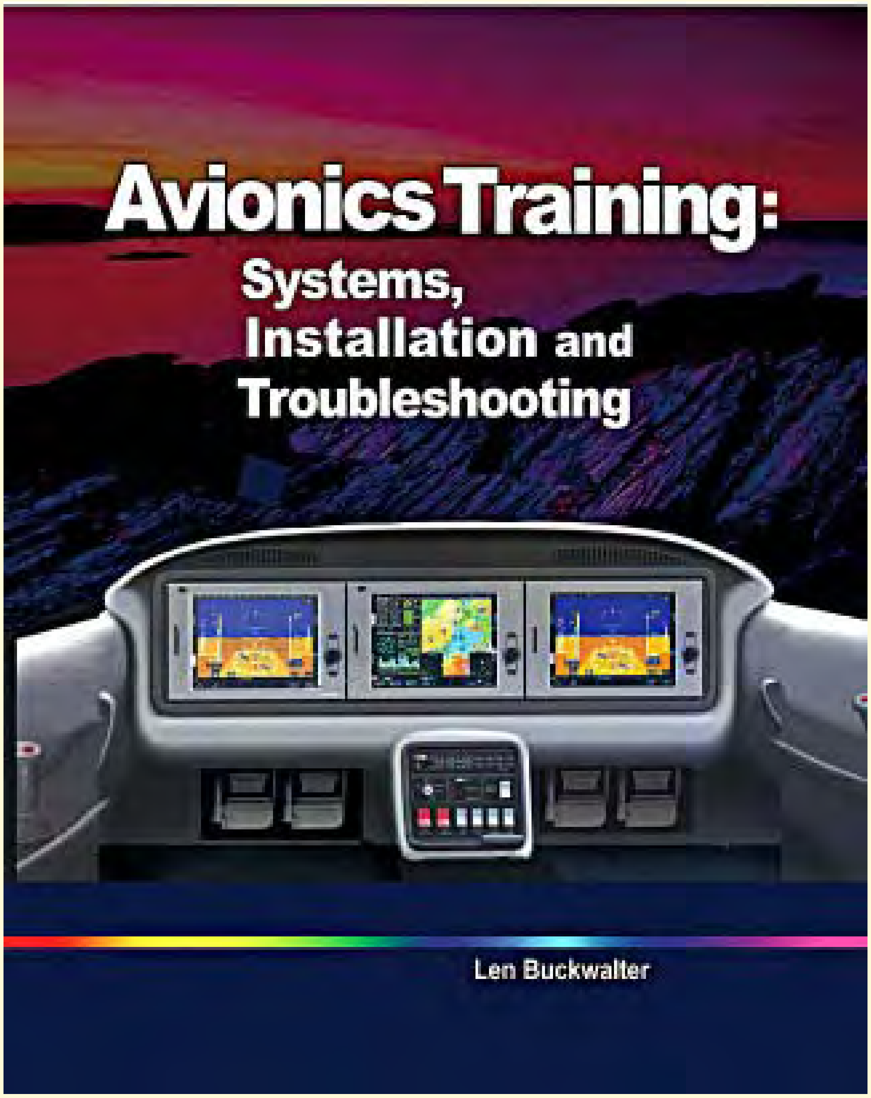
Avionics Training:
Systems,
Installation and
Troubleshooting
Len Buckwalter

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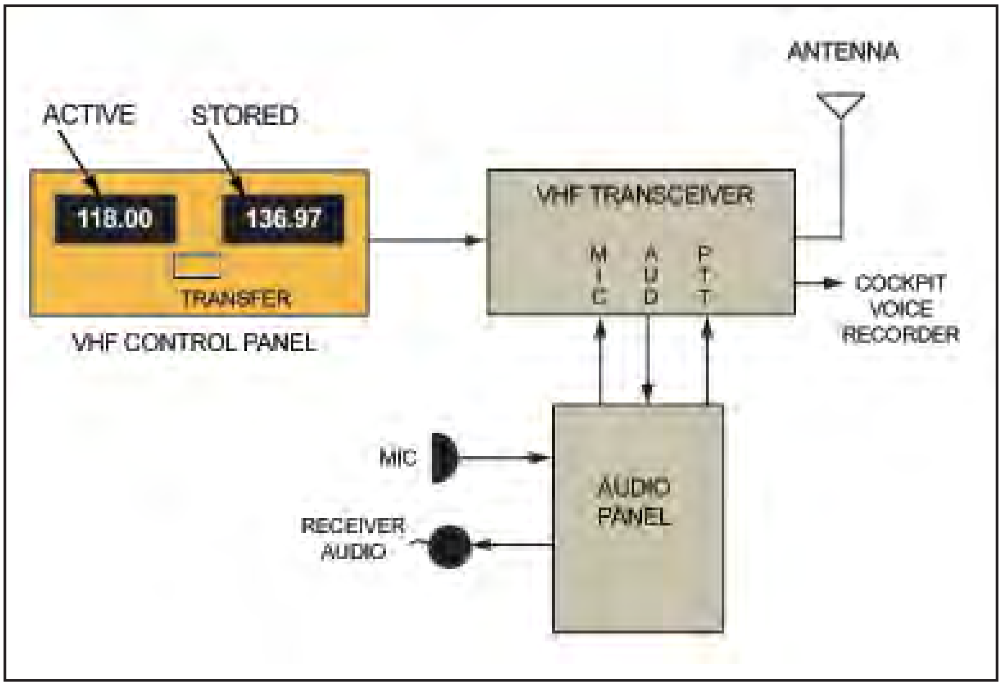
## Section 2 Installation

## Section 3

## VHF-Com System




**A com radio typically found in airliners and large aircraft. The pilot operates the VHF Control Panel, while the main unit of the VHF transceiver is in a remote electronics bay.**

**Two frequencies may be selected at one time; the *active* channel sends and receives, the *stored* channel remains inactive. When the transfer button is pressed, the two channels exchange places.**

**The Audio Panel connects pilot microphone and headset or loudspeaker. "PTT" is the push-to-talk button that switches the radio between transmit and receive. The button is on the microphone or the control yoke.**

**The transceiver also provides an audio output to the Cockpit Voice Recorder to retain radio messages in the event of a safety investigation.**

