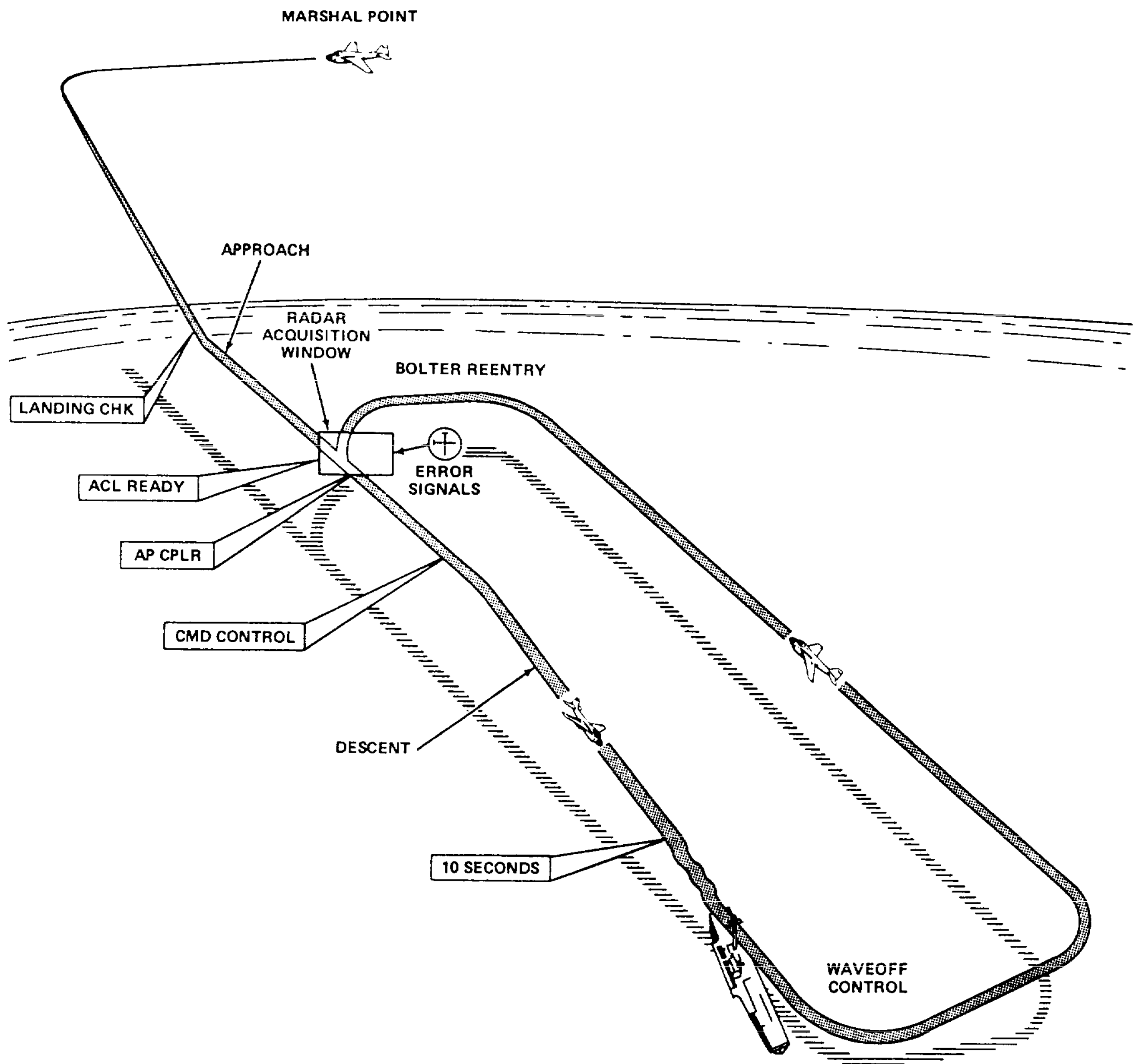


Figure 9-2.-Automatic carrier landing sequence.

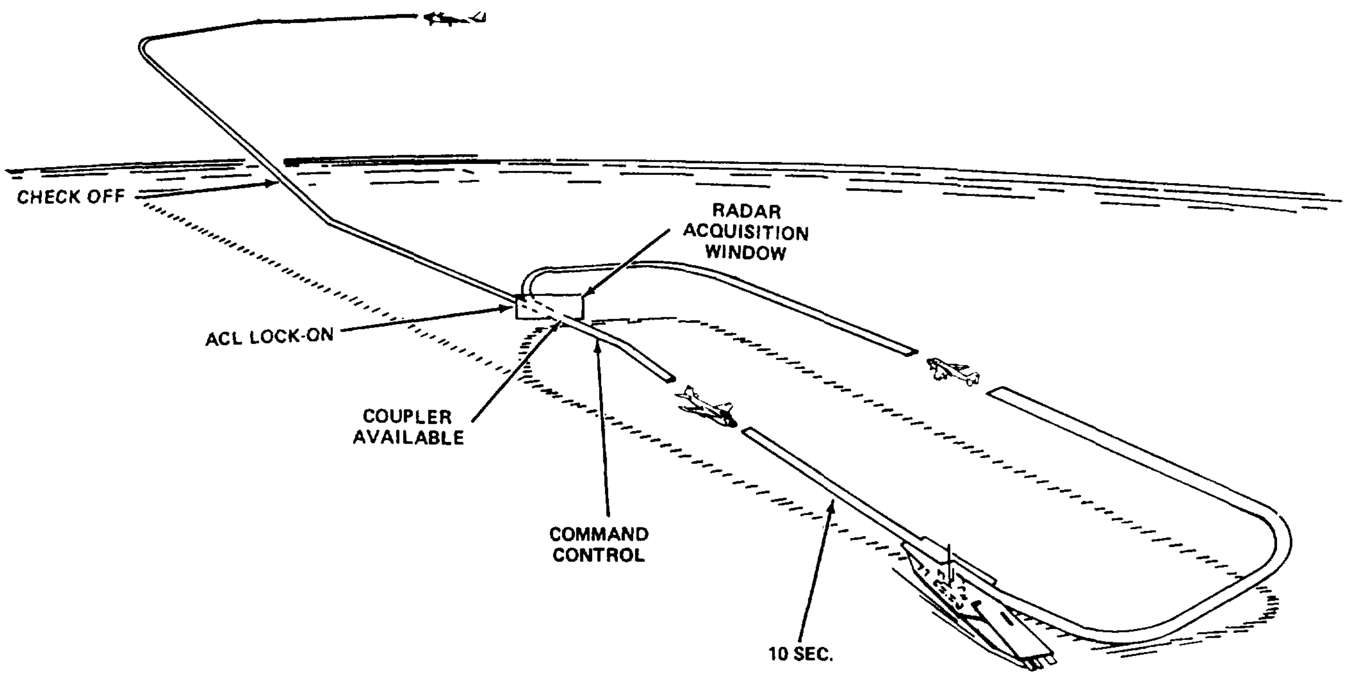


Figure 9-3.-Mode I landing sequence.

to fuel or safety status to determine landing priorities. It is here that the aircraft is assigned a data link channel for automatic landing. The pilot is cleared for approach when the LDG CHK indicator illuminates on the discrete message indicator. The pilot prepares for landing by ensuring the APC is in automatic and that all the other subsystems are on and operating.

As the aircraft continues its approach and passes through the acquisition radar window, the LCC radar acquires the aircraft, and the ACL RDY lamp lights on the discrete message indicator. The acquisition radar window is located approximately 4 miles astern of the ship. When the ACL RDY lamp lights, the CATCC system begins sending vertical and lateral error signals, which represent the actual displacement of the aircraft from the approach path. These signals are converted to a display on the VGI. At this time, the pilot requests the approach mode desired—Mode I for fully automatic touchdown.

The LCC system transmits a COUPLE discrete signal to the aircraft. This signal indicates that pitch and bank commands may be coupled to the autopilot. At this time, the pilot ensures that the APC is engaged; the landing gear, flaps, and speed brakes are extended; and the aircraft is near the approach speed with wings level. With the autopilot turned ON and in AUTO, the pilot then switches the ACL/OFF/PCD switch to ACL. This couples the data link to the autopilot. The pilot will then verbally acknowledge engagement of the autopilot. The ground command controller then sends the CMD CONT discrete signal to the aircraft. At this time, the system begins sending pitch and bank command signals to the aircraft. As the aircraft continues down the approach path, and at approximately 12.5 seconds from touchdown, the 10 SEC discrete message will be sent. This message informs the pilot that deck motion compensation is being added to the glide-path commands. Compensation is in the form of a slight increase or decrease in aircraft attitude as needed to adjust for the movement of the touchdown point in response to the carrier's movement. At 1.5 seconds from touchdown, the landing system freezes the pitch and bank commands, and the autopilot holds the aircraft attitude until touchdown.

SAFETY PROVISIONS

The automatic carrier landing system has many provisions to protect the pilot and the aircraft from human errors or equipment failures. The monitor link uses the ILS AN/SPN-41 to independently check the LCCS flight path progress. This allows the pilot to monitor position in relation to the safe glide path. When the aircraft exceeds the Mode I flight path control envelope boundaries, as shown in figures 9-4 and 9-5, the system ceases transmitting the COUPLE discrete signals. This turns off the lamp on the discrete message indicator and causes the autopilot to uncouple and revert to the STAB AUG mode. The aircraft can continue to approach the carrier, but the pilot must be in Mode II or III. If the flight path error increases to the point where a large maneuver is required of the aircraft to bring it back on course, the ground controller sends a wave-off message. This wave-off message totally disengages the carrier landing system, lights a WAVEOFF lamp on the discrete indicator, and allows the pilot to execute his wave-off routine.

Between 12.5 and 1.5 seconds from touchdown, the tracking and comparison radar sends a wave-off signal automatically if the aircraft exceeds the boundaries shown in figures 9-4 and 9-5. A manual wave-off signal may also be sent by the appropriate carrier personnel anytime the aircraft approach is considered unsafe.

The pilot can override the system at anytime after engaging the ACL mode by applying a control stick force of 10 pounds fore or aft (pitch), or 7 pounds laterally (roll). Either of these motions will uncouple the ACLS and automatically down mode the autopilot to the STAB AUG position. The pilot can continue the approach manually under Mode II, Mode III, ILS, or visually, or decide not to chose any of these and go around for another try.

If the information stored in the data link is not updated within any 2-second period after the first receipt of glide-path error data, a TILT discrete signal is transmitted and displayed on the discrete indicator. This causes the autopilot to disconnect from the

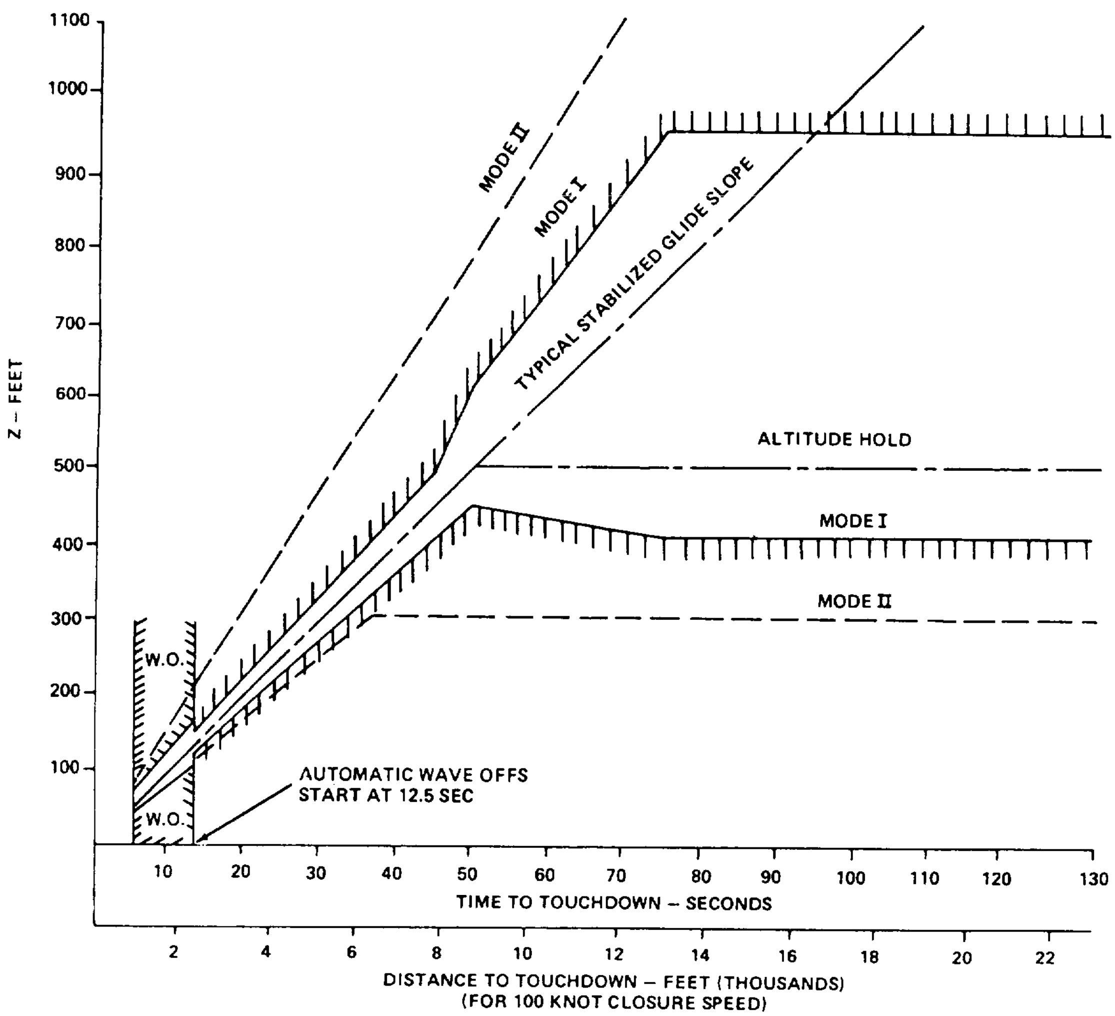


Figure 9-4.-Vertical flight path control and automatic wave-off boundaries.

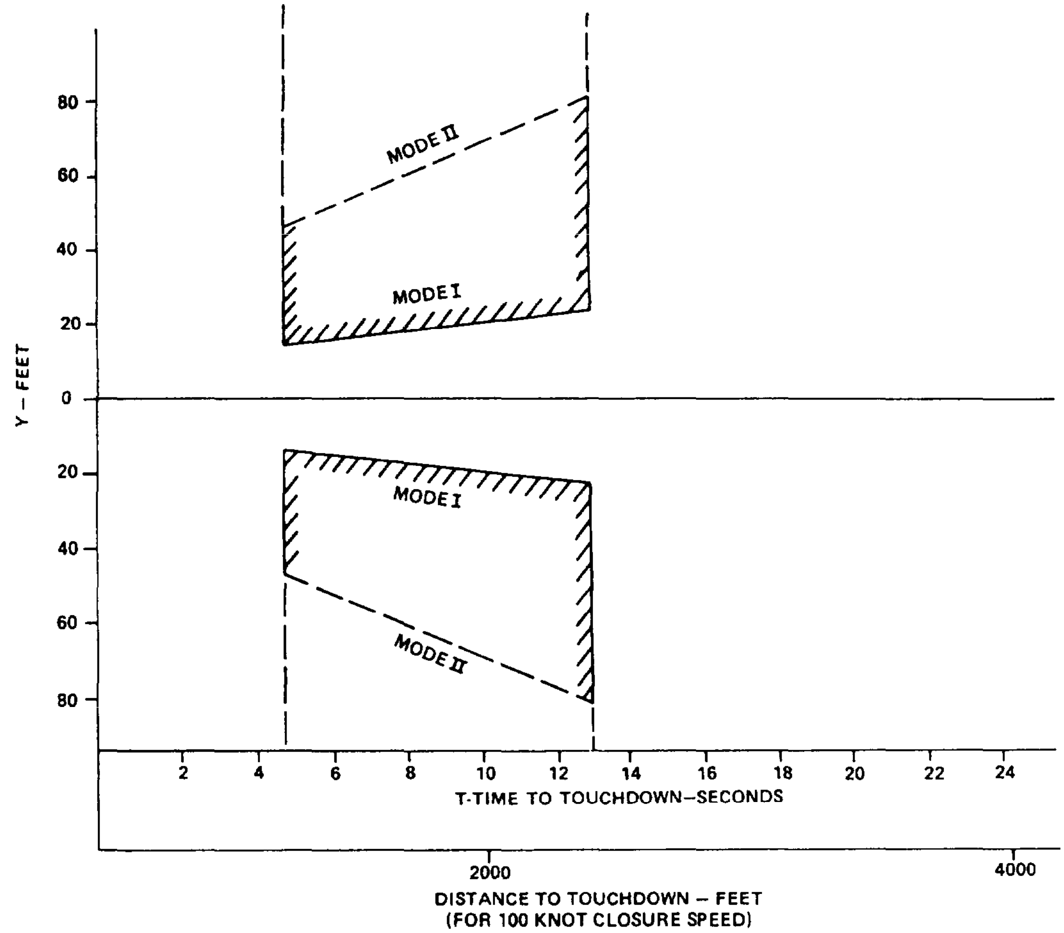


Figure 9-5.-Lateral automatic wave-off boundaries.

ACLS and revert back to STAB AUG. Whenever the autopilot disconnects from the ACL mode, the AFCS OUT indicator (on the discrete indicator) lights for 20 seconds, and then goes out.

If the pilot is monitoring glide path errors from the data link on the VGI cross pointers and a display of a TILT or WAVEOFF discrete signal appears, the cross pointers will drive out of view. There is no effect on the cross pointers, from these discretes, if the monitor link is being used. If the monitor link is being used for glide-path error display and the received RF signal is lost, the cross pointers are driven to a fly-up, fly-right indication. This will alert the pilot to take corrective action. If the monitor link is turned off or if primary power is lost, the cross pointers are driven out of view. When the radar beacon is being interrogated and is transmitting a replay in the ACLS mode, the BCN ON lamp (on the discrete indicator) lights, informing the pilot that the beacon is operating. When power to the VGI is removed or interrupted, a warning flag is immediately displayed on the indicator. All of these functions guard against any system malfunctions that may endanger the pilot or the aircraft.

REVIEW QUESTIONS

Q1. *True or False. The ACLS is a self-contained system located completely on the aircraft.*

Q2. *What are the three modes of operation of the ACLS?*

Q3. *At what point in the sequence does the LCC radar acquire the aircraft?*

Q4. *If the autopilot decouples from the ACL mode of operation, does the pilot have to initiate wave-off procedures?*

CHAPTER 10

ELECTROSTATIC DISCHARGE PROGRAM

The electrical noise generated in a radio or radar receiver is often confused with electrical noise generated external to the receiver and coupled into the receiver. The internally generated noise is the result of circuit deficiencies in the receiver itself, and can be eliminated by replacing the defective component or replacing the entire receiver. Electrical noise produced external to the receiver enters the receiver by various means. The noise causes interference in the receiver, as well as poor reception.

In early naval aircraft, electrical noise interference was not a major problem because there were fewer external sources of electrical noise. Receiver sensitivities were low, and the aircraft control components were manually operated. In today's aircraft, however, there are considerably more sources of externally generated electrical noise. The aircraft now contains numerous receivers with higher sensitivities, and the aircraft controls are operated by various electrical and/or mechanical devices. These devices include control surface drive motors, fuel and hydraulic boost pumps, ac inverters, and cabin pressurization systems. In addition, pulsed electronic transmitters, such as TACAN, radar, and IFF, can be sources of electrical noise interference. Listening to electrical noise interference in the output of a radio receiver can cause nervous fatigue in aircrew personnel. Electrical noise may also reduce the performance (sensitivity) of the receiver. For these reasons, electrical noise should be kept at the lowest possible level.

The overall objective of this chapter is to assist you in recognizing various types of electrical/ electronic noise, their effects on radio and radar receivers, and what the electrostatic discharge program means to you as the work center supervisor. This chapter also provides you with information for keeping electrical noise interference as low as possible in electronic equipment aboard naval aircraft.

TYPES AND EFFECTS OF RECEIVER NOISE INTERFERENCE

Learning Objective: *Recognize the types and effects of radio noise, including natural and man-made interference.*

The types of electrical noise interference that enter aircraft receivers are broadly categorized as natural interference and man-made interference.

NATURAL INTERFERENCE

Radio interference caused by natural electrical noise is separated into three types: atmospheric static, precipitation static, and cosmic noise. Each type is discussed below.

Atmospheric Static

Atmospheric static is a result of the electrical breakdown between masses (clouds) of oppositely charged particles in the atmosphere. An extremely large electrical breakdown between two clouds or between the clouds and ground is called "lightning." Atmospheric static is completely random in nature, both as to rate of recurrence and as to intensity of individual discharges. Atmospheric static produces irregular popping and crackling in audio outputs and "grass" on visual output devices. Its effects range from minor annoyance to complete loss of receiver usefulness. Atmospheric interference is seldom of a crippling intensity at frequencies from 2 MHz to 30 MHz, but it can be annoying. Above 30 MHz, the noise intensity decreases to a very low level. At frequencies below 2 MHz, natural static is the principal limiting factor on usable receiver sensitivity.

The intensity of atmospheric static varies with location, season, weather, time of day, and the frequency to which the receiver is tuned. It is most intense at the lower latitudes, during the summer season, during weather squalls, and at the lower radio frequencies. Many schemes have been devised to minimize the effects of atmospheric static. However, the best technique is to avoid those frequencies associated with intense static, if possible.

Precipitation Static

Precipitation static is a type of interference that occurs during dust, snow or rain storms. The principal cause of precipitation static is the corona discharge of high-voltage charges from various points on the airframe. These charges may reach several hundred thousand volts before discharge occurs. The charge can be built up in two ways. First, an electrostatic field existing between two oppositely charged thunderclouds induces bipolar charges on the surfaces of the aircraft as it passes through the charged clouds. Second, a high unipolar charge on the entire airframe occurs from frictional charging by collision of atmospheric particles (low altitudes) or fine ice particles (high altitudes) with the aircraft's surface. The effects of corona discharge vary with temperature. The effects increase as altitude and airspeed increase. Doubling airspeed increases the effect by a factor of about 8; tripling airspeed increases the effect by a factor of about 27.

The effect of precipitation static is a loud hissing or frying noise in the audio output of a communication receiver and a corresponding "grass" indication on a visual output device. The radio frequency range affected by precipitation static is nearly the same as for atmospheric static. When present, precipitation interference is severe, and often totally disables all receivers tuned to the low- and medium-frequency bands.

Cosmic Noise

Cosmic noise is usually heard in the UHF band and above. However, it is occasionally heard at frequencies as low as 10 MHz. Cosmic noise is caused by the radiation of stars. Although its effect is generally unnoticed, at peaks of cosmic activity, cosmic noise interference could conceivably be a limiting factor in the sensitivity of navigational and height-finder radar receivers.

MAN-MADE INTERFERENCE

Man-made interference is generally categorized according to the spectrum of its influence, such as broadband and narrow band. Each type of man-made interference is discussed below.

Broadband Interference

Broadband interference is generated when the current flowing in a circuit is interrupted or varies at a rate that departs radically from a sinusoidal rate. A current whose waveform is a sine wave is capable of interfering only at a single frequency. Any other waveform contains harmonics of the basic frequency. The steeper the rise or fall of current, the higher the upper harmonic frequency will be. A perfect rectangular pulse contains an infinite number of odd harmonics of the frequency represented by its pulse recurrence rate. Typical types of electrical disturbances that generate broadband interference are electrical impulses, electrical pulses, and random noise signals.

For purposes of this discussion, *impulse* is the term used to describe an electrical disturbance, such as a switching transient that is an incidental product of the operation of an electrical or electronic device. The impulse recurrence rate may or may not be regular. *Pulse* is the term used to describe an intentional, timed, momentary flow of energy produced by an electronic device. The pulse recurrence rate is usually regular.

Switching transient or impulses result from the make or break of an electrical current. They are extremely sharp pulses. The duration and peak value of these pulses depend upon the amount of current and the characteristics of the circuit being opened or closed. The effects are sharp clicks in the audio output of a receiver and sharp spikes on an oscilloscope trace. The isolated occasional occurrence of a switching transient has little or no significance. However, when repeated often enough and with sufficient regularity, switching transients are capable of creating intolerable interference to audio and video circuits, thus degrading receiver performance. Typical sources of sustained switching transients are ignition timing systems, commutators of dc motors and generators, and pulsed navigational lighting.

Pulse interference is normally generated by pulsed electronic equipment. This type of interference is characterized by a popping or buzzing in the audio output device and by noise spikes on an oscilloscope. The interference level depends upon the pulse severity, repetition frequency, and the regularity of occurrence. Pulse interference can trigger beacons and IFF equipment and cause false target indications on the radar screens. In certain types of navigational beacons, these pulses cause complete loss of reliability.

Random noise consists of impulses that are of irregular shape, amplitude, duration, and recurrence rate. Normally, the source of the random noise is a variable contact between brush and commutator bar or slip ring, or an imperfect contact or poor isolation between two surfaces.

Narrow-Band Interference

Narrow-band interference is almost always caused by oscillators or power amplifiers in receivers and transmitters. In a receiver, the cause is usually a poorly shielded local oscillator stage. In a transmitter, several of the stages could be at fault. The interference could be at the transmitter operating frequency, a harmonic of its operating frequency, or at some spurious frequency. A multichannel transmitter that uses crystal-bank frequency synthesizing circuits can produce interference at any of the frequencies present in the synthesize. Narrow-band interference in a receiver can range in severity from an annoying heterodyne whistle in the audio output to the complete blocking of received signals. Narrow-band interference affects single frequencies or spots of frequencies in the tuning range of the affected receiver.

SOURCES OF ELECTRICAL NOISE

Learning Objective: *Recognize the various sources of electrical noise and the operating characteristics of each.*

Any circuit or device that carries a varying electrical current is a potential source of receiver interference. The value of the interference voltage depends upon the amount of voltage change. The frequency coverage depends upon the abruptness of the change. The principal sources of man-made interference in aircraft include rotating electrical machines, switching devices, pulsed electronic equipment, propeller systems, receiver oscillators, nonlinear elements, and ac power lines. Each of these sources of noise is discussed in the following sections.

ROTATING ELECTRICAL MACHINES

Rotating electrical machines are a major source of receiver interference because of the large number of electric motors used in the aircraft. Rotating electrical machines used in aircraft may be divided into three general classes: dc motors, ac motors and generators, and inverters.

DC Motors

Modern aircraft use dc motors in great numbers, such as in flight control actuators, armament actuators, and flight accessories. Most electronic equipment on the aircraft include one or more dc motors for driving cycling mechanisms, compressor pumps, air circulators, and antenna mechanisms. Each of these motors can generate voltages capable of causing radio interference over a wide band of frequencies. Types of interfering voltages generated by dc motors areas follows:

- Switching transients generated as the brush moves from one commutator bar to another (commutation interference)
- Random transients produced by varying contact between the brush and the commutator (sliding contact interference)
- Audio-frequency hum (commutator ripple)
- Radio frequency and static charges built up on the shaft and the rotor assembly

The dc motors used in aircraft systems are of three general types: the series- wound motor, the shunt-wound motor, and the permanent-magnet (PM) motor. The field windings of both series- and shunt-wound motors afford some filter action against transient voltages generated by the brushes. The PM motor's lack of such inherent filtering makes it a very common source of interference. The size of a dc motor has little bearing upon its interference generating characteristics. The smallest motor aboard the aircraft can be the worst offender.

AC Generators and Motors

The output of an ideal alternating-current generator is a pure sine wave. A pure sine-wave voltage is incapable of producing interference except at its basic frequency. However, a pure waveform is difficult to produce, particularly in a small ac generator. Nearly all types of ac generators used in naval aircraft are potential sources of interference at frequencies other than the output power frequency. Interference voltages are produced by the following sources:

- Harmonics of the power frequency. Generally, the harmonics are caused by poor waveform.
- Commutation interference. This condition originates in a series-wound motor.

- Sliding-contact interference. This condition originates in an alternator and in a series-wound motor.

Generally, an ac motor without brushes does not create interference.

Inverters

An inverter is a dc motor with armature taps brought out to slip rings to supply an ac voltage. The ac output contains some of the interference voltages generated at the dc end, as well as the brush interference at the ac end of the inverter.

SWITCHING DEVICES

A switching device makes abrupt changes in electrical circuits. Such changes are accompanied by transients capable of interfering with the operation of radio and other types of electronic receivers. The simple manual switch (occasionally operated) is of little consequence as a source of interference. Examples of switching devices (frequently operated) capable of causing appreciable or serious interference are the relay and the thyratron.

Relays

A relay is an electromagnetically operated remote-control switch. Its main purpose is to switch high-current, high-voltage, or other critical circuits. Since the relay is used almost exclusively to control large amounts of power with relatively small amounts of power, the relay is always a potential source of interference. This is especially true when the relay is used to control an inductive circuit. Relay-actuating circuits should not be overlooked as possible interference sources. Even though the actuating currents are small, the inductances of the actuating coils are usually quite high. It is not unusual for the control circuit of a relay to produce more interference than the controlled circuit.

Thyratrons

A thyratron is a gas-filled, grid-controlled, electronic switching tube used mainly in radar modulators. The current in a thyratron is either ON or OFF; there is no in-between. Since the time required to turn a thyratron ON is only a few microseconds, the current waveform in a thyratron circuit always has a sharp leading edge. As a result, the waveform is rich in radio interference energy. The voltage and peak power in a radar modulator are usually very high, and the waveforms are intentionally made as sharp and flat as possible. Although these factors are essential for proper radar operation, they also increase the production of interference energy.

