

## CHAPTER 13

### COMMUNICATIONS AND NAVIGATION SYSTEMS

#### GENERAL

Communications and navigation are the two major functions of airborne radio. Communication systems primarily involve voice transmission and reception between aircraft or aircraft and ground stations. Radios are used in aircraft as navigational aids in a number of applications. They range from a simple radio direction finder to navigational systems which use computers and other advanced electronic techniques to automatically solve the navigational problems for an entire flight. Marker beacon receivers, instrument landing systems (involving radio signals for glide slope and direction), distance measuring equipment, radar, area navigation systems, and omnidirectional radio receivers are but a few basic applications of airborne radio navigation systems available for installation and use in aircraft.

Safe aircraft operation is dependent to a large degree upon the satisfactory performance of the airborne communications and navigation systems. Reliability and performance of the radio and radar system are directly related to the skills of those who perform the maintenance.

Federal Aviation Regulations require an inspection of radio equipment installations at regular intervals. These inspections include a visual examination for security of attachment, condition of wiring, bonding, shock mounts, radio racks and supporting structure. In addition, a functional check is usually performed to determine that the equipment is operating properly and that its operation does not interfere with the operation of other systems.

Aircraft mechanics' responsibilities include the installation and inspection of radios, antennas, navigation equipment, and associated wiring. In addition, the FAA has certified radio repair facilities to perform maintenance on radios, antennas, navigation, and radar equipment. Transmitting equipment is calibrated by persons licensed by the FCC (Federal Communications Commission).

To be in a more favorable position to inspect

system installations, a mechanic should possess some basic knowledge and understanding of the principles, purposes, and operation of the radio equipment used in aircraft.

Because of the many different makes and models of equipment and the various systems in use, it is not feasible to describe each in this handbook. The information presented in this chapter is general in nature and provides a broad introduction to radio, its principles, and application to aircraft from a mechanic's viewpoint.

#### BASIC RADIO PRINCIPLES

The principle of radio communication can be illustrated by using a simple transformer. As shown in figure 13-1, closing the switch in the primary circuit causes the lamp in the secondary circuit to be illuminated. Opening the switch extinguishes the light.

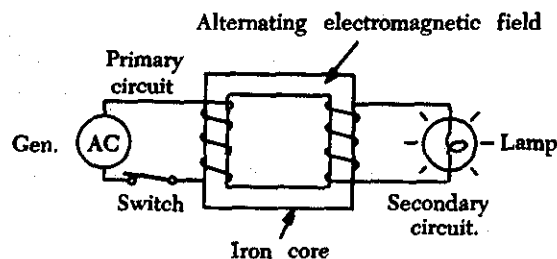


FIGURE 13-1. A simple transformer circuit.

There is no direct connection between the primary and secondary circuits. The energy that illuminates the light is transmitted by an alternating electromagnetic field in the core of the transformer. This is a simple form of wireless control of one circuit (the secondary) by another circuit (the primary).

The basic concept of radio communications involves the transmission and reception of electromagnetic (radio) energy waves through space. Alternating current passing through a conductor creates electromagnetic fields around the conductor. Energy

is alternately stored in these fields and returned to the conductor. As the frequency of current alternation increases, less and less of the energy stored in the field returns to the conductor. Instead of returning, the energy is radiated into space in the form of electromagnetic waves. A conductor radiating in this manner is called the transmitting antenna.

For an antenna to radiate efficiently a transmitter must supply it with an alternating current of the selected frequency. The frequency of the radio wave radiated will be equal to the frequency of the applied current. When current flows through a transmitting antenna, radio waves are radiated in all directions in much the same way that waves travel on the surface of a pond into which a rock has been thrown. Radio waves travel at a speed of approximately 186,000 miles per second.

If a radiated electromagnetic field passes through a conductor, some of the energy in the field will set electrons in motion in the conductor. This electron flow constitutes a current that varies with changes in the electromagnetic field. Thus, a variation of the current in a radiating antenna causes a similar varying current in a conductor (receiving antenna) at a distant location. Any intelligence being produced as current in a transmitting antenna will be reproduced as current in a receiving antenna.

#### Frequency Bands

The radio frequency portion of the electromagnetic spectrum extends from approximately 30 kHz (kilohertz) to 30,000 MHz (Megahertz). As a matter of convenience, this part of the spectrum is divided into frequency bands. Each band or frequency range produces different effects in trans-

mission. The radio frequency bands proven most useful and presently in use are:

Frequency Range	Band
Low frequency (L/F) -----	30 to 300 kHz
Medium frequency (M/F) --	300 to 3,000 kHz
High frequency (H/F) -----	3,000 kHz to 30 MHz
Very high frequency (VHF) _	30 to 300 MHz
Ultra high frequency (UHF) _	300 to 3,000 MHz
Superhigh frequency (SHF) _	3,000 to 30,000 MHz

In practice, radio equipment usually covers only a portion of the designated band, *e.g.*, civil VHF equipment normally operates at frequencies between 108.0 MHz and 135.95 MHz.

#### BASIC EQUIPMENT COMPONENTS

The basic components (figure 13-2) of a communication system are: microphone, transmitter, transmitting antenna, receiving antenna, receiver, and a headset or loudspeaker.

##### Transmitters

A transmitter may be considered as a generator which changes electrical power into radio waves. A transmitter must perform these functions: (1) Generate a RF (radio frequency) signal, (2) amplify the RF signal, and (3) provide a means of placing intelligence on the signal.

The transmitter contains an oscillator circuit to generate the RF signal (or a subharmonic of the transmitter frequency, if frequency doublers or multipliers are used) and amplifier circuits to increase the output of the oscillator to the power level required for proper operation.

The voice (audio) intelligence is added to the RF

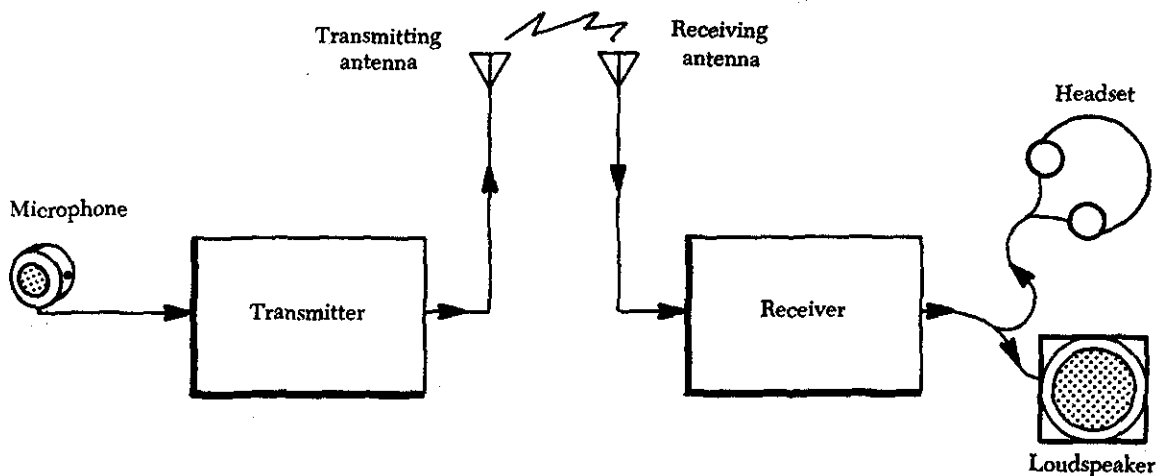


FIGURE 13-2. Basic communication equipment.

signal by a special circuit called the modulator. The modulator uses the audio signal to vary the amplitude or frequency of the RF signal. If the amplitude is varied, the process is called amplitude modulation or AM. If the frequency is varied, the process is known as frequency modulation or FM.

Transmitters take many forms, have varying degrees of complexity and develop various levels of power. The amount of power generated by a transmitter affects the strength of the electromagnetic field radiating from the antenna. Thus, it follows that the higher the power output from a transmitter, the greater the distance its signal may be received.

VHF transmitters used in single engine and light twin-engine aircraft vary in power output from 1 watt to 30 watts, depending on the particular model radio. However, radios having 3 to 5 watt ratings are used most frequently. Executive and large transport aircraft are usually equipped with VHF transmitters having a power output of 20 to 30 watts.

Aviation communication transmitters are crystal-controlled in order to meet the frequency tolerance requirements of the FCC. Most transmitters are selectable for more than one frequency. The frequency of the channel selected is determined by a crystal. Transmitters may have from one to 680 channels.

### Receivers

The communications receiver must select radio frequency signals and convert the intelligence contained on these signals into a usable form; either audible signals for communication and audible or visual signal for navigation.

Radio waves of many frequencies are present in the air. A receiver must be able to select the desired frequency from all those present and amplify the small a.c. signal voltage.

The receiver contains a demodulator circuit to remove the intelligence. If the demodulator circuit is sensitive to amplitude changes, it is used in AM sets and called a detector. A demodulator circuit that is sensitive to frequency changes is used for FM reception and is known as a discriminator.

Amplifying circuits within the receiver increases the audio signal to a power level which will operate the headset or loudspeaker properly.

### Antenna

An antenna is a special type of electrical circuit designed to radiate and receive electromagnetic energy. As mentioned previously, a transmitting an-

tenna is a conductor which radiates electromagnetic waves when a radio frequency current is passed through it. Antennas vary in shape and design (figure 13-3) depending upon the frequency to be transmitted, and specific purposes they must serve. In general, communication transmitting stations radiate signals in all directions. However, special antennas are designed that radiate only in certain directions or certain beam patterns.

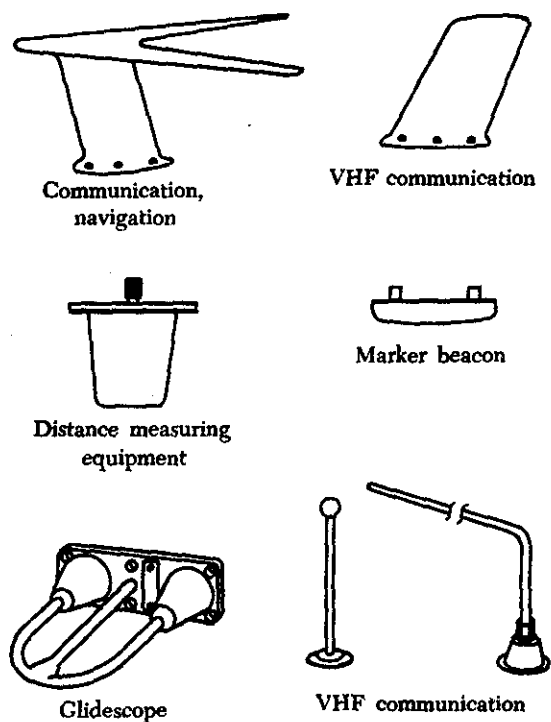


FIGURE 13-3. Antennas.