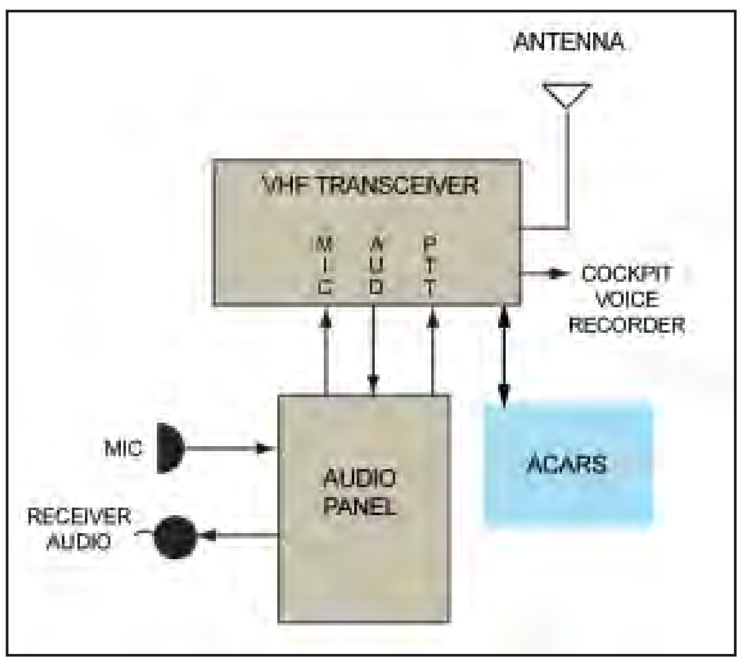
**There are usually three VHF com radios aboard an airliner. One radio, however, is operated in the ACARS system, as described below.**

## Third Com Radio

**This is the same as the other two com radios, except for modifications to operate on ACARS (Aircraft Communication and Reporting System) described in a later chapter.There is no pilot control panel because the frequency is pre-set to an assigned ACARS channel. ACARS automatically receives and transmits messages about company operations.**

**A pilot may also use voice on this radio through the mic and receiver audio connection.**

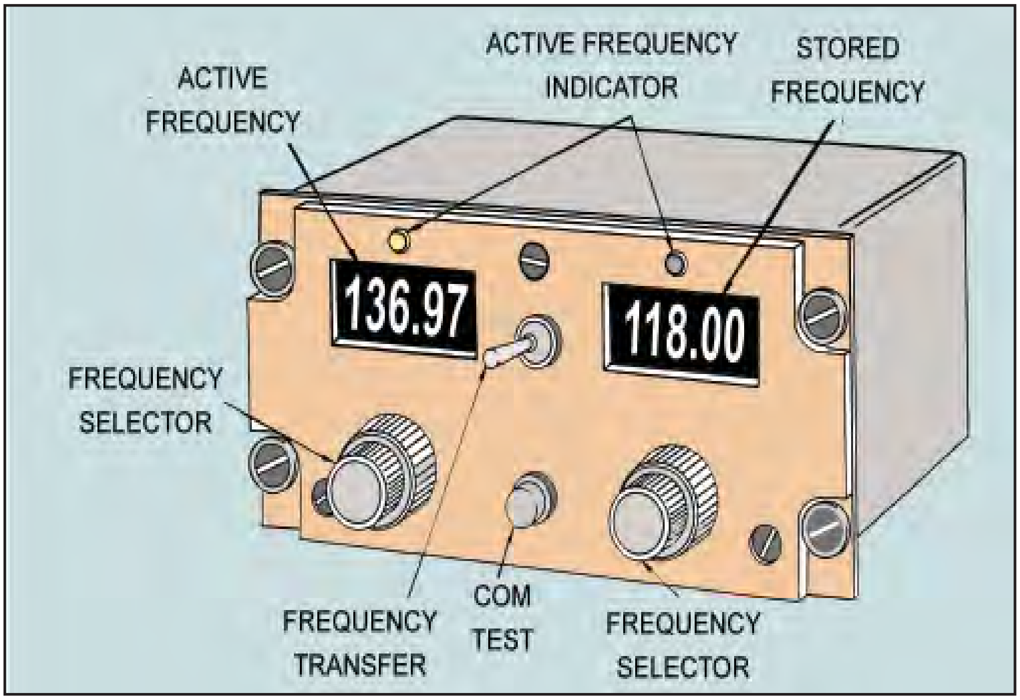
**VHF com radios in large aircraft typically operate from a 28 VDC power source. The transmitter is often rated at 25 watts of radio frequency output power.**