PULSED ELECTRONIC EQUIPMENT

Pulse interference is generated by pulsed electronic equipment. Types of systems that fall within this category include radar, beacons, transponders, and coded-pulse equipment.

Radar

In radar equipment, range resolution depends largely on the sharpness of the leading and trailing edges of the pulse. The ideal pulse is a perfect square wave. Target definition is also dependent on the narrowness of the pulse. Both the steepness and the narrowness of a pulse determine the number and amplitudes of harmonic frequencies. With respect to the shape of a radar pulse, the better the radar is working, the greater the interference it is capable of producing. Most of the interference is produced at frequencies other than those leaving the radar antenna, except in receivers operating with the radar band.

Radar interference at frequencies below the antenna frequency severely affects all receivers in use. Principal sources of such interference are the modulator, pulse cables, and transmitter.

Transponders, Coded-Pulse Equipment, and Beacons

This group includes IFF, beacons, TACAN, teletype, and other coded-pulse equipment. The interference energy produced by this group is the same as that produced by radar-pulsing circuits. The effects of this interference energy are lessened because the equipment is usually self-contained in one shielded case, and uses lower pulse power. The effects are increased because the radiating frequencies are lower, which allows fundamental frequencies and harmonics to fall within the frequency bands used by other equipment. Each piece of equipment is highly capable of producing interference outside the aircraft where it can be picked up by receiver antennas.

PROPELLER SYSTEMS

Propeller systems, whether hydraulically or electrically operated, are potent generators of radio interference. The sources of interference include propeller pitch control motors and solenoids, governors and associated relays, synchronizers and associated relays, deicing timers and relays, and inverters for synchro operation.

Propeller control equipment generates clicks and transients as often as 10 per second. The audio frequency envelope of commutator interference varies from about 20 to 1000 Hz. The propeller deicing timer generates intense impulses at a maximum rate of about 4 impulses per minute.

Values of current in the propeller system are relatively high; consequently, the interference voltages generated are severe. They are capable of producing moderate interference at frequencies below 100 kHz and at frequencies above 1 MHz. However, the interference voltages can cause severe interference at intermediate frequencies.

RECEIVER OSCILLATORS

Either directly or through frequency multipliers or synthesizers, the local oscillator in a superheterodyne receiver generates an RF signal at a given frequency. The local oscillator signal is mixed with another RF signal to produce an intermediate frequency (IF) signal. Depending on receiver design, the frequency of the local oscillator signal is either above or below the frequency of the RF signal by a frequency equal to the IF.

The amount of interference leaving the receiver through its antenna is roughly proportional to the ratio of the tuned input frequency to the intermediate frequency. For any tuning band on the receiver, oscillator leakage is highest at the low end of the band. Also, the lower the intermediate frequency, the greater the leakage probability.

Although the receiver antenna is the principal outlet of oscillator leakage, leakage can occur from other points. Any path capable of introducing interference into a receiver is also capable of carrying internally generated interference out of the receiver. The paths of entry are discussed in more detail later in this chapter.

Oscillator leakage from a single communications receiver in an aircraft is not likely to be a direct source of interference, except in a very large aircraft where two or more frequencies in the same band are used simultaneously. However, high-order harmonics of the oscillator frequency can become troublesome in the VHF band and above.

Oscillator leakage from a swept-tuning receiver can produce interference in any receiver aboard the aircraft. This is done directly (on harmonics) or by nonlinear mixing, as shown in the following example:

- Receiver A, operating at a frequency of 2100 kHz, with an IF of 500 kHz, has oscillator leakage at 2600 kHz (or 1600 kHz).

- Receiver B, operating at 150 MHz, with an IF of 10 MHz, has oscillator leakage at 160 MHz (or 140 MHz).

- Receiver C, sweeping a frequency band from 200 to 300 MHz, with an IF of 30 MHz, has oscillator leakage across the band 170 to 270 MHz (or 230 to 330 MHz).

Each receiver is capable of interfering with the other receivers at the oscillator frequency and its harmonics. In addition, with the presence of a nonlinear detector, the leakage signals from the three receivers can be mixed and interfere with the following frequencies:

- Receivers A and B, after nonlinear mixing, can produce interference at 160±2.6 MHz.

- Receivers A and C can similarly produce interference at any frequency from 200±2.6 to 300 ±2.6 MHz; receivers B and C between 200 ±160 to 300±160 MHz.

NONLINEAR ELEMENTS

A nonlinear element is a conductor, semiconductor, or solid-state device whose resistance or impedance varies with the voltage applied across it. Consequently, the resultant voltage is not proportional to the original applied voltage. Typical examples of nonlinear elements are metallic oxides, certain nonconducting crystal structures, semiconductor devices, and electron tubes. Nonlinear elements that could cause radio interference in aircraft systems are overdriven semiconductors and vacuum tubes, oxidized or corroded joints, cold-solder joints, and unsound welds.

In the presence of a strong signal, a nonlinear element acts like a detector or mixer. It produces sum and difference frequencies and any harmonics from the signal applied to it. These spurious frequencies are called "external cross-modulation." These spurious frequencies (sum, difference, and harmonics) can be expected to cause interference problems when the combined product of their field strengths exceed 1 millivolt.

A common example of this action is the entry of a strong off-frequency RF voltage into the mixer stage of a superheterodyne receiver. By the time the interfering signal has passed through the preselector stages of the receiver, it has undergone distortion by clipping. Therefore, the interfering signal is essentially a rectangular wave that is rich in harmonics. Frequency components of the wave beat both above and below the local oscillator frequency and its harmonics, and produce, at the output of the mixer, signals that are acceptable to the IF amplifier.

POWER LINES

Alternating current power sources have already been briefly discussed as broadband interference. Even though they are conducting a nearly sinusoidal waveform, ac signals on power lines are capable of interfering with audio signals in receivers. In such cases, only the power-line frequency appears. However, where multiple sources of ac power are present, these signals are capable of being mixed in the same manner as discussed under receiver oscillators. Sum and difference frequencies appear.

In at-powered equipment, ac hum can appear at the power frequency or at the rectification ripple frequency. The rectification ripple frequency is twice the power frequency times the number of phases. Normally, aircraft systems use only single- and three-phase sources at a nominal 400 Hz. Full-wave rectification with single-phase 400-Hz power gives a ripple frequency of 800 Hz. A three-phase source would give a 2400 Hz ripple. This ripple produces interference varying from annoyance to complete unreliability of equipment, depending upon the severity and its coupling to susceptible elements.

INTERFERENCE COUPLING

Learning Objective: *Identify the various types of electrical interference caused by coupling, and recognize the means used to reduce the interference.*

Openings in the outer shields of equipment are necessary for the entrance of power leads, control leads, mechanical linkages, ventilation, and antenna leads. Interference entering these openings is amplified by various amounts, depending upon the point of entry into the equipment's circuits. Coupling between the entry path and the sensitive points of the receiver can be in any form.

CONDUCTIVE COUPLING

Interference is often coupled from its source to a receiver by metallic conduction. Normally, this is done by way of mutual impedance, as shown in figure 10-1. Note in the figure that A is the power source, B the receiver, and C the interference source. The interference is maximum at the interference source (C), and attenuates rapidly to a relatively low value at the battery (A). This occurs because of the very low impedance of the battery. It is apparent from the size of the arrows that the nearer the power tap of the receiver (B) to the interference source (C), the greater the amplitude of interfering current in the BC loop.

INDUCTIVE-MAGNETIC COUPLING

Every current-carrying conductor is surrounded by a magnetic field whose intensity variations are faithful reproductions of variations in the current in the conductor. When another parallel conductor is cut by the lines of force of this field, the conductor has a current induced into it. The amplitude of the induced current depends upon the following factors:

- The strength of the current in the first conductor
- The nearness of the conductors to each other
- The angle between the conductors
- The length through which the conductors are exposed to each other

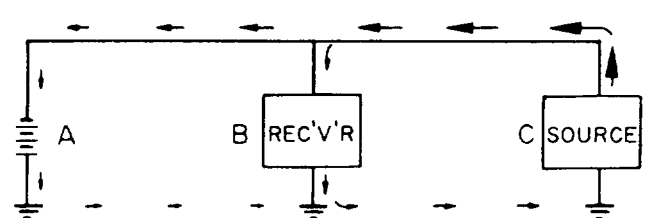


Figure 10-1.-Path of conducted interference.

The amount of the variation in the current that directly affects variation in the magnetic field surrounding the conductor depends upon the nature of the current. When the conductor is a power lead to an electric motor, all the frequencies and amplitudes associated with broadband interference are present in the magnetic field. When the lead is an ac power lead, a strong sinusoidal magnetic field is present. When the lead is carrying switched or pulsed currents, extremely complex broadband variations are present. As the magnetic field cuts across a neighboring conductor, a voltage replica of its variation is induced into the neighboring wire. This causes a current to flow in the neighboring wire. When the neighboring wire leads to a sensitive point in a susceptible receiver, serious interference with that receiver's operation can result. Similarly, a wire carrying a steady, pure dc current of high value sets up a magnetic field capable of affecting the operation of equipment whose operation is based upon the earth's magnetic field.

Shielding a conductor against magnetic induction is both difficult and impractical. Nonferrous shielding materials have little or no effect upon a magnetic field. Magnetic shielding that is effective at low frequencies is prohibitively heavy and bulky.

In aircraft wiring, the effect of induction fields should be minimized. This can be done by use of the proper spacing and coupling angle between wires. The degree of magnetic coupling diminishes rapidly with distance. Interference coupling is least when the space between active and passive leads is at a maximum, and when the angle between the leads approaches a right angle.

INDUCTIVE-CAPACITIVE COUPLING

Capacitive (electric) fields are voltage fields. Their effects depend upon the amount of capacitance existing between exposed portions of the noisy circuit and the noise-free circuit. The power transfer capabilities are directly proportional to frequency. Thus, high-frequency components are more easily coupled to other circuits. Capacitive coupling is relatively easy to shield out by placing a grounded conducting surface between the interfering source and the susceptible conductor.

COUPLING BY RADIATION

Almost any wire in an aircraft system can, at some particular frequency, begin to act like an antenna through a portion of its length. Inside an airframe, however, this occurs only at very high frequencies. At high frequencies, all internal leads are generally well shielded against pickup of moderate levels of radiated energy. Perhaps the only cases of true inside-the-aircraft radiation at HF and below occur in connection with unshielded or inadequately shielded transmitter antenna leads.

COMPLEX COUPLING

Some examples of interference coupling involve more than one of the types (conduction, induction, or radiation) just discussed. When more than one coupling occurs simultaneously, corrective actions, such as bonding, shielding, or filtering, used to correct one type of coupling can increase the coupling capabilities of another type of coupling. The result may be an increase in the transfer of interference. For example, an unbended, unfiltered dc motor can transfer interference to a sensitive element by conduction, inductive coupling, capacitive coupling, and by radiation. Some frequencies are transmitted predominately by one form of coupling and some frequencies by others. At still other frequencies, all methods of transmission are equally effective. On the motor used in the example above, bonding almost always eliminates radiation from the motor shell. It also increases the intensity in one of the other methods of transmission, usually by conduction. The external placement of a low-pass filter or a capacitor usually reduces the intensity of conducted interference. At the same time, it may increase the radiation and induction fields. This occurs because the filter appears to interference voltages to be a low-impedance path across the line. Relatively high interference currents then flow in the loop formed between the source and the filter. For complex coupling problems, multiple solutions may be required to prevent the interference.

RADIO INTERFERENCE REDUCTION COMPONENTS

Learning Objective: *Recognize various methods and components used to reduce radio interference caused by electrical noise.*

Radio interference reduction at the source maybe accomplished to varying degrees by one or more of the following methods: short circuiting, dissipation, open circuiting, or a combination of all three.

Discrete components are normally used to achieve interference reduction at the source. Capacitors, resistors, and inductors are used to short circuit, dissipate, and open circuit the interference, respectively.

CAPACITORS

Short circuiting of interference is done by using capacitors connected across the source. The perfect capacitor looks like an open circuit to dc or the power frequency, and progressively as a shoft circuit to ac as the frequency is increased.

Function

The function of a capacitor in connection with radio interference filtering is to provide a low-impedance, radio-frequency path across the source. When the reactance of the capacitor is lower than the impedance of the power lines to the source, high-frequency voltages see the capacitor as a shorter path to ground. The capacitor charges to the line voltage. It then tends to absorb transient rises in the line voltage and to provide energy for canceling transient drops in the line voltage.

Limitations

The efficiency of a perfect capacitor in bypassing radio interference increases indirect proportion to the frequency of the interfering voltage, and in direct proportion to the capacitance of the capacitor. All capacitors have both inductance and resistance. Any lead for connecting the capacitor has inductance and resistance as a direct function of lead length and inverse function of lead diameter. Some resistance is inherent in the capacitor itself in the form of dielectric leakage. Some inductance is inherent in the capacitor, which is usually proportional to the capacitance.

The effect of the inherent resistance in a high-grade capacitor is negligible as far as its filtering action is concerned. The inherent inductance, plus the lead inductance, seriously affects the frequency range over which the capacitor is useful. The bypass value of a capacitor with inductance in series varies with frequency.

At frequencies where inductive reactance is much less than capacitive reactance, the capacitor looks very much like a pure capacitance. As the frequency approaches a frequency at which the inductive reactance is equal to the capacitive reactance, the net series reactance becomes smaller until the resonant frequency, a point of zero impedance, is reached. At this point, maximum bypass action occurs. At frequencies above the resonant frequency, the inductive reactance becomes greater than the capacitive reactance. The capacitor then exhibits a net inductive reactance, whose value increases with frequency. At frequencies much higher than the resonant frequency, the value of the capacitor as a bypass becomes lost.

The frequency at which the reversal of reactance occurs is controlled by the size of the capacitor and the length of the leads. For instance, the installation of a very large capacitor frequently requires the use of long leads. As an example of the influence of lead length upon the bypass value of a capacitor, the following data is presented to a typical 4-microfarad capacitor whose inherent inductance is 0.0129 henrys:

LEAD LENGTH	CROSSOVER FREQUENCY
1 inch	0.47 MHz
2 inches	0.41 MHz
3 inches	0.34 MHz
4 inches	0.30 MHz
6 inches	0.25 MHz

Note that for the 4-μF capacitor, each additional inch of lead causes the capacitance-inductance crossover point to be reduced.

In figure 10-2, notice the capacitance-to-inductance crossover frequencies for various lead lengths of a 0.05 microfarad capacitor. Also, notice the difference in the crossover frequencies for the 3-inch lead for the 4-μF capacitor, discussed above, and for the 3-inch lead for the 0.05-capacitor referenced in figure 10-2.

Coaxial Feedthrough Capacitors

Coaxial feedthrough capacitors are available with capacitances from 0.00005 to about 2 μF. These capacitors work well up to frequencies several times those at which capacitors with leads become useless.

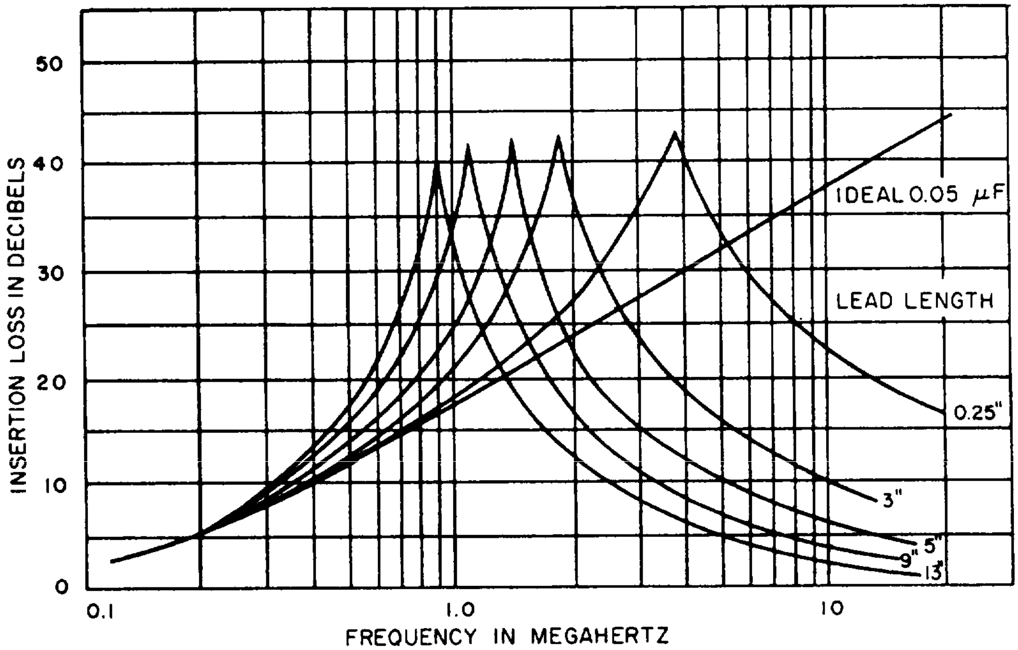


Figure 10-2.-Crossover frequency of a 0.05-microfarad capacitor with various lead lengths.

The curves in figure 10-3 compare the bypass value of a feedthrough capacitor of 0.05 μF with that of a hypothetically perfect capacitor of the same capacitance. The feedthrough capacitor differs from the capacitor with leads in that the feedthrough capacitor type forms a part of both the circuit being filtered and the shield used to isolate the filtered source. Lead length has been reduced to zero. The center conductor of the feedthrough capacitor must carry all the current of the filtered source and must have an adequate current rating to ensure against dc loss or power frequency insertion loss. The internal

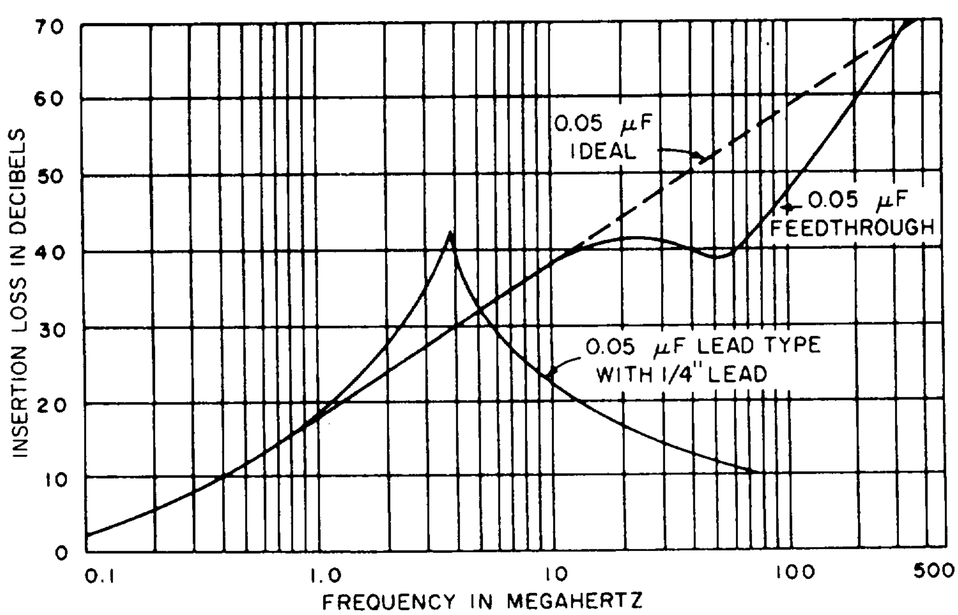


Figure 10-3.-Crosover frequency of a 0.05-microfarad feedthrough capacitor.

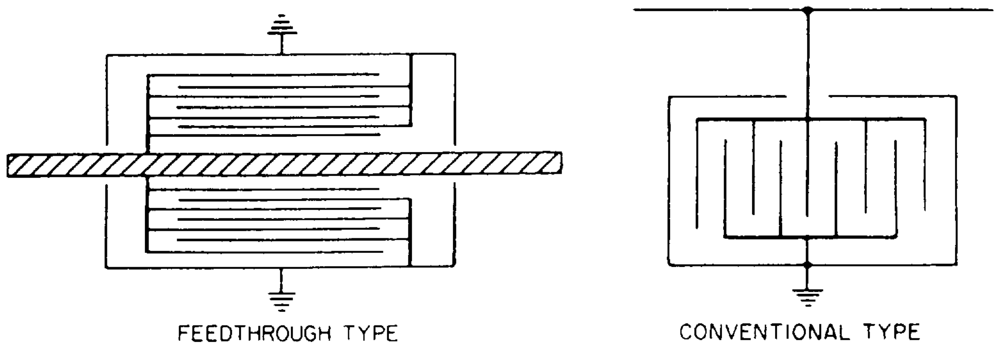


Figure 10-4.-Internal construction of feedthrough and conventional capacitor.

constructions of feedthrough and conventional capacitors are shown in figure 10-4. Notice the differences in the two types.

Selection of Capacitors

Capacitors used for filtering circuits in aircraft should be selected for characteristics such as physical size, high temperature and humidity tolerances, and physical ruggedness. The capacitors should have an adequate voltage rating (at least twice that of the circuit to be filtered), and should be installed with minimum lead length.

Application of Capacitive Filters

Every circuit carrying an unintentionally varying voltage or current capable of causing radio interference should be bypassed to ground by suitable capacitors. When the nature of the variations are such that interference is caused at both high and low frequencies, a capacitor should be chosen and installed to provide an adequate insertion loss at the lowest frequency where interference exists. When the overall capacitance required at low frequency provides inadequate insertion loss at high frequencies, it should be bridged in the shortest and most direct manner possible by a second capacitor.

A capacitive filter should be installed as near as possible to the actual source of interference. Lead length should be held to an absolute minimum for two reasons. First, the lead to the capacitor carries interference that must not be allowed to radiate. Second, the lead has inductance that tends to lower the maximum frequency for which the capacitor is an effective bypass.

To the extent possible, a filter capacitor should be installed to make use of any element of the filtered circuit that provides a better filtering action. Figures 10-5, 10-6, and 10-7 illustrate proper use of filter capacitors.

Capacitive Filtering in an AC Circuit

The radio interference generated in slip ring ac motors and generators is a transient caused by sliding contacts plus high-frequency energy from other internal sources. For this reason, filtering should be aimed at reducing high-frequency and very-high-frequency noise components with the use of low-capacitance, high-grade capacitors. Wherever possible, feedthrough capacitors should be used. Capacitances should be chosen low enough in value to represent a high impedance at the power frequency and to avoid resonance with the internal inductances of the filtered unit. Voltage ratings should be at least twice the peak voltage across the capacitors.

In a four-wire electrical system, the neutral lead carries all three phases; a large quantity of the third harmonic of the power frequency is present. This

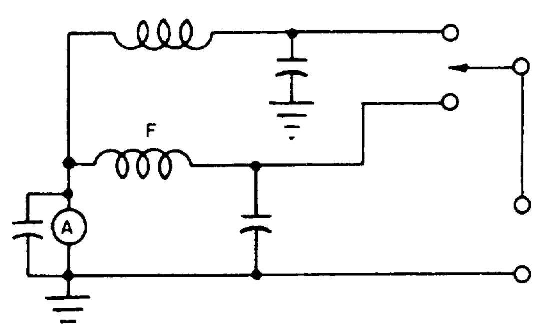


Figure 10-5.-Capacitive filtering of a reversible dc series motor.

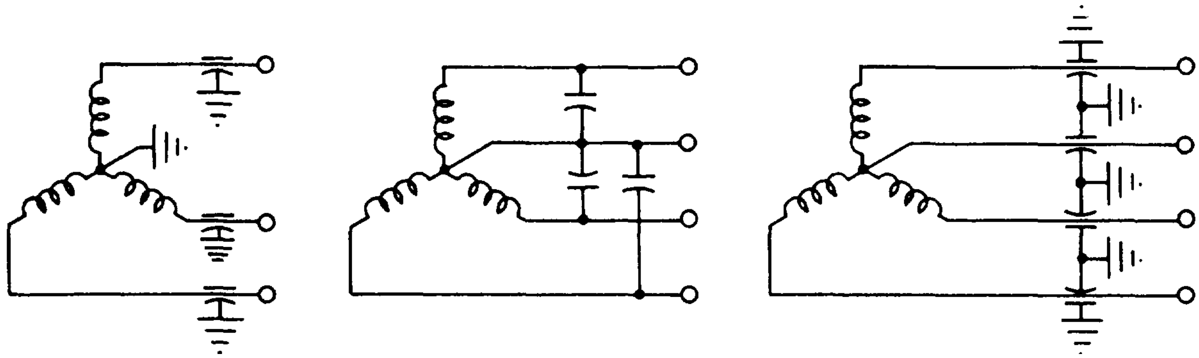


Figure 10-6.-Capacitive filtering of a three-phase attenuator.

frequency must be considered in setting capacitance limits and in filtering the return lead. Normal values of capacitance for filtering 400-hertz leads vary from 0.05 to 0.1 µF.

Capacitive Filtering of Switching Devices

Normally, a capacitor should not be used by itself as a filter on a switch in a dc system. In the open position, the capacitor bridging the switch assumes a charge equal to the line voltage. When the switch closes, the capacitor discharges at such a rapid rate that it generates a transient energy, whose interference value exceeds that caused by the opening of the unfiltered circuit. The capacitor across a switch should have enough series resistance to provide a slow discharge when the capacitor is shorted by the switch.

RESISTIVE-CAPACITIVE FILTERS

A resistive-capacitive (RC) filter is an effective arc and transient absorber. The RC filter reduces interference in two ways—by changing the waveform of transients and by dissipating transient energy. Figure 10-8 shows how an RC filter is connected across a switch.

Without the RC filter, the voltage appearing across the switch at the instant the switch is opened is equal to the sum of the line voltage and an inductive voltage of the same polarity. The amplitude of the inductive surge depends upon the inductance of the line and the amplitude of the closed-circuit current.

When the sum of the voltages appearing across the switch is great enough, arcing occurs. When the capacitance is large enough, the capacitor absorbs sufficient transient energy to reduce the voltage to below arcing value. During the charging time of the capacitor, the resistor is passing current and dissipating some of the transient energy.

For maximum absorption of the circuit opening transients, resistance should be small and capacitance should be large. Good representative values are R = 1/5 load resistance and C = 0.25 µF.

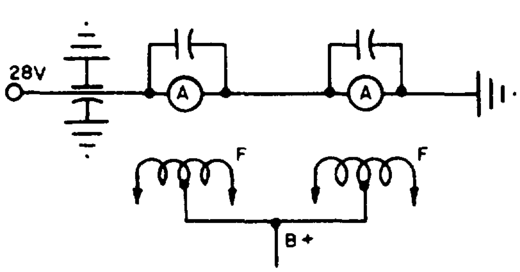


Figure 10-7.-Capacitive filtering of a servomotor.

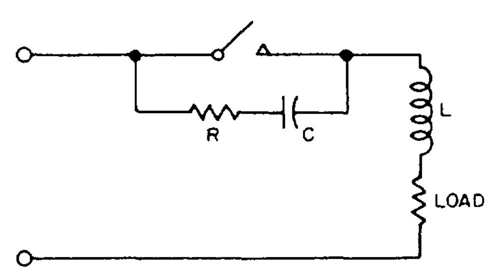


Figure 10-8.-An RC filter connected across a switch.

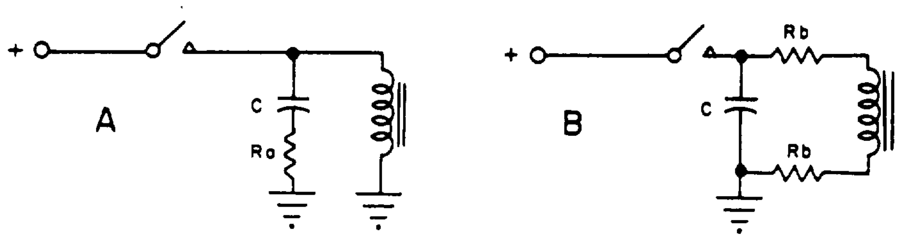


Figure 10-9.-Methods for using RC filters in relay circuits.

Figure 10-9 shows two RC filters used to absorb the transient interference resulting from the opening of a relay field. In circuit A, the value of Ra should be low enough to provide a resistance path to ground less than the line impedance and high enough to lower the Q sufficiently. The capacitor should be at least 0.25 µF with a voltage rating several times the lone voltage. Circuit B has the advantages of reducing the capacitor and coil leads to absolute minimum and reducing the relay field current. It has the disadvantage of carrying the dc coil current. Normal values of each resistance (Rb) in circuit B is 5 percent of the dc resistance of the coil. The capacitor is normally 0.25 µF. Circuit B serves as both a damping load and a high-loss transmission line.

INDUCTIVE-CAPACITIVE FILTERS

Filtering of radio interference is done by means of an inductor inserted in series with the ac power source. The inductor offers negligible impedance to the ac or power-line frequency and an increasingly high impedance to transient interference as frequency is increased. Combinations of inductance and capacitance are widely used to reduce both broadband and narrow-band interference.

Filters used to reduce radio interference transmissions are available in the Navy supply system. The filters come in a large variety of types and sizes. Filters are classified as to their frequency characteristics-namely, low-pass, high-pass, bandpass, and band-reject filters.

Filters are also classified as to their applications-namely, power-line, antenna, and audio filters. The type most often used in aircraft is the low-pass, power-line filter.

Low-Pass Filters

A low-pass filter is used in an aircraft to filter power leads coming from interference sources. The filter prevents the transmission of interference voltages into the wiring harness, and blocks transmission or reception of radio-frequency energy above a specified frequency.