The receiving antenna must intercept the electromagnetic waves that are present in the air. The shape and size of the receiving antenna will also vary according to the specific purpose for which it is intended. In airborne communications the same antenna is normally used for both transmission and reception of signals.

### Microphones

A microphone is essentially an energy converter that changes acoustical (sound) energy into corresponding electrical energy. When spoken into a microphone, the audio pressure waves generated strike the diaphragm of the microphone causing it to move in and out in accordance with the instantaneous pressure delivered to it. The diaphragm is

attached to a device that causes current to flow in proportion to the pressure applied.

For good quality sound, the electrical waves from a microphone must correspond closely in magnitude and frequency to the sound waves that cause them, so that no new frequencies are introduced. A desirable characteristic is the ability of the microphone to favor sounds coming from a nearby source over random sounds coming from a relatively greater distance. When talking into this type of microphone, the lips must be held as close as possible to the diaphragm.

Persons inexperienced in the use of the microphone are usually surprised at the quality of their own transmissions when they are taped and played back. Words quite clear when spoken to another person can be almost unintelligible over the radio. Readable radio transmissions depend on the following factors: (1) Voice amplitude, (2) rate of speech, and (3) pronunciation and phrasing. Clarity increases with amplitude up to a level just short of shouting. When using a microphone, speak loudly, without exerting extreme effort. Talk slowly enough so that each word is spoken distinctly. Avoid using unnecessary words.

### POWER SUPPLY

The power supply is a component that furnishes the correct voltages and current needed to operate the communication equipment. The power supply can be a separate component or it may be contained within the equipment it supplies. Electromechanical devices used as electronic power supplies include dynamotors and inverters.

The dynamotor performs the dual functions of motor and generator, changing the relatively low voltage of the aircraft electrical system into a much higher value. The multi-vibrator is another type of voltage supply used to obtain a high a.c. or d.c. voltage from a comparatively low d.c. voltage.

In many aircraft, the primary source of electric power is direct current. An inverter is used to supply the required alternating current. Common aircraft inverters consist of a d.c. motor driving an a.c. generator. Static, or solid-state inverters are replacing the electromechanical inverters in many applications. Static inverters have no moving parts, but use semiconductor devices and circuits that periodically pulse d.c. current through the primary of a transformer to obtain an a.c. output from the secondary.

### COMMUNICATION SYSTEMS

The most common communication system in use today is the VHF system. In addition to VHF equipment, large aircraft are usually equipped with HF communication systems.

Airborne communications systems vary considerably in size, weight, power requirements, quality of operation, and cost, depending upon the desired operation.

Many airborne VHF and HF communication systems use transceivers. A transceiver is a self-contained transmitter and receiver which share common circuits; i.e., power supply, antenna, and tuning. The transmitter and receiver both operate on the same frequency, and the microphone button determines when there is an output from the transmitter. In the absence of transmission, the receiver is sensitive to incoming signals. Since weight and space are of great importance in aircraft, the transceiver is widely used. Large aircraft may be equipped with transceivers or a communications system that uses separate transmitters and receivers.

The operation of radio equipment is essentially the same whether installed on large aircraft or small aircraft. In some radio installations the controls for frequency selection, volume, and the "on-off" switch are integral with the radio main chassis. In other installations, the controls are mounted on a panel located in the cockpit and the radio equipment is located in racks in another part of the aircraft.

Because of the many different types and models of radios in use, it is not possible to discuss the specific techniques for operating each in this manual. However, there are various practices of a non-specific nature which apply to all radios. These general practices will be described.

### VHF (Very High Frequency) Communications

VHF airborne communication sets operate in the frequency range from 108.0 MHz to 135.95 MHz. VHF receivers are manufactured that cover only the communications frequencies, or both communications and navigation frequencies. In general, the VHF radio waves follow approximately straight lines. Theoretically, the range of contact is the distance to the horizon and this distance is determined by the heights of the transmitting and receiving antennas. However, communication is sometimes possible many hundreds of miles beyond the assumed horizon range.

Many VHF radios have the transmitter, receiver, power supply, and operating controls built into a

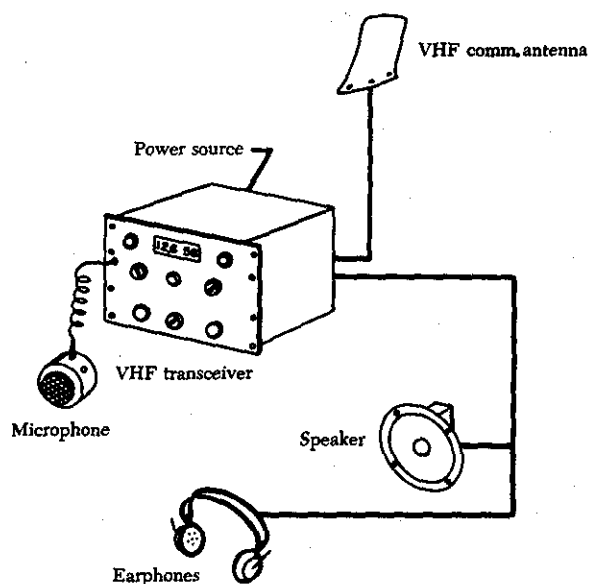


FIGURE 13-4. VHF system diagram.

single unit. This unit is frequently installed in a cutout in the instrument panel. A system diagram of a typical panel-mounted VHF transceiver is shown in figure 13-4. Others have certain portions of the

communication system mounted on the instrument panel and the remainder remotely installed in a radio or baggage compartment.

To perform an operational check of a VHF communication system, a source of electric power must be available. After turning the radio control switch "on", allow sufficient time for the equipment to warm up before beginning the operational checks. Using the frequency selector, select the frequency of the ground station to be contacted. Adjust the volume control to the desired level.

With the microphone held close to the mouth, press the microphone button and speak directly into the microphone to transmit; when through talking, release the button. This action will return the communication receiver to operation. When the ground station acknowledges the initial transmission, request that an operational check be made on all frequencies or channels. Prior to transmitting, make certain that a station license is displayed in the aircraft. In addition, the person operating the transmitter must hold a current Restricted Radiotelephone Operator's permit. Both the station license and the operator's permit are issued by the FCC.

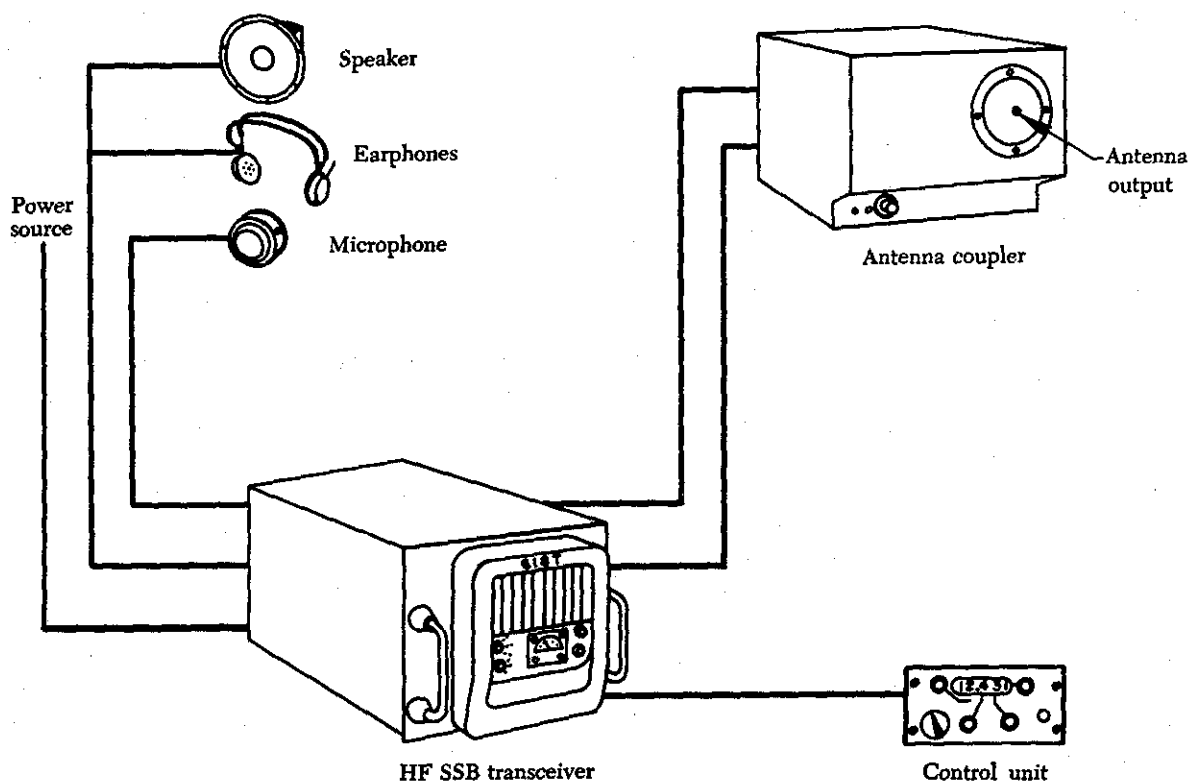


FIGURE 13-5. HF system diagram.

### HF (High Frequency) Communications

A high frequency communication system (figure 13-5) is used for long-range communication. HF systems operate essentially the same as a VHF system, but operate in the frequency range from 3 MHz to 30 MHz. Communications over long distances are possible with HF radio because of the longer transmission range. HF transmitters have higher power outputs than VHF transmitters.

The design of antennas used with HF communication systems vary with the size and shape of the aircraft. Aircraft which cruise below 300 m.p.h. generally use a long wire antenna. Higher speed aircraft have specially designed antenna probes installed in the vertical stabilizer. Regardless of the type antenna, a tuner is used to match the impedance of the transceiver to the antenna.

An operational check of an HF radio consists of turning the control switch to "on," adjusting the RF gain and volume controls, selecting the desired channel and transmitting the appropriate message to the called station. Best adjustment of the gain control can be obtained with the volume control set at half range. The gain control is used to provide the strongest signal with the least amount of noise. The volume control is used to set sound level and affects only the loudness of the signal.