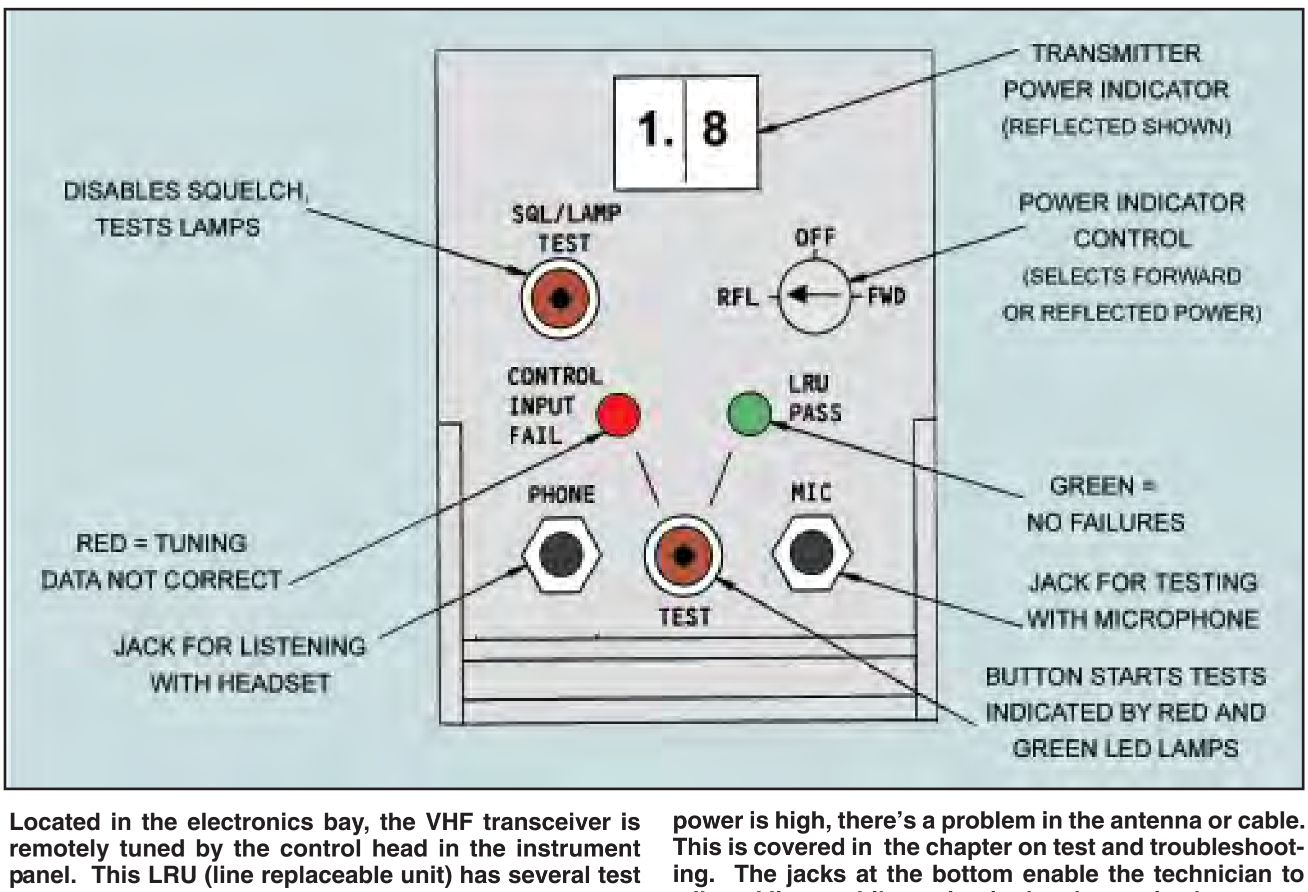


# VHF-Com Control Panel

Typical airline control head for one VHF transmitter-receiver (transceiver). The pilot is communicating on the left display; the frequency transfer switch is pointing left. He has stored the next frequency on the right side. A flip of the transfer switch activates the next frequency. This panel-mounted unit controls a remote transceiver in the electronics bay.

The "Com Test" button at the bottom disables the automatic squelch. This allows atmospheric noise to be heard, which is an approximate test of whether the radio is operating.




Located in the electronics bay, the VHF transceiver is remotely tuned by the control head in the instrument panel. This LRU (line replaceable unit) has several test features built in. The indicator at the top shows transmitter power in the forward direction (toward the antenna) or power reflected back to the transmitter. If reflected power is high, there's a problem in the antenna or cable. This is covered in the chapter on test and troubleshooting. The jacks at the bottom enable the technician to talk and listen while testing in the electronics bay. .

Chapter 4

# HF Com

## High Frequency Communications

### HF Control-Display


Bendix/King

**Control-Display for an HF radio for General Aviation. With output power of 150 watts (Single Sideband, or SSB) it tunes 280,000 channels. An antenna coupler (remotely located with the receiver and transmitter) ) automatically tunes the antenna when the microphone button is pressed. Some models, like this one, have a "Clarifier" control (lower left) to fine tune the incoming voice.**

**The radio also solves the problem of hunting for a workable frequency under changing ionospheric conditions. With circuit called "automatic link establishment" it searches for the best available channel. This model is the Bendix/King HF-950. Weighing about 20 lbs, it is also used by helicopters, which often fly in remote areas beyond VHF communicating range.**

When an airplane leaves the coastline for a transoceanic flight, moves into a polar region or ventures over a remote area, it loses VHF communications. VHF signals are line of sight and cannot curve over the horizon. For long-range flight, the airplane switches to HF---high frequency---communications.

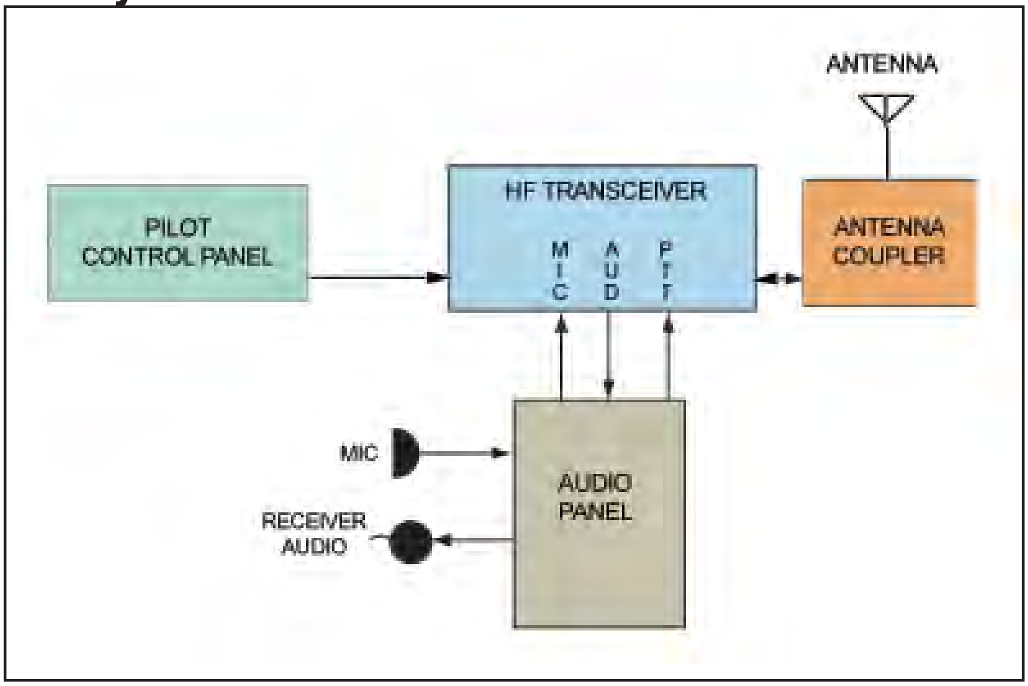
In a band from 2-30 MHz, HF radio travels 2000-6000 miles by "skipping" through the ionosphere, an electrical mirror that reflects radio waves back to earth.

HF has never been a pilot's favorite radio. Early models didn't have the reliability of VHF because the ionosphere is always changing---between day and night and season to season. It is struck by magnetic storms from the sun which repeat over an 11-year sunspot cycle, interrupting communications for hours, even days.

The cure is the eventual elimination of HF radio by satellite communications. Nevertheless, thousands of aircraft will continue to fly with HF for decades before the transition is complete. Fortunately, HF has enjoyed several improvements.