The ideal low-pass filter has no insertion loss at frequencies below its cutoff frequency, but has an infinite insertion loss at all higher frequencies. Practical filters fall short of the ideal in three ways. First, a filter of acceptable physical size and weight has some insertion loss, even under dc conditions. Second, because of the lack of a pure inductor, the transition from low to high impedance is gradual instead of abrupt. Third, the impedance is held to a finite value for the same reason. Figure 10-10 compares the insertion loss of a typical low-pass filter with that of the hypothetical ideal filter.

Figure 10-11 shows the arrangement and typical parameters of a low-pass filter that has a design cutoff frequency of 100 kHz. Inductor L must carry load current. It must be wound of wire large enough that Its dc insertion loss is negligible. Therefore, filters are rated as to maximum current. The capacitors C1

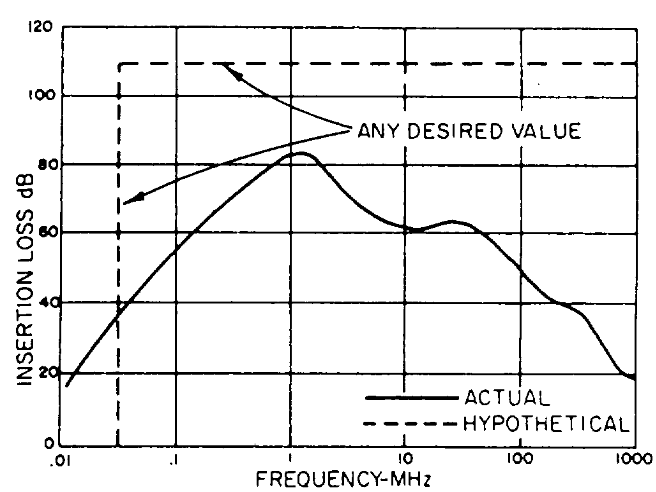


Figure 10-10.-Insertion loss curve of a low-pass power-line filter.

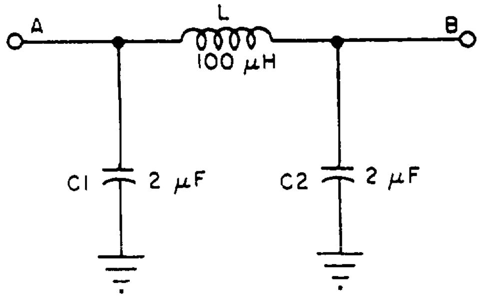


Figure 10-11.-Low-pass filter circuit.

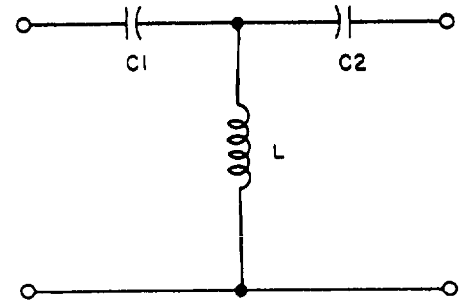


Figure 10-12.-Schematic diagram of a high-pass filter section.

and C2 must withstand the line voltage. Therefore, filters are also rated as to maximum voltage.

At frequencies immediately below cutoff, the filter looks capacitive to both the generator and the load. Inductive reactance X_L has very little influence, and no filtering action takes place. However, at frequencies above cutoff, the series reactance of coil L becomes increasingly higher. The series reactance of coil L is limited only by the resistance of the coil and its distributed capacitance. Coil L then functions as a high-frequency disconnect. The bypass values of both C1 and C2 become increasingly higher, and are limited only by the inductance of the capacitors and their leads. As a result of these two actions, high-frequency isolation between points A and B is achieved.

High-Pass Filters

In almost all radio transmitters operating at high frequencies (HF) and above, the master oscillator signal is generated at a submultiple of the output frequency. By use of one or more frequency multipliers, the basic oscillator frequency is raised to the desired output frequency. At the input to the antenna, an overdriven output amplifier may output the output frequency and harmonics of the output frequency. A high-pass filter is very effective in preventing the undesired harmonics from reaching the antenna and being radiated.

High-pass filters are also useful for isolating a high-frequency receiver from the influence of energy of signals of lower frequencies. Figure 10-12 shows a typical high-pass filter being used to reduce radio-noise interference. In symmetrical high-pass filter sections ($Z_{in} = Z_{out}$), the series combination of C1 and L should resonate at $\sqrt{2}$ times the desired cutoff frequency. The L/C ratio that is chosen should have a square root equal to the terminal impedance.

Bandpass Filters

Bandpass filters provide a very high impedance above and below a desired band of frequencies within that band. Bandpass filters find their greatest application in the following reamer:

- Decoupling the receiver from shock and overload by transmitters operating above and below the receiver band

- Multiplexing and decoupling two or more receivers or transmitters using the same antenna

A bandpass filter can be one of many forms and configurations, depending upon its application. For filtering antennas, a bandpass filter normally consists of one or more high-pass filter sections, followed by one or more low-pass filter sections. The configuration of sections is normally selected so the upper limit of the pass band approaches or exceeds twice the frequency of the lower limit of the pass band. Figure 10-13 shows typical arrangements for bandpass filters.

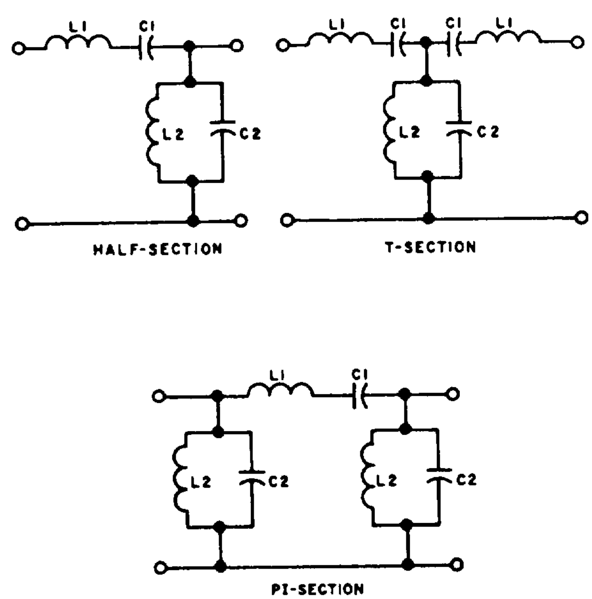


Figure 10-13.-Examples of bandpass filter circuits.

Band-Rejection Filters

A band-rejection (band-stop) filter is used to reject or block a band of frequencies from being passed. This filter allows all frequencies above and below this band to be passed with little or no attenuation.

The band-stop filter circuit consists of inductive and capacitive networks combined and connected to form a definite frequency response characteristic. The band-stop filter is designed to attenuate a specific frequency band and to permit the passage of all frequencies not within this specific band. The frequency range over which attenuation or poor transmission of signals occurs is called the "attenuation band." The frequency range over which the passage of signals readily occurs is called the "bandpass." The lowest frequency at which the attenuation of a signal starts to increase rapidly is known as the lower cutoff frequency. The highest frequency at which the attenuation of a signal starts to increase rapidly is known as the upper cutoff frequency. The basic configurations into which the band-reject filter elements can be arranged or assembled are known as the L- or half-section, the T-section, and the Pi-section configurations. These configurations are shown in figure 10-14. For a more in-depth discussion on the various filters discussed in this chapter, you should refer to NAVSHIPS 0967-000-0120, (EIMB), section 4.

BONDING

Learning Objective: *Identify purposes and techniques of bonding.*

Aircraft electrical bonding is defined as the process of obtaining the necessary electrical conductivity between all the metallic component parts of the aircraft. Bonding successfully brings all items of empennage and internal conduction objects to essentially the same dc voltage level appearing on the basic structure of the fuselage. However, bonding for radio frequencies is not quite so simple. Only direct bonding between affected components can accomplish the desired results at all frequencies. Only when direct bonding is impossible or operationally impracticable should bonding jumpers be used. Regardless of its dc resistance, any length of conductor has inductive reactance that increases directly with frequency. At a frequency for which the length of a bond is a quarter wavelength, the bond becomes a high impedance. The impedance of such a resonant lead becomes greater without limit as the dc resistance becomes lower. Multiple bonding using the same length of bonding jumper increases the impedance at the resonant frequency, but also tends to sharpen the high-impedance area around the resonant frequency. This sharpening is done by the rapid fall of impedance on each side of resonance.

PURPOSES OF BONDING

Bonding must be designed and executed to obtain the following results:

- Protect the aircraft and personnel from hazards associated with lightning discharges

- Provide power-current and fault-current return paths

- Provide sufficient homogeneity and stability of conductivity for RF currents affecting transmission and reception

- Prevent development of ac potentials on conducting frames, enclosures, cables of electrical and electronic equipment, and on conducting objects adjacent to unshielded transmitting antenna lead-ins

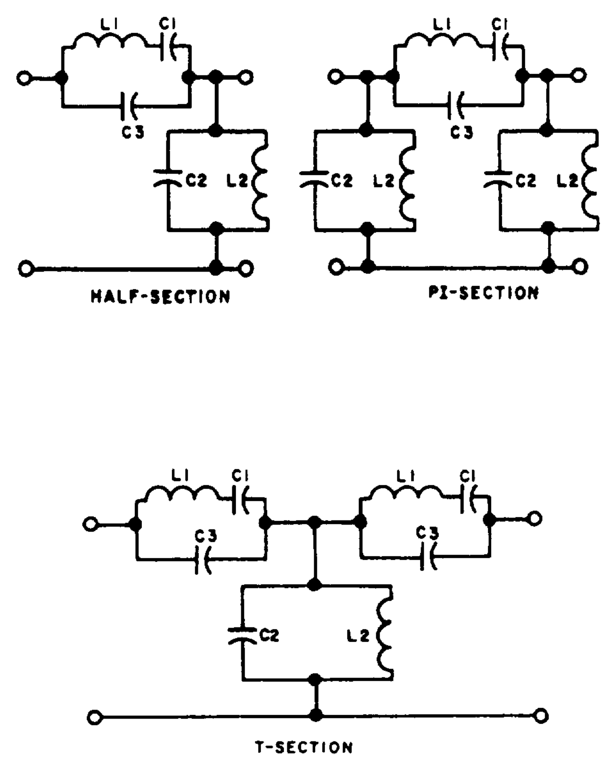


Figure 10-14.-Examples of band-reject filter circuits

- Protect personnel from the shock hazard resulting from equipment that experiences an internal power failure

- Prevent the accumulation of static charges that could produce radio interference or be an explosion hazard due to periodic spark discharge

BONDING FOR LIGHTNING PROTECTION

Close-riveted skin construction that divides any lightning current over a number of rivets is considered adequately bonded to provide a lightning discharge current path. Control surfaces and flaps should have a bonding jumper across each hinge. To protect the control cables and levers, additional jumpers should be connected between the control surface and the structure. The length of a discharge path through the control system should be at least 10 times the length of the path of the jumper or jumpers.

All external electrically isolated conducting objects (except antennas) should have a bonding jumper to the aircraft to ensure a low-impedance path. This is done so the voltage drop developed across the jumper system by the lightning discharge is minimized. The bonding jumpers must be kept as short as possible. When practical, a bonding jumper should not exceed 3 inches.

ELECTROSTATIC DISCHARGE

Learning Objective: *Recognize the hazards to electrostatic discharge-sensitive devices, to include proper handling and packaging techniques.*

The sensitivity of electronic devices and components to electrostatic discharge (ESD) has recently become clear through use, testing, and failure analysis. The construction and design features of current microtechnology have resulted in devices being destroyed or damaged by ESD voltages as low as 20 volts. The trend in this technology is toward greater complexity, increased packaging density, and thinner dielectrics between active elements. This trend will result in devices even more sensitive to ESD.

Various devices and components are susceptible to damage by electrostatic voltage levels commonly generated in production, test, operation, and by maintenance personnel. The devices and components include the following:

- All microelectronic and most semiconductor devices, except various power diodes and transistors

- Thick and thin film resistors, chips and hybrid devices, and crystals

All subassemblies, assemblies, and equipment containing these components/devices without adequate protective circuitry are ESD sensitive (ESDS).

You can protect ESDS items by implementing simple, low-cost ESD controls. Lack of implementation has resulted in high repair costs, excessive equipment downtime, and reduced equipment effectiveness.

The operational characteristics of a system may not normally show these failures. However, under internal built-in-test monitoring in a digital application, they become pronounced. For example, the system functions normally on the ground; but, when placed in an operational environment, a damaged PN junction might further degrade, causing its failure. Normal examination of these parts will not detect the damage unless you use a curve tracer to measure the signal rise and fall times, or check the parts for reverse leakage current.

STATIC ELECTRICITY

Static electricity is electrical energy at rest. Some substances readily give up electrons while others accumulate excessive electrons. When two substances are rubbed together, separated or flow relative to one another (such as gas or liquid over a solid), one substance becomes negatively charged and the other positively charged. An electrostatic field or lines of force emanate between a charged object to an object at a different electrostatic potential or ground. Objects entering this field will receive a charge by induction.

The capacitance of the charged object relative to another object or ground also has an effect on the field. If the capacitance is reduced, there is an inverse linear increase in voltage, since the charge must be conserved. As the capacitance decreases, the voltage increases until a discharge occurs via an arc.

Causes of Static Electricity

Generation of static electricity on an object by rubbing is known as the *triboelectric effect.* The following is a list of substances in the triboelectic series. The list is arranged in such an order that when any two substances in the list contact one another and then separate, the substance higher on the list assumes a positive charge.

Acetate

Glass

Human hair

Nylon

Wool

Fur

Aluminum

Polyester

Paper

Cotton

Wood

Steel

Acetate fiber

Nickel, copper, silver

Brass, stainless steel

Rubber

Acrylic

Polystyrene foam

Polyurethane foam

Saran

Polyethylene

Polypropylene

PVC (vinyl)

KEL F

Teflon®

The size of an electrostatic charge on two different materials is proportional to the separation of the two materials. Electrostatic voltage levels generated by nonconductors can be extremely high. However, air will slowly dissipate the charge to a nearby conductor or ground. The more moisture in the air, the faster a charge will dissipate. Table 10-1 shows typical measured charges generated by personnel in a manufacturing facility. Note the decrease in generated voltage with the increase in humidity levels of the surrounding air.

Table 10-1.-Typical Measured Electrostatic Voltages

MEANS OF STATIC GENERATION	VOLTAGE LEVELS @ RELATIVE HUMIDITY	
	LOW 10-20%	HIGH 65-90%
WALKING ACROSS CARPET	35,000	1,500
WALKING OVER VINYL FLOOR	12,000	250
WORKER AT BENCH	6,000	100
VINYL ENVELOPES FOR WORK INSTRUCTIONS	7,000	600
COMMON POLY BAG PICKED UP FROM BENCH	20,000	1,200
WORK CHAIR PADDED WITH URETHANE FOAM	18,000	1,500

Effects of Static Electricity

The effects of ESD are not recognized. Failures due to ESD are often misanalyzed as being caused by electrical overstress due to transients other than static. Many failures, often classified as other, random, unknown, etc., are actually caused by ESD. Misclassification of the defect is often caused by not performing failure analysis to the proper depth.

COMPONENT SUSCEPTIBILITY

All solid-state devices, except for various power transistors and diodes, are susceptible to damage by discharging electrostatic voltages. The discharge may occur across their terminals or through subjection of these devices to electrostatic fields.

LATENT FAILURE MECHANISMS

The ESD overstress can produce a dielectric breakdown of a self-healing nature when the current is unlimited. When this occurs, the device may retest good, but contain a hole in the gate oxide. With use, metal will eventually migrate through the puncture, resulting in a shorting of this oxide layer.

Another structure mechanism involves highly limited current dielectric breakdown from which no apparent damage is done. However, this reduces the voltage at which subsequent breakdown occurs to as low as one-third of the original breakdown value. ESD damage can result in a lowered damage threshold at which a subsequent lower voltage ESD will cause further degradation or a functional failure.

ESD ELIMINATION

The heart of an ESD control program is the ESD-protected work area and ESD grounded work station. When you handle an ESD-sensitive device outside of its ESD protective packaging, you need to provide a means to reduce generated electrostatic voltages below the levels at which the item is sensitive. The greater the margin between the level at which the generated voltages are limited and the ESDS item sensitivity level, the greater the probability of protecting that item.

PRIME GENERATORS

All common plastics and other generators should be prohibited in the ESD protected work area. Carpeting should also be prohibited. If you must use carpet, it should be of a permanently antistatic type. Perform weekly static voltage monitoring where carpeting is in use.

PERSONAL APPAREL AND GROUNDING

An essential part of the ESD program is grounding personnel and their apparel when handling ESDS material. Means of doing this are described in this section.

Smocks

Personnel handling ESDS items should wear long sleeve, ESD-protective smocks, short sleeve shirts or blouses, and ESD-protective gauntlets banded to the bare wrist and extending toward the elbow. If these items are not available, use other antistatic material (such as cotton) that will cover sections of the body that could contact an ESDS item during handling.

Personnel Ground Straps

Personnel ground straps should have a minimum resistance of 250,000 ohms. Based upon limiting leakage currents to personnel to 5 milliamperes, this resistance will protect personnel from shock from voltages up to 125 volts RMS. The wrist, leg, or ankle bracelet end of the ground strap should have some metal contact with the skin. Bracelets made completely of carbon-impregnated plastic may burnish around the area in contact with the skin, resulting in too high an impedance to ground.

ESD-PROTECTIVE MATERIALS

There are two basic types of ESD-protective material—conductive and antistatic. Conductive materials protect ESD devices from static discharges and electromagnetic fields. Antistatic material is a nonstatic generating material. Other than not generating static, antistatic material offers no other protection to an ESD device.

Conductive ESD-Protective Materials

Conductive ESD-protective materials consist of metal, metal-coated, and metal-impregnated materials. The most common conductive materials used for ESD protection are steel, aluminum, and carbon-impregnated polyethylene and nylon. The latter two are opaque, black, flexible, heat sealable, electrically conductive plastics. These plastics are composed of carbon particles, impregnated in the plastic, that provide volume conductivity throughout the material.

Antistatic ESD-Protective Materials

Antistatic materials are normally plastic-type materials (such as polyethylene, polyolefin, polyurethane, and nylon) that are impregnated with an antistatic substance. This antistatic migrates to the surface and combines with the humidity in the air to form a conductive sweat layer on the surface. This layer is invisible, and although highly resistive, it is amply conductive to prevent the buildup of electrostatic charges by triboelectric methods in normal handling. Simply stated, the primary asset of an antistatic material is that it will not generate a charge on its surface. However, this material won't protect an enclosed ESD device if it comes into contact with a charged surface.

This material is of a pink tint—a symbol of its being antistatic. Antistatic materials are for inner-wrap packaging. However, antistatic trays, vials, carriers, boxes, etc., are not used unless components and/or assemblies are wrapped in conductive packaging.

Hybrid ESD-Protective Bags

Lamination of different ESD-protective material is available. This combination of conductive and antistatic material provides the advantage of both types in a single bag.

ESDS DEVICE HANDLING

The following are general guidelines applicable to the handling of ESDS devices:

- Make sure that all containers, tools, test equipment, and fixtures used in ESD-protected areas are grounded before and during use. This may be done either directly or by contact with a grounded surface.

- Personnel handling ESDS items must avoid physical activities that are friction-producing in the vicinity of ESDS items. Some examples are putting on or removing smocks, wiping feet, and sliding objects over surfaces.

- Personnel handling ESDS items must wear cotton smocks and/or other antistatically treated clothing.

- Avoid the use or presence of plastics, synthetic textiles, rubber, finished wood, vinyls, and other static-generating materials (table 10-1) where ESDS items are handled out of their ESD-protective packaging.

- Place the ESD-protective material containing the ESDS item on a grounded work bench surface to remove any charge before opening the packaging material.

- Personnel must attach personnel grounding straps to ground themselves before removing ESDS items from their protective packaging.

- Remove ESDS items from ESD-protective packaging with fingers or metal grasping tool only after grounding, and place on the ESD-grounded work bench surface.

- Make periodic electrostatic measurements at all ESD-protected areas. This assures the ESD-protective properties of the work station and all equipment contained have not degraded.

- Perform periodic continuity checks of personnel ground straps, ESD-grounded work station surfaces, conductive floor mats, and other connections to ground. Perform this check with a megohmmeter to make sure grounding resistivity requirements are met.

ESDS DEVICE PACKAGING

Before an ESDS item leaves an ESD-protected area, package the item in one of the following ESD protective materials:

- Ensure shorting bars, clips, or noncorrective conductive materials are correctly inserted in or on all terminals or connectors.

- Package ESDS items in an inner wrap, of type II material conforming to MIL-B-81705, and an outer wrap of type I material conforming to MIL-B-81 705. You may use a laminated bag instead of the above provided it meets the requirements of MIL-B-81705. Cushion-wrap the item with electrostatic-free material conforming to PPP-C-1842, type III, style A. Place the cushioned item into a barrier bag fabricated from MIL-C-131 and heat-seal closed, method 1A-8. Place the wrapped, cushioned, or pouched ESDS item in bags conforming to MIL-B-117, type I, class F, style I. Mark the packaged unit with the ESD symbol and caution as shown in figure 10-15.

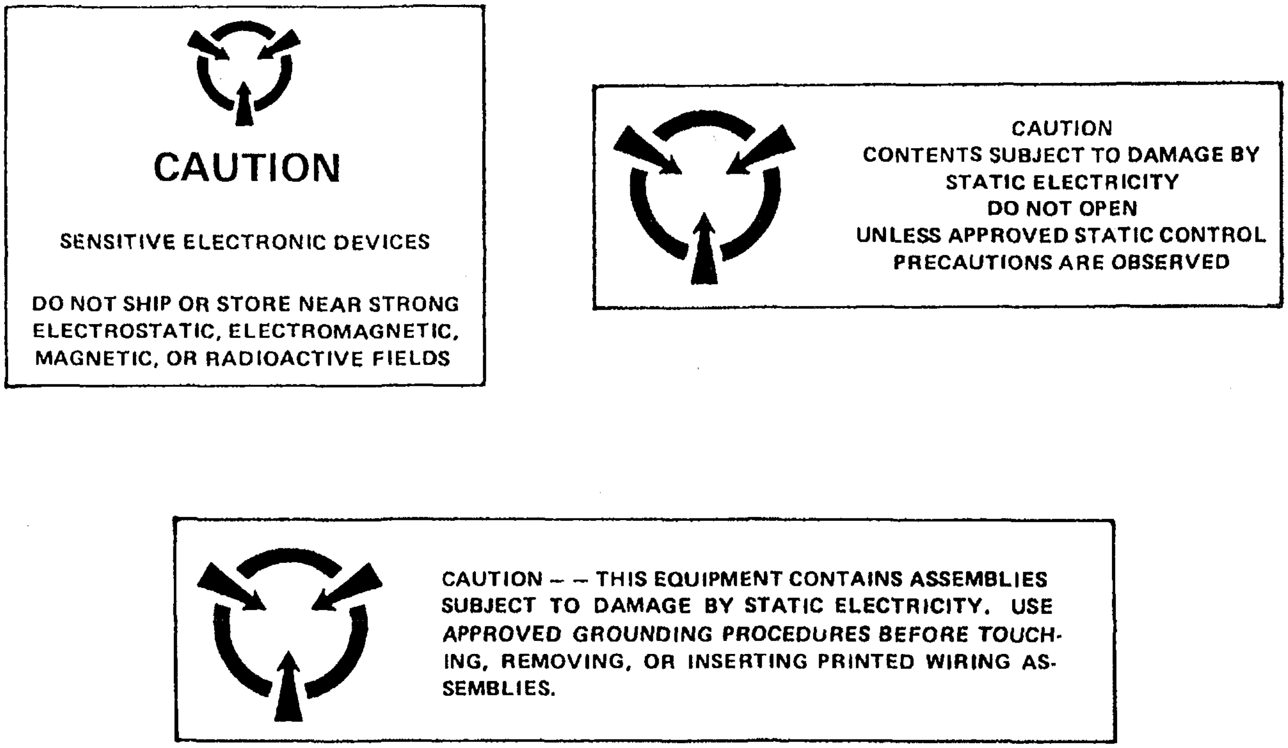


Figure 10-15.-ESDS markings.

REVIEW QUESTIONS

Q1. *What causes internally generated noise in a receiver?*

Q2. *Atmospheric static produces what indication on a visual output device?*

Q3. *What is the definition of a nonlinear device?*

Q4. *What is the crossover frequency of a 4μF capacitor with 2-inch leads?*

Q5. *A bonding jumper should not exceed how many inches in length?*

Q6. *What problems can arise if the ESD program is not implemented?*

Q7. *What voltage level can be built up by walking across a carpet in low humidity?*

Q8. *What are the two types of ESD-protective material?*

APPENDIX 1

REFERENCES USED TO DEVELOP THE TRAMAN

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

Chapter 1

Communication, TACAN, ADF Electronic Altimeter and IFF Systems, Navy Model F/TF-18A 160775 thru 161251, A1-F18AA-600-100, Naval Air Systems Command, Washington, D.C., 1 March 1980; Change 2, 15 October 1980.

Electronic Systems, Navy Model EA-6A Aircraft, NAVAIR 01-85ADB-2-3, Naval Air Systems Command, Washington, D.C., 15 April 1980; Change 3, 1 March 1991.

Integrated Navigation/Communication Station, Navy Model P-3C Aircraft, NAVAIR 01-75PAC-2-10, Naval Air Systems Command, Washington, D.C., 15 September 1991; Rapid Action Change 4, 15 June 1992.

Navy Electricity and Electronics Training Series (NEETS), Module 17, *Radio Frequency Communication Principles,* NAVEDTRA 172-17-00-84, Naval Education and Training Program Development Center, Pensacola, Fla., 1984.

Chapter 2

Air Navigation, NAVAIR 00-80V-49, Chapters 1,2,4,7, 18, and 19, Office of the Chief of Naval Operations, Washington D.C., 15 March 1983.

Principles of Operation - Avionic Systems - Nonacoustic Sensors, Electronic Countermeasures, Navigation, Automatic Flight Control and Communications, Navy Model S-3A, NAVAIR 01-S3AAA-2-2.14, Naval Air Systems Command, Washington, D.C., 15 April 1979; Change 7, 15 April 1989.

Electronic Systems, Navy Model EA-6A Aircraft, NAVAIR 01-85ADB-2-3, Naval Air Systems Command, Washington, D.C., 15 April 1980; Change 3, 1 March 1991.

Electronics Installation and Maintenance Book (EIMB), General, NAVSEA SE000-00-EIM-100, Naval Sea Systems Command, Washington D.C., 1983.

Integrated Navigation/Communication Station, Navy Model P-3C Aircraft, NAVAIR 01-75PAC-2-10, Naval Air Systems Command, Washington, D.C., 15 September 1991; Rapid Action Change 4, 15 June 1992.

Principles of Operation, Navigation Systems, Navy Models F-14A and F-14A (PLUS) Aircraft, NAVAIR 01-F14AAA-2-2-10, Naval Air Systems Command, Washington, D.C., 16 January 1989.

Chapter 3

Principles of Operation - Avionic System - Nonacoustic Sensors, Electronic Countermeasures, Navigation, Automatic Flight Control and Communications, Navy Model S-3A, NAVAIR 01-S3AAA-2-2.14, Naval Air Systems Command, Washington, D.C., 15 April 1979; Change 7, 15 April 1989.

Communication, TACAN, ADE Electronic Altimeter and IFF Systems, Navy Model F/TF-18A 160775 thru 161251, A1-F18AA-600-100, Naval Air Systems Command, Washington, D.C., 1 March 1980; Change 2, 15 October 1980.

Integrated Sensor Station 3, Navy Models P-3C Aircraft, NAVAIR 01-75PAC-2-8, Naval Air Systems Command, Washington, D.C., 1 October 1984; Change 3, 1 March 1991.

Chapter 4

NATOPS Flight Manual S-3A Aircraft, NAVAIR 01-S3AAA-1, Naval Air System Command, Washington D.C., September 1982; Change 1, January 1983.

General Information and Principles of Operation, Volume II, Avionics, Navy Model SH-3H, NAVAIR 01-230HLH-2-1.2, Naval Air Systems Command, Washington, D.C., 1 November 1989; Change 7, 15 February 1992.

Integrated Sensor Stations 1 and 2 - Update III, Navy Model P-3C Aircraft, NAVAIR 01-75PAC-2-15, Naval Air Systems Command, Washington, D.C., 1 April 1985; Change 5, 15 January 1989.

Chapter 5

Attitude Heading Reference System, AN/ASN-50, NAVAIR 05-35LAA-1, Naval Air Systems Command, Washington D.C., January 1984.

Principles of Operation - Avionics Systems - Data Processing Display and Control Acoustic Processing, Armament and Stores Control, NAVAIR 01-S3AAA-2-2.13, Naval Air System Command, Washington D.C., February 1976, Change 5, December 1987.

NATOPS Flight Manual S-3A Aircraft, NAVAIR 01-S3AAA-1, Naval Air System Command, Washington D.C., September 1982; Change 1, January 1983.

Integrated Flight Station Systems, Navy Model P-3C Aircraft, NAVAIR 01-75PAC-2-9, Naval Air Systems Command, Washington, D.C., 31 October 1984; Change 9, 1 February 1991.

Chapter 6

Forward Linking Infrared System, Navy Model F/TF-18A 160782 and 160785 thru 161251, A1-F18AA-744-100, Naval Air Systems Command, Washington, D.C., 1 February 1981.