### AIRBORNE NAVIGATION EQUIPMENT

"Airborne navigation equipment" is a phrase embracing many systems and instruments. These systems include VHF omnirange (VOR), instrument landing systems, distance-measuring equipment, automatic direction finders, doppler systems, and inertial navigation systems.

When applied to navigation, the radio receivers and transmitters handle signals which are used to determine bearing and in some cases distance, from geographical points or radio stations.

### VHF OMNIRANGE SYSTEM

The VHF VOR (omnidirectional range) is an electronic navigation system. As the name implies, the omnidirectional or all-directional range station provides the pilot with courses from any point within its service range. It produces 360 usable radials or courses, any one of which is a radio path connected to the station. The radials can be considered as lines that extend from the transmitter antenna like spokes of a wheel. Operation is in the VHF portion of the radio spectrum (frequency range of 108.0 MHz - 117.95 MHz) with the result

that interference from atmospheric and precipitation static is negligible. The navigational information is visually displayed on an instrument in the cockpit.

The typical airborne VOR receiving system (figure 13-6) consists of a receiver, visual indicator, antennas, and a power supply. In addition, a unit frequency selector is required and in some cases located on the receiver unit front panel. Some manufacturers design a remote control frequency selector so the equipment may be installed in some other area of the aircraft. This frequency selector is used to tune the receiver to a selected VOR ground station.

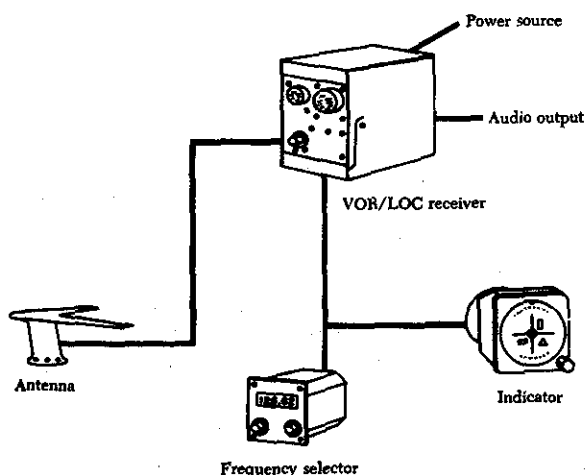


FIGURE 13-6. VOR system diagram.

The VOR receiver, in addition to course navigation, functions as a localizer receiver during ILS (instrument landing system) operation. Also, some VOR receivers include a glide slope receiver in a single case. Regardless of how individual manufacturers may design the VOR equipment, the intelligence from the VOR receiver is displayed on the CDI (course deviation indicator).

The CDI, figure 13-7, performs several functions. During VOR operation the vertical needle is used as the course indicator. The vertical needle also indicates when the aircraft deviates from the course and the direction the aircraft must be turned to attain the desired course. The "TO-FROM" indicator presents the direction to or from the station along the omniradial. The course deviation indicator also contains a "VOR-LOC" flag alarm. Normally this is a small arm which extends into view

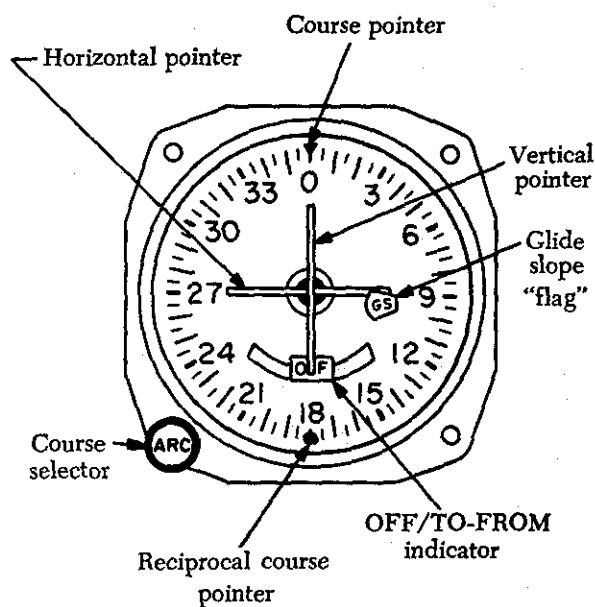


FIGURE 13-7. Course deviation indicator.

only in the case of a receiver malfunction or the loss of a transmitted signal.

When localizer signals are selected on the receiver, the indicator shows the position of the localizer beam relative to the aircraft and the direction the aircraft must be turned to intercept the localizer.

During VOR operation the VOR radial to be used is selected by rotating the OBS (omnibearing selector). The OBS is generally located on the CDI; however, in some installations it is a part of the navigation receiver. The OBS is graduated in degrees from zero to 360. Each degree is a VOR course to be flown in reference to a ground station.

The following steps are typical of those performed during a ground operational check. When checking a VOR system, follow the specific procedures recommended by the equipment manufacturer. The operational check can be performed using appropriate test equipment, VOT (Very High Frequency Omnirange Test) or the terminal VOR facility.

- (1) Place the on/off switch in the "ON" position.
- (2) Adjust the frequency selector to the desired station.
- (3) Allow sufficient time for equipment to warm up.
- (4) The VOR flag will disappear when the VOR station signal is received.

- (5) Adjust the volume control to the desired level; assure that the selected VOR station identification is clear and correct.
- (6) Check the CDI for vertical needle deflection.
- (7) Center the vertical needle by rotating the OBS.
- (8) Check "TO-FROM" indicator for "TO" indication.
- (9) Rotate the OBS to read  $10^\circ$  higher than the setting at which the vertical needle was centered. The vertical needle should move left and cover the last dot which corresponds to  $10^\circ$  course displacement.
- (10) Return the OBS to the original position. The vertical needle should return to the center position.
- (11) Rotate the OBS to read  $10^\circ$  lower than the original setting. The vertical needle should move right and cover the last dot which corresponds to  $10^\circ$  course displacement.
- (12) Assure that the vertical needle moves an equal distance in both directions. This total course width or course sensitivity should be  $20^\circ$ .

NOTE: When "TO-FROM" indicator reads "FROM", the vertical needle will deflect in the direction opposite that stated in the above procedures.

If the operational check is unsatisfactory, it will be necessary to remove the VOR receiver and associated instruments from the aircraft and have them calibrated.

### INSTRUMENT LANDING SYSTEM

The ILS (instrument landing system), one of the facilities of the Federal airways, operates in the VHF portion of the electromagnetic spectrum. The ILS can be visualized as a slide made of radio signals on which the aircraft can be brought safely to the runway.

The entire system consists of a runway localizer, a glide slope signal, and marker beacons for position location. The localizer equipment produces a radio course aligned with the center of an airport runway. The on-course signals result from equal reception of two signals; one containing 90 Hz modulation and the other containing 150 Hz modulation. On one side of the runway center line the radio receiver develops an output in which the 150 Hz tone predominates. This area is called the blue

sector. On the other side of the centerline the 90 Hz output is greater. This area is the yellow sector.

The localizer facility operates in the frequency range of 108.0 MHz to 112.0 MHz on the "odd tenths" of the megahertz steps. The VOR receiver also operates in this frequency range on the "even tenths" of the megahertz steps. The airborne VOR receiver functions as the localizer receiver during ILS operation.

The glide slope is a radio beam which provides vertical guidance to the pilot, assisting him in making the correct angle of descent to the runway. Glide slope signals are radiated from two antennas located adjacent to the touchdown point of the runway. Each glide slope facility operates in the UHF frequency range from 329.3 MHz to 335.0 MHz.

The glide slope and VOR/localizer receivers may be separate receivers or combined in a single case. The glide slope receiver is paired to the localizer and one frequency selector is used to tune both receivers. A component diagram of an ILS is shown in figure 13-8.

The information from both localizer and glide slope receivers is presented on the CDI; the vertical needle displays localizer information and the horizontal needle displays glide slope information (figure 13-9). When both needles are centered, the aircraft is on course and descending at the proper

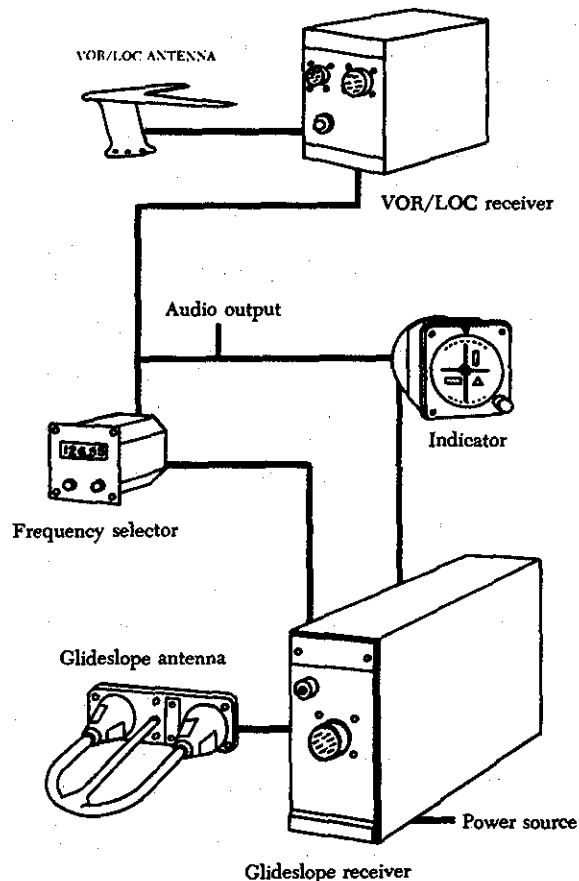


FIGURE 13-8. Component diagram of an ILS.