Early HF radios were difficult to operate. Most antennas for aircraft measure from inches to several feet long. The length tunes the antenna to one-quarter wavelength, which is standard for aircraft. A VHF antenna at 120 MHz, for example, has a quarter-wavelength of only two feet, easy enough to mount as a small whip or blade on the airframe. But as operating frequency goes lower, wavelength grows longer. A

## HF System




**When the pilot keys the transmitter on a new channel, a 1000 Hz (audio) tone is modulated onto the radio wave and sent to the antenna coupler. This enables the coupler to match the antenna to any HF frequency. A tone is used because, unlike voice, it produces a steady radio-frequency output for the coupler to measure. Antenna tuning usually takes less than four seconds.**

quarter-wave HF antenna on 2 MHz would have to run over 100 feet long!

Radio pioneers solved this with a "trailing wire" antenna----reeling it out to float behind the airplane. If radio conditions changed, they hunted for a new frequency and changed antenna length. They also had to manually adjust an antenna tuner.

A breakthrough happened when Arthur Collins (founder of a company that produces air transport avionics) came up with an improvement called "Autotune." It is a tuning unit that matches a short, fixed antenna on the airplane to the wavelength of any HF frequency. It's done automatically when the pilot selects a channel.

The concept of automatic antenna tuning is based on "reflected power." If an antenna and antenna tuner are adjusted for, say, an operating frequency of 12 MHz and the pilot changes to 5 MHz, there will be a large electrical mismatch between the antenna and feedline from the transmitter. This causes radio frequency power to reflect back from the antenna and be lost. The Autotune system measures the reflected power and operates tuning elements in the antenna coupler to reduce the reflection to the lowest possible value. (The concept of reflected power reappears in the chapter on test and troubleshooting, where it's called VSWR, for voltage standing wave ratio.)

In today's HF radios, changing frequencies and retuning the antenna can occur in less than a second from the time the pilot turns the channel selector.

Automatic HF antenna tuning, which greatly reduced pilot workload, was followed by a development that improved HF radio's ability to avoid fading signals and poor radio conditions caused by variations in the ionosphere.

**SSB** HF radio originally transmitted in the AM (amplitude modulation) mode, the same as AM broadcast radio today. An AM transmitter generates three components; a radio-frequency (RF) carrier, an upper sideband and lower sideband. The audio (or voice) is found only in the sidebands. This was discovered in the 1920's, along with the observation that the RF carrier served only to create the sidebands inside the transmitter. The carrier doesn't "carry" the sidebands. Sidebands travel just as well with or without a carrier. Because the sidebands lie just above and below the carrier frequency, they are termed USB and LSB (for upper and lower).

In regular amplitude modulation, more than two-thirds of the transmitter power is lost in the carrier. What's more, the upper and lower sidebands carry the identical information. So all that's required for transmitting the voice is a "single sideband."

It took several decades for the electronics industry to develop stable transmitters and receivers and sharp filtering to make "SSB" practical. As a result, today's HF-SSB transceiver places nearly all transmitter power into a single sideband, producing a powerful signal that punches through worsening ionospheric conditions.

**HF Datalink**. Despite the improvement of SSB, pilots were not yet completely satisfied; HF still didn't provide the solid reliability of VHF communications. In seeking further improvement, the avionics industry considered digital communications to handle routine messages. The first experiments failed as researchers discovered that digital signals barely survived the turbulent ride through the ionosphere. Too many digital bits were lost in transmission.

At about this time, the first communications satellites were rising in orbit, offering solid long range communications to the aeronautical industry. This threatened to kill further development in HF, but the airline industry wasn't ready for "satcom." Satellite installations at the time proved too expensive for many carriers, which motivated researchers to design a workable HF datalink.

Today, HF datalink is a reality. The new radios perform "soundings"---listening for short bursts of data from ground stations around the world. A link is established to the best one for communications. If conditions deteriorate, the radio automatically searches for, and switches to, a better channel. If there are errors in transmission, the ground station senses them and automatically calls for repeats until the data is correct.

## Remote Line Replaceable Units (HF)


Honeywell

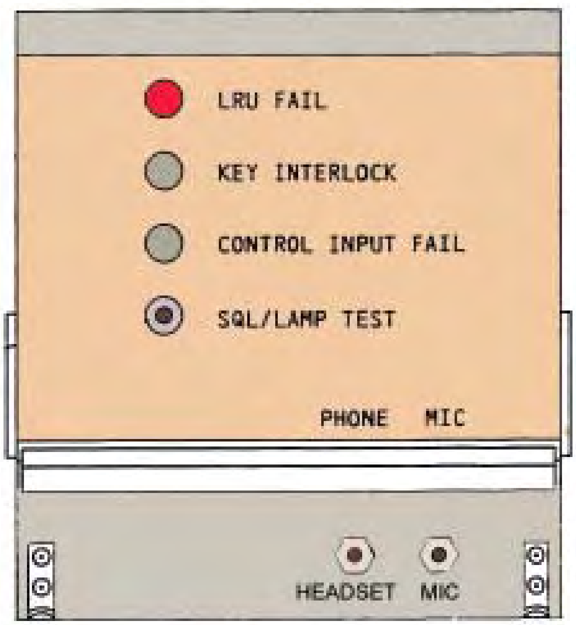
**Three remote-mount boxes for an HF radio installed on business aircraft. They are controlled by the pilot on the flight deck.**

**The radio tunes 280,000 channels and stores 99 user-programmable frequencies (for quick retrieval). For sending distress calls, the international maritime distress frequency on 2.182 MHz is pre-programmed. The model shown here, the Primus HF-1050, is upgradeable for HF datalink.**

## HF Control Panel:  Airline


**Pilot's HF control panel. Frequency is selected by two outer knobs. RF SENSE adjusts receiver sensitivity. The knob at bottom---OFF - USB - AM---selects mode of operation. Most HF communications for aircraft are on USB (Upper Sideband). Lower sideband is not permitted in aeronautical service. The AM knob selects old-type Amplitude Modulation, which is much less effective than SSB, but enables pilot to talk to ground stations not equipped for SSB,**

## HF Transceiver




**Mounted in an electronics bay, the HF transceiver is operated from the pilot's HF control panel. It has several provisions for testing. Three lights show system status (the red lamp is indicating "LRU FAIL," meaning this transceiver, a line-replaceable unit. The button "SQL/LAMP" is pressed for two tests; all lamps should light, and the squelch is disabled. During a disabled squelch, the technician should hear atmospheric noise, which is an approximate test that the receiver is working. He can also plug a microphone into the "MIC" jack and talk on the radio during troubleshooting.**