Integrated Sensor Station 3, Navy Models P-3C Aircraft, NAVAIR 01-75PAC-2-8, Naval Air Systems Command, Washington, D.C., 1 October 1984; Rapid Action Change 9, 9 June 1988.

Chapter 7

Airborne Weapons/Stores Loading Manual, Navy Model F-14A/A+ Aircraft, NAVAIR 01-F14AAA-75, Naval Air Systems Command, Washington, D.C., 1 July 1990; Rapid Action Change 23, 1 November 1990.

Principles of Operation, Instruments and Displays, Navy Models F-14A and F-14A (PLUS) Aircraft, NAVAIR 01-F14AAA-2-2-8, Naval Air Systems Command, Washington, D.C., 16 January 1989.

LAMPS MK III Weapon System Manual, A1-H60BB-NFM-010, Naval Air Systems Command, Washington, D.C., 1 March 1992.

Chapter 8

Navy Electricity and Electronics Training Series (NEETS), Module 22, *Introduction to Digital Computers,* NAVEDTRA B72-22-00-88, Naval Education and Training Program Management Support Activity, Pensacola, Fla., 1988

Chapter 9

Automatic Flight Control Systems AN/ASW-16 and AN/ASW-42, Navy Models A-6E and KA-6D Aircraft, NAVAIR 01-85 ADA-2-5.1, Naval Air Systems Command, Washington, D.C., 15 July 1974; Rapid Action Change 2, 15 May 1991.

Chapter 10

Electronics Installation and Maintenance Book (EIMB), General, NAVSEA SE000-00-EIM-100, Naval Sea Systems Command, Washington D.C., 1983.

Electronics Installation and Maintenance Book (EIMB), General Maintenance, NAVSEA SE000-00-EIM-160, Naval Sea Systems Command, Washington D.C., 1981.

Installation Practices Aircraft Electric and Electronic Wiring, NAVAIR 01-1A-505, Naval Air Systems Command, Washington D.C., 1 December 1987.

APPENDIX II

ANSWERS TO REVIEW QUESTIONS

CHAPTER 1

A1. *Radio.*

A2. *3 GHz to 30 GHz*

A3. *Three.*

A4. *Manchester word encoding/decoding.*

A5. *116.000 to 155.975 MHz*

A6. *20.*

A7. *An interface fault.*

A8. *7.9000 to 9.1000 MHz and 18.9000 to 20.1000 MHz*

A9. *To protect the radio if lightning strikes the long-wire antenna.*

A10. *HF-1, HF-2, and UHF-2.*

A11. *The NAV/COMM.*

A12. *The TTY signal data converter.*

A13. *Communications Interface No. 1.*

CHAPTER 2

A1. *The position of one point in space relative to another without reference to the distance between them.*

A2. *12 miles.*

A3. *Parallels of latitudes and meridians of longitudes.*

A4. *The actual height that an aircraft is above the surface of the earth.*

A5. *One.*

A6. *20 to 5,000 feet.*

A7. *It automatically resets.*

A8. *ADF mode, loop mode, and antenna mode.*

A9. *RECEIVE mode.*

A10. *10.2 kHz, 11.3 kHz and 13.6 kHz.*

A11. *Drift; angle and ground speed.*

CHAPTER 3

A1. Airborne X-band.

A2. 20 degrees down to 10 degrees up.

A3. Scan switch.

A4. Four.

A5. 6 RPM.

A6. Three (search, fire control, and bomb director).

A7. 3,500 yards.

A8. Jizzle.

A9. Greater than 700 knots.

A10. A large X is displayed.

A11. 1, 2, 3/A, C, and 4.

A12. The UHF L-band blade antennas.

A13. 1030 MHz carrier.

A14. The fail light on the control box.

CHAPTER 4

A1. From the initial letters of SOund, NAvigation and Ranging.

A2. The transducer

A3. The salinity, the pressure, and the temperature.

A4. It controls the brightness of the cursor.

A5. 500±5 feet.

A6. Oil.

A7. A detectable distortion.

A8. The magnetic field will change.

A9. One.

A10. 50.

CHAPTER 5

A1. HSI.

A2. No.

A3. A fixed reference mark used to read the heading on the compass card.

A4. Head-Up Display.

A5. Tactical Display System.

A6. A transparent mirror positioned directly in front of the pilot at eye level.

A7. Seven.

A8. Five.

A9. The ADP

A10. A pickup device.

A11. The breaking up of the scene into minute elements and using these elements in an orderly manner.

A12. Four.

CHAPTER 6

A1. Between wavelengths 0.72 and 1,000 micrometers.

A2. They differ only in wavelength and frequency of oscillation.

A3. About 0.98 on a scale of 0 to 1.

A4. Photographic film.

A5. Each detector element requires a supporting electronic circuit.

A6. One element width.

A7. Passive.

A8. 180.

A9. Three are connected in a wye configuration, and three are connected in a delta configuration.

A10. The position mode, the FWD mode, the computer track mode, and the manual track mode.

A11. False. The status light and the picture are the only indications of a properly functioning indicator.

CHAPTER 7

A1. False.

A2. Notify the appropriate person(s).

A3. It symbolizes that the weapon station is loaded, ready, and selected.

A4. The armament safety override switch.

A5. AIM-7 missiles.

A6. Eight.

A7. 52.

A8. 25.

CHAPTER 8

A1. Cathode-ray tubes, transistors, microchips, and printed circuit cards.

A2. False.

A3. Binary, octal, decimal equivalents.

A4. Control unit, arithmetic-logic unit, and internal data storage unit.

A5. Coincident-current technique.

A6. 12.7 to 50.8 centimeters (5 to 20 inches).

A7. Linking two or more computers together.

A8. Speed versus power dissipation.

A9. The use of subroutines.

A10. Statement, analysis, flow diagram, encoding, debugging, and documentation.

CHAPTER 9

A1. False.

A2. Automatic, semiautomatic, and manual.

A3. As the aircraft passes through the acquisition window.

A4. No, the pilot can continue in any other mode.

CHAPTER 10

A1. Circuit deficiencies.

A2. Grass.

A3. A conductor semiconductor or solid-state device whose resistance or impedance varies with the voltage applied across it.

A4. 0.41 MHz

A5. 3 inches.

A6. High repair costs, excessive equipment downtime, and reduced equipment effectiveness.

A7. 35,000 volts.

A8. Conductive and antistatic.

APPENDIX III

FORMULAS

FORMULAS

Ohm's Law for dc Circuits

$$I = \frac{E}{R} = \frac{P}{E} = \sqrt{\frac{P}{R}}$$

$$R = \frac{E}{I} = \frac{P}{I^2} = \frac{E^2}{P}$$

$$E = IR = \frac{P}{I} = \sqrt{PR}$$

$$P = EI = \frac{E^2}{R} = I^2R$$

Resistors in Series

$$R_T = R_1 + R_2 + \ldots$$

Resistors in Parallel

Two resistors

$$R_T = \frac{R_1R_2}{R_1 + R_2}$$

More than two

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$$

RL Circuit Time Constant

$$\frac{\text{L (in henrys)}}{\text{R (in ohms)}} = \text{t (in seconds), or}$$

$$\frac{\text{L (in microhenrys)}}{\text{R (in ohms)}} = \text{t (in microseconds)}$$

RC Circuit Time Constant

R (ohms) $\times$ C (farads) = t (seconds)

R (megohms) $\times$ C (microfarads) = t (seconds)

R (ohms) $\times$ C (microfarads) = t (microseconds)

R (megohms) $\times$ C (micromicrofarads) = t (microseconds)

Capacitors in Series

Two capacitors

$$C_T = \frac{C_1C_2}{C_1 + C_2}$$

More than two

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

Capacitors in Parallel

$$C_T = C_1 + C_2 + \ldots$$

Capacitive Reactance

$$X_C = \frac{1}{2\pi fC}$$

Impedance in an RC Circuit (Series)

$$Z = \sqrt{R^2 + (X_C)^2}$$

Inductors in Series

$L_T = L_1 + L_2 + \ldots$ (No coupling between coils)

Inductors in Parallel

Two inductors

$$L_T = \frac{L_1L_2}{L_1 + L_2} \text{ (No coupling between coils)}$$

More than two

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots \text{ (No coupling between coils)}$$

Inductive Reactance

$$X_L = 2\pi fL$$

Q of a Coil

$$Q = \frac{X_L}{R}$$

Impedance of an RL Circuit (Series)

$$Z = \sqrt{R^2 + (X_L)^2}$$

Impedance with R, C, and L in Series

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Parallel Circuit Impedance

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2}$$

Sine-Wave Voltage Relationships

Average value

$$E_{ave} = \frac{2}{\pi} \times E_{max} = 0.637E_{max}$$

Effective or rms value

$$E_{eff} = \frac{E_{max}}{\sqrt{2}} = \frac{E_{max}}{1.414} = 0.707E_{max} = 1.11E_{ave}$$

Maximum value

$$E_{max} = \sqrt{2}(E_{eff}) = 1.414E_{eff} = 1.57E_{ave}$$

Voltage in an ac circuit

$$E = IZ = \frac{P}{I \times PF}$$

Current in an ac circuit

$$I = \frac{E}{Z} = \frac{P}{E \times PF}$$

Power in AC Circuit

Apparent power: $P = EI$

True power: $P = EI \cos\theta = EI \times PF$

Power Factor

$$PF = \frac{P}{EI} = \cos\theta$$

$$\cos\theta = \frac{\text{true power}}{\text{apparent power}}$$

Transformers

Voltage relationship

$$\frac{E_p}{E_s} = \frac{N_p}{N_s} \text{ or } E_s = E_p \times \frac{N_s}{N_p}$$

Current relationship

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

Induced voltage

$$E_{eff} = 4.44 \times BAfN \times 10^{-8}$$

Turns ratio

$$\frac{N_p}{N_s} = \sqrt{\frac{Z_p}{Z_s}}$$

Secondary current

$$I_s = I_p \times \frac{N_p}{N_s}$$

Secondary voltage

$$E_s = E_p \times \frac{N_s}{N_p}$$

Three-Phase Voltage and Current Relationships

With wye connected windings

$$E_{line} = \sqrt{3}(E_{coil}) = 1.732E_{coil}$$

$$I_{line} = I_{coil}$$

With delta connected windings

$$E_{line} = E_{coil}$$

$$I_{line} = 1.732I_{coil}$$

With wye or delta connected winding

$$P_{coil} = E_{coil}I_{coil}$$

$$P_t = 3P_{coil}$$

$$P_t = 1.732E_{line}I_{line}$$

(To convert to true power multiply by $\cos\theta$)

Resonance

At resonance

$$X_L = X_C$$

Resonant frequency

$$F_o = \frac{1}{2\pi\sqrt{LC}}$$

Series resonance

$$Z \text{ (at any frequency)} = R + j\,(X_L - X_C)$$

$$Z \text{ (at resonance)} = R$$

Parallel resonance

$$Z_{max} \text{ (at resonance)} = \frac{X_L X_C}{R} = \frac{X_L{}^2}{R} = QX_L = \frac{L}{CR}$$

Bandwidth

$$\Delta = \frac{F_o}{Q} = \frac{R}{2\pi L}$$

Tube Characteristics

Amplification factor

$$\mu = \frac{\Delta e_p}{\Delta e_g} \text{ (}i_p\text{ constant)}$$

$$\mu = g_m r_p$$

AC plate resistance

$$r_p = \frac{\Delta e_p}{\Delta i_p} \text{ (}e_g\text{ constant)}$$

Grid-plate transconductance

$$g_m = \frac{\Delta i_p}{\Delta e_g} \text{ (}e_p\text{ constant)}$$

Decibels

NOTE: Wherever the expression "log" appears without a subscript specifying the base, the logarithmic base is understood to be 10.

Power ratio

$$\text{dB} = 10 \log \frac{P_2}{P_1}$$

Current and voltage ratio

$$\text{dB} = 20 \log \frac{I_2\sqrt{R_2}}{I_1\sqrt{R_1}}$$

$$\text{dB} = 20 \log \frac{E_2\sqrt{R_1}}{E_1\sqrt{R_2}}$$

NOTE: When R_1 and R_2 are equal they may be omitted from the formula. When reference level is one milliwatt

$$\text{dBm} = 10 \log \frac{P}{0.001} \text{ (when P is in watts)}$$

Synchronous Speed of Motor

$$\text{rpm} = \frac{120 \times \text{frequency}}{\text{number of poles}}$$

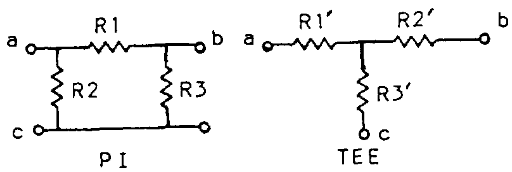
Wavelength

$$\text{wavelength (in meters)} = \frac{300}{\text{frequency (in megahertz)}}$$

$$\lambda = \frac{300}{f\ (\text{MHz})}$$

BRIDGE CIRCUIT CONVERSION FORMULAS

PI to Tee

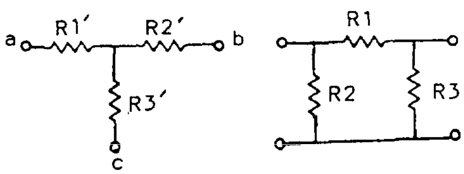


$$R_{1'} = \frac{R_1R_2}{R_1 + R_2 + R_3}$$

$$R_{2'} = \frac{R_1R_3}{R_1 + R_2 + R_3}$$

$$R_{3'} = \frac{R_2R_3}{R_1 + R_2 + R_3}$$

Tee to PI

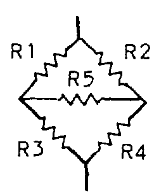


$$R_1 = \frac{R_{1'}R_{2'} + R_{2'}R_{3'} + R_{1'}R_{3'}}{R_{3'}}$$

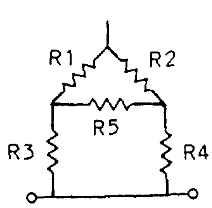
$$R_2 = \frac{R_{1'}R_{2'} + R_{2'}R_{3'} + R_{1'}R_{3'}}{R_{2'}}$$

$$R_3 = \frac{R_{1'}R_{2'} + R_{2'}R_{3'} + R_{1'}R_{3'}}{R_{1'}}$$

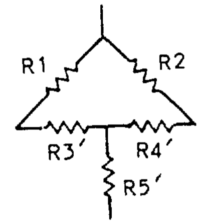
Calculating R_T for Bridge



1. **Redraw**



2. **Convert PI network made up of resistors $R_3R_4R_5$ to Tee network made up of $R_{3'}R_{4'}R_{5'}$**

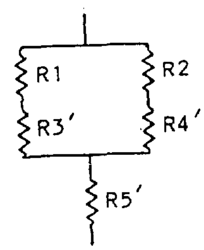


$$R_{3'} = \frac{R_3R_5}{R_3 + R_4 + R_5}$$

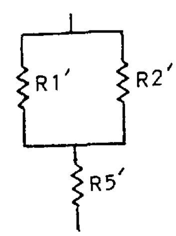
$$R_{4'} = \frac{R_4R_5}{R_3 + R_4 + R_5}$$

$$R_{5'} = \frac{R_3R_4}{R_3 + R_4 + R_5}$$

3. **Redraw circuit**

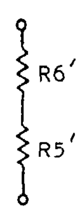


4. **Simplify circuit by combining**



$R_{1'} = R_1 + R_{3'}$ $\qquad$ $R_{2'} = R_2 + R_{4'}$

5. **Simplify again**



$$R_{6'} = \frac{R_{1'}R_{2'}}{R_{1'} + R_{2'}}$$

6. **Solve for R_T**

$$R_T = R_{6'} + R_{5'}$$

Comparison of Units in Electric and Magnetic Circuits

	Electric circuit	Magnetic circuit
Force, ...	Volt, E, or emf	Gilberts, F, or mmf
Flow	Ampere, I	Flux, ϕ, in maxwells
Opposition	Ohms, R	Reluctance, $\mathcal{R}$
Law	Ohm's law, $I = \frac{E}{R}$	Rowland's law, $\phi = \frac{F}{\mathcal{R}}$
Intensity of force	Volts per cm of length.	$H = \frac{1.257IN}{L}$, gilberts per centimeter of length.
Density	Current density—for example, amperes per cm^2.	Flux density—for example, lines per cm^2 or gausses.

INDEX

H

U

Assignment Questions

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

ASSIGNMENT 1

Textbook Assignment: "Communications," chapter 1, pages 1-1 through 1-25.

1-1. Electrical energy used by electronic communication travels at what rate?

1. The speed of light
2. The speed of sound
3. Speed proportional to transmitter power
4. Speed proportional to receiver sensitivity

1-2 l What is/are the major disadvantage(s) of radiotelegraph?

1. Slow speed only
2. Experienced sender only
3. Experienced receiver only
4. Slow speed and the need for experienced operators at both ends

1-3. What frequency bands were originally used for radiotelegraphy?

1. ELF and EHF
2. VLF and LF
3. MF and HF
4. VHF and UHF

1-4. What frequency bands have the prominent feature of ionospheric reflection?

1. ELF and EHF
2. VLF and LF
3. MF and HF
4. VHF and UHF

1-5. VHF and UHF bands are known as what type of transmission band?

1. Over-the-horizon
2. Fleet broadcast
3. Line-of-sight
4. Tactical

1-6. Which of the following functions is NOT performed by the IRC panel?

1. Controls VHF radio modes and functions
2. Controls UHF radio modes and functions
3. Controls HF radio modes and functions
4. Displays IFPM status of communication subsystems and components

1-7. The BITE indicator on the IRC panel will illuminate when a fault is detected in the

1. IRC panel
2. UHF1 or UHF2 only
3. HF,DTS, or SLU only
4. UHF1, UHF2, HF, DTS, or SLU

1-8. The LS-601/AI crew control panels are all identical and operate the same at each station.

1. True
2. False

1-9. Which of the following control(s) is/are located on the LS-602/AI control panel?

1. Radio select only
2. ICS select only
3. Volume control only
4. Radio select, ICS select, and volume control

1-10. What is the interrogation rate for each crew ICS panel and IRC by the change-of-status request from the SLU?

1. 25 microseconds
2. 25 milliseconds
3. 10 microseconds
4. 10 milliseconds

1-11. What will the S indicator illumination on the crew control panels indicate for a particular radio system?

1. System off
2. System available
3. System selected only
4. System secure mode selected

1-12. In the ICCG, which of the following components does NOT have identical binary coding and decoding circuits?

1. SLU
2. IRC
3. LS-601/AI
4. LS-602/AI

1-13. What binary number is recognized by the SLU as the pilot crew ICS panel in bits 2 through 6 of the 36-bit format?

1. 01110
2. 01010
3. 10101
4. 10110

1-14. What is bit 36 of the 36-bit format used for by the ICCG?

1. Parity bit
2. Entry bit
3. Tag bit
4. Flag bit

1-15. In the Manchester word format, what is the clock pulse rate?

1. 210 MHz
2. 210 kHz
3. 120 MHz
4. 120 kHz

1-16. What component generates the roll call for the communication system?

1. IRC
2. SLU
3. GPDC
4. LS-601/AI

1-17. The exhale word is a status word between the SLU and which component(s)?

1. IRC only
2. LS-601/AI only
3. GPDC only
4. IRC, LS-601/AI, and GPDC

1-18. Which components in the ICCG respond to more than one roll call address?

1. IRC and SLU
2. IRC and LS-601/AI
3. SLU and LS-601/AI
4. SLU and LS-602/AI

1-19. Which ICCG component recognizes and processes the first part of roll call 1 through the digital control section, line receiver, and inhale word register?

1. LS-601/AI
2. LS-602/AI
3. IRC
4. SLU

1-20. Which ICCG component generates the second part of roll call 1?

1. LS-601/AI
2. LS-602/AI
3. IRC
4. SLU

1-21. Where are the data and clock pulses separated in the SLU?

1. Digital control section
2. Line receiver
3. Input register
4. Inhale word register

1-22. What circuit in the SLU is used to shift data from one buffer to another once the data is shifted to the input register in the SLU?

1. Valid word register
2. Inhale word register
3. Master clock
4. Derived clock

1-23. What happens in the SLU if the input word is invalid three times?

1. The control register sets the BITE indicator on the SLU
2. The status register sets the BITE indicator on the component that sent the word
3. The status register sets the BITE indicator on the SLU
4. The control register sets the BITE indicator on the component that sent the word

1-24. When does the IRC/SLU roll call exchange end?

1. Last part of roll call 8
2. First part of roll call 8
3. First part of roll call 12
4. Last part of roll call 12

1-25. Which CREW ICS panel processes the first part of roll call 9?

1. TACCO
2. SENSO
3. Pilot
4. Copilot

1-26. What is the frequency range of the AN/ARC-197 VHF transceiver?

1. 116.000 to 151.975 Mhz
2. 108.000 to 151.975 Mhz
3. 116.000 to 151.975 kHz
4. 108.000 to 151.975 kHz

1-27. What are the microphone and headphone jacks on the RT-1397/ARC-197 transceiver NOT used for?

1. Maintenance
2. Normal operation
3. Emergency reception
4. Emergency transmission

1-28. What increments are the frequencies selectable on the AN/ARC-197?

1. Every 1 kKz
2. Every 1 MHz
3. Every 25 kHz
4. Every 25 MHz

1-29. What component reduces the crosstalk between the VHF and UHF systems?

1. VHF antenna
2. UHF antenna
3. UHF and VHF antenna coax routing
4. VHF bandpas filter

1-30. The VHF transmitter uses a total of how many stages of amplification to increase the output to 20 watts?

1. One
2. Two
3. Three
4. Five

1-31. Which of the following types of operation(s) is/are provided by the AN/ARC-187 UHF communication system?

1. AM only
2. FM only
3. FSK only
4. AM, FM, and FSK

1-32. The MEMORY read display only displays the frequency that has been selected by the manual selector switches.

1. True
2. False

1-33. The FAULT status indicator on the C-11950/ARC-187 indicates which of the following types of fault(s)?

1. Receiver transmitter only
2. Interface only
3. Control box only
4. Receiver transmitter, interface, and control box

1-34. What mode of frequency selection on the C-11950/ARC-187 control box disables the guard receiver?

1. SONOBUOY COMMAND
2. MANUAL
3. PRESET
4. GUARD

1-35. UHF-1 does NOT provide what type of operation?

1. ADF navigation
2. Cipher voice
3. Link 11 data
4. Cipher voice guard

1-36. UHF-2 does NOT provide what type of operation?

1. ADF navigation
2. Cipher voice
3. Link 11 data
4. Cipher voice guard

1-37. How many channels are available for automatic tuning in the UHF transceivers?

1. 8750
2. 8500
3. 7500
4. 7000

1-38. What system is used as a backup transmitter for the CASS system?

1. UHF-1
2. UHF-2
3. UHF-3
4. UHF-4

1-39. Which of the following components interface(s) the UHF-1 radio set with the voice and data sources?

1. COMM switching matrix
2. UHF-1 set control only
3. UHF-1 voice selector only
4. UHF-1 set control and voice selector

1-40. What component activates the SATCOM relay panel to the SATCOM mode of operation?

1. UHF-1 RT
2. UHF-2RT
3. UHF-1 control box
4. UHF-2 control box

1-41. What high-frequency security unit provides cipher voice communication with the AN/ARC-161 HF radio system?

1. TSEC/KY-75
2. TSEC/KY-58
3. TSEC/KY-28
4. TSEC/KW-7

1-42. How many channels does the AN/ARC-161 HF radio system tune to automatically?

1. 820,000
2. 280,000
3. 180,000
4. 128,000

1-43. Coupling might NOT be possible on the HF-1 antenna in which of the following frequency ranges?

1. 2.0000 to 4.8000 MHz
2. 6.0000 to 12.0000 MHz
3. 12.0000 to 13.2000 MHz
4. 13.2000 to 19.2000 MHz

1-44. What component of the AN/ARC-161 HP radio system includes the lightening arrester?

1. RT-1000/ARC-161
2. AM-6561/ARC-161
3. C-9245/ARC-161
4. CU-2070/ARC

1-45. Illumination of the CPLR READY indicator on the C-9245/ARC-161 indicates the associated coupler has passed the self-test routine.

1. True
2. False

1-46. What indicator on the C-9245/ARC-161 will illuminate anytime the radio set fails self-test?

1. CPLR FAULT
2. CONT FAULT
3. SYS FAULT
4. RT FAULT

1-47. When does the XMTR OFF indicator illuminate on the C-9245/ARC-161?

1. First 5 minutes of initial power up
2. Operating frequency change less than 1 Mhz
3. System fault that affects the transmitter
4. BLANKER ON deselected

1-48. What switch on the C-9245/ARC-161 sets the transmitter for high-power output?

1. COND
2. RESET
3. SQ OFF
4. BLANKER ON

1-49. What switch on the C-9245/ARC-161 permits AHE transmission and reception?

1. AME
2. COND
3. RESET
4. MODE

1-50. What component of the AN/ARC-161 HP radio system provides Impedance matching between the antenna and the receiver transmitter?

1. CU-2070/ARC
2. AM-6561/ARC-161
3. RT-1100/ARC-161
4. C-9245/ARC-161

1-51. What component of the AN/ARC-161 HF radio system provides a spark gap to protect the radio if lightning strikes the long-wire antenna?

1. CU-2070/ARC
2. AM-6561/ARC-161
3. RT-1100/ARC-161
4. C-9245/ARC-161

1-52. What type of mount are the top mounts for the HF long-wire antennas?

1. Fixed
2. Breakaway
3. Feed-through
4. Movable

1-53. What switch on the TSEC/KY-75 RCU selects the storage area when the key Is loaded in the KY-75?

1. SIG CLR
2. PWR/FILL
3. KY-75 RCU
4. ALARM

1-54. What component of the AN/ARC-161 HF radio system has a mic/headset connection for emergency and maintenance operation of voice and keying signals?

1. CU-2070/ARC
2. RT-1100/ARC-161
3. AM-6561/ARC-161
4. C-9245/ARC-161

1-55. Which of the following radio systems may be used to transmit and receive data link?

1. HF-1, UHF-1, and UHF-2
2. HF-2, UHF-1, and UHF-2
3. HF-1, HF-2, and UHF-1
4. HF-1, HF-2, and UHF-2

1-56. What component of the data link system converts serial digital data into audio tones for transmission over a voice radio?

1. PP-6140/ACQ-5
2. C-7790/ACQ-5
3. CV-2528/ACQ-5
4. RT-1254/ACQ-5

1-57. What unit converts 30-bit parallel binary computer data words Into 26-bit serial data transmission language?

1. Conmunications switching matrix
2. Communications secure switching matrix
3. Communications interface No. 1
4. Communications interface No. 2

1-58. Who has the primary responsibility for the hardware setup of the data link system?

1. COTAC
2. TACCO
3. NAV/COMM
4. SENSOR 3

1-59. What are the fixed-length blocks that the data link system formats tactical information into called?

1. Frames
2. Sections
3. Sectors
4. Rings

IN ANSWERING QUESTIONS 1-60 THROUGH 1-63, SELECT FROM COLUMN B THE DATA LINK DEFINITION THAT DEFINES THE DATA LINK TERM IN COLUMN A.

	A. DATA LINK TERMS	B. DATA LINK DEFINITIONS
1-60.	Participating unit	1. Any station that is not the DNCU
1-61.	Data net control unit	2. Any ship, or shore station active in the data link net
1-62.	Picket unit	3. Any unit that has overall control over the link net
1-63.	Data link reference position	4. Latitude and longitude reference position for all data transmitted on the net

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1-64. What is the data link system's normal mode of operation?

1. LONG BROADCAST
2. SHORT BROADCAST
3. Roll call
4. Picket

1-65. Which of the following selections are made on the DTS when this system is acting as the DNCU?

1. PICKET and CONTROL
2. PICKET and ROLL CALL
3. DNCU and CONTROL
4. CONTROL and ROLL CAIL

1-66. What selection is made on the DTS when a surface ship or ASWOC is the DNCU?

1. CONTROL
2. ROLL CALL
3. PICKET
4. DNCU

1-67. How long will the LONG BROADCAST function transmit when selected?

1. 5 minutes
2. Continuously
3. Through a single set of data
4. Through all data twice

1-68. How long will the SHORT BROADCAST function transmit when selected?

1. 5 minutes
2. Continuously
3. Through a single set of data
4. Through all data twice

1-69. Pickets use the broadcast functions during roll call.

1. True
2. False

1-70. When radio silence is selected, the DTS will NOT receive data.

1. True
2. False

1-71. Which of the following radio systems may be used to transmit and receive TTY?

1. HF-1, HF-2, and UHF-2
2. HF-1, HF-2, and UHF-1
3. HF-1, HF-2, and VHF
4. HF-1, UHF-1, and VHF

1-72. What security unit provides encryption and decryption for all teletype data in the aircraft?

1. TSEC/KW-7
2. TSEC/KY-7
3. TSEC/KW-28
4. TSEC/KY-28

1-73. What unit provides an Interface between the TTY system and the radios?

1. Teleprinter secure interface
2. TTY signal data converter
3. Communcations interface No. 1
4. Communications interface No. 2

1-74. What unit connects the TTY system with the central computer?

1. Teleprinter secure Interface
2. TTY signal data converter
3. Communications interface No. 1
4. Communications interface No. 2

1-75. What selection is made on the HSP to produce hard copy of computer data?

1. CMPTR
2. HRD CPY
3. CONST
4. EDIT

ASSIGNMENT 2

Textbook Assignment: "Navigation," chapter 2, pages 2-1 through 2-19.