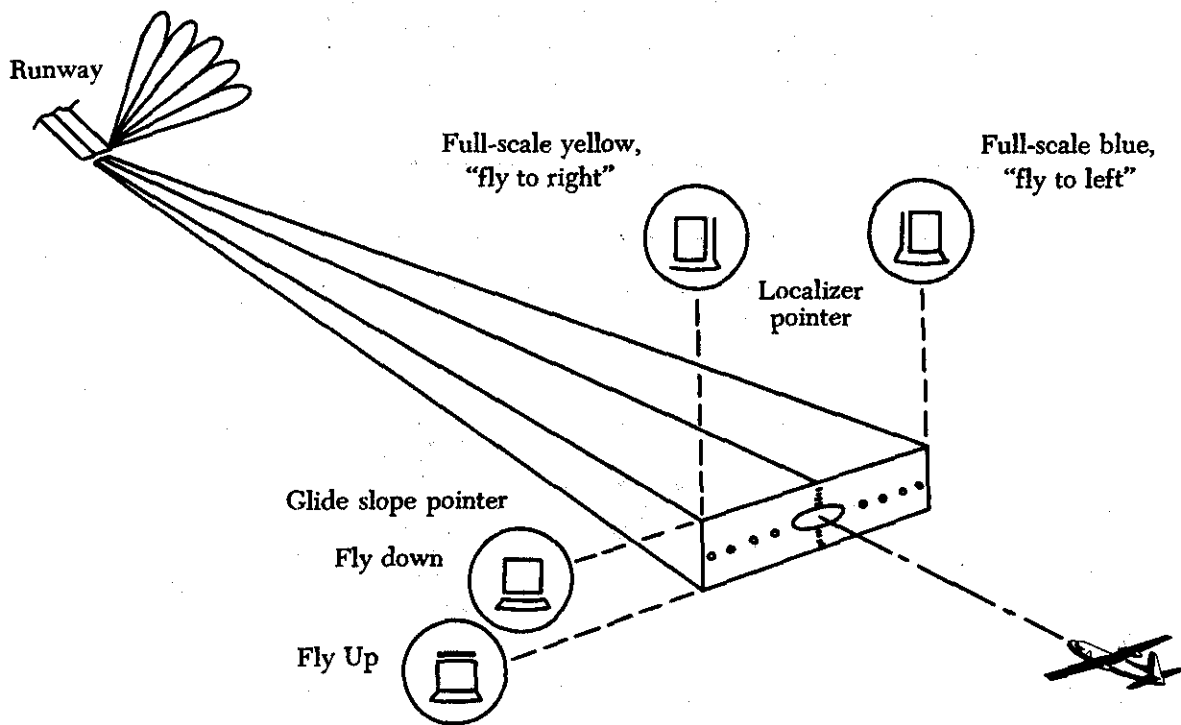


FIGURE 13-9. Glide slope information.



rate. In addition the CDI contains a red warning flag for each system which comes into view when the receiver fails or the loss of a transmitted signal occurs.

Two antennas are usually required for ILS operation. One for the localizer receiver, also used for VOR navigation, and one for the glide slope. Some of the small aircraft use a single multi-element antenna for both glide slope and VOR/LOC operation. The VOR/localizer antenna is normally installed on the top of the aircraft fuselage or flush mounted in the vertical stabilizer. The glide slope antenna is, in most cases, installed on the nose of the aircraft. On aircraft equipped with radomes, the glide slope antenna is installed under the radome.

### Marker Beacons

Marker beacons are used in connection with the instrument landing system. The markers are signals which indicate the position of the aircraft along the approach to the runway. Two markers are used in each installation. The location of each marker is identified by both an aural tone and a signal lamp. The marker beacon transmitters, operating on a fixed 75 MHz frequency, are placed at specific locations along the approach pattern of an ILS facility. The antenna radiation pattern is beamed straight up.

A marker receiver (figure 13-10) installed in the aircraft receives the antenna signals and converts them into power to illuminate a signal lamp and produce an audible tone in a headset. The outer

marker marks the beginning of the approach path. The outer marker signal is modulated by a 400-Hz signal which produces a tone keyed in long dashes. In addition to providing aural identification, the signal lights a purple lamp in the cockpit. The middle marker is usually about 3,500 ft. from the end of the runway and is modulated at 1,300 Hz which produces a higher-pitched tone keyed with alternate dots and dashes. An amber lamp flashes to indicate that the aircraft is passing over the middle marker.

Marker beacon receivers vary in design from simple receivers that have no operating controls and no aural output to more sophisticated receivers that produce an aural tone and have an on/off switch and a volume control to adjust the sound level of the identification code.

Where three lights are used, a white light indicates the aircraft positions at various points along the airways. In addition to the light, a rapid series of tones (six dots per second) of 3,000 Hz is received in the headset. Distance-measuring equipment is rapidly replacing the "along-route" marker system. A 3,000-Hz tone and white light marker are also being used for inner markers (missed approach point) on some Category II, ILS-equipped runways.

The ILS system cannot be ground tested fully without using test equipment simulating localizer and glide slope signals.

If an aircraft is located at an airport which has an ILS-equipped runway, it may be possible to determine if the receiver is functioning by performing

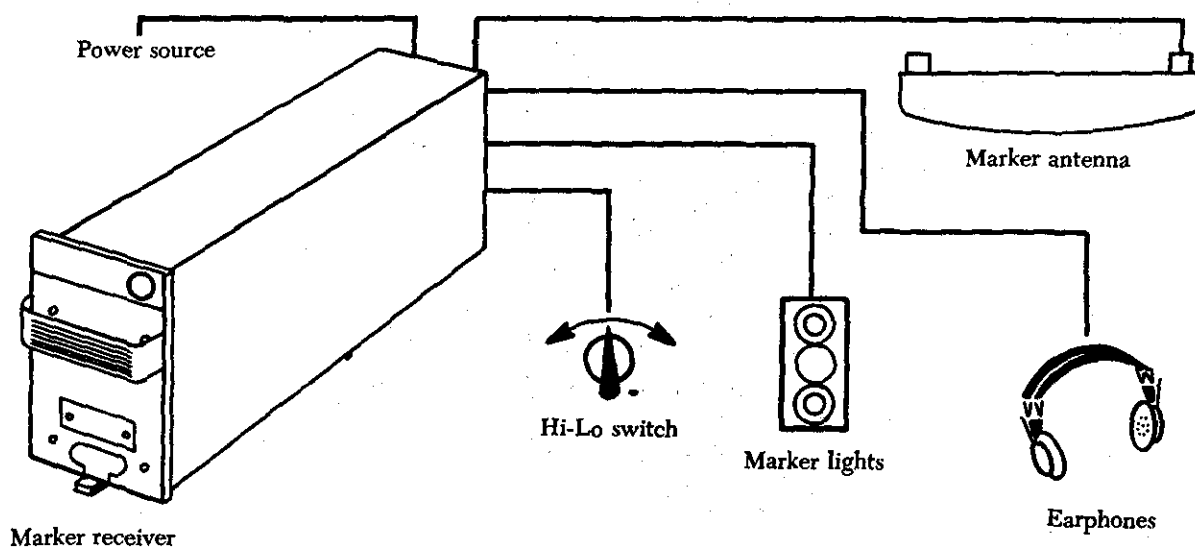


FIGURE 13-10. Marker receiver system diagram.

the following. Place the on/off switch (if so equipped) in the "on" position and adjust the frequency selector to the proper ILS channel for the airport where the aircraft is located. Allow sufficient time for the equipment to warm up. In a strong signal area, both the localizer and glide slope warning flags will either start to move or go completely out of view. Observe that both cross pointers are deflected to their maximum displacement.

Some of the more sophisticated solid-state ILS equipment contains self-monitoring circuits. These circuits can be used for performing an operational test using the procedures in the aircraft or equipment manufacturer's service manuals.

#### DISTANCE-MEASURING EQUIPMENT

The purpose of DME (distance-measuring equipment) is to provide a constant visual indication of the distance the aircraft is from a ground station. A DME reading is not a true indication of point-to-point distance as measured over the ground. DME indicates the slant range between the aircraft and the ground station. Slant-range error increases as the aircraft approaches the station. At a distance of 30 to 60 nautical miles the slant range error is negligible.

DME operates in the UHF range of the radio frequency spectrum. The transmitting frequencies are in two groups, between 962 MHz to 1,024 MHz and 1,151 MHz to 1,212 MHz; the receiving frequencies are between 1,025 MHz to 1,149 MHz. Transmitting and receiving frequencies are given a channel number which is paired with a VOR channel. In some aircraft installations the DME channel selector is ganged with the VOR channel selector to simplify the radio operation. A typical DME control panel is shown in figure 13-11.

The aircraft is equipped with a DME transceiver which is tuned to a selected DME ground station. Usually DME ground stations are colocated with a

VOR facility (called VORTAC). The airborne transceiver transmits a pair of spaced pulses to the ground station. The pulse spacing serves to identify the signal as a valid DME interrogation. After reception of the challenging pulses, the ground station responds with a pulse transmission on a separate frequency to send a reply to the aircraft. Upon reception of the signal by the airborne transceiver, the elapsed time between the challenges and the reply is measured. This time interval is a measure of the distance separating the aircraft and the ground station. This distance is indicated in nautical miles by a cockpit instrument similar to the one shown in figure 13-12.

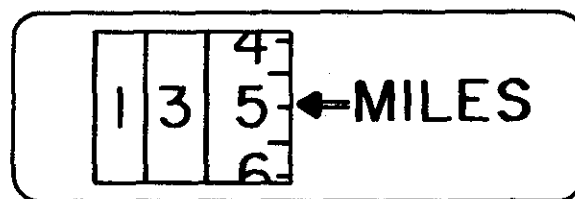


FIGURE 13-12. DME digital indicator.

A typical DME antenna is shown in figure 13-13. Most DME antennas have a cover installed to protect them from damage. The DME antenna is usually a short, stub type mounted on the lower surface of the aircraft. To prevent an interruption in DME operation, the antenna must be located in a position that will not be blanked by the wing when the aircraft is banked.

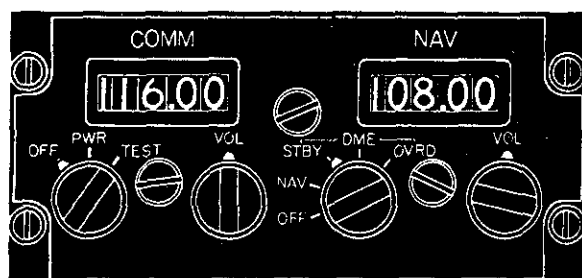


FIGURE 13-11. Typical navigation DME control.

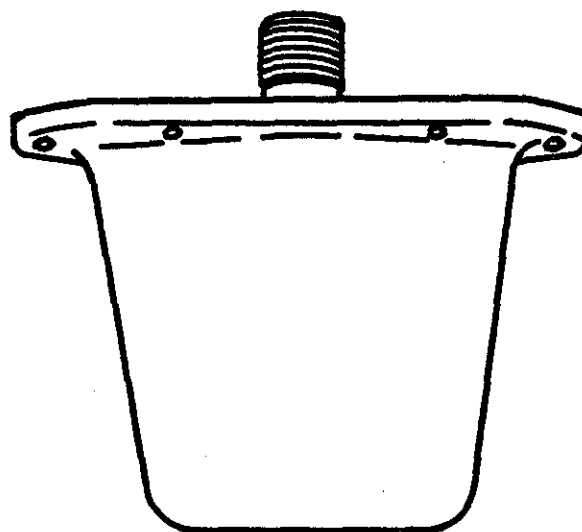


FIGURE 13-13. Typical DME antenna.