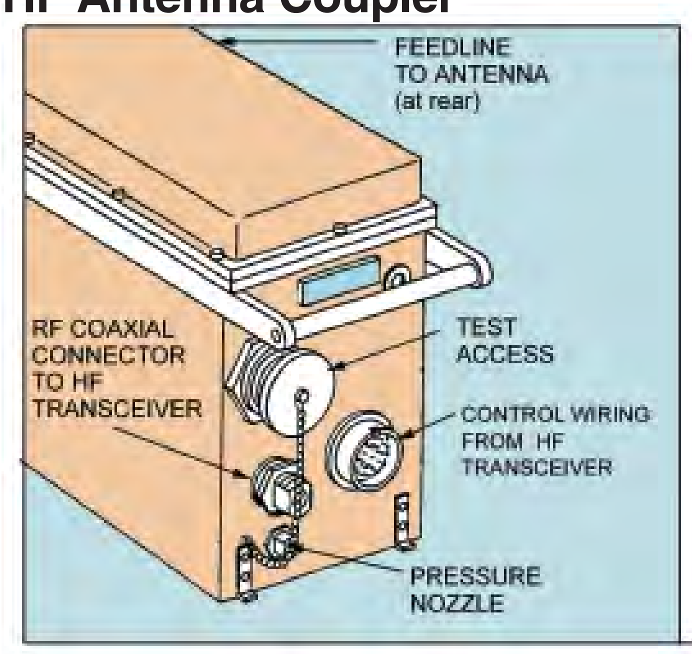
**The transmitter in airline service is usually rated at 400 watts of radio frequency power during single-sideband (SSB) transmission; 125 watts in the AM mode.**

## Advantages of HF Datalink

- •Lower Pilot Workload
- •Shorter Message Transmission Time (less than 3 seconds vs more than 1 minute)
- •Channel Access Time (less than 60 seconds vs up to 10 minutes)
- •Less Operational Training for Flight Crew
- •Data Relieves Congestion on Voice Frequencies
- •Automatic Selection of Frequency and Data Rates
- •Voice Is Prone To Human Error and Interpretation
- •Data Detects Errors and Automatically Retransmits
- •Data Extracts Signals in Noisier Environments (3dB/10dB)
- •Increased HF Traffic Capability
- •Assured Communication Link Automatic Air/Ground HF linkage With Less Acquisition and Message Cost (Compared to Satcom)
- •Improved Voice/Data Quality
- •Data Link Messages Are Not **Written or Sensitive to Verbal Language**

*(The above list is based on a Honeywell report)*

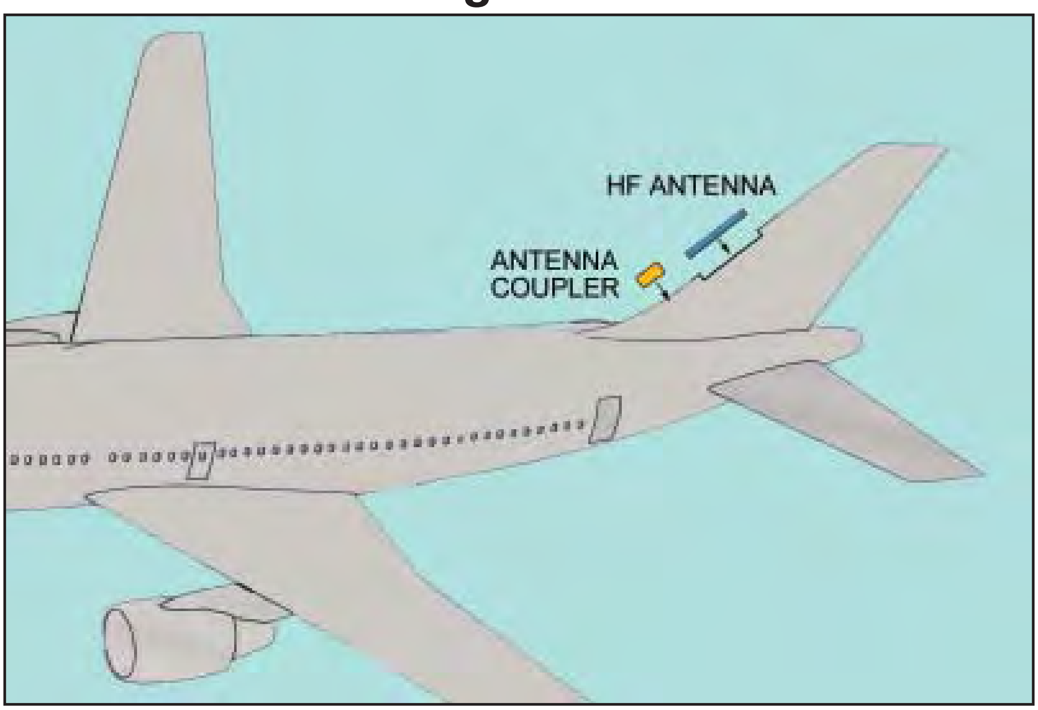
# HF Antenna Coupler




**Mounted below antenna in rudder fin, HF antenna coupler tunes antenna to the frequency in less than 4 seconds after pilot selects a channel.**

**Pressure Nozzle at the bottom pressurizes the coupler enclosure. Otherwise, low air pressure at altitude would cause high voltage in tuning coils to arc over and short.**

# HF Antenna Mounting




**The HF antenna on a typical airliner is located in the vertical tail fin. The radiating antenna is inside a U-shaped fiberglass leading edge. The antenna coupler is just below, inside the rudder fin. The coupler matches any HF frequency (2 - 30 MHz) and sends it through a feedline to the antenna.**

# Chapter 5

# Satcom
## Satellite Communications

Satcom provides communications between aircraft and ground through most of the world. Free from atmospheric interference and limited bandwidth, it is the replacement for High Frequency (HF) as the band for long-range communications. Satcom signals penetrate the ionosphere without bending or reflecting and are unaffected by electrical noise or weather. As satcom avionics build through aircraft fleets, they will eventually replace VHF com, as well. The signals of satcom are digital, not only for data communications, but voice, as well. This means voice messages can be encrypted for security.

Satcom is also the foundation for the next generation of air traffic control. After a half-century of aircraft confined to narrow routes and tracks, a changeover is beginning to a new architecture known as FANS, for Future Air Navigation Systems. More airplanes will fly safely within the same airspace under a concept known as "Free Flight." Satcom makes it possible, as well as providing information, entertainment and other services for passengers in the cabin.