2-1. Which of the following Instrument(s) invention in the early 1700s made accurate navigation possible, even when far away from land?

1. Astrolabe
2. Sextant only
3. Chronometer only
4. Sextant and chronometer

IN ANSWERING QUESTIONS 2-2 THROUGH 2-5, SELECT THE NAVIGATION TERM FROM COLUMN B THAT IS DEFINED BY THE NAVIGATION DEFINITION IN COLUMN A.

	A. DEFINITIONS	B. TERMS
2-2.	Position of one point In space relative to another point without reference to distance	1. Position
2-3.	A point defined by stated or implied coordinates	2. Direction
2-4.	An elapsed interval	3. Distance
2-5.	Separation of two points, measured by the length of the line joining them	4. Time

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2-6. What distance is the approximate difference between the highest point and lowest point on the earth's crust?

1. 10 miles
2. 12 miles
3. 15 miles
4. 18 miles

2-7. In reference to the earth's size and shape, which of the following conditions best describes the term ellipticity of the earth?

1. The diameter of the earth measured around the equator (6,887.91 nmi)
2. The diameter of the earth measured through the poles (6864.57 nmi)
3. The ratio between the equatorial and polar diameters (.9966 to 1)
4. The difference between the diameters around the equator and through the poles (23.34 nmi)

2-8. The arc of a great circle is the shortest distance between two points on a plane.

1. True
2. False

2-9. How many sections is a meridian divided into by the equator and the poles?

1. Six
2. Two
3. Eight
4. Four

2-10. The arbitrary starting point for longitude is identified by which of the following terms?

1. Greenwich or zero meridian only
2. Prime or zero meridian only
3. First or prime meridian only
4. Greenwich, zero, prime, or first meridian

2-11. Which of the following are the subdivisions of a degree of arc?

1. Minutes and seconds, or minutes end tenths of minutes
2. Hours, seconds, and tenths of seconds
3. Hours, minutes, and seconds
4. Hours, minutes, end tenths of minutes

2-12. Which of the following is the nautical miles to statute miles conversion ratio?

1. 6,000 ft = 1 statute mile
2. 1.15 nautical mile = 1 statute mile
3. 1.15 statute mile = 1 nautical mile
4. 5,280 ft = 1 nautical mile

2-13. A speed of 500 knots and a speed of 500 nautical miles per hour are equivalent.

1. True
2. False

IN ANSWERING QUESTIONS 2-14 AND 2-15, REFER TO FIGURE 2-5 IN THE TEXTBOOK.

2-14. What circle represents the horizon divided into 360 degrees?

1. Compass gyro
2. Wet compass
3. Compass rose
4. Magnetic compass

2-15. What is the true heading of the aircraft?

1. 000 degree
2. 062 degrees
3. 110 degrees
4. 295 degrees

IN ANSWERING QUESTIONS 2-16 AND 2-17, REFER TO FIGURE 2-6 IN THE TEXTBOOK.

2-16. If the true heading of the aircraft shown is changed to 225 degrees, what is the true bearing to the island?

1. 045 degrees
2. 090 degrees
3. 180 degrees
4. 225 degrees

2-17. If the true heading of the aircraft shown is changed to 225 degrees, what is the relative bearing to the island?

1. 045 degrees
2. 090 degrees
3. 180 degrees
4. 225 degrees

2-18. What type of navigation uses only speed and heading measurements to compute position changes from an initial position fix?

1. Inertial
2. Dead reckoning
3. Magnetic
4. Doppler

2-19. World War II fostered the development of which of the following radio aids?

1. Doppler
2. TACAN
3. Omega
4. Loran

2-20. Altitude is defined as the horizontal distance of a level, a point, or en object measured from a given point.

1. True
2. False

2-21. Every aircraft has what type of altimeter?

1. Pressure
2. Laser
3. Radar
4. Absolute

IN ANSWERING QUESTIONS 2-22 THROUGH 2-28, SELECT FROM THE FOLLOWING LIST THE TERM DESCRIBED IN THE QUESTION.

A. Absolute altitude
B. Calibrated altitude
C. Density altitude
D. Indicated altitude
E. Pressure altitude
F. True altitude
G. Standard datum plane

2-22. The zero-elevation level of an Imaginary atmosphere known as the standard atmosphere

1. A
2. C
3. E
4. G

2-23. The value of altitude that is displayed on the pressure altimeter

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

2-24. Indicated altitude corrected for installation/position error

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

2-25. The height above the standard datum plane

1. A
2. C
3. E
4. G

2-26. Pressure altitude corrected for temperature

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

2-27. The actual vertical distance above mean sea level

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

2-28. The height above the terrain

1. A
2. C
3. E
4. G

IN ANSWERING QUESTION 2-29, REFER TO FIGURE 2-7 IN THE TEXTBOOK.

2-29. At standard pressure, how many inches of mercury are equal to 670.2 millibars?

1. 17.58
2. 19.79
3. 20.58
4. 29.92

2-30. What type of altitude is indicated on the pressure altimeter?

1. Absolute altitude
2. Calibrated altitude
3. Density altitude
4. Indicated altitude

2-31. What part of the reference plane is indicated on the barometric scale of the pressure altimeter?

1. The barometric pressure (in.Hg)
2. The barometric pressure (millibars)
3. The standard temperature (°C)
4. The standard temperature (°F)

2-32. Which of the following types of pressure altimeters is/are used in aircraft?

1. Counter-drum only
2. Counter-pointer only
3. Counter-drum-pointer only
4. Counter-drum-pointer and counter-pointer

2-33. What increments in feet, from 0 to 80,000, does the counter-pointer altimeter two-digit display indicate?

1. 100
2. 500
3. 1,000
4. 10,000

2-34. Misinterpreting altitude by 1,000 feet immediately before or after the 1,000-foot counter moves is a problem with which of the following types of pressure altimeters?

1. Counter-drum only
2. Counter-pointer only
3. Counter-drum-pointer only
4. Counter-drum-pointer and counter-pointer

2-35. Misinterpreting altitude by 1,000 feet immediately before and after the 1,000-foot counter moves is prevented by which of the following types of altimeters?

1. Counter-drum only
2. Counter-pointer only
3. Counter-drum-pointer only
4. Counter-drum-pointer and counter-pointer

2-36. What mode of operation of the counter-drum-pointer altimeter uses static pressure from the static system that is NOT corrected for position error?

1. Standby
2. Servoed
3. Code
4. Decode

2-37. If electrical power is lost to the counter-drum-pointer altimeter, the altimeter automatically switches to what mode of operation?

1. Standby
2. Servoed
3. Code
4. Decode

IN ANSWERING QUESTIONS 2-38 THROUGH 2-42, SELECT FROM THE FOLLOWING LIST THE TYPE OF PRESSURE ALTIMETER ERROR DESCRIBED IN THE QUESTION.

A. Mechanical
B. Scale
C. Installation/position
D. Reversal
E. Hysteresis

2-38. The lag in the altitude indication due to the elastic properties of the materials within the altimeter

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

2-39. A momentary indication in the opposite direction

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

2-40. Caused by the airflow around the static ports

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

2-41. Caused by the irregular expansion of the aneroid cells

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

2-42. Caused by the misalignment in the gears and the levers

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

2-43. What method does the AN/APN-194(V) radar altimeter use to determine altitude?

1. Doppler shift
2. Frequency change
3. Time delay
4. Signal strength

2-44. The control knob on the ID-1760A/APN-194(V) has which of the following functions?

1. Power switch only
2. Self-test switch only
3. Position control for the limit bug
4. Power and self-test switch and position control for the limit bug

2-45. Locked at 550 feet, in what altitude mode is the RT-1042/APN-194(V) operating?

1. Search
2. Track
3. Low-level
4. High-level

2-46. Locked at 2,500 feet, in what range mode is the RT-1042/APN-194(V) operating?

1. Search
2. Track
3. Low-level
4. High-level

2-47. What component of the AN/APN-194(V) system provides isolation of the receiver from the transmit antenna?

1. BZ-157A
2. RT-1042/APN-194(V)
3. ID-1760A/APN-194(V)
4. MX-9132A/APN-194(V)

2-48. What component in the EA-6A aircraft applies a 2-second tone alternating between 700 and 1,700 Hz at 2-Hz intervals to the Its?

1. BZ-157A
2. RT-1042/APN-194(V)
3. ID-1760A/APN-194(V)
4. MZ-9132A/APN-194(V)

2-49. What altitude is the high-altitude index on the AN/APQ-107 system when installed in the P-3C aircraft?

1. 170 (±20) feet
2. 380 (±20) feet
3. 700 (±20) feet
4. 830 (±20) feet

2-50. What altitude above takeoff altitude does the RAWS inhibit the radar altimeter reliability signal?

1. 170 feet
2. 380 feet
3. 700 feet
4. 830 feet

2-51. What control on the C-6899/ARN-83 causes a tone to be produced for tuning purposes?

1. ADF switch
2. LOOP switch
3. ANT switch
4. BFO switch

2-52. The loop antenna signals are mixed with the sense antenna signal in the R-1391/ARN-83 in what mode of operation?

1. ADF
2. BFO
3. LOOP
4. ANTENNA

2-53. What mode of operation causes the R-1391/ARN-83 to act as a normal receiver?

1. ADF
2. BFO
3. LOOP
4. ANTENNA

IN ANSWERING QUESTIONS 2-54 THROUGH 2-56, REFER TO FIGURE 2-12 IN THE TEXTBOOK.

2-54. What type of radiation pattern is generated by the parasitic antenna elements in the outer rotating cylinder of a typical TACAN station?

1. Nine-lobe for course bearing
2. Nine-lobe for fine bearing
3. Cardioid for course bearing
4. Cardioid for fine bearing

2-55. What type of radiation pattern Is generated by the parasitic antenna element in the inner rotating cylinder of a typical TACAN station?

1. Nine-lobe for course bearing
2. Nine-lobe for fine bearing
3. Cardioid for course bearing
4. Cardioid for fine bearing

2-56. How many auxiliary reference bursts per revolution is/are there in the pattern from a typical TACAN station?

1. One
2. Five
3. Eight
4. Nine

2-57. At what interval does the TACAN ground station identify itself by transmitting its call letters in Morse code?

1. 37.2 seconds
2. 39.7 seconds
3. 45.0 seconds
4. 53.8 seconds

2-58. Which of the following items facilitate(s) calculation of slant range from the aircraft to the ground station?

1. Ground station bearing
2. Ground station identity
3. Time between ground station interrogation and aircraft reply
4. Time between aircraft interrogation and ground station reply

2-59. Which of the following information is computed and/or processed in the RT-1022/ARN-84(V)?

1. Station bearing and slant range only
2. Station bearing and identity only
3. Station slant range and identity only
4. Station bearing, slant range, and identity

2-60. Which of the following station information is provided by the AN/ARN-84 system in the receive mode?

1. Bearing and identity only
2. Range and identity only
3. Bearing and range only
4. Bearing, range, and identity

2-61. Which of the following station information is provided by the AN/ARN-84 system in the T/R mode?

1. Bearing and identity only
2. Range and identity only
3. Bearing and range only
4. Bearing, range, and identity

2-62. Two aircraft are using the A/A mode of operation. The first aircraft is on channel 23. On what channel is the second aircraft on?

1. 23
2. 63
3. 86
4. 126

2-63. Which of the following indications will be seen if a fault is detected during interruptive self-test in the AN/ARN-84 system?

1. GO indicator till light on the control panel for 9 seconds
2. NO-GO indicator will light on the control panel only
3. NO-GO indicator will light on the RT only
4. NO-GO indicators will light on the control panel and the RT

2-64. What distance is the maximum range to receive usable loran signals over water?

1. 2,000 miles
2. 2,800 miles
3. 3,000 miles
4. 3,800 miles

2-65. What antenna is used to receive loran signals for the AN/ARN-83 system?

1. UHF1 top blade
2. HF2 long-wire
3. ADF sense
4. VHF stub

2-66. The omega ground stations transmit on which of the following frequencies?

1. 10.0, 11.3, and 13.6 kHz
2. 10.2, 11.3, and 13.6 kHz
3. 10.2, 11.6, and 13.6 kHz
4. 10.6, 11.3, and 13.2 kHz

2-67. Omega ground station(s) is/are deselected at what range(s)?

1. Less than 600 nmi only
2. More than 7,200 nmi only
3. Less than 600 nmi and more than 7,200 nmi
4. Between 600 nmi and 7,200 nmi

2-68. After synchronization of the AN/ARN-99(V) omega system, what component controls the antenna selection?

1. Central computer
2. Antenna coupler
3. Control panel
4. Receiver-converter

2-69. What section of the OR-90/ARN-99(V) enables test signals to be injected into the omega system?

1. Correlator
2. Receiver
3. Digital converter
4. Discrete storage

2-70. What section in the OR-90/ARN-99(V) acts as an interface between the communication and the receiver sections?

1. Correlator
2. Digital converter
3. Discrete storage
4. Power supply

2-71. The AN/APN-153(V) navigational set provides which of the following types of navigational information?

1. Airspeed and altitude
2. Ground speed and drift angle
3. Airspeed and drift angle
4. Ground speed and altitude

2-72. What information is derived from the antenna azimuth position of the AN/APN-153(V) navigational set?

1. Altitude
2. Airspeed
3. Drift angle
4. Ground speed

2-73. What component of the AN/APN-153(V) uses a magnetron power oscillator?

1. Receiver-transmitter
2. Control indicator
3. Central computer
4. Antenna

2-74. What component of the AN/APN-153(V) contains the pitch and roll rotary couplers?

1. Receiver-transmitter
2. Control indicator
3. Central computer
4. Antenna

2-75. On the C-4418A/APN-153(V) after the TEST position is selected on the mode switch, what is the delay time prior to proper test indications?

1. 1 minute
2. 2 minutes
3. 15 seconds
4. 45 seconds

ASSIGNMENT 3

Textbook Assignments "Radar," chapter 3, pages 3-1 through 3-23.

3-1. The AN/APS-115B radar set is what band of radar?

1. W
2. X
3. Y
4. Z

3-2. What component of the AN/APS-115B radar set combines the radar video?

1. APP
2. RIU
3. CRS
4. SDD

3-3. What component displays radar video information?

1. APP
2. RIU
3. CRS
4. SDD

3-4. Tilt stabilization of the radar antennas is accomplished by use of pitch and roll data from what component?

1. APP
2. RIU
3. CRS
4. SDD

3-5. With both antennas in full scan, which of the following points are the crossover points relative to aircraft heading?

1. 000° and 180°
2. 060° and 270°
3. 090° and 270°
4. 120° and 300°

3-6. What operator station contains the radar system operating controls?

1. Acoustic sensor
2. Nonacoustic sensor
3. Tactical coordinator
4. Navigator/communicator

3-7. What is the manual tilt range of the radar antenna control from aircraft horizontal?

1. ±15°
2. ±30°
3. +10° to -20°
4. +20° to -10°

3-8. What will 000° displayed indicate with HEADING STAB selected on the radar antenna control?

1. Aircraft heading
2. True heading
3. Magnetic heading
4. Target heading

3-9. With respect to the aircraft, what is the mechanical limit for radar antenna stabilization?

1. ±10°
2. ±15°
3. ±20°
4. ±30°

3-10. With the scan switch In FULL on the radar antenna control, how many degrees will the antenna scan during single system operation?

1. 45°
2. 90°
3. 180°
4. 240°

3-11. With the scan switch in SECTOR on the radar antenna control, how many degrees will the antennas scan?

1. 45°
2. 90°
3. 180°
4. 240°

3-12. The antenna position programmer generates which of the following signals?

1. Signals for antenna azimuth drive motors only
2. Signals for antenna tilt drive motors only
3. Signals for timing and synchronization of the RTs, RIU, and IFF only
4. Signals for antenna azimuth and tilt drive motors and signals for timing and synchronization of the RTs, RIU, and IFF

3-13. What position is selected on the APP fault isolation switch for the normal mode of operation?

1. ON
2. OFF
3. NORMAL
4. OPERATE

3-14. What frequency agile component in the radar transmitter of the AN/APS-115B radar system is NOT in a standard radar transmitter?

1. Magnetron
2. Klystron
3. Modulator
4. Synchronizer

3-15. The frequency agility of the AN/APS-115B radar system has what positive effect on the system?

1. Doubles the PW of the transmitter
2. Enhances the clutter elimination capability
3. Decreases the antenna scan speed
4. Decreases PRF, which increases operational range

3-16. What component generates the synchronization that locks the transmitter and receiver AFC together?

1. Manual varactor
2. Motor-driven varactor
3. Receiver agile modulator-demodulator
4. Transmitter agile modulator-demodulator

3-17. What subsection of the radar RT contains a desiccant cartridge?

1. Waveguide pressurization system
2. Transmitter
3. Receiver
4. BITE

3-18. Which of the following two beam modes will the radar antenna radiate?

1. Pencil and conical
2. Elliptical and cosecant squared
3. Pencil and cosecant squared
4. Elliptical and conical

3-19. What are the dimensions of the AS-2146/APS-115 radar antenna spoiled beam?

1. 2.5° by 2.5°
2. 2.5° by 3.8°
3. 2.5° by 20.0°
4. 3.8° by 20.0°

3-20. The antenna elevation parking control is used to stow the aft antenna at zero-degree relative aircraft heading when the aft radar is secured.

1. True
2. False

3-21. What mode is selected on the forward radar control panel to operate the forward radar in the sweep frequency mode?

1. LONG
2. SHORT
3. FIXED
4. AGILE

3-22. What mode is selected on the radar control panels to operate the radar antennas at a 6-RPM scan rate?

1. LONG
2. SHORT
3. STC
4. FTC

3-23. On the radar control panels, what section on the high voltage select switch indicates to the operator that the radar system Is ready for use when illuminated?

1. WARM-UP
2. STANDBY
3. HV OFF
4. HV FAIL

3-24. What selection is made on the radar control panels to improve the display when a target is near a landmass?

1. LONG
2. SHORT
3. STC
4. FTC

3-25. What knob is adjusted on the radar control panels to match the radar noise levels between the forward and aft radars?

1. STC DEPTH
2. STC RANGE
3. RCVR GAIN
4. MAN TUNE

3-26. What knob on the radar control panels varies the amount of receiver attenuation for close-in targets?

1. STC DEPTH
2. STC RANGE
3. RCVR GAIN
4. MAN TUNE

3-27. What knob on the radar control panels varies the distance between 0 and 20 nautical miles to which intensity of close-in targets is effectively reduced?

1. STC DEPTH
2. STC RANGE
3. RCVR GAIN
4. MAN TUNE

3-28. With the AFC/MAN switch In the MAN position on the radar control panels, the radars are in what mode of operation?

1. Short
2. Long
3. Sweep
4. Fixed

3-29. The radar scan converter control routes the on-line/off-line selection of the radar set operation to what component?

1. APP
2. RIU
3. CRS
4. SDD

3-30. Selection of the on-line operation on the radar scan converter control will disable all manual selections with the exception of the power switch on the front panel of what component?

1. CP
2. APP
3. RIU
4. LU 1

3-31. What light will illuminate on the radar scan converter control to indicate the radar set is in the off-line mode of operation?

1. APP
2. RIU
3. TEST
4. OFF LINE

3-32. The 128 nautical mile range is selected on the radar scan converter control during off-line operation of the radar set. How many range marks are added to the radar video?

1. 8
2. 2
3. 12
4. 4

3-33. What component combines and amplifies radar and IFF video, and then routes this data to the nonacoustic operator's display?

1. APP
2. RIU
3. CRS
4. SDD

3-34. On the RIU, what control is used by the operator to input commands selected on the front switch panel into the logic circuits?

1. ENTER push button
2. LOAD push button
3. STOR switch
4. OPER switch

3-35. Which of the following types of display presentations are selectable by the operator on the RIU front switch panel?

1. A-scan and PPI scan only
2. B-scan and PPI scan only
3. A-scan and B-scan only
4. A-scan, B-scan, and PPI scan

3-36. What component processes and coordinates forward and aft antenna position and scan functions, the application of power to both sets, and controls transmit and receive modes of the two RTs?

1. Logic unit one
2. Central computer
3. Radar interface unit
4. Antenna position programmer

3-37. The sensor station 3 keyset generates primary control signals in the on-line mode of operation, which are processed through the central computer, LU 1, and the RIU.

1. True
2. False

3-38. What is the range of the 11D13A radar maintenance trainer?

1. 0 to 80,000 miles
2. 0 to 80,000 kilometers
3. 0 to 80,000 yards
4. 0 to 80,000 feet

3-39. In what unit of measure is an actual weapons control radar ranges normally expressed?

1. Foot
2. Yard
3. Kilometer
4. Mile

3-40. What are the modes of operation of the 11D13A trainer?

1. Track, bomb director, and fire control
2. Bomb director, track, and search (PPI)
3. Fire control, bomb director, and track
4. Search (PPI), bomb director, and fire control

3-41. What is the total number of submodes available in the fire control mode?

1. Five
2. Two
3. Six
4. Four

3-42. What is the automatic time-out (time-delay) circuit used to prevent in most radar sets?

1. Power application to the filaments
2. Power application to the high-voltage sections prior to proper warm-up time
3. Radar transmission until airborne
4. Personnel injury during radar maintenance

3-43. During the search mode of operation, which of the following functions is NOT available?

1. Selectable range marks
2. Horizon antenna scan
3. Manual antenna control
4. Operable B-scope

3-44. In the fire control mode. operation is limited to what minimum range in yards?

1. 40,000
2. 20,000
3. 3,500
4. 2,500

3-45. Which of the following functions is NOT available in the bomb director mode?

1. PPI display
2. Controllable range and azimuth marks
3. Depressed-center sector scan
4. Operating ranges same as the search mode

3-46. The basic controls of the 11D13A are grouped into what total number of major categories?

1. Five
2. Two
3. Six
4. Four

3-47. The standby position of the 11D13A power switch applies which of the following types of power to the system?

1. Filament power only
2. Keep alive voltage to the TR tubes only
3. Filament power and keep alive voltage to the TR tubes
4. High voltage power to the varactor

3-48. The mode switch of the 11D13A selects one of the submodes of operation.

1. True
2. False

3-49. What component of the 11D13A allows the operator to select manual search operation?

1. Antenna control
2. Mode switch
3. Receiver gain
4. Power selector

3-50. With the 11D13A in the basic search mode, what type of display is presented?

1. Depressed-center PPI
2. A-scope
3. B-scope
4. PPI

3-51. With the 11D13A in the automatic search mode, which of the following indicators will display information?

1. A-scope and B-scope
2. A-scope and PPI
3. B-scope and PPI
4. B-scope and depressed-center PPI

3-52. Which of the following items causes the “jizzle” on the display in a fire control radar set during the automatic search mode of operation?

1. Antenna nutation
2. Antenna beamwidth
3. Acquisition marks
4. Target return

IN ANSWERING QUESTION 3-53, REFER TO FIGURE 3-11 IN THE TEXTBOOK.

3-53. With the 11D13A in the automatic search mode, what feature on the B-scope can be used to mark an area of target return?

1. Range sweep
2. Acquisition symbol
3. Jizzle
4. Horizon line

3-54. What does the artificial horizon line indicate in a fire control radar set automatic search mode of operation?

1. Target elevation
2. Target track
3. Aircraft track
4. Aircraft attitude

3-55. Which of the following items does NOT constitute the major display differences between the automatic and manual search modes?

1. The acquisition marks bracket the B-trace
2. The acquisition marks move with the B-trace
3. The antenna is controllable in azimuth
4. Artificial horizon line is manually controlled

3-56. In the operation of a fire control radar set, what action begins the time period for acquisition?

1. Lock on is obtained
2. Power is applied
3. The operator switches antenna control from automatic to manual search
4. The operator places the acquisition symbol over the selected target

IN ANSWERING QUESTION 3-57, REFER TO FIGURE 3-13 IN THE TEXTBOOK.

3-57. Which of the following indications is removed from the B-scope display during automatic track mode of a fire control radar set?

1. Acquisition symbol
2. Range strobe
3. Steering dot
4. Range circle

3-58. What is indicated by the steering dot of a fire control radar set?

1. Antenna azimuth
2. Antenna elevation
3. Antenna position
4. Antenna range

3-59. In the automatic track mode of a fire control radar set, what happens when the system breaks lock on?

1. The system reverts to the manual search mode
2. The system reverts to the automatic search mode
3. The system reverts to the manual track mode
4. The system remains in automatic track mode and reacquires the target when it is within required parameters

3-60. Which of the following events occurs in the fire control radar set breakaway mode?

1. The range circle appears
2. The large X appears
3. The steering dot disappears
4. The range notch disappears

3-61. Which of the following displays is used in the fire control radar bomb director mode of operation?

1. A-scope
2. E-scope
3. C-scope
4. Depressed-center PPI

3-62. What component of the IFF transponder system on the S-3 aircraft provides lobing action to prevent the antenna system from being blanked out during aircraft maneuvers?

1. C-6280(P)/APX
2. SA-1769/A
3. RT-859/APX-72
4. TS-1843/APX

3-63. What component on the S-3 aircraft provides the IFF transponder operation and test controls?

1. C-6280(P)/APX
2. SA-1769/A
3. RT-859/APX-72
4. TS-1843/APX

3-64. What component on the S-3 aircraft provides the GO/NO-GO indications on the IFF transponder control?

1. C-6280(P)/APX
2. SA-1769/A
3. RT-859/APX-72
4. TS-1843/APX

3-65. What is the frequency of received signals for the IFF transponder?

1. 1030 kHz
2. 1090 kHz
3. 1030 MHz
4. 1090 MHz

3-66. On the S-3 aircraft, what component determines the Mode C information pulses for the IFF transponder?

1. The transponder control
2. The transponder RT
3. Airspeed-altitude computer
4. COTAC pressure altimeter

3-67. What is the total number of possible codes available in Mode C IFF?

1. 2,048
2. 2,465
3. 4,096
4. 4,930

3-68. When the IDENT function is used in Mode 1 of the IFF transponder, how many total times is the reply pulse train containing the code in use transmitted for each trigger pulse received?

1. One
2. Two
3. Three
4. Four

3-69. When is the SPI pulse present in the reply pulse train in Mode C?

1. When a D4 pulse is present
2. When a D4 pulse is not present
3. When a F2 pulse is present
4. When a F2 pulse is not present

3-70. In an IFF/SIF system, the X-pulse is used for which of the following purposes?

1. Emergencies
2. Timing
3. Helicopters
4. Drones

3-71. The IFF interrogator transmits on what frequency?

1. 1030 kHZ
2. 1090 kHz
3. 1030 MHz
4. 1090 MHz

3-72. What component of the interrogator set generates the initiation and interrogation cycles of the system?

1. RT-868A/APX-76A(V)
2. SN-416A/APX-76A(V)
3. SA-1568A/APX-76A(V)
4. C-7383/APX-76A(V)

3-73. What is the nominal peak power level of the RF pulses generated by the RT-868A/APX-76A(V)?

1. 1 kW
2. 2 kW
3. 6 kW
4. 8 kW

3-74. What is the nominal peak power level of the RF pulses from the switch-amplifier to the difference antenna pattern?

1. 1 kW
2. 2 kW
3. 6 kW
4. 8 kW

3-75. When the TEST-CHAN CC switch is set to TEST on the C-7383/APX-76A(V) interrogator control box, what signal is modified in the IFF system to place the zero-range replies at approximately 4 nautical miles on the radar display?

1. Normal suppression
2. ISLS
3. RSLS
4. Trigger timing

ASSIGNMENT 4

Textbook Assignment: "Antisubmarine Warfare," chapter 4, pages 4-1 through 4-17.

4-1. Sonar is an acronym derived from using the first letters of what terms?

1. Sound, Navy, return
2. Sound, naval, rate
3. Sound, navigation, ranging
4. Sound, NAVAIR, range

4-2. Echo-ranging sonar relies on the reception of an echo to determine what information about a target?

1. Range only
2. Bearing only
3. Range and bearing only
4. Range, bearing, and frequency

4-3. What type of sonar does NOT transmit sound, but functions by receiving sound from the target?

1. Active
2. Passive
3. Reverberation
4. Return

4-4. A high-pressure area occurs in the water next to a hydrophone each time the hydrophone moves in what direction?

1. Inward only
2. Outward only
3. Upward only
4. Downward only

4-5. The high-pressure area in a sound wave is known as a

1. depression
2. rarefaction
3. compression
4. wavelength

4-6. The low-pressure area in a sound wave is known as a

1. depression
2. rarefaction
3. compression
4. wavelength

4-7. The wavelength of a sound wave is equal to the distance between two successive

1. rarefactions only
2. compressions only
3. rarefactions or compressions
4. diaphragm vibrations

4-8. The frequency of a sound wave is defined as the number of which of the following item that occurs in 1 second?

1. Wavelengths
2. Compressions
3. Rarefactions
4. Depressions

4-9. Absorption of sound waves in the ocean is least during which of the following water conditions?

1. White-capped waves
2. Smooth sea surface
3. Ship's wake
4. Riptides

4-10. Absorption of sound waves in the ocean is greatest during which of the following transmissions?

1. Low frequency
2. High frequency
3. Low amplitude
4. High amplitude

4-11. Foreign matter in seawater includes which of the following items?

1. Silt and animal life only
2. Animal life and seaweed only
3. Silt and seaweed only
4. Silt, animal life, seaweed, and air bubbles

4-12. Sonar transmission losses can be caused by

1. low-frequency pinging signals
2. low transducer power output
3. high foreign matter content of water
4. weak pinging signals

4-13. Assume that the crew on a destroyer which was conducting passive sonar operations, witnessed a surface mine explosion at a distance of several hundred yards. If the sonar equipment detected the sound 4 seconds after the explosion, approximately how many seconds were required for the sound traveling through the air to reach the crew?