To determine if the DME operates, turn the on/off switch to the "on" position and select the appropriate channel. Allow sufficient time for the equipment to warm up. During this period, the distance indicator, both digital or pointer, will travel from minimum to maximum readings (sweep or search). When the DME has locked on a station, the indicator will stop searching and the red warning flag (if the indicator is equipped with one) will disappear. In most installations, no functional check can be made on the ground without a DME test set.

### AUTOMATIC DIRECTION FINDERS

ADF (automatic direction finders) are radio receivers equipped with directional antennas which are used to determine the direction from which signals are received. Most ADF receivers provide controls for manual operation in addition to automatic direction finding. When an aircraft is within reception range of a radio station, the ADF equipment provides a means of fixing the position with reasonable accuracy. The ADF operates in the low and medium frequency spectrum from 190 kHz through 1,750 kHz. The direction to the station is displayed, on an indicator located in the cockpit, as a relative bearing to the station.

The airborne equipment (figure 13-14), consists of a receiver, loop antenna, sense or nondirectional antenna, indicator, and control unit. Most ADF receivers used in general aviation aircraft are panel mounted. Their operating controls appear on the front of the radio case.

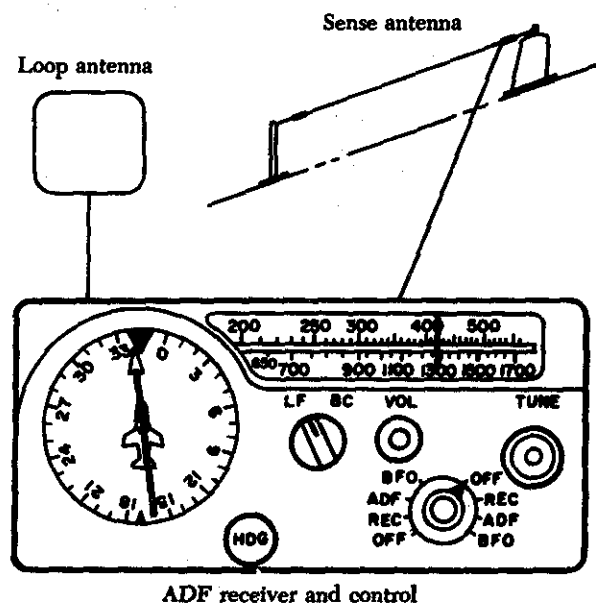


FIGURE 13-14. Typical ADF installation.

In one type ADF system, the loop antenna (figure 13-15) rotates through 360° and receives maximum signal strength when in a parallel position with the direction of the transmitted signal. As the loop is rotated from this position, the signal becomes weaker and reaches a minimum when the plane of the loop is perpendicular to the direction of the transmitted signal. This position of the loop is called the null position. The null position of the loop is used for direction finding. When the loop is rotated to a null position the radio station is being received on a line perpendicular to the plane of the loop. However, the direction of the radio station from the aircraft may be either of two directions 180° apart. The inability of the loop antenna to determine from which of the two directions the transmitted signal is being received necessitates the installation of a sense antenna.

The loop and sense antenna are both connected to the ADF receiver. When the signal strength of the sense antenna is superimposed on the signal received from the loop antenna, it results in only

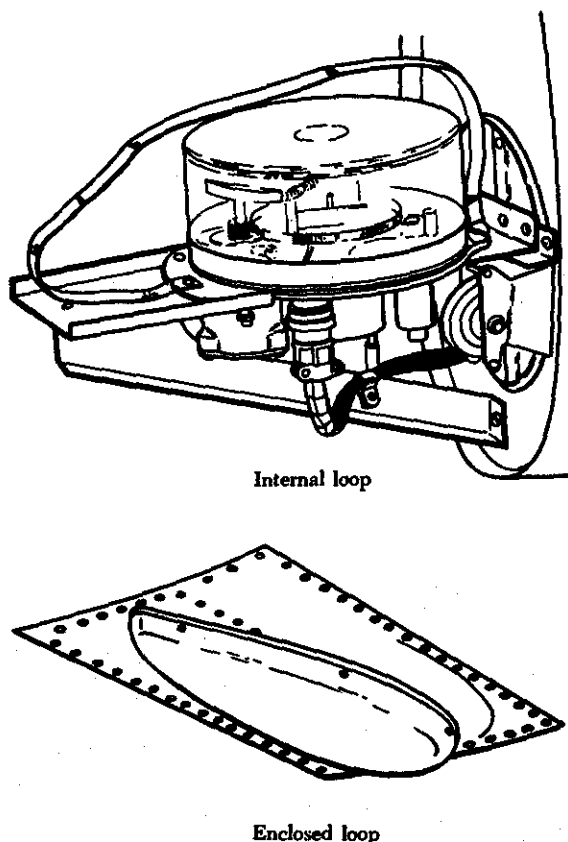


FIGURE 13-15. Typical ADF antennas.

one null position of the loop. The one null position always indicates the direction to the transmitting facility.

Another type ADF system uses fixed, ferrite core loops in conjunction with a rotatable transformer called a resolver or goniometer. It operates essentially the same as the rotating loop, except that one of the windings of the goniometer rotates instead of the loop.

A general procedure for performing an operational check of the ADF system is as follows:

- (1) Turn on/off switch to the "on" position and allow the radio to warm up. On installations that use the RMI (Radio Magnetic Indicator) pointer as an ADF indicator, assure that the switch has been positioned to present ADF information.
- (2) Tune to the desired station.
- (3) Adjust the volume control to an appropriate level.
- (4) Rotate loop antenna and determine that only one null is received.
- (5) Check that the ADF needle points towards the station. If the aircraft is situated among buildings or any other large reflecting surfaces, the ADF needle may indicate an error as a result of a reflected signal.

#### **RADAR BEACON TRANSPONDER**

The radar beacon transponder system is used in conjunction with a ground base surveillance radar to provide positive aircraft identification directly on the controller's radar scope.

The airborne equipment or transponder receives a ground radar interrogation for each sweep of the surveillance radar antenna and automatically dispatches a coded response. Civil transponders operate in two modes labeled "Mode A" and "Mode AC" which are switch controlled. The flight identification code, a four-digit number, is assigned during the flight planning procedure.

Some aircraft transponders are equipped with an altitude encoding feature. The aircraft's altitude is transmitted to the ground station through the transponder. The mode selector switch is placed in the "AC" mode when it is necessary to transmit altitude information.

There are several different aircraft transponders in use. They all perform the same function and are basically the same electrically. The major differ-

ences are in construction; either a single unit or a control unit for remotely operating the transponder.

A typical transponder is shown in figure 13-16. The front panel of the illustrated transponder contains all the switches and dials needed for operation.

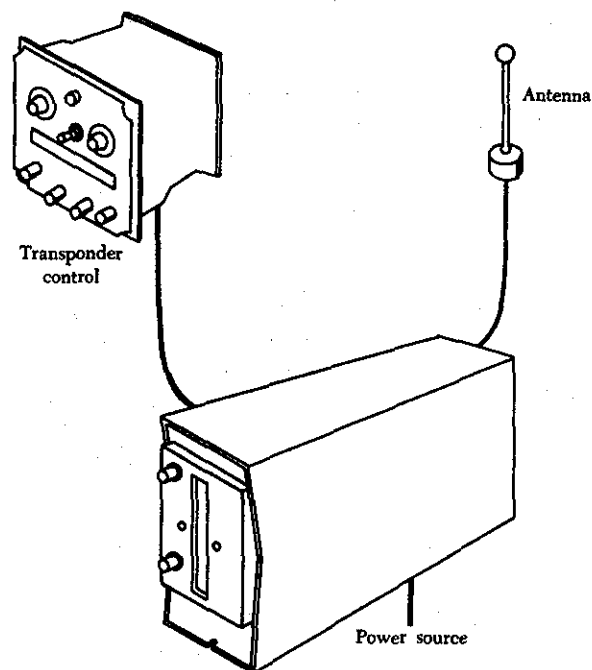


FIGURE 13-16. Typical transponder system.

A short stub or covered stub antenna is used for transponder operation and is usually mounted on the lower surface of the aircraft fuselage.

To ground check the radar beacon transponder the appropriate test equipment must be used.

#### **DOPPLER NAVIGATION SYSTEMS**

Doppler navigational radar automatically and continuously computes and displays ground speed and drift angle of an aircraft in flight without the aid of ground stations, wind estimates, or true airspeed data. The Doppler radar does not sense direction as search radar does. Instead, it is speed conscious and drift-conscious. It uses continuous carrier wave transmission energy and determines the forward and lateral velocity components of the aircraft by utilizing the principle known as Doppler effect.

The Doppler effect, or frequency change of a signal, can be explained in terms of an approaching

and departing sound. As shown in figure 13-17, the sound emitter is a siren located on a moving ambulance and the receiver is the ear of a stationary person. Notice the spacing between the emitter when it is approaching and when it is departing from the stationary receiver. When the sound waves are closely spaced the listener hears a sound that is higher in pitch. The reverse is true when the emitter is moving away from the listener. Doppler radar uses the frequency change phenomenon just described, except in the radio frequency range.

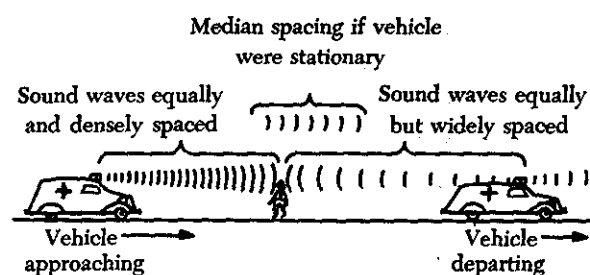


FIGURE 13-17. Doppler effect with sound waves.

The Doppler radar emits narrow beams of energy at one frequency, and these waves of energy strike the earth's surface and are reflected. Energy waves returning from the earth are spaced differently than the waves striking the earth. The earth-returned energy is intercepted by the receiver and compared with the outgoing transmitter energy. The difference, due to Doppler effect, is used to develop ground speed and wind drift angle information.

A ground operational check of a Doppler system consists of setting a precise airspeed, and a deviation angle which will give a distance-off-course reading. Always refer to the equipment manufactur-

er's instruction manual or the aircraft's operation manual for the proper test procedure.