(Inmarsat)

**A Ground Earth Station communicates with orbiting Inmarsat satellites, which relay messages to and from aircraft. The Ground Earth Station receives and sends those messages through telephone companies and other telecommunications services throughout the world.**

### Inmarsat

The London-based organization providing satellites and ground support is Inmarsat (International Maritime Satellite). Consisting of more than 60 member

# Generations of Inmarsat Spacecraft

**Inmarsat - 2 (called I-2) was launched in 1991 after the first generation raised the demand in aviation for more satellite services. I-2 provides four times more capacity than I-1. The constellation consists of four active satellites, with four spares in orbit to assure continuous service.**

**All satellites are monitored by control centers on the ground. As gravity causes a satellite to drift from orbit, the vehicle's attitude and orbit are adjusted by a control station. When the satellite moves into the dark side of the earth at night, its solar cells are eclipsed. Batteries provide power in the dark. Controllers monitor the battery backup to be sure satellite power is sufficient.**

**Inmarsat-3 has ten times the capacity of I-2. Each of the four spacecraft has one global beam which covers a wide area of the earth. Each also has 7 spot beams which concentrate power over a narrower area (usually where demand is high, along heavily traveled routes). Backup for I -3 is the previous generation of I-2 spacecraft.**

**The next constellation is I-4, designed to be 100 times more powerful and have ten times the communications capacity.**

countries, it provides the space segment known as "Inmarsat Aero. Using four satellites, it provides two-way voice and data (fax, Internet, e-mail, ATC) over most of the world. Because the satellites hover over the equator, their beams cannot extend into the North and South Pole regions. Future systems will add polar orbits to fill in these limited areas. The four Inmarsat satellites:

Pacific Ocean Region (POR)
Indian Ocean Region (IOR)
Atlantic Ocean Region West (AOR-W)
Atlantic Ocean Region East (AOR-E)

Each satellite is backed up with a spare orbiting in same vicinity. The other two major components of the satcom system are:

**Ground Earth Station (GES**). These radio stations around the world operate large dishes for communicating with satellites. They receive messages sent to a satellite by an aircraft, then pass them to a telecommunications company for relaying them to any telephone or data terminal in the world.

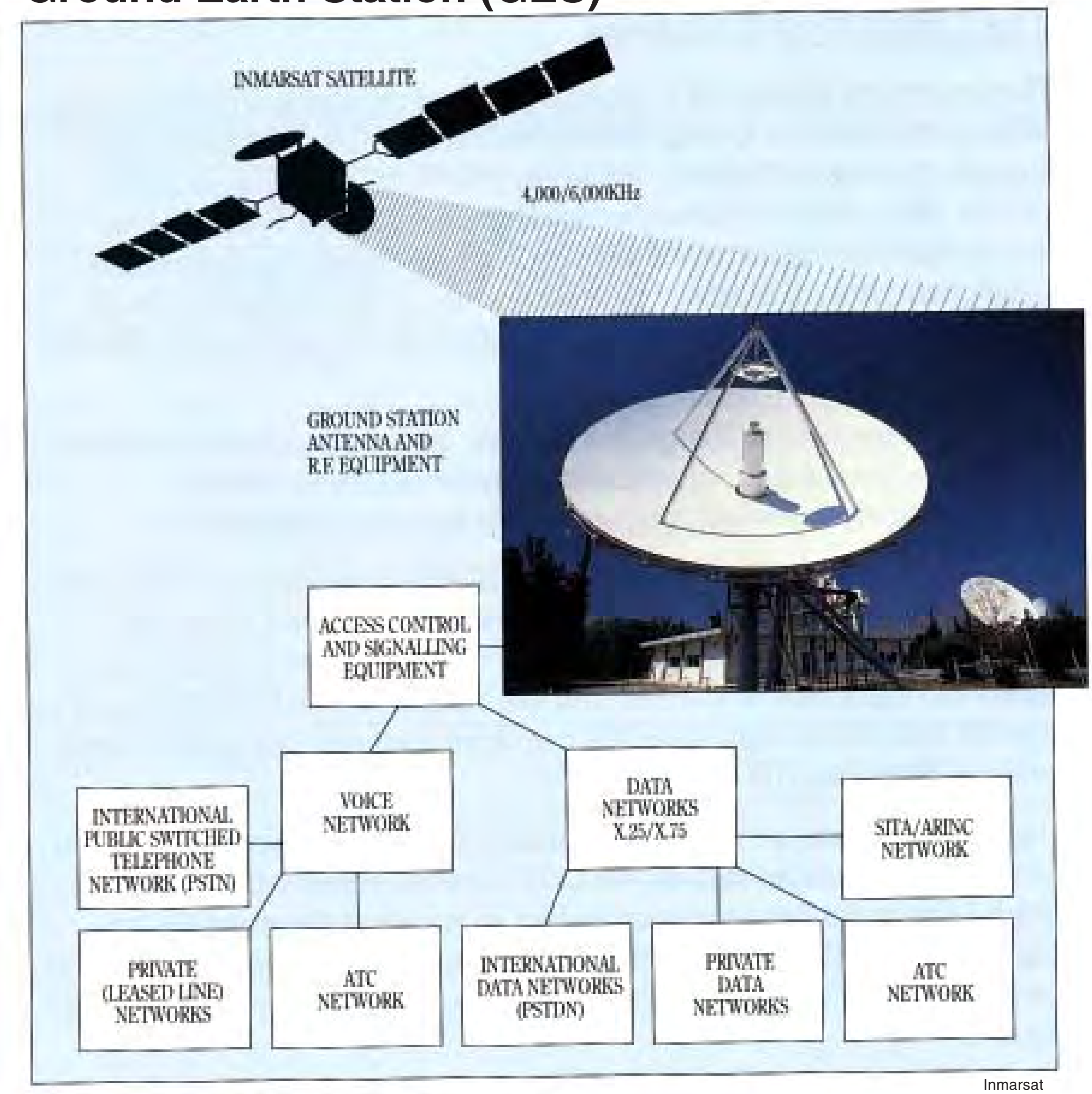
If the message is intended for an aircraft in flight, the ground earth station receives it through telecommunications networks and beams it up to a satellite for relay to the airplane.

**Aircraft Earth Station.** This is the avionics system aboard the aircraft for communicating with satellites. It must conform to Inmarsat standards and the specification for ARINC 741.