1. 1 sec
2. 8 sec
3. 16 sec
4. 4 sec

4-14. What is the effect on a sound wave traveling in the ocean when the wave strikes the sea surface?

1. Downward reflection
2. Downward refraction
3. Upward reflection
4. Upward refraction

4-15. At what angle must a sound beam strike the side of a submarine to produce an echo?

1. 180°
2. 90°
3. 45°
4. 0°

4-16. Of the following surfaces, which one will cause the LEAST amount of reflections?

1. Calm sea
2. Rough and rocky bottom
3. Sandy bottom
4. Soft and muddy bottom

4-17. Most individual sound reflections are sharp and clear, but vary in intensity. Why does reverberation appear as a continuous sound?

1. The sound waves are reflected at different intensities from various objects
2. The individual reflections intermingle, and set up sound waves of different speeds
3. The individual reflections occur at different distances from the sonar, and arrive at different times
4. The sound waves are reflected at different frequencies from various objects

4-18. Which of the following conditions will cause the greatest amount of reverberation in deep water?

1. A smooth ocean surface
2. A sudden change in water density
3. Choppy waves on the surface
4. A sandy ocean bottom

4-19. The factor that will most likely determine maximum sonar range when sound propagation conditions are ideal is

1. absorption
2. refraction
3. reverberation
4. divergence

4-20. Varying temperature differences in the ocean have which of the following effects on a sound beam traveling therein?

1. Bends and distorts only
2. Splits and distorts only
3. Bends and splits only
4. Splits, bends, and distorts

4-21. The bending of a sound beam when it passes from a medium of given temperature to a medium of different temperature is known as

1. refraction
2. deflection
3. reflection
4. diffraction

4-22. An increase in refraction of a sonar sound beam has what effect, if any, on the range of the sonar?

1. Increases range only
2. Decreases range only
3. Increases range initially, then decreases it
4. None

4-23. Relative to propagation of sound in the ocean, which of the following statements is correct?

1. Speed is affected by salinity, pressure, and temperature
2. The higher the temperature, the lower the speed
3. Refraction increases effective range
4. Sound bends toward higher temperature

4-24. What is the density of seawater per cubic foot?

1. 6.24 lb
2. 6.40 lb
3. 62.40 lb
4. 64.00 lb

4-25. The effect of pressure on a sound wave in the ocean tends to bend the wave in what direction?

1. Upward only
2. Downward only
3. Upward or downward

IN ANSWERING QUESTIONS 4-26 through 4-28, SELECT THE TEMPERATURE CONDITION FROM COLUMN B THAT IS MOST CLOSELY RELATED TO EACH OF THE OPERATING CONDITIONS LISTED IN COLUMN A. NOT ALL RESPONSES IN COLUMN B ARE USED.

	A. OPERATING CONDITIONS	B. TEMPERATURE CONDITIONS
4-26.	Unusual condition that results in upward refraction	1. Positive thermal gradient
4-27.	Sound refracted downward because temperature decreases with depth	2. Thermocline
		3. Isothermal
		4. Negative gradient
4-28.	Even-temperature water throughout operating area	

IN ANSWERING QUESTION 4-29, REFER TO FIGURE 4-4 IN THE TEXTBOOK.

4-29. The isothermal and cool water conditions shown in the figure have what effect, if any, on the sound beam?

1. Causes the beam to bend upward only
2. Causes the beam to converge on the target
3. Causes the beam to split, bending part upward and part downward
4. None

4-30. The definition for layer depth is the depth from the ocean

1. surface to the top of a sharp positive gradient
2. surface to the top of a sharp negative gradient
3. bottom to the top of a sharp positive gradient
4. bottom to the top of a sharp negative gradient

4-31. When positive gradient conditions exist in the ocean, layer depth is defined as the depth of which of the following temperatures?

1. Minimum temperature
2. Maximum temperature
3. Optimum temperature
4. Relative temperature

4-32. Which of the following cruising maneuvers by a submarine should prove most effective in causing a surface vessel to lose contact with the submarine?

1. Cruising in a uniform temperature area
2. Cruising above layer depth
3. Cruising below a thermocline
4. Cruising in an isothermal layer

4-33. A car is waiting at a crossing for a train to go by. The driver of the car honks the horn as the train approaches. After the train passes the crossing, the engineer on the train blows the whistle. How will the sound of the car horn heard by the train engineer compare to the sound of the whistle heard by the car driver?

1. The horn will sound lower than it actually is, and the whistle will sound higher than it actually is
2. The horn will sound lower than it actually is, and the whistle will sound lower than it actually is
3. The horn will sound higher than it actually is, and the whistle will sound higher than it actually is
4. The horn will sound higher than it actually is, and the whistle will sound lower than it actually is

4-34. As a sound emitter moves away from a receiver, which of the following apparent changes will occur?

1. Only frequency will increase
2. Only wavelength will increase
3. Wavelength and frequency will increase
4. Wavelength will decrease

4-35. Which of the following sounds are rarely heard by the sonar operator?

1. Pings
2. Target echoes only
3. Reverberations only
4. Reverberations and target echoes

IN ANSWERING QUESTIONS 4-36 THROUGH 4-39, SELECT FORM COLUMN B THE RELATIVE PITCH OF THE REFLECTED SOUND THAT IS MOST DESCRIPTIVE OF EACH OF THE MOTION CONDITIONS LISTED IN COLUMN A. NOT ALL RESPONSES IN COLUMN B ARE USED.

	A. RELATIVE MOTIONS	B. RELATIVE PITCH
4-36.	Sonar stationary, all signals received classed as reverberation echoes	1. Higher 2. Lower 3. Same
4-37.	Sonar and target moving in opposite directions, and separating	4. Undulating
4-38.	Sonar and target moving toward each other	
4-39.	Sonar and target moving abreast and in the same direction	

IN ANSWERING QUESTIONS 4-40 THROUGH 4-43, SELECT FROM COLUMN B THE COMPONENT OF THE SONAR SET THAT IS ASSOCIATED WITH THE FUNCTIONS LISTED IN COLUMN A.

A. FUNCTIONS	B. COMPONENTS
4-40. Displays target echoes on a CRT	1. Dome control
4-41. Provides the pilot with digital range and bearing information	2. Azimuth and range indicator
4-42. Energizes the reeling machine raise and lower sequence	3. Recorder
4-43. Displays target echoes on a paper chart	4. Bearing and range indicator

---

4-44. In the event the hydraulic system fails in the cable reeling machine, the sonar set operator should activate what switch to raise the dome?

1. RAISE/LOWER switch
2. SEAT switch
3. TRAIL switch
4. AUXILIARY RAISE switch

4-45. What tool is provided the sonar set operator to manually retrieve lowered cable and dome in the event of an electrical or hydraulic failure?

1. Speed wrench
2. Block and tackle
3. Turnbuckle
4. Pulley arrangement

4-46. What is/are the function(s) of a hydrophone?

1. Sound transmission only
2. Sound reception only
3. Sound transmission and reception only
4. Sound transmission, reception, and inversion

IN ANSWERING QUESTIONS 4-47 THROUGH 4-49, SELECT FROM COLUMN B THE FUNCTION OF EACH OF THE PROJECTOR ASSEMBLY COMPONENTS LISTED IN COLUMN A. NOT ALL RESPONSES IN COLUMN B ARE USED.

A. COMPONENTS	B. FUNCTIONS
4-47. Projector	1. Radiates directional pulses into the air
4-48. Fluxgate compass	2. Converts electrical pulses to acoustic pulses
4-49. Pressure potentiometer	3. Provides a signal to indicate dome azimuth deviation relative to magnetic north
	4. Provides a signal to indicate how deep the dome is submerged

---

4-50. The stave assemblies in the hydrophone assembly function to

1. measure the temperature of the water
2. measure the depth of the dome in the water
3. convert acoustic signals into electrical signals
4. convert low-level ac signals Into acoustic signals

4-51. How often, if ever, must the hydrophone be adjusted?

1. Every 28 days
2. Every 56 days
3. Every 112 days
4. Never

4-52. The function of the dual cursor position control is to

1. determine the position of the cursor in range only
2. determine the position of the cursor in azimuth and range
3. apply a signal to control the direction in which the transducer will radiate
4. apply bearing and range information to the pilot's bearing and range indicator

IN ANSWERING QUESTION 4-53, REFER TO FIGURE 4-19 IN THE TEXTBOOK.

4-53. Which of the following components is NOT mounted on the front panel of the sonar transmitter?

1. FAULT indicator
2. CURSOR POSITION switch
3. POWER circuit breaker
4. STANDBY indicator

4-54. The SDC has which of the following functions?

1. Provides a digital readout of target range, speed, and depth
2. Processes and displays LOFAR, DIFAR, and CASS sonobuoy signals on the sonar set's CRT
3. Provides a digital readout of target size
4. Processes and displays LOFAR, DIFAR, and ASPECT sonobuoy signals on the sonar set's CRT

4-55. Which of the following modes is NOT classified as an operational mode?

1. PASSIVE
2. TEST
3. RANGE
4. ECHO-RANGING

4-56. Which of the following modes is NOT classified as a recording mode?

1. BT
2. TEST
3. COMM
4. ASPECT

4-57. When the sonar set is operating in ECHO-RANGING mode, the set presents target bearings by scanning (a) what number of sectors of (b) what size each?

1. (a) Four (b) 90°
2. (a) Eight (b) 90°
3. (a) Four (b) 45°
4. (a) Eight (b) 45°

4-58. The sonar operator can determine target bearing by noting the position of the target with respect to what part of the sector in which the target appears?

1. Top
2. Center
3. Bottom
4. Edge

4-59. The sonar operator can determine the nature of a target by noting which of the following features of the target?

1. Display outlines only
2. Audio quality and display outline
3. Range
4. Closeness to other targets

4-60. What information is displayed on the RANGE RATE-KNOTS meter?

1. Range and speed of the target within the cursor circle
2. Range and speed of all targets
3. Only the range of the target within the cursor circle
4. Only the speed of the target within the cursor circle

4-61. While operating in the PASSIVE mode, the operator notices a noise spoke on the CRT. What does the spoke indicate?

1. The CRT is burned
2. The hydrophore is malfunctioning
3. An underwater sound source is present
4. A nearby sonar set is operating in the PASSIVE mode

4-62. The sonar operator can use voice communications by moving the MODE switch to COMM position and activating the microphone by

1. depressing a switch on the microphone
2. turning a panel switch
3. depressing a foot switch
4. speaking into a voice-activated microphone

4-63. When the sonar set operates in TEST mode, system voltages and functions are sampled to see if they are within preset limits. How does the operator know when a preset limit is exceeded?

1. A special blip appears on the CRT
2. A fault indicator lights up
3. A sound is audible in the headset
4. A meter indicates the discrepancy

4-64. When the sonar set is operating in BT mode, the recorder plots temperature on what part of the moving chart?

1. Vertical axis
2. Horizontal axis
3. Left side
4. Right side

4-65. When the sonar set is operating in BT mode, the recorder plots dome depth on what part of the chart?

1. Top
2. Bottom
3. Horizontal axis
4. Vertical axis

4-66. The recorder RANGE mode provides which of the following indications?

1. A continuous digital display of target range
2. A series of range scale marks of target range
3. A strip-chart display of target range
4. A selectable digital display of target range

4-67. The recorder ASPECT mode provides which of the following indications?

1. A strip-chart display of target echoes of varying intensity
2. A strip-chart display of target echoes of constant intensity
3. A stylus sweep that draws the outline of the target on a chart
4. A stylus sweep that draws half of the target outline on one side of the chart and the other half of the target outline on the other side of the chart

4-68. Which of the following is a practical means of detecting a submerged submarine from an in-flight aircraft?

1. Detecting radio waves reflected from the submarine's surface to the aircraft
2. Detecting acoustic waves reflected from the submarine's surface to the aircraft
3. Detecting disturbances in the submarine's magnetic field caused by interaction with the earth's magnetic field
4. Detecting disturbances in the earth's magnetic field caused by the submarine's magnetic field

4-69. Magnetic lines of force are essentially undistorted in passing from water to air because both media have approximately the same

1. reactance
2. retentivity
3. permeability
4. dielectric strength

4-70. The angle of change in the east-west direction of the earth's natural magnetic field is known as the

1. angle of variation
2. angle of incidence
3. entry angle
4. dip angle

4-71. The angle between a magnetic line of force and the horizontal of the surface of the earth is known as the

1. angle of variation
2. angle of incidence
3. entry angle
4. dip angle

4-72. MAD equipment is used to measure which of the following changes in the earth's magnetic field near a large mass of ferrous material?

1. Long-trace variation and dip angle
2. Short-trace variation and incident angle
3. Long-trace variation and incident angle
4. Short-trace variation and dip angle

IN ANSWERING QUESTION 4-73, REFER TO FIGURE 4-20 IN THE TEXTBOOK.

4-73. The dip angle at the North Pole comprises approximately how many degrees?

1. 45°
2. 90°
3. 135°
4. 180°

4-74. Which of the following conditions determines the amount of distortion a submarine will cause in the earth's magnetic field?

1. The submarine's alignment in the earth's magnetic field only
2. The submarine's magnetic qualities only
3. The submarine's latitude position on the earth's surface only
4. The submarine's alignment in the earth's magnetic field, magnetic qualities, and latitude position

4-75. The strength of the magnetic field of a submarine varies in which of the following ways with respect to the distance from the submarine?

1. As the square of the distance
2. As the inverse square of the distance
3. As the cube of the distance
4. As the inverse cube of the distance

ASSIGNMENT 5

Textbook Assignment: "Antisubmarine Warfare," chapter 4, pages 4-17 through 4-28.

5-1. MAD equipment must be operated at very low altitudes for which of the following reasons?

1. To place the detector as close as possible to the anomaly
2. To minimize noise caused by the ionosphere
3. To prevent high-voltage arc-over in the detector
4. To prevent detection by the submarine's radar

5-2. MAD equipment must be capable of detecting distortion of the earth's magnetic field at a rate of 1 part in

1. 90,000
2. 80,000
3. 60,000
4. 40,000

IN ANSWERING QUESTIONS 5-3 THROUGH 5-5, REFER TO FIGURE 4-23 IN THE TEXTBOOK.

5-3. What does the zero reference line represent in view C?

1. The points of the anomaly where maximum concentration of the earth's field is located
2. The path traveled by the aircraft in determining the parameters of the anomaly
3. The intensity of the earth's field at a given latitude and longitude after distortion by a ferrous metal mass
4. The intensity of the earth's field at a given latitude and longitude under normal conditions

5-4. Position d of view A is represented by what value on the anomaly record shown in view C?

1. 0.4
2. 0.2
3. 0.1
4. 0.0

5-5. What position in view A represents where a peak minus intensity is reached?

1. f
2. e
3. d
4. c

5-6. Which of the following items determines the stylus swing magnitude in a MAD recorder?

1. Recorder calibration
2. Magnetometer alignment
3. Stronger signal at higher altitude
4. Anomaly signal intensity

5-7. With MAD equipment, what two major categories of magnetic noise must be compensated for?

1. Permanent magnetic and induced magnetic noise
2. Maneuver and permanent magnetic noise
3. Maneuver and direct current circuit noise
4. Induced magnetic and direct current circuit noise

5-8. Aircraft maneuver noise may be caused by which of the following types of fields?

1. Induced magnetic, permanent, and eddy current
2. Induced magnetic, permanent, and direct current
3. Induced magnetic, direct current, and eddy current
4. Permanent, direct current, and eddy current

IN ANSWERING QUESTIONS 5-9 THROUGH 5-12, SELECT FROM COLUMN B THE CAUSE OF EACH TYPE OF MAGNETIC NOISE LISTED IN COLUMN A.

	A. TYPES OF NOISE	B. CAUSES
5-9.	Induced magnetic field	1. An aircraft electrical load change
5-10.	Eddy current field	2. The parts of an aircraft's structure
5-11.	Permanent magnet field	3. An aircraft flight direction change
5-12.	Direct current circuit	4. The current flow in the aircraft structure

---

5-13. Which of the following is NOT an axial coordinate term used to describe the direction of a magnetic field?

1. Vertical
2. Horizontal
3. Lateral
4. Longitudinal

5-14. Which of the following types of fields are constant for a given type of aircraft?

1. Eddy current and direct current circuit
2. Induced magnetic and permanent magnetic
3. Eddy current and induced magnetic
4. Permanent magnetic and direct current circuit

5-15. The detecting head is placed in a magnetically quiet area to compensate for what type of magnetic noise?

1. Permanent magnetic field
2. Induced magnetic field
3. Direct current circuit
4. Eddy current field

5-16. What type of magnetic noise is normally compensated for by the use of Permalloy strips?

1. Permanent magnetic field
2. Induced magnetic field
3. Direct current circuit
4. Eddy current field

5-17. Outrigger compensators of Permalloy are oriented near the detecting element to compensate for a magnetic field that varies under which of the following conditions?

1. After major internal structural changes are made to the aircraft
2. When the aircraft's direct current load changes
3. When the aircraft's heading changes
4. According to the rate at which a maneuver is conducted

5-18. Electrical coils are used to compensate for which of the following aircraft magnetic fields?

1. Permanent
2. Induced
3. Direct current circuit
4. Eddy current

5-19. Electromagnetic compensating loops are used to compensate for what aircraft magnetic field?

1. Permanent
2. Induced
3. Direct current circuit
4. Eddy current

5-20. The number of what factor determines how many sets of compensating loops that are used to compensate for dc magnetic noise on an aircraft?

1. Aircraft axes requiring compensation
2. Aircraft magnetic fields requiring compensation
3. Aircraft dc load distribution centers
4. Aircraft detector magnetometers used

5-21. Of the following manufacturing practices, which one minimizes the size of the electromagnetic compensating loops used in newer aircraft?

1. Installing ground return wires in the aircraft
2. Removing the ground return wires in tie aircraft
3. Increasing the size of the variable resistor connected across the loops
4. Decreasing the size of the variable resistor connected across the loops

5-22. What are the flight characteristics of an aircraft during adjustment of the MAD dc compensation system?

1. Straight and any heading
2. Level and any heading
3. Straight and level, and two cardinal headings
4. Straight and level, and four cardinal headings

5-23. MAD equipment compensation is usually performed under which of the following conditions?

1. On a test bench at AIMD
2. With a test set at compass rose
3. In flight at sea
4. In flight over land

5-24. What is the purpose of MAD compensation?

1. To eliminate all magnetic fields near the magnetometer
2. To eliminate the effect of the earth’s natural magnetic field on the magnetometer
3. To balance the magnetic field of the magnetometer
4. To balance the magnetic fields near the magnetometer

5-25. Due to the arrangement of the helium absorption cells and the IR detectors, the final output of what component of the AN/ASQ-81 MAD set is NOT affected by aircraft maneuvers?

1. AM-4535
2. DT-323
3. DT-355
4. C-6983

5-26. What component detects the anomaly signal from the AN/ASQ-81 MAD set magnetic detector output signal?

1. AM-4535
2. DT-323
3. DT-355
4. C-6983

5-27. On the AN/ASQ-81 MAD set amplifier-power supply, what switch is used to check the quick replaceable assemblies in the amplifier-power supply?

1. RES OSC ADJ switch
2. CONF SELECT switch
3. BUILT IN TEST switch
4. MODE SELECT switch

5-28. On the maintenance panel of the AN/ASQ-81 MAD set amplifier-power supply, what switch is used to select various system configurations necessary for proper maintenance and troubleshooting?

1. RES OSC ADJ switch
2. CONF SELECT switch
3. BUILT IN TEST switch
4. MODE SELECT switch

5-29. What component contains the operating switches and indicators for the AN/ASQ-81 MAD system?

1. AM-4535
2. DT-323
3. DT-355
4. C-6983

IN ANSWERING QUESTIONS 5-30 THROUGH 5-32, REFER TO FIGURE 4-27 IN THE TEXTBOOK.

5-30. What indicator number indicates an amplifier failure?

1. No. 1
2. No. 2
3. No. 3
4. No. 4

5-31. What knob inhibits system output when depressed?

1. **γFS**
2. REC ZERO
3. BANDPASS (right)
4. BANDPASS (left)

5-32. What knob is used to select sensitivity ranges or self-test?

1. **γFS**
2. REC ZERO
3. BANDPASS (right)
4. BANDPASS (left)

5-33. The SAD inhibit signal is generated in cases of excessive aircraft pitch and yaw rates.

1. True
2. False

5-34. Compensation currents for the MAD boom compensation coils are provided by what component of the AN/ASA-65 magnetic compensator group?

1. AM-6459
2. C-8935
3. CP-1390
4. ID-2254

5-35. The potentiometers for adjusting the maneuver and correlated signals into compensating terms are located on what AN/ASA-65 system component?

1. AM-6459
2. C-8935
3. CP-1390
4. ID-2254

IN ANSWERING QUESTIONS 5-36 THROUGH 5-38, REFER TO FIGURE 4-28 IN THE TEXTBOOK.

5-36. The adjustment index for the potentiometer in the transverse, longitudinal, and vertical magnetometer circuits is provided by what set of index indicators?

1. The top three
2. The bottom three
3. The top six
4. The bottom six

5-37. Except when compensation is required, in what position must the MAG TERM knob be?

1. UP
2. DOWN
3. ON
4. OFF

5-38. What switch provides voltage directly to the servomotor selected?

1. POWER-OFF
2. UP-DOWN
3. RATE
4. SERVO-OFF

5-39. Three coils oriented to sense magnetic strength in each of the basic axes are contained in what component of the AN/ASA-65 magnetic compensator group?

1. DT-355
2. CP-1390
3. ID-2254
4. DT-323

5-40. The adjustment value for the nine magnetic terms is calculated simultaneously by what component of the AN/ASA-65 magnetic compensator group?

1. DT-355
2. CP-1390
3. ID-2254
4. DT-323

5-41. The operator initiates auto compensation on what component of the AN/ASA-65 magnetic compensator group?

1. C-8935
2. CP-1390
3. ID-2254
4. DT-323

IN ANSWERING QUESTIONS 5-42 THROUGH 5-44, REFER TO FIGURE 4-29 IN THE TEXTBOOK.

5-42. What component initiates all commands?

1. MODE switch
2. WPN LOAD switch
3. EXEC button
4. BITE button

5-43. What component provides computer identification and control of fixed compensation functions?

1. MODE switch
2. WPN LOAD switch
3. EXEC button
4. BITE button

5-44. What component provides compensation for at least 80 percent of the weapons interference field?

1. MODE switch
2. WPN LOAD switch
3. EXEC button
4. BITE button

5-45. What component of the AN/ASA-71 selector group selects the signal to be recorded on the MAD recorder?

1. C-7693
2. C-8935
3. RO-32
4. MX-8109

5-46. What component of the AN/ASA-71 selector group generates a SAD mark 1-kHz tone for the SENSOR operator’s ICS?

1. C-7693
2. C-8935
3. RO-32
4. MX-8109

5-47. What component makes a hardcopy of MAD contacts and SAD marks?

1. C-7693
2. C-8935
3. RO-32
4. MK-8109

5-48. Where should the black pen trace on the MAD recorder with B selected on the mode knob?

1. The +4 line
2. The +2 line
3. The +1 line
4. The zero line

5-49. All sonobuoys perform the same mission?

1. True
2. False

5-50. When an area of the ocean is thought to contain a submarine, what minimum number of sonobuoy(s) is/are usually dropped?

1. One
2. Two
3. Three
4. Four

5-51. What type of RF output signal is transmitted from a sonobuoy antenna?

1. Frequency modulated VHF signal
2. Frequency modulated UHF signal
3. Amplitude modulated VHF signal
4. Amplitude modulated UHF signal

5-52. You should refer to which of the following manuals before handling, storing, or disposing of sonobuoys?

1. NAVAIR 28-AQS-500-1
2. NAVAIR 28-ASQ-500-1
3. NAVAIR 28-SQS-500-1
4. NAVAIR 28-SSQ-500-1

5-53. What total number of channels are selectable on an EFS system sonobuoy?

1. 99
2. 50
3. 32
4. 31

5-54. What total number of channels are used in the older sonobuoys that are preset at the factory?

1. 99
2. 50
3. 32
4. 31

5-55. Which of the following information is stamped on both ends of a non-EFS system sonobuoy?

1. Depth setting and RF frequency
2. Serial number and manufacturer's code
3. Contract lot number and weight
4. Sonobuoy type and RF channel number

5-56. The sonobuoy is aircraft deployable by what total number of methods?

1. Five
2. Two
3. Three
4. Four

5-57. Sonobuoys equipped with parachutes and rotochutes are NOT intermixed in the same tactical pattern for which of the following reasons?

1. To maintain minimum interference between sonobuoys
2. To maintain proper sonobuoy spacing in the water
3. To prevent rotochute and parachute entanglement
4. To prevent hydrophore cross talk

5-58. What component is deployed from a sonobuoy when the bottom plate is jettisoned?

1. The hydrophore
2. The parachute/rotochute
3. The antenna
4. The float

5-59. What component(s) is/are deployed by some sonobuoys that have a seawater-activated battery that fires a squib?

1. A float and a hydrophore
2. A float containing an antenna
3. A hydrophore and an antenna
4. A parachute/rotochute and a bottom plate

5-60. Most sonobuoys in the fleet contain what type of battery to provide power to the sonobuoy circuits?

1. Lithium dry cell
2. Seawater-activated lithium
3. Seawater-activated
4. Zinc-oxide dry cell

5-61. Data transmission usually starts within at least how many minutes after the sonobuoy enters the water?

1. 1.0 minute
2. 2.0 minutes
3. 3.0 minutes
4. 0.5 minute

5-62. What category of sonobuoy only has the listening feature?

1. Active
2. Passive
3. Special purpose
4. Multiple purpose

5-63. What system is an improved passive acoustic sensing system?

1. DIFAR
2. LOFAR
3. CASS
4. DICASS

5-64. What are characteristics of the sonar pulse output from the self-timed active sonobuoy?

1. Fixed pulse length and fixed pulse interval
2. Fixed pulse length and variable pulse interval
3. Variable pulse length and fixed pulse interval
4. Variable pulse length and variable pulse interval

5-65. The command activated sonobuoy will ping in response to command signals from what source?

1. The random generator in the CASS sonobuoy
2. The automatic generator in the CASS sonobuoy
3. The controlling aircraft
4. The underwater target

5-66. What is the BT temperature probe descent rate?

1. 15 feet per second
2. 10 feet per second
3. 5 feet per second
4. 4 feet per second

IN ANSWERING QUESTIONS 5-67 THROUGH 5-72, SELECT FROM COLUMN B THE TYPE OF SONOBUOY ASSOCIATED WITH EACH OF THE FUNCTIONS LISTED IN COLUMN A. SOME ITEMS IN COLUMN B WILL BE USED MORE THAN ONCE.

	A. FUNCTIONS	B. TYPES OF SONOBUOY
5-67.	Used for submarine detection and localization	1. SAR
		2. BT
5-68.	Measures water temperature	3. ATAC/DLC
		4. CASS
5-69.	Provides data for determining water depth	
5-70.	Used as a floating RF beacon for rescue purposes	
5-71.	Provides one-way voice communication	
5-72.	Provides aircraft/submarine two-way communication	

5-73. How many separate sonobuoy channels can be received simultaneously on the AN/ARR-75 radio receiving set?

1. 8
2. 16
3. 31
4. 99

5-74. What component of the SASP system is a high-speed signal processor used to extract acoustic target information from active and passive sonobuoy data?

1. PP-7467
2. C-11104
3. TS-4008
4. SP-2143

5-75. What component of the SASP system controls the power to the CASS transmitter?

1. PP-7467
2. C-11104
3. TS-4008
4. SP-2143

ASSIGNMENT 6

Textbook Assignment: "Indicators," chapter 5, pages 5-1 through 5-27.

6-1. Which of the following systems supply information displayed on the HSIs and BDHIs?

1. Communication systems
2. Radar systems only
3. Navigation systems only
4. Radar/navigation systems

6-2. In the HSI group, which, if any, of the following components are interchangeable between the pilot's, copilot's, and NAV/COMM's station?

1. HSI group controls only
2. HSI group indicators only
3. HSI group controls and indicators
4. None of the above

6-3. On the ID-1540/A horizontal situation indicator, what is the reference line for reading the aircraft's heading on the compass card?

1. The lubber line
2. The bearing line
3. The marker line
4. The range line

IN ANSWERING QUESTIONS 6-4 THROUGH 6-8, SELECT FROM COLUMN B THE FUNCTION OF THE HSI ITEMS LISTED IN COLUMN A. SOME ITEMS IN COLUMN B WILL BE USED MORE THAN ONCE.

	A. HSI ITEMS	B. FUNCTIONS
6-4.	Bearing pointer No. 1	1. Indicates the lubber line
6-5.	COURSE indicator	2. Points to the bearing of the selected navigational point
6-6.	To-From indicator	3. Displays the course arrow setting in a digital readout in degrees
6-7.	Bearing pointer No. 2	4. Indicates whether the selected course is going toward or away from the selected beacon station
6-8.	Aircraft symbol	

6-9. What component controls the inputs to the pilot's HSI?

1. A208
2. A279
3. A280
4. A309

6-10. The HDG selector switch on the pilot’s HSI control selects which of the following heading signal sources for display on the HSI compass card?

1. INS-1 and INS-2
2. INS-1 and STBY GYRO
3. INS-2 and STBY GYRO
4. Vertical gyro and STBY GYRO

6-11. On the pilot’s HSI control, the ATTD selector controls which of the following sources of attitude signals for the pilot’s FDI sphere?