### INERTIAL NAVIGATION SYSTEM

The inertial navigation system is presently being used on large aircraft as a long-range navigation aid. It is a self-contained system and does not require signal inputs from ground navigational facilities. The system derives attitude, velocity, and heading information from measurement of the aircraft's accelerations. Two accelerometers are required, one referenced to north and the other to east. The accelerometers (figure 13-18) are mounted on a gyro-stabilized unit, called the stable platform, to avert the introduction of errors resulting from the acceleration due to gravity.

An inertial navigation system is a complex system containing four basic components. They are:

- (1) A stable platform which is oriented to maintain accelerometers horizontal to the earth's surface and provide azimuth orientation.
- (2) Accelerometers arranged on the platform to supply specific components of acceleration.
- (3) Integrators which receive the output from the accelerometers and furnish velocity and distance.
- (4) A computer which receives signals from the integrators and changes distance traveled to position in selected coordinates.

The diagram in figure 13-18 shows how these components are linked together to solve a navigation problem. Initial conditions are set into the system and the navigation process is begun. In inertial navigation, the term initialization is used to denote the process of bringing the system to a set of

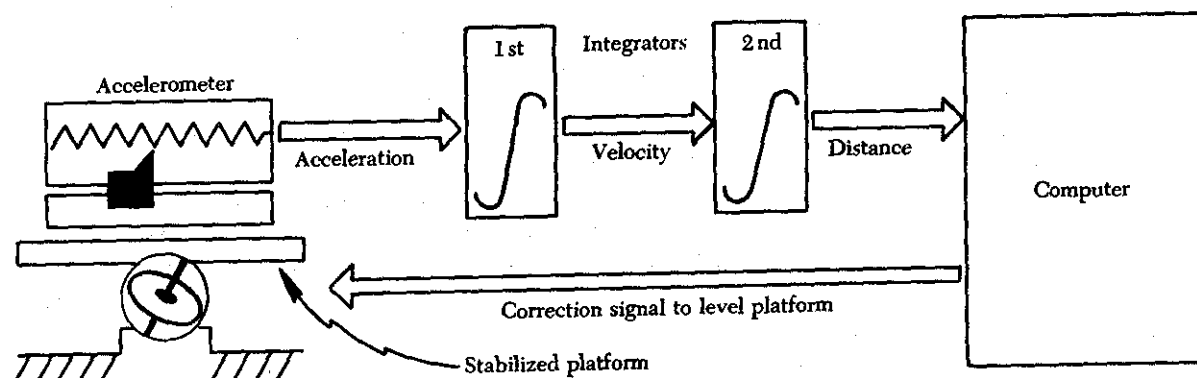


FIGURE 13-18. A basic inertial navigation system.

initial conditions from which it can proceed with the navigation process. These conditions include leveling the platform, aligning the azimuth reference, setting initial velocity and position, and making any computations required to start the navigation.

Although all inertial navigation systems must be initialized, the procedure varies according to the equipment and the type aircraft in which it is installed. The prescribed initialization procedures are detailed in the appropriate manufacturer's manuals.

From the diagram it can be seen that the accelerometers are maintained in a horizontal position to the earth's surface by a gyro-stabilized platform. As the aircraft accelerates, a signal from the accelerometer is sent to the integrators. The output from the integrators, or distance, is then fed into the computer, where two operations are performed. First, a position is determined in relation to the preset flight profile, and second, a signal is sent back to the platform to position the accelerometer horizontally to the earth's surface. The output from high-speed gyros and accelerometers, when connected to the flight controls of the aircraft, resists any changes in the flight profile.

#### AIRBORNE WEATHER RADAR SYSTEM

Radar (radio detection and ranging) is a device used to see certain objects in darkness, fog, or storms, as well as in clear weather. In addition to the appearance of these objects on the radar scope, their range and relative position are also indicated.

Radar is an electronic system using a pulse transmission of radio energy to receive a reflected signal from a target. The received signal is known as an echo; the time between the transmitted pulse and received echo is computed electronically and is displayed on the radar scope in terms of nautical miles.

A radar system (figure 13-19) consists of a transceiver and synchronizer, an antenna installed in the nose of the aircraft, a control unit installed in the cockpit, and an indicator or scope. A waveguide connects the receiver/transmitter to the antenna.

In the operation of a typical weather radar system, the transmitter feeds short pulses of radio-frequency energy through a waveguide to the dish antenna in the nose of the aircraft. In one typical installation the antenna radiates the energy in a beam  $3.8^\circ$  wide. Part of the transmitted energy is reflected from objects in the path of the beam and

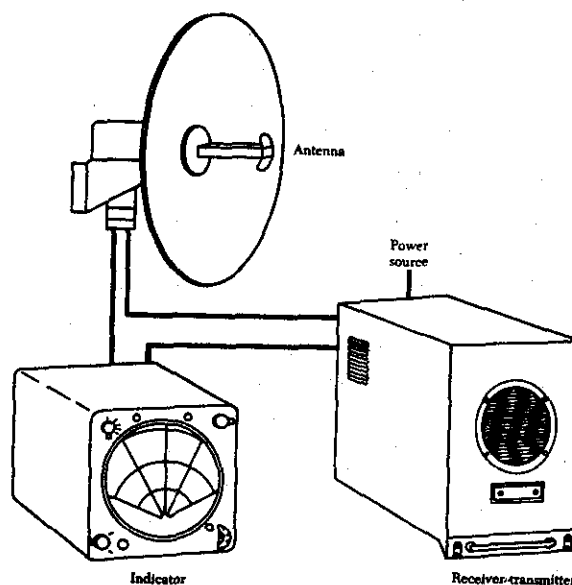


FIGURE 13-19. Weather radar system diagram.

is received by the dish antenna. Electronic switching simultaneously connects the antenna to the transmitter and disconnects the receiver during pulse transmission. Following the completion of pulse transmission, the antenna is switched from the transmitter to the receiver. The switching cycle is performed for each transmitted pulse.

The time required for radar waves to reach the target and reflect to the aircraft antenna is directly proportional to the distance of the target from the aircraft. The receiver measures the time interval between transmission of radar signals and reception of reflected energy and uses this interval to represent the distance, or range, of the target.

Rotation or sweep of the antenna and radar beam gives azimuth indications. The indicator sweep trace rotates in synchronization with the antenna. The indicator display shows the area and the relative size of targets, whose azimuthal position is shown relative to the line of flight.

The weather radar increases safety in flight by enabling the operator to detect storms in the flight path in order to chart a course around them. The terrain-mapping facilities of the radar show shorelines, islands, and other topographical features along the flight path. These indications are presented on the visual indicator in range and azimuth relative to the heading of the aircraft.

An operational check consists of the following:

- (1) Tow or taxi the aircraft clear of all buildings and parked aircraft.

- (2) Apply power to the equipment, and allow sufficient warmup time.
- (3) Tilt the antenna to an upward position.
- (4) Check the scan on the radar scope for an indication of targets.

### RADIO ALTIMETER

Radio altimeters are used to measure the distance from the aircraft to the ground. This is accomplished by transmitting radio frequency energy to the ground and receiving the reflected energy at the aircraft. Most modern day altimeters are pulse type and the altitude is determined by measuring the time required for the transmitted pulse to hit the ground and return. The indicating instrument will indicate the true altitude of the aircraft, which is its height above water, mountains, buildings, or other objects on the surface of the earth.

The present day generation of radio altimeters are primarily used during landing and are a Category II requirement. The altimeter provides the pilot with the altitude of the aircraft during approach. Altimeter indications determine the decision point whether to continue to land, or execute a climb-out.

A radio altimeter system (figure 13-20) consists

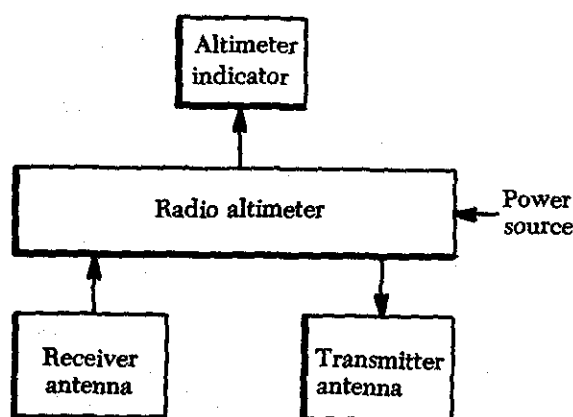


FIGURE 13-20. Typical radio altimeter system diagram.

of a transceiver, normally located in an equipment rack, an indicator installed in the instrument panel and two antennas located on the belly of the aircraft.

### EMERGENCY LOCATOR TRANSMITTER (ELT)

Emergency locator transmitters are self-contained, self-powered radio transmitters designed to transmit a signal on the international distress bands of 121.5 MHz (civilian) and 243 MHz (military).

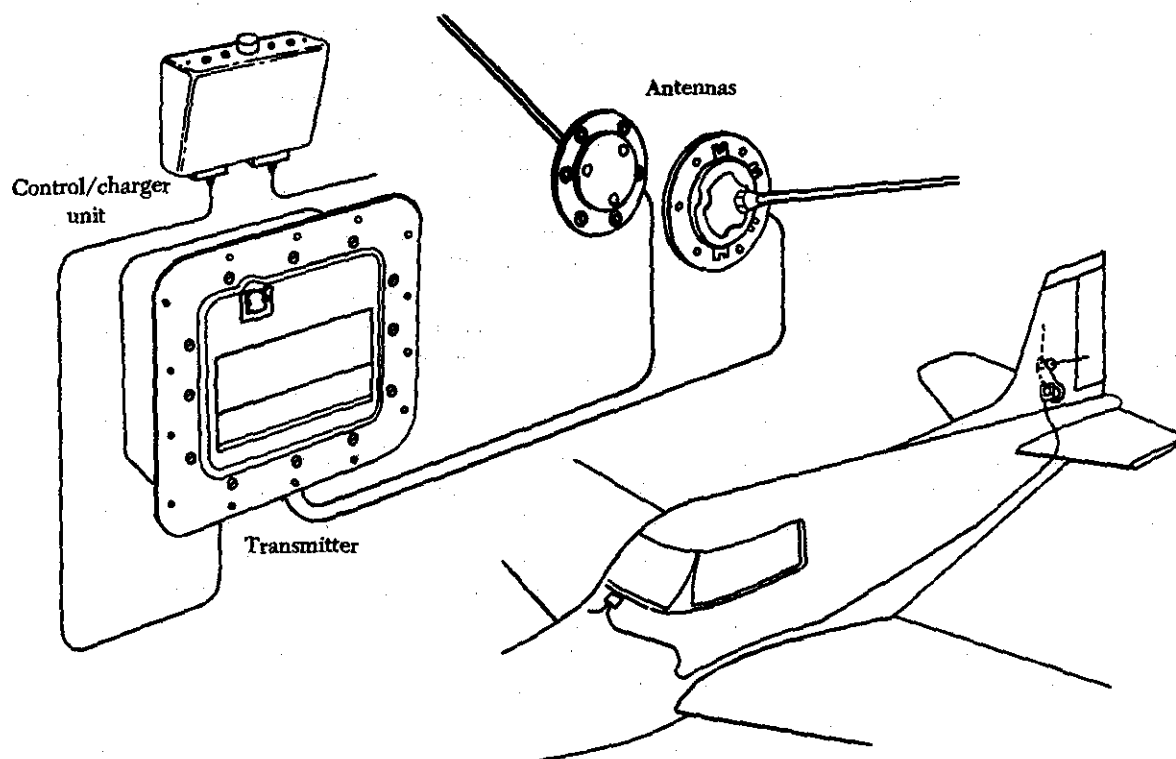


FIGURE 13-21. Emergency locator transmitter (ELT).