**Satcom antennas**. A component of the airborne system is the antenna, which must always aim directly at the satellite (to receive all of its services). Although Inmarsat satellites appear never to move (they are in geostationary orbit), the airplane often cruises over 500 mph, rapidly changing position. This is solved by a beam steering unit on the airplane that operates a motor-driven antenna or an electronic system known as a "phased array." Consider the satcom antenna categories:

**Low Gain.** Various communications via satellite require a different amount of power. A message consisting only letters and numbers moving at a slow rate (300-1200 bits per second) uses relatively little power and can operate on a "low gain" antenna on the airplane. The antennas is simple, little more than a blade, and picks up signals from any direction.

# Ground Earth Station (GES)




Inmarsat

Ten ground stations like this one are located around the world for communicating with aircraft via satellite. The ground station connects to international telecommunications networks to route calls and messages to any telephone, fax machine or data terminal in the world.

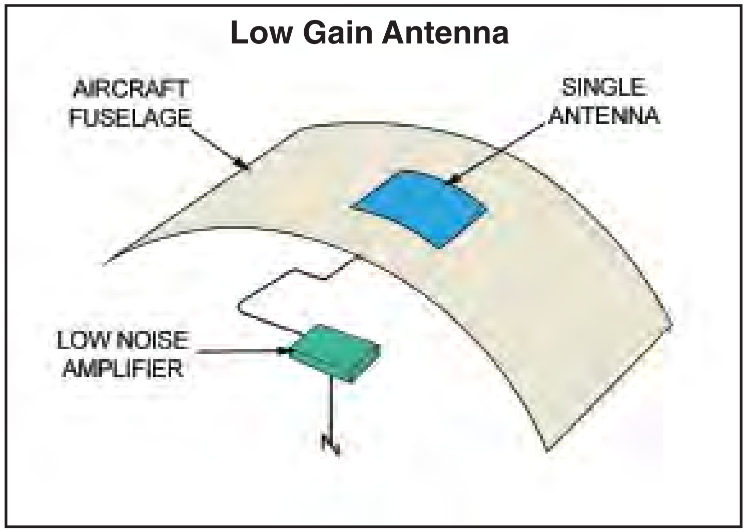
The station's dish antenna is typically 10 meters in diameter and operates in the satcom band between 4 and 6 GHz.

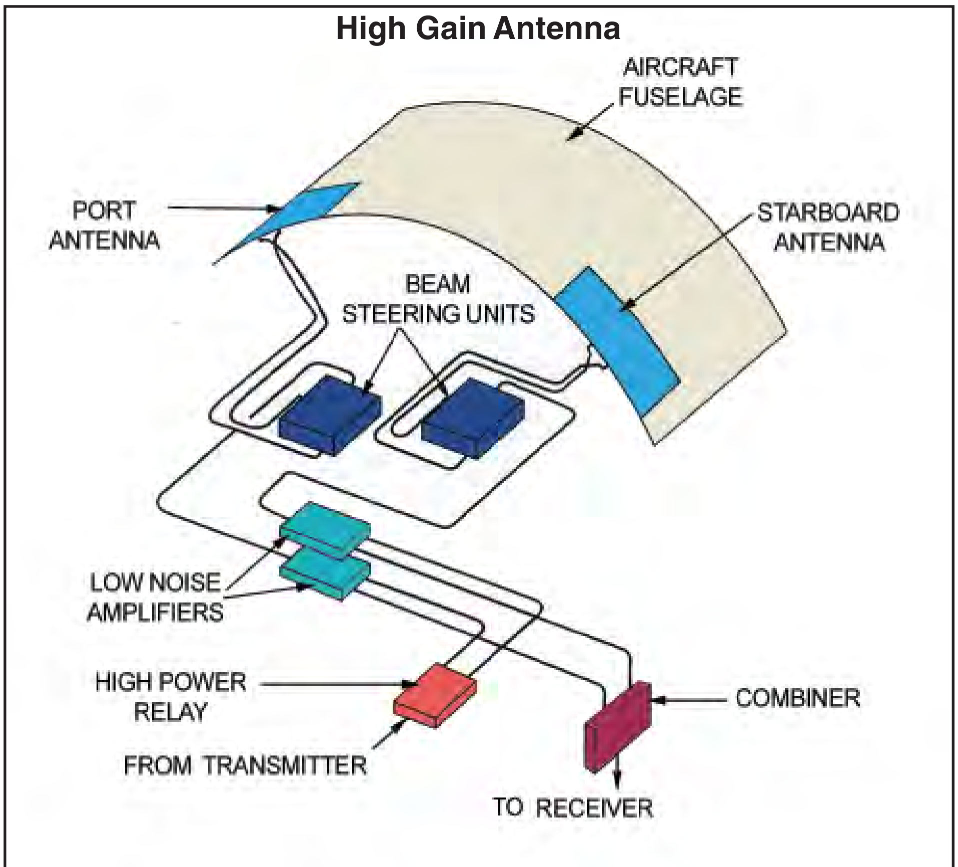
Voice sent via satellite uses "codec," for digital voice coding and decoding. Digitizing the voice reduces error in transmission and speech is high in quality.

The various blocks seen at the bottom of the illustration reveal a wide range of satellite services for aircraft, including air traffic control, passenger telephone, airline operations and data.

# Low and High Gain Satcom Antennas for Aircraft

Low-gain model has conformal antenna mounted on fuselage. Because of its simplicity it operates only on services with slow data rates (600 bits per second) such as air traffic control and airline operational messages. Such data may be a stream of characters (letters and numbers) displayed on a screen. Low in cost, the low gain system operates in the "Aero L" service.




AlliedSignal

The high gain satcom antenna supports services with higher rates, such as "Swift 64," which handles multichannel voice, data, fax and Internet connectivity. The transmission rate is 64K bits per second.