1. INS-1 and INS-2
2. INS-1 and STBY GYRO
3. INS-2 and STBY GYRO
4. Vertical gyro and STBY GYRO

6-12. On the pilot’s HSI control, with the BRG 1 switch in DA, the COURSE HSI-FDI selector switch must be in what position to receive signals from the central computer?

1. TACAN
2. VOR-1/ILS
3. VOR-2
4. TAC NAV

6-13. The BRG 1 switch selects the source of the bearing signal displayed on the bearing pointer 1 on which of the following HSIs?

1. Pilot’s, copilot’s, and TACCO’s
2. Pilot’s, NAv/COMM’S, and TACCO‘s
3. Copilot’s, NAV/COMM’S, and TACCO‘s
4. Pilot’s, copilot’s, and NAV/COMM’s

6-14. On the copilot’s HSI control, the ATTD selector controls which of the following sources of attitude signals for the copilot’s FDI sphere?

1. INS-1 and INS-2
2. INS-1 and STBY GYRO
3. INS-2 and STBY GYRO
4. Vertical gyro and STBY GYRO

6-15. The BRG 2 switch on the copilot’s HSI control selects the source of the bearing signal displayed on the bearing pointer 2 on which of the following HSIs?

1. Pilot’s and copilot’s
2. Copilot’s and NAV/COMM’s
3. Copilot’s and TACCO’s
4. TACCO’s and NAV/COMM’s

6-16. When there is a failure with the heading function in the central repeater system, what indicator illuminates on the NAV/COMM HSI control?

1. DIST NO-GO
2. ATTD BEARING NO-GO
3. INS NO-GO
4. HEADING NO-GO

6-17. Which of the following signals are selected for display on the NAV/COMM HSI by the NAV/COMM HDG switch?

1. MAG and TRUE heading signals
2. INS-1 and INS-2 heading signals
3. INS-1 and MAG heading signals
4. INS-2 and TRUE heading signals

6-18. What indication appears on the HSI with VOR-1 selected if the input signal from VOR-1 becomes unreliable?

1. VOR-1 NO-Go
2. NAV NO-GO
3. VOR-1 flag
4. NAV flag

6-19. What signal will be supplied to the HSI by the UHF-DF/OPTI and the ADF systems when either is selected?

1. Bearing signal
2. To-From signal
3. Course deviation signal
4. NAV flag signal

6-20. On the HSI, when a tactical mode is selected, true heading information is switched out of the circuit, and the compass card will be driven by magnetic heading information.

1. True
2. False

6-21. What is/are the quantity of pointers on a BDHI?

1. One
2. Two
3. Three
4. Four

6-22. From what reference is the BDHI compass card read for aircraft heading?

1. Pointer No. 1
2. Pointer No. 2
3. Lubber index
4. Lubber line

6-23. The BDNI distance counter consists of how many total synchro torque receivers to position the numerals?

1. Five
2. Two
3. Three
4. Four

6-24. The visual display system used by aircrew to search for, attack, and destroy the enemy is commonly called the

1. MDS
2. PDS
3. SDS
4. TDS

6-25. To display attack information to the pilot, the electro-optical display system uses what type of source?

1. Electronic
2. Light
3. Analog
4. Digital

6-26. The electro-optical sight system used by the pilot is the

1. EOD
2. EODU
3. HUD
4. HUDU

6-27. Which of the following sources provide(s) aircraft performance data?

1. Bore sight reference
2. Aircraft systems
3. Tactical computer set
4. Aircraft flight sensors

6-28. The transparent mirror that displays information to the pilot in the HUD set is called a

1. reflector
2. combiner
3. mirror/reflector
4. windscreen

IN ANSWERING QUESTION 6-29 REFER, TO FIGURE 5-8 IN THE TEXTBOOK.

6-29. Which of the following information is/are NOT processed by the signal data processor for the head-up display unit?

1. Bore sight reference
2. Discrete signals
3. Tactical computer input
4. Aircraft flight sensor data

6-30. The HUD set signal data processor input receivers operate on which of the following channels at the same time?

1. One and two; three and four
2. One and three; two and four
3. One and four; two and three
4. One, two, three, and four

6-31. The identity signal for the HUD set input receivers of the signal data processor consists of how many total bits of data?

1. 24
2. 20
3. 13
4. 10

6-32. What digital computer section of the HUD set signal data processor distributes the clock pulses?

1. Control logic
2. Sequence control
3. Symbol generator
4. Processor counter

6-33. The symbol generator operates in three major modes. Each mode is dependent on the other, and all are completed simultaneously.

1. True
2. False

6-34. During the sixth and seventh operations of the line mode, what action occurs with respect to the X and Y data?

1. X data is shifted
2. Y data is shifted
3. The X and Y channel rate registers are shifted by the symbol generator
4. The BITE circuits check all data in the X and Y channel rate registers for correctness

6-35. The symbol generator samples the HUD busy signal for what reason?

1. To decode information
2. To generate a self-test mode
3. To transfer data to the HUD immediately
4. To transfer data to the HUD when it is ready

6-36. When the circle mode of operation in the symbol generator is being used, the circle is drawn (a) in what direction and (b) begins at what point on the CRT?

1. (a) Clockwise (b) top
2. (a) Clockwise (b) bottom
3. (a) Counterclockwise (b) top
4. (a) Counterclockwise (b) bottom

6-37. What is the purpose of the bright-up pulse delay in the circle mode of the signal generator?

1. To compensate for the slow response time of the deflection circuits in the HUD
2. To compensate for the fast response time of the deflection circuits in the HUD
3. To turn off the symbol generator
4. To turn on the signal generator

6-38. What voltage is applied to the CRT anode of the HUD?

1. 5,000 volts
2. 10,000 volts
3. 15,000 volts
4. 20,000 volts

6-39. The electrical power used for the operation of the standby reticle of the HUD is obtained from what source?

1. The high-voltage power supply
2. The low-voltage power supply
3. Outside of the HUD
4. The HUD battery

6-40. In the optical module of the HUD, what is the purpose of the autobrilliance sensor?

1. To detect ambient light changes
2. To adjust output voltage level to the sensor
3. To amplify manual brightness input signals from the control panel
4. To detect ambient light changes and amplify output voltage level to the sensor

6-41. At what rate are the symbols drawn on the CRT of the HUD video module?

1. 15 times per second
2. 25 times per second
3. 50 times per second
4. 100 times per second

6-42. What control(s) the symbol brightness of the CRT in the HUD?

1. The X and Y bright-up signal
2. The X and Y amplifiers
3. The control grid circuit of the CRT
4. The cathode bias circuit

6-43. Which, if any, of the following ordnance information is available to the pilot on the AVA-12 HUD?

1. Armed/unarmed
2. Type of fusing
3. Type of weapon selected
4. None of the above

IN ANSWERING QUESTION 6-44, REFER TO FIGURE 5-9 IN THE TEXTBOOK.

6-44. In the takeoff mode, what is the maximum radar altitude indication?

1. 1,400 ft
2. 1,500 ft
3. 1,600 ft
4. 1,700 ft

6-45. Which of the following is a function of the declutter feature of the AVA-12 HUD?

1. To rearrange the symbols on the HUD
2. To operate the air-to-ground mode
3. To remove preselected unwanted symbols from the display
4. To remove all symbols from the display

6-46. The AVA-12 HUD has what total number of basic modes of operation?

1. One
2. Two
3. Three
4. Five

6-47. Which of the following information is NOT available to the pilot in the landing mode of the AVA-12 HUD?

1. Radar altitude
2. Target designator
3. Angle-of-attack
4. Vertical descent

6-48. On the TDS display, tactical plot data, required to maintain the aircraft position, is limited to what station?

1. Pilot’s
2. Copilot’s
3. Tactical coordinator’s (TACCO‘S)
4. Sensor operator’s (SENSO’s)

6-49. The display generator unit (DGU) sends all data types to all displays.

1. True
2. False

6-50. The data presented on the pilot’s display, produced by the GPDC, is controlled by which, if any, of the following systems?

1. GPDC
2. INCOS
3. DGU
4. None of the above

6-51. Which of the following information is NOT available to the COTAC display?

1. Raw radar
2. S/C radar
3. FLIR
4. MAD

6-52. What is the only information presented on the ARU display?

1. FLIR
2. Analog passive acoustic data
3. MAD
4. Raw radar

6-53. A television system has how many total basic elements?

1. One
2. Two
3. Three
4. Four

6-54. Which of the following is NOT a pickup devise?

1. Image orthicon
2. Microwave relay link
3. SEC tube
4. Vidicon

6-55. What type of scanning is used in television systems?

1. Synchronized
2. Nonsynchronized
3. Horizontal
4. Vertical

IN ANSWERING QUESTION 6-56, REFER TO FIGURE 6-22 IN THE TEXTBOOK.

6-56. In the transmitter, what is added to the electrical picture signal from the camera to make a composite video signal?

1. A sync operator signal
2. A signal from the pickup device
3. A receiver signal
4. A synchronizing signal

6-57. What total amount of time is required for one scan of the picture in the television systems in the United States?

1. 1/15 second
2. 1/30 second
3. 1/60 second
4. 1/75 second

6-58. In commercial broadcast television, for resolution of the fine detail in the horizontal direction, what total number of scanning lines are used?

1. 100
2. 275
3. 350
4. 525

6-59. Of the following scanning methods, which is the simplest?

1. Interlaced
2. Noninterlaced
3. Vertical
4. Horizontal

6-60. Interlaced scanning is used in most television systems for which of the following reasons?

1. To increase flicker
2. To decrease bandwidth by a factor of 2
3. To increase bandwidth by a factor of 2
4. To decrease resolution

6-61. What is the horizontal scanning frequency of commercial broadcast and most CCTV systems?

1. 30 Hz
2. 60 Hz
3. 525 Hz
4. 15,750 Hz

6-62. The standard television signal consists of what total number of elements?

1. One
2. Two
3. Three
4. Four

6-63. For commercial television picture information, what is (a) the maximum percentage for black and (b) the minimum percentage for white of the maximum carrier voltage ?

1. (a) 75 (b) 5
2. (a) 65 (b) 5
3. (a) 75 (b) 15
4. (a) 65 (b) 15

6-64. The kinescope blanking pulse suppresses the scanning beam during what time?

1. Vertical flyback time only
2. Horizontal flyback time only
3. Vertical and horizontal flyback time

6-65. Which, if any, of the following types of picture synchronizing pulses provides a means of frequency discrimination?

1. Vertical sync pulse
2. Horizontal sync pulse
3. Serrated horizontal sync pulse
4. None of the above

6-66. A television system that uses random interlace, no special sync pulses, exhibits which, if any, of the following undesirable characteristics?

1. Circuit complexity
2. Long-range transmission use only
3. Insufficient resolution
4. None of the above

6-67. What is the video bandwidth of a slow-speed scan television system?

1. 500 Hz to 250 kHZ
2. 750 kHz to 10 MHz
3. 10 MHz to 100 MHz
4. 100 MHz to 10 GHz

6-68. If four dynodes having a gain of 5 were used in the image orthicon tube, what would the be the gain of the multiplier section?

1. 5
2. 25
3. 125
4. 625

6-69. The polarity of the signal developed by the isocon is the same as the polarity of the orthicon.

1. True
2. False

6-70. What is the transparent conductive coating on the inner surface of the vidicon camera tube known as?

1. Signal electrode
2. Signal grid
3. Signal cathode
4. Signal anode

6-71. A plumbicon tube with a designation of 67423B has a color response for what color?

1. Red
2. Green
3. Blue
4. White

IN ANSWERING QUESTIONS 6-72 AND 6-73, REFER TO FIGURE 5-31 IN THE TEXTBOOK.

6-72. The tin dioxide contained on the faceplate inner surface is what type of semiconductor?

1. N-type
2. P-type
3. PNP-type
4. NPN-type

6-73. What type of junction is formed in view B?

1. PNP
2. NPN
3. PN
4. PIN

6-74. Which of the following is NOT an application of the SEC tube?

1. Commercial television
2. Extremely low-light
3. High internal amplification
4. Fast response to moving objects

6-75. What is the basic difference between color and monochrome picture tubes?

1. The type of phosphors coating the screen
2. The type of biasing used
3. The cathode circuit
4. The grid circuit

ASSIGNMENT 7

Textbook Assignment: "Infrared," chapter 6, pages 6-1 through 6-28.

7-1. Which of the following types of remote sensing is natural light photography?

1. Active only
2. Passive only
3. Active and passive
4. Interactive

7-2. What are the differences between IR waves and light, RF, and other electromagnetic waves?

1. Reflection and frequency
2. Refraction and absorption
3. Wavelengths and speed
4. Frequency and wavelengths

7-3. What is the IR frequency range?

1. 300 MHz to 400 GHz
2. 400 MHz to 300 GHz
3. 300 GHz to 400 THz
4. 400 GHz to 300 THz

7-4. The IR region lies between what wavelengths of the electromagnetic spectrum?

1. 1.00 and 7,200 nanometers
2. 1.00 and 7,200 micrometers
3. 0.72 and 1,000 nanometers
4. 0.72 and 1,000 micrometers

7-5. Thermal imaging is referenced in terms of

1. temperature
2. reflectivity
3. visible light
4. color

7-6. The types of IR imaging systems generally used are fast-framing, mechanical-scanning devices know as

1. BLIR
2. FLIR
3. SLIR
4. WLIR

IN ANSWERING QUESTION 7-7, REFER TO FIGURE 6-2 IN THE TEXTBOOK.

7-7. What effect does the atmosphere have on the target signal?

1. Attenuates and blurs the signal
2. Enhances and sharpens the signal
3. Attenuates and sharpens the signal
4. Enhances and blurs the signal

IN ANSWERING QUESTION 7-8, REFER TO TABLE 6-1 IN THE TEXTBOOK.

7-8. IR radiation is broken into how many total regions?

1. One
2. Two
3. Three
4. Four

IN ANSWERING QUESTION 7-9, REFER TO FIGURE 6-3 IN THE TEXTBOOK.

7-9. The best IR windows in the transmission spectrum of the atmosphere are between which of the following wavelengths?

1. 2 μm and 5 μm, 8 μm and 13 μm
2. 3 μm and 5 μm, 8 μm and 14 μm
3. 3 μm and 6 μm, 8 μm and 15 μm
4. 2 μm and 7 μm, 9 μm and 15 μm

7-10. All rotter emits IR radiation above what temperature?

1. -273°C
2. -273°F
3. 0°C
4. 0°F

7-11. If the temperature of a black body is increased 10 times, the IR radiation will be increased what number of times?

1. 100
2. 1,000
3. 10,000
4. 100,000

7-12. All materials commonly used in visible light optics are transparent at IR frequencies.

1. True
2. False

7-13. Which of the following qualities is desired in optical material used In IR imaging systems?

1. Transparent to visible light
2. High coefficient of thermal expansion
3. Low mechanical strength
4. High surface hardness

7-14. What optical materials, if any, have all of the qualities desired in IR optics?

1. Silicon, germanium, and zinc selenide
2. Silicon, germanium, and zinc sulfide
3. Silicon, zinc selenide, and zinc sulfide
4. None

7-15. What component in the JR imaging system is the most important?

1. Detector
2. Optic
3. Receiver
4. Sensor

7-16. A photographic film is an example of what type of detector?

1. Elemental
2. Imaging
3. Photon
4. Thermal

7-17. What type of energy-matter interaction involves the absorption of radiant energy in the detector?

1. Thermal effect
2. Photon effect
3. Elemental
4. Imaging

IN ANSWERING QUESTIONS 7-18 THROUGH 7-21, SELECT THE DESCRIPTION FROM COLUMN B THAT MATCHES THE TERM LISTED IN COLUMN A.

	A. TERM	B. DESCRIPTION
7-18.	Photon effect	1. Radiation causes photocathode surface electron emission to the surrounding space
7-19.	Photoconductivity	2. Radiant energy photons interact directly with detector material
7-20.	Photoelectric	3. Radiant energy changes detector material’s electrical conduction
7-21.	Photoemissive	4. Radiant signal causes a difference of potential across a PN junction

IN ANSWERING QUESTIONS 7-22 THROUGH 7-25, SELECT THE COMPONENT FROM COLUMN B THAT MATCHES THE DESCRIPTION IN COLUMN A.

	A. DESCRIPTION	B. COMPONENT
7-22.	Collects the incoming energy and focuses the image at the detectors	1. Detectors
		2. Scene dissection system
7-23.	Converts the IR radiation signal into an electrical signal	3. Front-end optics
		4. Image processing system
7-24.	Converts the data collected by the detectors into a video display	
7-25.	Scans the scene image	

7-26. What type of detector cooling system uses a heat exchanger and a compressor?

1. Tricycle
2. Quad-cycle
3. Closed-cycle
4. Opened-cycle

7-27. What term is synonymous with FLIR so far as system operation is concerned?

1. FIRS
2. IRDS
3. FLIRDS
4. IRFLDS

7-28. What assembly of a FLIR system converts IR energy into a usable video signal?

1. IRDS control
2. Power supply-video converter
3. Receiver-converter
4. Video indicator

7-29. What type of housing is used for the FLIR receiver-converter?

1. Forward section of a station-mounted FLIR pod only
2. Separate pod mounted on the forward, lower aircraft fuselage only
3. Separate pod mounted on the aft, lower aircraft fuselage only
4. Dependent on the aircraft model

7-30. The FLIR receiver-converter breaks down functionally into how many total subsystems?

1. One
2. Two
3. Three
4. Four

7-31. In the wide FOV mode of operation, what components are NOT in the signal optical path?

1. The TV camera optics
2. The IR imaging optics
3. The afocal optic lenses
4. The visible collimating lenses

7-32. Changes in temperature of an optical lens changes what index?

1. Refraction
2. Reflection
3. Diffraction
4. Deflection

7-33. The bottom side of the scan mirror scans the visible light signals and reflects the signal into what component?

1. The visible collimating lens
2. The afocal optics unit
3. The TV camera optics
4. The IR imaging optics

7-34. A scan mirror is indexed three line widths in the vertical direction, making a total of 400 lines of video, with only 100 detectors and amplifier channels. What is the interlacing ratio?

1. 4:1
2. 3:1
3. 2:1
4. 1:1

7-35. For proper operation, the IR detectors are kept at what temperature level?

1. 0°C
2. 0°F
3. Cryogenic
4. Carcinogenic

7-36. For each IR detector within the array, the video amplifier module contains one preamplifier and three postamplifiers for which of the following purposes?

1. To decrease the video interference
2. To increase the IR signal to a useable level
3. To Increase the video ac level
4. All the above

7-37. The output of the LED array is applied to what unit?

1. The reticle optics
2. The IR imaging optics
3. The collimating lens
4. The afocal lens

7-38. A light signal is applied to the TV camera to indicate the receiving head position from what unit?

1. The reticle optics
2. The IR imaging optics
3. The collimating lens
4. The afocal lens

7-39. The FLIR heat exchanger supplies conditioned air to what assembly for environmental control?

1. Power supply-video converter
2. Control servomechanism
3. Target tracking sight control
4. Receiver-converter

IN ANSWERING QUESTIONS 7-40 AND 7-41, REFER TO FIGURE 6-14 IN THE TEXTBOOK.

7-40. B-1 operates when which of the following conditions occurs?

1. The FLIR system is turned on
2. K-1 is energized
3. K-2 is energized
4. K-3 is energized

7-41. B-2 operates when which of the following conditions occurs?

1. The FLIR system is turned on
2. K-1 is energized
3. K-2 is energized
4. K-3 is energized

7-42. The FLIR heat exchanger will maintain the receiver-converter compartment at what temperature range?

1. 50°F to 68°F
2. 50°C to 68°C
3. 68°F to 77°F
4. 68°C to 77°C

7-43. Which of the following is a function of the receiver-converter stabilized gimbal subsystem?

1. To ensure coolant fluids are not spilled
2. To maintain a steady image of IR patterns
3. To ensure stabilized operating temperatures
4. To maintain constant LOS with the nose of the aircraft

7-44. Azimuth and elevation commands are processed, and then applied to the receiver head positioning motors and gimbals by what WRA?

1. Receiver-converter
2. Control servomechanism
3. Target tracking sight control
4. Power supply-video converter

7-45. The CS assembly inhibits the stabilization system when LOS of the receiver is operated by what component?

1. An aircraft computer,
2. Target tracking sight control
3. IR detecting set control
4. FLIR detecting set control

7-46. The BITE logic module is located in what assembly?

1. Power supply-video converter
2. Control servomechanism
3. Video indicator
4. Target tracking sight control

7-47. What subsystem Is NOT a power supply-video converter subsystem?

1. Power supply
2. BITE
3. Video processing
4. Scan and interlace

7-48. Receiver-converter synchronizing drive and timing signals are generated by what power supply-video converter subsystem?

1. Power supply
2. BITE
3. Video processing
4. Scan and interlacing

7-49. Gray scale video is displayed on the indicator as ten different shades of gray. The operator uses these shades of gray to perform which of the following actions?

1. Estimate the depth of the target
2. Calibrate the camera assembly
3. Estimate the target's temperature
4. Calibrate the TTSC

7-50. The video processor receives raw video signals from what device?

1. The LED array
2. The TV camera
3. The sync generator control
4. The scanning mirror

7-51. In the BITE mode of operation, a signal is generated to indicate that the sync generator has failed. This signal is generated by what BITE module?

1. Receiver-converter
2. TV video
3. IRDSC
4. CS

7-52. To position the receiver head, the position and rate commands from the IRDSC are processed as

1. analog drive signals
2. digital drive signals
3. clamped dc averages
4. sync voltage pulses

7-53. In the position mode, the azimuth drive signal is amplified to a signal large enough to drive the receiver head azimuth motor by what azimuth module?

1. Mode logic
2. Position compensation
3. Rate compensation
4. Heat sink

7-54. In the FWD mode of operation the receiver head is driven to what azimuth position?

1. 0°
2. 45°
3. 90°
4. 180°

7-55. What signal enables the azimuth rate compensation module to accept azimuth position rate signals from the D/A converter only?

1. Computer track command
2. Rate compensation
3. Decoder conversion
4. Gimbal control

7-56. What is the primary difference between the azimuth and elevation drive subsystems?

1. Manual override is only used for azimuth
2. A computer is not used for azimuth
3. Tachometer feedback is not used in elevation circuitry
4. Gimbal drive circuitry is different

7-57. In the FWD mode of operation, the receiver head is slewed to what elevation position?

1. 0°
2. -2°
3. -3°
4. -4°

7-58. What is the primary function of the control servomechanism BITE subsystem?

1. To maintain constant servo sync pulses
2. To automatically locate servo-system failures
3. To isolate component failures
4. To convert computer Inputs to gimbal bits

7-59. When a BITE initiate signal is started, each test sequence lasts what approximate length of time?

1. 10 to 12 seconds
2. 15 to 17 seconds
3. 20 to 22 seconds
4. 25 to 27 seconds

7-60. During the fault isolate test, the DCI fault isolate signal goes to mode logic and

1. coder storage module
2. decoder storage module
3. clock module
4. memory module

7-61. During BITE 1 test, the receiver head is slewed to what position?

1. 0° azimuth and 0° elevation
2. 0° azimuth and 4° elevation
3. 0° azimuth and -4° elevation
4. 4° azimuth and -4° elevation

7-62. During BITE 2 test, the receiver head is slewed to what position?

1. 60° azimuth and -130° elevation
2. 60° azimuth and 130° elevation
3. 130° azimuth and -60° elevation
4. 130° azimuth and 60° elevation

7-63. The TTSC is used in what mode of operation?

1. Computer
2. Azimuth
3. Elevation
4. Manual

7-64. Adjusting the thumb control on the TTSC produces voltage outputs from which of the following transducer?

1. Rate and climb angle
2. Climb and azimuth angle
3. Elevation and rate angle
4. Elevation and azimuth angle

IN ANSWERING QUESTIONS 7-65 THROUGH 7-67, REFER TO FIGURE 6-26 IN THE TEXTBOOK.

7-65. With the MODE switch in the STBY position, the receiver head is stowed in what position?

1. CW and up limits
2. CCW and up limits
3. CW and down limits
4. CCW and down limits

7-66. The FOV switch selects either a wide or narrow field of view by switching what assembly in or out of the receiver's optical path?

1. The afocal lens
2. The collimating lens
3. The imaging optics
4. The camera optics

7-67. The brightness of the reticle that is superimposed on the video signal applied to the video indicator is controlled by what knob?

1. GAIN
2. LEVEL
3. RTCL BRT
4. WHT HOT

7-68. When a failure occurs in the video indicator, what module extinguishes the STATUS light?

1. Sweep heat sink
2. Video line driver
3. Video amplifier/sync stripper
4. Vertical and horizontal sweep

ASSIGNMENT 8

Textbook Assignment: "Weapons Systems," chapter 7, pages 7-1 through 7-21.

8-1. The computer-controlled weapons systems provide a higher degree of safety by significantly reducing the degree of which of the following factors?

1. Mechanical failure
2. Electronic failure
3. Electronic error
4. Human error

8-2. The ACM panel in the F-14 is located in the

1. aft cockpit, center console
2. aft cockpit, left console
3. forward cockpit, center console
4. forward cockpit, left console

8-3. Which of the following components is NOT located on the ACM panel in the F-14?

1. Armament safety override switch
2. Weapon status indicator
3. Master arm switch
4. ACM JETT switch

8-4. Before applying external power, the technician must ensure that all armament switches are in their proper position?

1. True
2. False

8-5. The stores on the station selected on the armament panel in the F-14 are jettisoned when what switch is pressed?

1. Weapon status
2. HOT TRIGGER
3. Master arm
4. ACM JETT

8-6. With the F-14 weapon station IA loaded, ready, and selected, what indication will the weapon status indicator labeled 1A show on the ACM panel?

1. Black
2. White
3. Gray
4. Checkerboard

8-7. What F-14 control contains the DLC/CHAFF dispense push button?

1. Control stick
2. Displays control
3. ACM JETT control
4. HOT TRIGGER control

8-8. Master arm power on the F-14 Is removed by what component when the aircraft is on the ground?

1. Port main landing gear weight-on-wheels switch
2. Starboard main landing gear weight-on-wheels switch
3. Nose landing gear weight-on-wheels switch
4. Landing gear handle switch assembly

8-9. The armament safety override switch on the F-14 is located in the

1. forward cockpit, center console
2. nosewheel well
3. control stick
4. landing gear handle

8-10. The purpose of the armament safety override switch on the F-14 is to

1. arm weapons
2. bypass missile control system
3. bypass landing gear safety circuit for ground maintenance
4. remove master arm power for ground maintenance

8-11. On the F-14, what are the modes of operation in the M61A1 20-mm gunfire control system?

1. A/G and A/A only
2. A/G and ACM encounter only
3. A/A and ACM encounter only
4. A/G, A/A, and ACM encounter

8-12. The AN/AWW-4 fuze function control system on the F-14 provides (a) what type of voltage for charging and arming and (b) what type of armament electrical fuzes?

1. (a) High ac (b) bomb
2. (a) High dc (b) bomb
3. (a) High ac (b) missile
4. (a) High dc (b) missile

8-13. The decoy dispensing system ejects what types of decoy rounds on the F-14?

1. Flares only
2. Chaff packages only
3. Flares and chaff packages

8-14. What jettison modes are pilot controlled on the F-14?

1. Emergency and ACM encounter
2. Emergency and selective
3. ACM encounter and auxiliary
4. Selective and auxiliary

8-15. The landing gear handle may be in the DOWN position for what jettison mode on the F-14?

1. Emergency
2. ACM encounter
3. Selective
4. Auxiliary

8-16. The F/A-18 armament system contains what data link system?

1. AN/AWW-4
2. AN/AWW-7
3. AIM-7
4. AIM-9

8-17. On the F/A-18 ground power control panel, the application of external power to the instrument and avionic systems is controlled by what total number of toggle switches?

1. One
2. Two
3. Three
4. Four

8-18. On the F/A-18 ground power control panel, the RESET position of the external power switch accomplishes which, if any, of the following functions?

1. Provides electrical power to the aircraft
2. Removes electrical power from the aircraft
3. Provides a circuit breaker for an overload
4. None of the above

IN ANSWERING QUESTIONS 8-19 AND 8-20, REFER TO FIGURE 7-9 IN THE TEXTBOOK.

8-19. Normal weapon release, launch, and fire signals are disabled with the LDG GEAR control handle in the DN position.

1. True
2. False

8-20. With the LDG GEAR control handle in the UP position, 28-volt dc power is applied to the master arm circuit breaker from what relay?

1. Main landing gear weight-on-wheels
2. Main landing gear weight-off-wheels
3. Nose landing gear weight-on-wheels
4. Nose landing gear weight-off-wheels

8-21. With the landing gear handle in the DN position to enable F/A-18 weapons systems for ground operational maintenance, what switch is used for override?

1. Landing gear override
2. Armament safety override
3. Master arm override
4. Weight-on-wheels override

8-22. With the F/A-18 master arm switch in the SAFE position, what is the only armament release mode that can be initiated?

1. Bomb jettison
2. Missile jettison
3. Emergency jettison
4. Selectable jettison

8-23. The F/A-18 aircraft controller grip assembly contains which of the following switches?

1. The bomb release only
2. The A/A only
3. The trigger only
4. The bomb release, A/A, and trigger

IN ANSWERING QUESTIONS 8-24 THROUGH 8-28, REFER TO FIGURE 7-13 IN THE TEXTBOOK.

8-24. When will the DDIs display a program list?