Operation is automatic on impact. The transmitter may also be activated by a remote switch in the cockpit or a switch integral with the unit. If the "C" force switch in the transmitter is activated from impact it can be turned off only with the switch on the case. (See figure 13-21.)

#### **Transmitter**

The transmitter may be located anywhere within the aircraft, but the ideal location is, as far aft as possible but just forward of the vertical fin. It must be accessible to permit monitoring the replacement date of the battery and for arming or disarming of the unit. A remote control arm/disarm switch may be installed in the cockpit.

The external antenna must be installed as far as practicable from other antennas to prevent interaction between avionics systems.

#### **Batteries**

Batteries are the power supply for emergency locator transmitters. When activated, the battery must be capable of furnishing power for signal transmission for at least 48 hours. The useful life of the battery is the length of time which the battery may be stored without losing its ability to continuously operate the ELT for 48 hours. This useful life is established by the battery manufacturer; batteries must be changed or recharged as required at 50% of the battery's useful life. This gives reasonable assurance that the ELT will operate if activated. The battery replacement date must be marked on the outside of the transmitter. This time is computed from the date of manufacture of the battery.

Batteries may be nickel-cadmium, lithium, magnesium dioxide, dry-cell batteries. Wet cell batteries have an unlimited shelf life until liquid is added. At that time their life in an ELT is regulated the same as dry cell batteries—change at 50% of shelf life. When replacing batteries use only those recommended by the manufacturer of the ELT. Do not use flashlight type batteries as their condition and useful life are unknown.

#### **Testing**

Testing of ELT's should be coordinated with the nearest FAA Tower or Flight Service Station and establish coordination for the test. Tests should be conducted only during the first five minutes of any hour and should be restricted to 3 audio sweeps. Any time maintenance is performed in the vicinity of the ELT, the VHF communication receiver should be tuned to 121.5 MHz and listen for ELT audio sweeps. If it is determined the ELT is operating, it must be turned off immediately.

#### **False Alarms**

False alarms have caused many of the problems with ELT's. Battery failures, with resulting corrosion of the unit results in either a complete failure or an unwanted transmission. Another type of unwanted transmission is the result of careless handling by the operators of the aircraft.

#### **Test Equipment**

Two monitors are available for identifying and/or locating unwanted ELT transmissions. A miniature scanning receiver may be mounted in the cockpit to warn the pilot if his ELT is transmitting. The other is a small portable ELT locator for use at general aviation airports to assist in finding an aircraft whose transmitter has accidentally become activated.

The operation of an ELT can be verified by tuning a communication receiver to the civil emergency frequency (121.5 MHz) and activating the ELT. Turn the ELT off immediately upon receiving a signal in the communication receiver.

In all maintenance and testing of ELT's the manufacturers instructions must be followed.

### **INSTALLATION OF COMMUNICATION AND NAVIGATION EQUIPMENT**

There are many factors which the mechanic must consider prior to altering an aircraft by the addition of radio equipment. These factors include the space available, the size and weight of the equipment, and previously accomplished alterations. In addition, the power consumption of the added equipment must be calculated to determine the maximum continuous electrical load. Each installation should be planned to allow easy access for inspection, maintenance, and exchange of units.

The installation of radios is primarily mechanical, involving sheet metal work in mounting the radios, racks, antennas, and controls. Routing of the interconnecting wires, cables, antenna leads, etc., is also an important part of the installation process. When selecting a location for the equipment, first consider the areas designated by the airframe manufacturer. If such information is not available, or if the aircraft does not contain provisions for adding equipment, select an area that will carry the loads imposed by the weight of the equipment, and which is capable of withstanding the additional inertia forces.



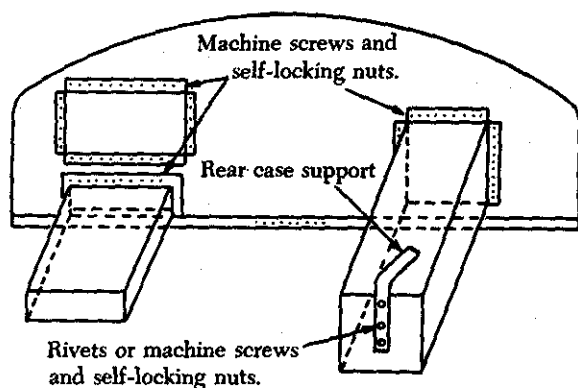


FIGURE 13-22. Typical radio installation in a stationary instrument panel.

If the radio is to be mounted in the instrument panel and no provisions have been made for such an installation, determine if the panel is primary structure prior to making any cutouts. To minimize the load on a stationary instrument panel, install a support bracket (figure 13-22) between the rear of the radio case or rack and a nearby structural member of the aircraft.

The radio equipment must be securely mounted to the aircraft. All mounting bolts must be secured by locking devices to prevent loosening from vibration.

Adequate clearance between the radio equipment and the adjacent structure must be provided to prevent mechanical damage to electric wiring or radio equipment from vibration, chafing, or shock landing.

Do not locate radio equipment and wiring near units containing combustible fluids. When separation is impractical, install baffles or shrouds to prevent contact of the combustible fluids with radio equipment in the event of a plumbing failure.

#### Cooling and Moisture

The performance and service life of most radio equipment is seriously limited by excessive ambient temperatures. The installation should be planned so that the radio equipment can dissipate its heat readily. In some installations it may be necessary to produce an airflow over the radio equipment, either with a blower or through the use of a venturi.

The presence of water in radio equipment promotes rapid deterioration of the exposed components. Some means must be provided to prevent the entry of water into the compartments housing the radio equipment.

#### Vibration Isolation

Vibration is a continued motion caused by an oscillating force. The amplitude and frequency of vibration of the aircraft structure will vary considerably with the type of aircraft.

Radio equipment is sensitive to mechanical shock and vibration and is normally "shock-mounted" to provide some protection against in-flight vibration and landing shock.

When special mounts (figure 13-23) are used to isolate radio equipment from vibrating structure, such mounts should provide adequate isolation over the entire range of expected vibration frequencies. When installing shock mounts, assure that the equipment weight does not exceed the weight-carrying capabilities of the mounts.

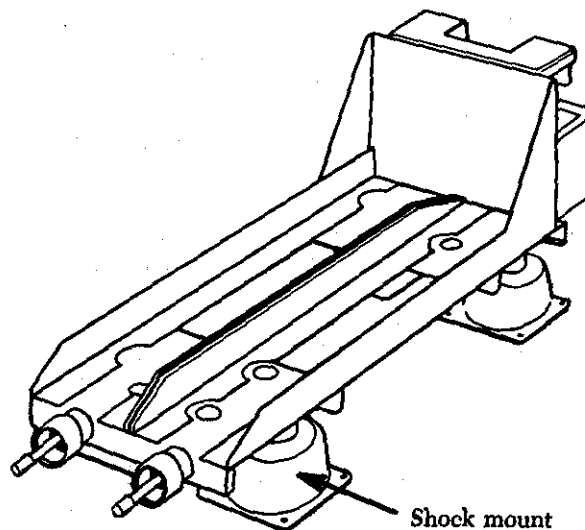


FIGURE 13-23. Typical shock-mounted base.

Radios installed in instrument panels do not ordinarily require vibration protection, since the panel itself is usually shock-mounted. However, make certain that the added weight can be safely carried by the existing mounts. In some cases it may be necessary to install larger capacity mounts or to increase the number of mounting points.

Radio equipment installed on shock mounts must have sufficient clearance from surrounding equipment and structure to allow for normal swaying of the equipment.

Periodic inspection of the shock mounts is required, and defective mounts should be replaced with the proper type. The factors to observe during the inspection are: (1) Deterioration of the shock-

absorbing material, (2) stiffness and resiliency of the material, and (3) overall rigidity of the mount. If the mount is too stiff, it may not provide adequate protection against the shock of landing. If the mount is not stiff enough, it may allow prolonged vibration following an initial shock.

Shock-absorbing materials commonly used in shock mounts are usually electrical insulators. For this reason, each electronic unit mounted with shock mounts must be electrically bonded to a structural member of the aircraft, similar to that shown in figure 13-24. This may also be accomplished by using sheets of high-conductivity metal (copper or aluminum) where it is impossible to use a short bond strap.

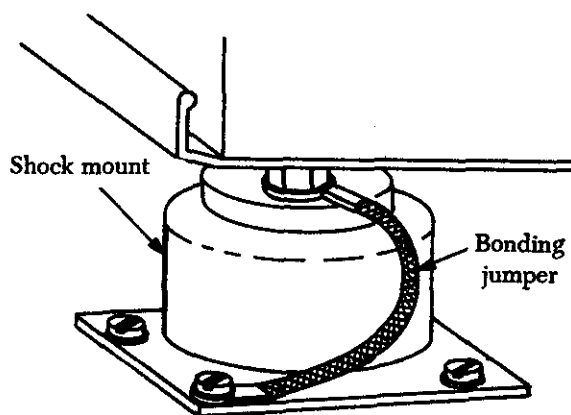


FIGURE 13-24. Typical shock mount bonding jumper.

## REDUCING RADIO INTERFERENCE

Suppression of radio interference is a task of first importance. The problem has increased in proportion to the complexity of both the electrical system and the electronic equipment. Almost every component of the aircraft is a possible source of radio interference. Radio interference of any kind deteriorates the performance and reliability of the radio and electronic systems.