1. When In the A/A mode
2. When in the A/G mode
3. When the wing-form is displayed
4. When the wing-form is not displayed

8-25. The wing-form display on the DDIs is displayed during what mode(s) of operation?

1. A/G only
2. A/A only
3. A/G and A/A
4. SMP

8-26. In the A/A and A/G computer modes, what weapon stations are always displayed on the DDIs?

1. 1 and 9
2. 2 and 8
3. 3 and 7
4. 4, 5, and 6

8-27. With the MASTER switch In the SAFE position and in the A/G mode, a weapon selection will change the weapon loaded display by adding which of the following indications on the DDIs?

1. A box around the acronym only
2. An X through the acronym only
3. A box around and an X through the acronym
4. A RDY indication below the acronym

8-28. When a weapon is selected, the first priority station that has this particular weapon loaded is indicated by what indication on the DDIs?

1. A box around the acronym only
2. An X through the acronym only
3. A box around and an X through the acronym
4. A RDY indication below the acronym

8-29. What component(s) control(s) the SMP?

1. Digital display indicators
2. Digital computers
3. Master arm switch
4. Armament safety override switch

8-30. A weapon-type code is NOT required on what weapons loaded on F/A-18 fuselage stations 4 and 6?

1. AIM-7 missiles
2. AIM-9 missiles
3. MK-82 bombs
4. MK-92 bombs

8-31. On the F/A-18 MC/HYD ISOL panel, when the MC switch is in the NORM position, power is applied to which of the following computers?

1. Computer No. 1 only
2. Computer No. 2 only
3. Computers Nos. 1 and 2 only
4. Armament computer and computers Nos. 1 and 2

8-32. The F/A-18 jettison system has how many total modes of release?

1. One
2. Two
3. Three
4. Four

8-33. The F/A-18 auxiliary jettison mode is used to jettison weapons on the five pylon stations at which of the following times?

1. When the emergency jettison mode fails only
2. When the selective jettison mode fails only
3. When the emergency or the selective jettison mode fails
4. When the emergency and the selective jettison modes fail

8-34. The F/A-18 normal bomb release has what total number of electrically controlled modes of operation?

1. One
2. Two
3. Three
4. Four

8-35. Voltage is applied to the F/A-18 bomb arming unit through aircraft wiring from what power source?

1. PS-6419
2. PP-6419
3. AN/AWW-7B
4. AN/AWW-4

8-36. Where on the F/A-18 is the CAGE/UNCAGE switch for the Walleye guided missile system located?

1. The throttle
2. The armament control panel
3. The flap control panel
4. The aircraft controller grip assembly

8-37. What F/A-18 system provides control and guidance to the Mk 21 and Mk 27 Walleye weapons?

1. AN/AWW-4
2. AN/AWW-7B
3. AN/AIM-7
4. AN/AIM-9

8-38. On the F/A-18 aircraft controller grip assembly, what trigger switch position, if any, initiates launch of the AGM-65 Maverick missile?

1. First detent
2. Second detent
3. Third detent
4. None

8-39. Control of the AGM-88 HARM missile is supplied through what F/A-18 component or system?

1. DDI
2. SMP
3. Data link
4. Radar

8-40. Control of the AIM-7 Sparrow missile in the F/A-18 is supplied through SW and what other component or system?

1. DDI
2. FLIR
3. Radar
4. Data link

8-41. On the F/A-18 DDI, what indication shows that the Sparrow missile selected is NOT tuned?

1. The SEL light will not illuminate
2. An X through the SP acronym
3. The box around the SP acronym flashes
4. No X through the SP acronym

8-42. With the F/A-18 AIM-9 Sidewinder missile IR COOL switch in the NORM position, coolant is enabled to all seeker heads at which of the following times?

1. When the weight is off the wheels
2. When the MASTER switch is in the ARM position
3. When the station is selected on the DDI
4. When the acronym SW has SEL displayed below on the DDI

8-43. The F/A-18 M61A1 20-mm gun system has what total number of submodes?

1. One
2. Two
3. Three
4. Five

8-44. The P-3C has what total number of bomb bay and wing stations?

1. 8
2. 10
3. 18
4. 66

8-45. The S-3A has what total number of bomb bay and wing stations?

1. Five
2. Two
3. Six
4. Four

8-46. What stores will the P-3C electrical jettison release system release or eject?

1. All kill stores only
2. All search stores only
3. All kill and search stores

8-47. What stores will the S-3A electrical jettison release system release or eject?

1. All wing stations stores only
2. All search stores only
3. All wing stations and search stores

8-48. What total number of free-fall search stores launch chutes, if any, is on the S-3A aircraft?

1. One
2. Two
3. Three
4. None

8-49. What is the approximate diameter of the P-3C size B chute?

1. 5 in.
2. 7 in.
3. 10 in.
4. 12 in.

8-50. On the P-3C, what device shears the pin lugs and ejects the sonobouy stores from the SLC?

1. The CAD
2. The SUS
3. The SLT
4. The TLC

8-51. On the P-3C and the S-3A, what action prevents the inadvertent firing of the SLT stores on the deck?

1. Manually placing the sono safety switch in the SAFE position
2. Leaving the sono safety switch access door open
3. Manually placing the sono safety switch to the OFF position
4. Deactivating the sono launch circuit breaker

8-52. In the S-3A, what item is always loaded in tube P2?

1. A MLM
2. A SUS
3. A SLT sonobuoy
4. A SAR sonobuoy

8-53. With the exception of tube P2 in the S-3, when the emergency jettison circuit is activated, all SLCs will jettison in less than 10 seconds.

1. True
2. False

8-54. The SH-3 contains what total number of size A launcher tubes?

1. 12
2. 24
3. 48
4. 72

8-55. What type of system is used to launch sonobuoys in the SH-60?

1. Hydraulic
2. Pneumatic
3. Free-fall
4. CAD

8-56. With multiple faults detected by the SH-60 ECU and launcher BITE test, the failure codes will cycle at what intervals?

1. 12-second
2. 10-second
3. 5-second
4. 3-second

8-57. Without electrical power, which of the following devices operate the P-3C bomb bay doors for ground maintenance?

1. A hand pump only
2. A hand pump and manual control valve
3. A 3/8-inch drive crank only
4. A 3/8-inch drive crank and manual control valve

8-58. Without electrical power, which of the following devices operate(s) the S-3A bomb bay doors for ground maintenance?

1. A hand pump only
2. A hand pump and manual control valve
3. A 3/8-inch drive crank only
4. A 3/8-inch drive crank and manual control valve

8-59. When working in the bomb bays of either the P-3C or S-3A, what item must be in place?

1. Electrical power
2. The 3/8-inch drive crank
3. The sono door safety pin
4. The bomb bay door safety pin

8-60. What crew member has final control of the release of bomb bay stores In the P-3C and S-3A?

1. The TACCO
2. The SENSO
3. The pilot
4. The copilot

8-61. The P-3C wing launcher assembly universal pylon uses what bomb rack?

1. Aero 58A-1
2. Aero 65A-1
3. BRU-11A/A
4. BRU-22A/A

8-62. The S-3A wing pylon supports what ejector rack?

1. Aero 58A-1
2. Aero 65A-1
3. BRU-11A/A
4. BRU-22A/A

8-63. In the P-3C, control and release of search and kill stores from the aircraft is concentrated between what crew members?

1. The pilot and TACCO
2. The pilot and SENSO
3. The copilot and SENSO
4. The copilot and TACCO

8-64. In the S-3A, control and release of search and kill stores from the aircraft is concentrated between what crew members?

1. The pilot and TACCO
2. The pilot and SENSO
3. The copilot and SENSO
4. The copilot and TACCO

8-65. The P-3C search store release and control in the manual mode is completed by what crew member?

1. The pilot
2. The SENSO
3. The TACCO
4. The ordnance

8-66. The jettison of wing stores In pairs on the P-3C is at what intervals?

1. 1-second
2. 2-second
3. 3-second
4. 4-second

8-67. What landing gear weight-on-wheels switches disable the P-3C and S-3A jettison circuits on the ground?

1. Main
2. Nose
3. Right
4. Left

ASSIGNMENT 9

Textbook Assignment: "Computers," chapter 8, pages 8-1 through 8-17.

9-1. Which of the following items are examples of computer hardware?

1. Compilers
2. Assmemblers
3. Transistors
4. Executive routines

9-2. Which of the following items are examples of computer software?

1. Microchips
2. Printed circuit cards
3. Input/output libraries
4. Cathode-ray tubes

IN ANSWERING QUESTIONS 9-3 THROUGH 9-6, SELECT FROM COLUMN B THE PROGRAMMING LANGUAGE THAT PERFORMS THE FUNCTION LISTED IN COLUMN A.

	A. FUNCTIONS	B. PROGRAMMING LANGUAGES
9-3.	Used for business only	1. Jovial
		2. FORTRAN
9-4.	Used for real-time systems	3. PL/1
9-5.	Used for business and scientific programs	4. COBOL
9-6.	Used for large scale command and control Systems	

9-7. What are the two basic types of computers?

1. Linear and octal
2. Binary and logic
3. Linear and digital
4. Analog and digital

9-8. As it applies to computers, what characteristic applies to the term analog?

1. Representation by means of continuously variable physical quantities
2. Representation by the use of numerical equivalents
3. Representation by the use of graphic analysis
4. Representation by the SWAG

9-9. Because of their design, analog computers have unlimited applications.

1. True
2. False

9-10. What method is used to represent the instructions used by a digital computer?

1. Numerical equivalents
2. Delayed transmission
3. Direct translation
4. Analog input

9-11. What are the two basic types of digital computers?

1. Special-purpose and linear
2. Special-purpose and nonlinear
3. Linear and Nonlinear
4. Special-purpose and general-purpose

9-12. What method is used to change the operation of a special-purpose digital computer?

1. The input frequency is changed
2. The construction of the machine is altered
3. The instruction input is changed
4. The primary RTMS is changed

9-13. What method is used to change the operation of a general-purpose digital computer?

1. The input frequency is changed
2. The construction of the machine is altered
3. The instruction Input is changed
4. The primary RTMS is changed

9-14. In a digital computer, what are a series of electronic devices for the temporary storage of a binary word?

1. Registers
2. Counters
3. Gates
4. Compilers

9-15. In a digital computer, what series of electronic devices progress through a specific binary sequence?

1. Registers
2. Counters
3. Gates
4. Compilers

9-16. In a digital computer, what series of electronic devices are used to set a flip-flop or generate a times condition signal?

1. Registers
2. Counters
3. Gates
4. Compilers

9-17. In a digital computer, what devices are used to control the transfer of data words from one register to another?

1. Registers
2. Compilers
3. Counters
4. Gates

IN ANSWERING QUESTION 9-18. REFER TO FIGURE 8-1 IN THE TEXTBOOK.

9-18. The digital data processor contains what total number of basic units?

1. Five
2. Two
3. Three
4. Four

IN ANSWERING QUESTIONS 9-19 THROUGH 9-21, PERTAINING TO A DIGITAL COMPUTER CP, SELECT THE UNIT FROM COLUMN B THAT PERFORMS THE FUNCTION LISTED IN COLUMN A. NOT ALL RESPONSES IN COLUMN B ARE USED.

	A. FUNCTIONS	B. UNITS
9-19.	Performs the actual processing	1. Control unit
9-20.	Stores the data to be processed	2. ALU
		3. I/O unit
9-21.	Directs the overall computer operation	4. Internal data storage unit

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IN ANSWERING QUESTIONS 9-22 THROUGH 9-25, PERTAINING TO A DIGITAL COMPUTER CONTROL SECTION, SELECT THE REGISTER FROM COLUMN B THAT IS DESCRIBED IN COLUMN A.

	A. DESCRIPTIONS	B. REGISTERS
9-22.	Holds the instruction code during execution	1. P 2. SC
9-23.	Contains the address of the next sequential instruction to be executed	3. General 4. Instruction
9-24.	Stores the quantity used for address modification	
9-25.	Consists of one or two registers to accomplish the holding of a shift count	

9-26. What computer is the most practical type to use when speed and fully automatic operation is desired.

1. Stored-program
2. Internally stored-program
3. Externally stored-program
4. Multiaddressed-program

9-27. Computer instructions are broken down into what four categories?

1. Bit, byte, digit, and literal
2. Input, output, shift, and double
3. Transfer, control, arithmetic, and logic
4. Binary, octal, digital, and hexadecimal

9-28. Instructions that provide the computer with the ability to make decisions based on the results of previously generated data are known as what category of instructions?

1. Literal
2. Logic
3. Shift
4. Binary

9-29. Each instruction refers to only one operand, and the instructions are normally taken from the memory in sequential order. This is a characteristic of what type of computer?

1. Single-address
2. Single-address-sequential
3. Multiaddress
4. Multiaddress-sequential

9-30. Logic and arithmetic operations are performed in what section of a digital computer?

1. RAM
2. I/O
3. CPA
4. ALU

9-31. After an arithmetic process is completed, the result is stored in what location in the arithmetic unit?

1. The assembler
2. The accumulator
3. The compiler
4. The input/output libraries

9-32. The process by which instructions and data are read into a stored-program type of computer before a calculation is started is known as

1. inputting
2. outputting
3. loading
4. down loading

9-33. Which of the following is the purpose of "bootstrap" Instructions?

1. To cause the program to "branch," depending on whether a certain condition is met
2. To place enough instructions into a computer memory so that these instructions can be used to bring in more instructions
3. To cause the program to terminate if a "bad-data" input is sensed
4. To perform multiplication of certain numbers

9-34. A nonmagnetic toroidal form is used in what type of memory storage device?

1. A tape wound core
2. A semiconductor
3. A ferrite core
4. A thin film

9-35. A toroidal form molded from ceramic iron oxide, possessing magnetic properties, is used in what type of memory storage device?

1. A tape wound core
2. A semiconductor
3. A ferrite core
4. A thin film

9-36. In magnetic core memories, a single core can store how many total bits of a word?

1. One
2. Two
3. Three
4. Four

9-37. In the core element of a magnetic core memory, what condition determines whether a 1 or a 0 is stored?

1. The temperature of the core aperture
2. The absence or presence of a magnetic field
3. The intensity of the magnetic field around the core
4. The direction of the current flow around the core

9-38. Most of the semiconductor memories used in modern digital computers are of what type?

1. ROM MSI
2. RAM SSI
3. MOS LSI
4. NIS NSI

9-39. A ferromagnetic material deposited on a substrate of thin glass is what type of memory storage device?

1. Magnetic disk
2. Magnetic drum
3. Magnetic tape
4. Thin film

9-40. A cylinder that rotates at a constant speed is what type of memory storage device?

1. Magnetic disk
2. Magnetic drum
3. Magnetic tape
4. Thin film

9-41. A storage medium NOT used as a main storage medium due to its long access time, but widely used to store large amounts of data or as a main storage backup, is what type of memory storage device?

1. Magnetic disk
2. Magnetic drum
3. Magnetic tape
4. Thin film

9-42. A convenient storage medium for semipermanent storage of mass volumes of production programs is what type of memory storage device?

1. Magnetic disk
2. Magnetic drum
3. Magnetic tape
4. Thin film

9-43. What section of the digital computer is the interface between the computer and external devices?

1. CU
2. I/O
3. ALU
4. IDSU

9-44. What two methods are used to transmit digital data?

1. Linear and nonlinear
2. Serial and nonserial
3. Serial and parallel
4. Parallel and nonparallel

9-45. Each bit of a binary word to be transmitted must have its own data path. This is a characteristic of what type of digital data transmission system?

1. Nonlinear
2. Nonserial
3. Serial
4. Parallel

9-46. What is the simpler and less expensive method of digital data transmission?

1. Nonlinear
2. Nonserial
3. Serial
4. Parallel

9-47. What type of data transmission permits data transmission by radio?

1. Nonlinear
2. Nonserial
3. Serial
4. Parallel

9-48. What is the least efficient general form of input data to a computer?

1. Manual inputs from a MMI, such as a keyboard or console
2. Analog inputs from instruments or sensors
3. Digital inputs from instruments or sensors
4. Inputs from a source on or in which data has been previously stored in a form intelligible to the computer

9-49. Which of the following limitations is common to most input devices?

1. Not compatible with the computer
2. Requires single-phase power
3. Located a great distance from the computer
4. Involves some mechanical operation

9-50. The output information from a computer generally takes which of the following forms?

1. Codes and symbols displayed on a monitor screen or other device
2. Manually generated control information
3. Information recorded in ROM
4. Software documentation

IN ANSWERING QUESTIONS 9-51 THROUGH 9-54, SELECT FROM COLUMN B THE DEVICE THAT MATCHES THE DESCRIPTION IN COLUMN A.

	A. DESCRIPTIONS	B. DEVICES
9-51.	12 or more circuits, equvalent in complexity to a typical logic gate	1. SSI
		2. MSI
		3. LSI
9-52.	Fewer than 10 circuits, no more complex than a typical logic gate	4. VSLI
9-53.	Contains the equivalent to 1,000 or more logic gates	
9-54.	Large and complex circuitry, equivalent to 100 or more logic gates	

9-55. A computer program that takes certain commands and translates them into instructions necessary for a computer to execute is what type of program?

1. Converter
2. Interpreter
3. Translator
4. Compiler

9-56. What is the purpose of a subroutine?

1. To store the entire program at various places in order to ensure reliability
2. To eliminate repeating certain groups of instructions throughout the program
3. To enter administrative data relative to the program instruction
4. To “delay” a program

9-57. What type of instructions control access to the various subroutines?

1. Operational routines of the main program
2. Executive routines of the main program
3. Selection routines of the main program
4. Access routines of the main program

9-58. Instructions that provide the computer with the ability to leave the sequential execution of the main program, perform a subroutine, and return to the sequential execution are what type of instructions?

1. Selection
2. Executive
3. Sequencing
4. Jump and return jump

IN ANSWERING QUESTIONS 9-59 THROUGH 9-62, SELECT FROM COLUMN B THE PROCESS THAT MATCHES THE DESCRIPTION LISTED IN COLUMN A.

	A. DESCRIPTIONS	B. PROCESSES
9-59.	To locate errors	1. Analysis
9-60.	To use symbols to represent the various operations to be performed	2. Debugging
		3. Encoding
9-61.	To lay out the problem in a form that will lend itself to interpretation	4. Flow diagram
9-62.	To convert flow chart operations into computer language	

9-63. A thorough and rapid method for the detection of failures in a specific portion of a computer is performed by what program?

1. Analysis
2. Debugging
3. Maintenance
4. Error check

9-64. What type of maintenance program is designed to detect the existence of errors?

1. Reliability
2. Diagnostic
3. Utility
4. Locator

9-65. What type of maintenance program is used to locate the circuits in which computer malfunctions originate?

1. Reliability
2. Diagnostic
3. Utility
4. Locator

ASSIGNMENT 10

Textbook Assignment: "Automatic Carrier Landing System," chapter 9, and "Electrostatic Discharge Program," chapter 10, pages 9-1 through 10-18.

IN ANSWERING QUESTIONS 10-1 THROUGH 10-4, SELECT FROM COLUMN B THE ITEMS DESCRIBED IN COLUMN A.

	A. DESCRIPTIONS	B. ITEMS
10-1.	Used to lock onto the landing pattern	1. ACLS system
10-2.	Used to establish the proper glide path	2. Autopilot system
10-3.	Provides warnings if automatic carrier landing mode becomes uncoupled or is degraded	3. Data link pitch commands
10-4.	Ensures that the pilot and the aircraft have the best and safest possible approach and descent to the carrier deck and touchdown	4. Data link roll commands

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10-5. What system provides the interface between the data link and the flight control surfaces?

1. APC
2. AFCS
3. DDCS
4. R-DG

10-6. Data link messages and signals are received, invalid messages are screened out, and signals are sent to the autopilot system by what system?

1. APC
2. AFCS
3. DDCS
4. R-DG

10-7. What system determines the glide-path errors from the carrier's instrument landing system radar?

1. APC
2. AFCS
3. DDCS
4. R-DG

10-8. The glide-path, pulse-coded, Ku-band information is transmitted from the carrier to the aircraft by what system?

1. LCCS
2. ACLS
3. ILS radar
4. Radar beacon

10-9. Ka-band signals are transmitted from the carrier to the aircraft to track the aircraft and compare the aircraft's position to the desired glide path by what system?

1. LCCS
2. ACLS
3. ILS radar
4. Radar beacon

10-10. What subsystem of the AN/SPN-42 system will generate a waveoff signal?

1. Control console
2. Data link monitor
3. Digital computer
4. Tracking pulse radar set

10-11. What system transmits X-band replies to the carrier to provide precise aircraft position data?

1. LCCS
2. ACLS
3. ILS radar
4. Radar beacon

10-12. To maintain the angle-of-attack, and thus the airspeed during aircraft landing approach, what system automatically adjusts the throttles?

1. APC
2. AFCS
3. DDCS
4. R-DG

IN ANSWERING QUESTIONS 10-13 THROUGH 10-16, SELECT FROM COLUMN B THE COMPONENT DESCRIBED IN COLUMN A.

	A. DESCRIPTIONS	B. COMPONENTS
10-13.	Determines and displays backup pitch and roll attitude	1. Discrete message indicator
		2. VGI
10-14.	Displays nine status indications from the one-way link system, the radar beacon, and autopilot	3. Approach indexer
		4. Warning indexer panel
10-15.	Provides another angle-of-attack in the pilot’s field of view	
10-16.	Provides status indications for the APC and AFCS, and whether a waveoff has been initiated	

10-17. A fully automatic approach from entry point to touchdown on the flight deck is what ACLS mode of operation?

1. Mode I
2. Mode II
3. Mode III
4. Mode IV

10-18. Manual pilot control to touchdown on the flight deck with talkdown guidance by a shipboard controller is what ACLS mode of operation?

1. Mode I
2. Mode II
3. Mode III
4. Mode IV

10-19. During Mode I landing operation, the pilot is cleared for approach by what indicator illumination on the discrete message indicator?

1. CMD CONTROL
2. ACL READY
3. AP CPLR
4. LDG CHK

10-20. During Mode I landing operation, deck motion compensation will be added to the glide-path commands at how many seconds from touchdown?

1. 1.5 sec
2. 12.5 sec
3. 15.0 sec
4. 17.5 sec

10-21. During Mode I landing operation, the landing system will freeze the pitch and bank commands at how many seconds from touchdown?

1. 2.5 sec
2. 2.0 sec
3. 1.5 Sec
4. 1.0 sec

IN ANSWERING QUESTION 10-22, REFER TO FIGURES 9-4 AND 9-5 IN THE TEXTBOOK.

10-22. During Mode I landing operation, the LCC sends a wave-off signal automatically if the aircraft exceeds the boundaries at how many seconds from touchdown?

1. From 2.5 to 17.5 sec
2. From 2.0 to 10.0 sec
3. From 1.5 to 12.5 sec
4. From 1.0 to 7.5 sec

10-23. At which of the following frequencies is atmospheric static most critical?

1. 500 kHz
2. 25 MHz
3. 50 MHZ
4. 500 MHz

10-24. Precipitation static is a severe problem in which of the following frequency bands?

1. Low only
2. Medium only
3. Low and medium
4. Ultra high

10-25. Cosmic noise is normally heard in which of the following frequency bands?

1. Low only
2. Medium only
3. Low and medium
4. Ultra high

10-26. Which of the following is a typical source of sustained switching transients?

1. Receivers
2. Transmitters
3. Synchronizers
4. Generators

10-27. Broadband random noise consists of impulses that have which of the following characteristics?

1. Regular in shape and recurrence rate
2. Irregular in shape and duration
3. Constant in voltage and duration only
4. Constant in voltage, duration, shape, and recurrence rate

10-28. A circuit or device that carries a varying electrical current is a potential source of receiver interference.

1. True
2. False

10-29. What type of dc motor, if any, is more apt to cause interference (noise) in a radio receiver?

1. Permanent magnet
2. Series wound
3. Shunt wound
4. None

10-30. The control circuit of a relay may cause more interference than the higher powered circuit being controlled by the relay.

1. True
2. False

10-31. Radio interference from operating radar is most likely caused by which of the following circuits?

1. Indicator
2. Modulator
3. Receiver
4. Synchronizer

10-32. In the tuning band of a receiver, oscillator leakage is the greatest at which of the following points?

1. Both the high and low ends
2. The low end
3. The middle range
4. The high end

10-33. If a receiver has an operating frequency of 150 MHz and an IF of 20 MHz. what is the oscillator leakage frequency?

1. 20 MHz or 150 MHz
2. 120 MHz or 150 MHz
3. 130 MHz or 170 MHz
4. 150 MHz or 170 MHz

10-34. Radio interference is caused by a cold-solder joint for which of the following reasons?

1. Its reactance varies with applied voltage
2. Its resistance varies with applied voltage
3. Its capacitance varies inversely with frequency
4. Its inductance varies with frequency

10-35. A receiver tuned to 2.4 kHz experiences extreme full-wave rectification interference. Which of the following aircraft components is the probable source?

1. Starter motor
2. Wing-flap motor
3. Single-phase invertor
4. Three-phase generator

IN ANSWERING QUESTION 10-36, REFER TO FIGURE 10-1 IN THE TEXTBOOK.

10-36. Interference is very low at the power source for which of the following reasons?

1. Source operation high frequency
2. Source operation low frequency
3. Battery high impedance
4. Battery low impedance

10-37. Which of the following actions will reduce inductive magnetic coupling in aircraft wiring?

1. Increasing the spacing between the wires
2. Decreasing the spacing between the wires
3. Decreasing the angle between the wires
4. Replacing all the existing wire with shielded wire

10-38. Which of the following antenna leads is a source of radio receiver noise in the HF range?

1. Shielded receiver
2. Unshielded receiver
3. Shielded transmitter
4. Unshielded transmitter

10-39. What elements are normally used to achieve interference reduction at the source?

1. High-frequency diodes
2. High-value components
3. Discrete components
4. Transistors

10-40. The efficiency of a perfect capacitor in bypassing radio interference increases in what proportion to the capacitance of the capacitor?

1. Linearly
2. Exponentially
3. Directly
4. Indirectly

10-41. The value of a capacitor as a bypass is lost at which of the following frequencies?

1. At the resonant frequency
2. At frequencies much lower than the resonant frequency only
3. At frequencies much higher than the resonant frequency only
4. At frequencies much higher and lower that the resonant frequency

10-42. The ideal position to place a capacitive filter to reduce radio interference is in what location?

1. Between the source of the interference and the receiver
2. Close to the source of interference
3. The receiver circuit
4. The source circuit

10-43. Feedthrough capacitors used to filter interference in an ac circuit should have a voltage rating of at least what magnitude across the capacitor?

1. Twice the applied voltage
2. Twice the peak voltage
3. Four times the applied voltage
4. Four times the peak voltage

10-44. A capacitor is NOT normally used alone as a filter in a dc switching circuit for which of the following reasons?

1. It only works in an ac circuit
2. Its reactance is too high for a dc circuit
3. Its value is too large for a dc circuit
4. Its interference exceeds that of opening an unfiltered circuit

10-45. A resistor used for proper RC filtering should be what size in respect to the load resistance?

1. One-fifth
2. One-fourth
3. One-third
4. One-half

10-46. When the inductance-capacitance filter method is used, the inductor should be connected in the dc power supply in what configuration with respect to the load?

1. In series only
2. In parallel only
3. In series or parallel, depending on the inductor rating
4. In series-parallel

10-47. An ideal low-pass filter has no insertion loss at which of the following frequencies?

1. At its cutoff frequency
2. Below its cutoff frequency only
3. Above its cutoff frequency only
4. Above or below its cutoff frequency

10-48. To eliminate radiation of harmonics produced by an overdriven output amplifier, what type of filter is used?

1. Bandpass
2. Band-reject
3. Low-pass
4. High-pass

10-49. The bandpass filter configuration of sections for an antenna is normally selected so the upper limit of the pass band approaches or exceeds the frequency of the lower limit of the pass band by what multiple factor?

1. Six
2. Two
3. Eight
4. Four

10-50. Band-reject filter elements are arranged in which of the following basic configuration?

1. W-section
2. V-section
3. P-section
4. L-section

10-51. Which of the following bonding methods is considered ideal for all frequencies?

1. Direct
2. Indirect
3. Simplex
4. Multiple

10-52. Which of the following lengths of bonding jumpers is the most effective in eliminating lightning discharge?

1. 8 in.
2. 2 in.
3. 6 in.
4. 4 in.

10-53. What is the lowest voltage that will destroy or damage an ESD-sensitive device?

1. 10 V
2. 20 V
3. 30 V
4. 35 V

10-54. The generation of static electricity on an object by rubbing is known as the

1. electrostatic charge
2. dielectric effect
3. triboelectric effect
4. prime charge

10-55. When rubbed against any of the other three, which of the following substances will assume the positive charge when separated?

1. Saran
2. Nickel
3. Steel
4. Aluminum

10-56. Under which of the following conditions is generated static electricity decreased?

1. Hot air
2. Dry air
3. Cold air
4. Humid air

10-57. Which of the following is NOT an ESD prime generator?

1. Synthetic mats
2. Vinyl
3. Common solder suckers
4. Carbon impregnated polyethylene

10-58. What is the minimum resistance for personnel ground straps?

1. 25,000 ohms
2. 150,000 ohms
3. 250,000 ohms
4. 500,000 ohms

10-59. Which of the following procedures should NOT be performed when working on ESD-sensitive devices?

1. Make continuity checks on personnel ground straps with a Simpson 260 meter or equivalent
2. Ground the work area, personnel ground straps, and equipment
3. Make periodic electrostatic measurements at all ESD-protected work areas
4. Wear cotton smocks when working with ESD-sensitive devices