Isolation is the easiest and most practical method of radio noise suppression. This involves separating the source of radio noise from the input circuits of the affected equipment. In many cases, the noise in a receiver may be entirely eliminated simply by moving the antenna lead-in wire just a few inches away from the noise source. Some of the sources of radio interference in aircraft are rotating electrical devices, switching devices, ignition systems, propeller control systems, a.c. powerlines, and voltage regulators.

An aircraft can become highly charged with static electricity while in flight. If the aircraft is improperly bonded, all metal parts will not have the same amount of charge. A difference of potential will exist between various metal surfaces. The neutralization of the charges flowing in paths of variable resistance, due to such causes as intermittent contact from vibration or the movement of the control surfaces, will produce electrical disturbances (noise) in the radio receiver.

Bonding provides the necessary electrical connection between metallic parts of an aircraft. Bonding jumpers and bonding clamps are examples of bonding connectors. Bonding also provides the low-resistance return path for single-wire electrical systems.

Bonding radio equipment to the airframe will provide a low-impedance ground return and minimize radio interference from static electricity charges. Bonding jumpers should be as short as possible and installed in such a manner that the resistance does not exceed 0.003 ohm. When a jumper is used only to reduce radio noise and is not for current-carrying purposes, a resistance of 0.01 ohm is satisfactory.

The aircraft structure is also the ground for the radio. For the radio to function correctly, a proper balance must be maintained between the aircraft structure and the antenna. This means the surface area of the ground must be constant. Control surfaces, for example, may at times become partially insulated from the remaining structure. This would affect radio operation if the condition was not alleviated by bonding.

Shielding is one of the most effective methods of suppressing radio noise. The primary object of shielding is to electrically contain the radio frequency noise energy. In practical applications, the noise energy is kept flowing along the inner surface of the shield to ground instead of radiating into space. The use of shielding is particularly effective in situations where filters cannot be used. A good example of this is where noise energy radiates from a source and is picked up by the various circuits that eventually connect to the receiver input circuits. It would be impractical to filter all of the leads or units that are affected by the radiated noise energy; thus the application of effective shielding at the noise source itself is preferred, for it eliminates the radiated portion of the noise energy by confining it within the shield at its source.

Ignition wiring and spark plugs are usually shielded to minimize radio interference. If an intolerable radio noise level is present despite shielding, it may be necessary to provide a filter between the magneto and magneto switch to reduce the noise. This may consist of a single bypass capacitor or a combination of capacitors and choke coils. When this is done, the shielding between the filter and magneto switch can usually be eliminated.

The size of a filter may vary widely, depending on the voltage and current requirements as well as the degree of attenuation desired. Filters are usually incorporated in equipment known to generate radio interference, but since these filters are often inadequate it is frequently necessary to add external filters.

### Static Discharger Wicks

Static dischargers are installed on aircraft to reduce radio receiver interference. This interference is caused by corona discharge emitted from the aircraft as a result of precipitation static. Corona occurs in short pulses which produce noise at the radio frequency spectrum. Static dischargers, normally mounted on the trailing edges of the control surfaces, wing tips, and vertical stabilizer, discharge the precipitation static at points a critical length away from the wing and tail extremities where there is little or no coupling of the static into the radio antenna.

Three major types of static dischargers are in use:

- (1) Flexible vinyl-covered, silver- or carbon-impregnated braid.
- (2) Semiflexible metallic braid.
- (3) Null-field.

Flexible and semiflexible dischargers are attached to the aircraft by metal screws and should be periodically checked for tightness. At least 1 in. of the

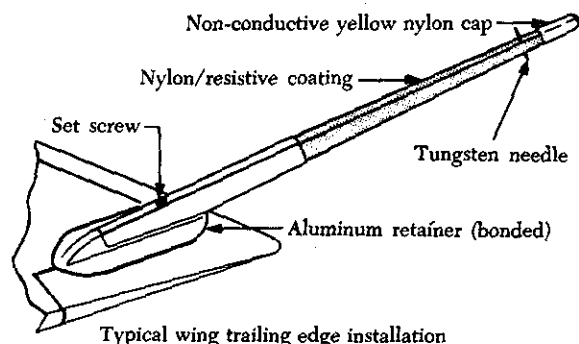


FIGURE 13-25. Null-field static discharger.

inner braid of vinyl covered dischargers should extend beyond the vinyl covering. Null-field dischargers (figure 13-25) are riveted and epoxy bonded to the aircraft structure. A resistance measurement from the mount to the airframe should not exceed 0.1 ohm.

### INSTALLATION OF AIRCRAFT ANTENNA SYSTEMS

An introductory knowledge of radio equipment is a valuable asset to the aviation mechanic, especially a knowledge of antenna installation and maintenance, since these tasks are often performed by the mechanic.

Antennas take many forms and sizes dependent upon the job they are to perform. Airborne antennas should be mechanically secure, mounted in interference-free locations, have the same polarization as the ground station, and be electrically matched to the receiver or transmitter which they serve.

The following procedures describe the installation of a typical rigid antenna:

- (1) Place a template similar to that shown in figure 13-26 on the fore-and-aft center line at the desired location. Drill the mounting holes and correct diameter hole for the transmission line cable in the fuselage skin.

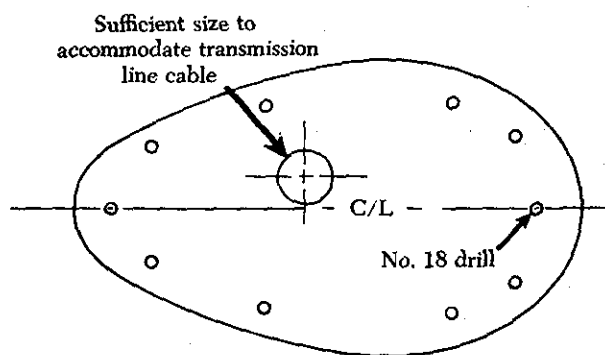


FIGURE 13-26. Typical antenna mounting template.

- (2) Install a reinforcing doubler of sufficient thickness to reinforce the aircraft skin. The length and width of the reinforcing plate should approximate the example shown in figure 13-27.
- (3) Install the antenna on the fuselage, making sure that the mounting bolts are tightened firmly against the reinforcing doubler and

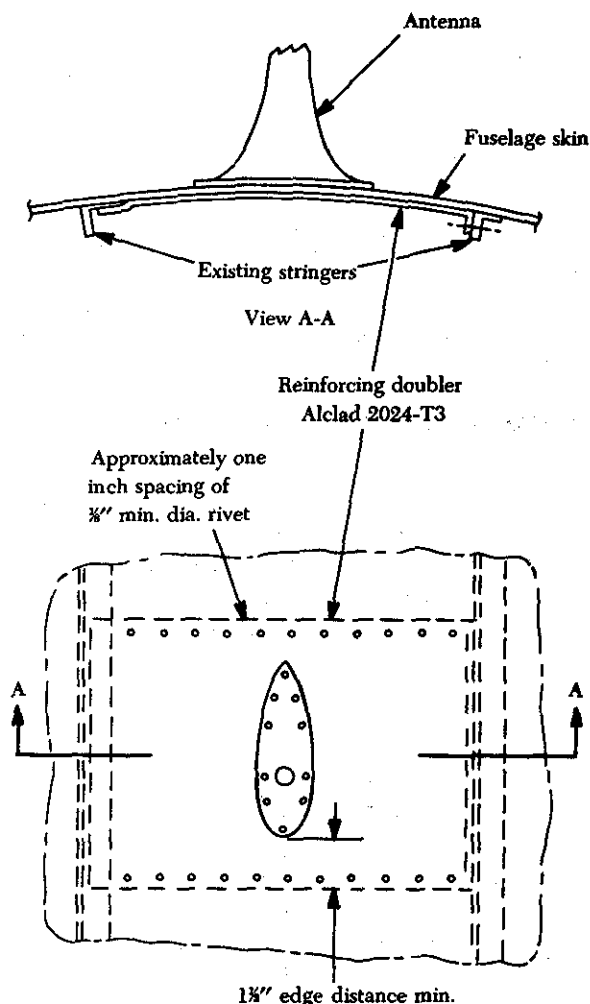


FIGURE 13-27. Typical antenna installation on a skin panel.

the mast is drawn tight against the gasket. If a gasket is not used, seal between the mast and the fuselage with a suitable sealer, such as zinc chromate paste, or equal.

The mounting bases of antennas vary in shape and sizes; however, the aforementioned installation procedure is typical and may be used for mast-type antenna installations.

#### Transmission Lines

A transmitting or receiving antenna is connected directly to its associated transmitter or receiver by wire(s) which are shielded. The interconnecting shielded wire(s) are called a coaxial cable which connects the antenna to the receiver or transmitter. The job of the transmission line (coaxial cable) is to get the energy to the place where it is to be used and to accomplish this with minimum energy loss.

A transmission line connects the final power amplifier of a transmitter to the transmitting antenna. The transmission line for a receiver connects the antenna to the first tuned circuit of the receiver. Transmission lines may vary from only a few feet to several feet in length.

Transponders, DME, and other pulse type transceivers require transmission lines that are precise in length. The critical length of the transmission lines provides minimum attenuation of the transmitted or received signal. Refer to the equipment manufacture installation manual for type and allowable length of transmission lines.

Coaxial cable is utilized in most airborne installations for transmission lines. Coaxial cable is an unbalanced line that functions with a balanced antenna. To provide the proper impedance matching and the most efficient power transfer a balun is used. The balun is an integral part of the antenna and is not visible without disassembling the antenna.

When installing coaxial cable (transmission lines) secure the cables firmly along their entire length at intervals of approximately 2 ft. To assure optimum operation, coaxial cables should not be routed or tied to other wire bundles. When bending coaxial cable, be sure that the bend is at least 10 times the size of the cable diameter.

#### Maintenance Procedures

Detailed instructions, procedures, and specifications for the servicing of radio equipment are contained in the manufacturer's operation and service manuals. In addition, instructions for removal and installation of the units are contained in the maintenance manual for the aircraft in which the equipment is installed.

Although installation appears to be a simple procedure, many radio troubles can be attributed to carelessness or oversight when replacing radio equipment. Specific instances are loose cable connections, switched cable terminations, improper bonding, lack of or improper safety wiring, or failure to perform an operational check after installation.

Two additional points concerning installation of equipment needs emphasis. Prior to re-installing any unit, inspect its mounting for proper condition of shock mounts and bonding straps. After installation, safety wire as appropriate.