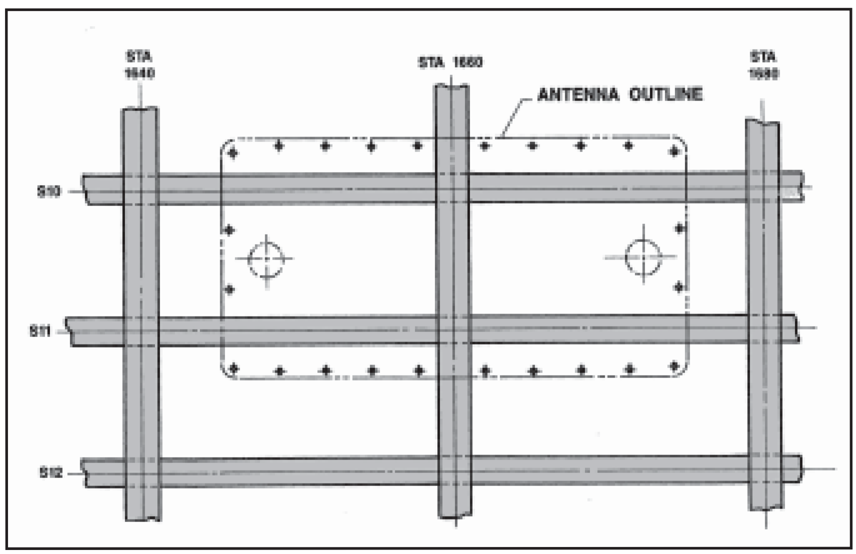
High gain is achieved by an array of antenna elements formed into a beam that focuses on the satellite.

Although the satellite is stationary, the airplane is moving. The antenna, therefore. needs the "beam steering unit," which keeps the beam aimed at the satellite. Steering information is obtained from the airplane's navigation system.

## Electronically Steered Conformal Antenna

High gain satcom antenna, the "Airlink" by Ball, measures 32-in x 16-in, with a depth of only .29-in. It is a conformal antenna, sufficiently flexible to curve to the aircraft body. It is attached by fasteners around the edges of the antenna. Frequency range is 1530-1559 MHz and 1626.5-1660.5 MHz, for communicating with Inmarsat satellites.

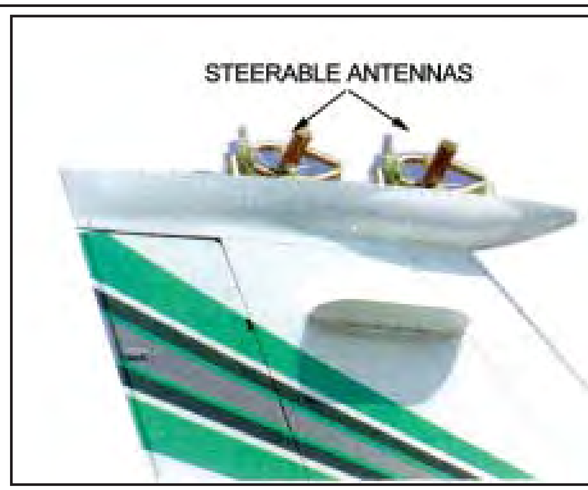
Antenna circuits inside the housing use microstrip technology, with no active electronic components. The outer assembly is fiberlass laminate.




Conformal antenna location for a B-747. Antenna is positioned so mounting holes along edges and two holes for the RF cables do not interfere with structure of the airplane.

## Electromechanically Steered Antenna

Two steerable satcom antennas mounted in a rudder cap. They operate electromechanically, under control of a beam steering unit. The antennas are aimed toward the satellite, regardless of aircraft position on earth, and provide high gain performance.



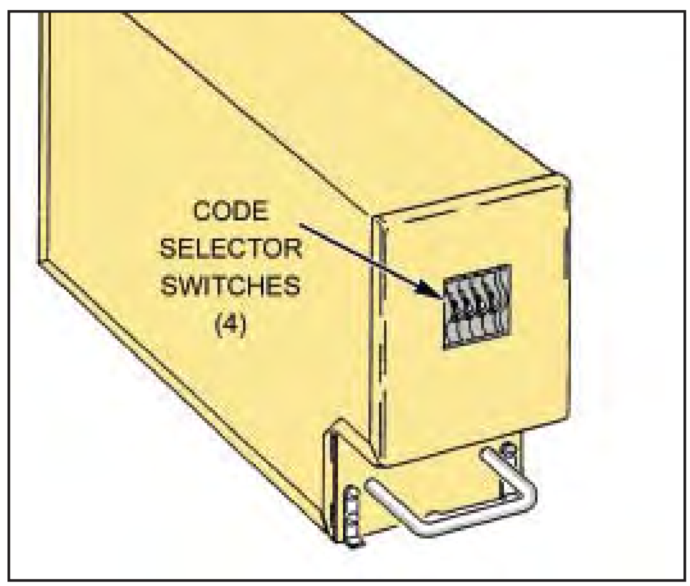

Honeywell/Thales

# Chapter 7

## Selcal

### Selective Calling

During oceanic flights, aircraft monitor a HF (high frequency) radio for clearances from a ground controller. Because HF reception is often noisy, and many messages are intended for other airplanes, a pilot prefers to turn down the audio He will not miss calls intended for him however, because of Selcal---selective calling. The ground controller sends a special code that sounds a chime or illuminates a light to warn the pilot of an incoming message and to turn the volume up. Because it's selective, Selcal "awakens" only the HF receiver with the appropriate code.




**Selcal decoder is an LRU (line replaceable unit) located remotely in the airplane's electronic bay. The four-letter code assigned to that airplane is programmed manually by four thumb wheels (code selector switches).**

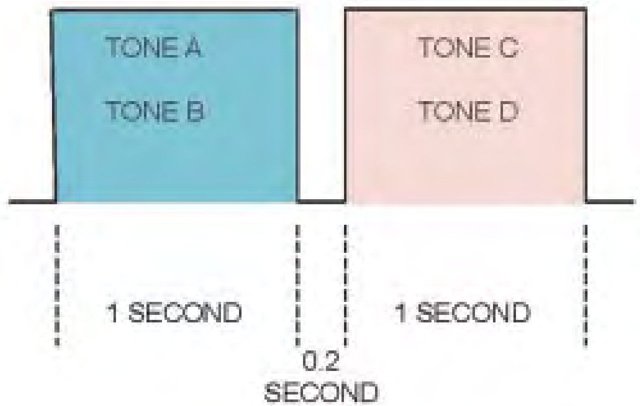
**The four-letter code (EG-KL, for example) is drawn from the letters A through S (I, N and O are excluded).**

**Some aircraft have two decoders, one to receive Selcal tones for up to four radios (2 VHF and 2 HF). The same assigned letters, however, are entered into the decoders.**


**This Selcal controller, located on the instrument panel, monitors two radios simultaneously (VHF or HF). An incoming tone code lights a green lamp and sounds an aural warning (chime). The pilot turns up the audio volume on the radio. Pressing the RESET button arms the system to receive the next call.**

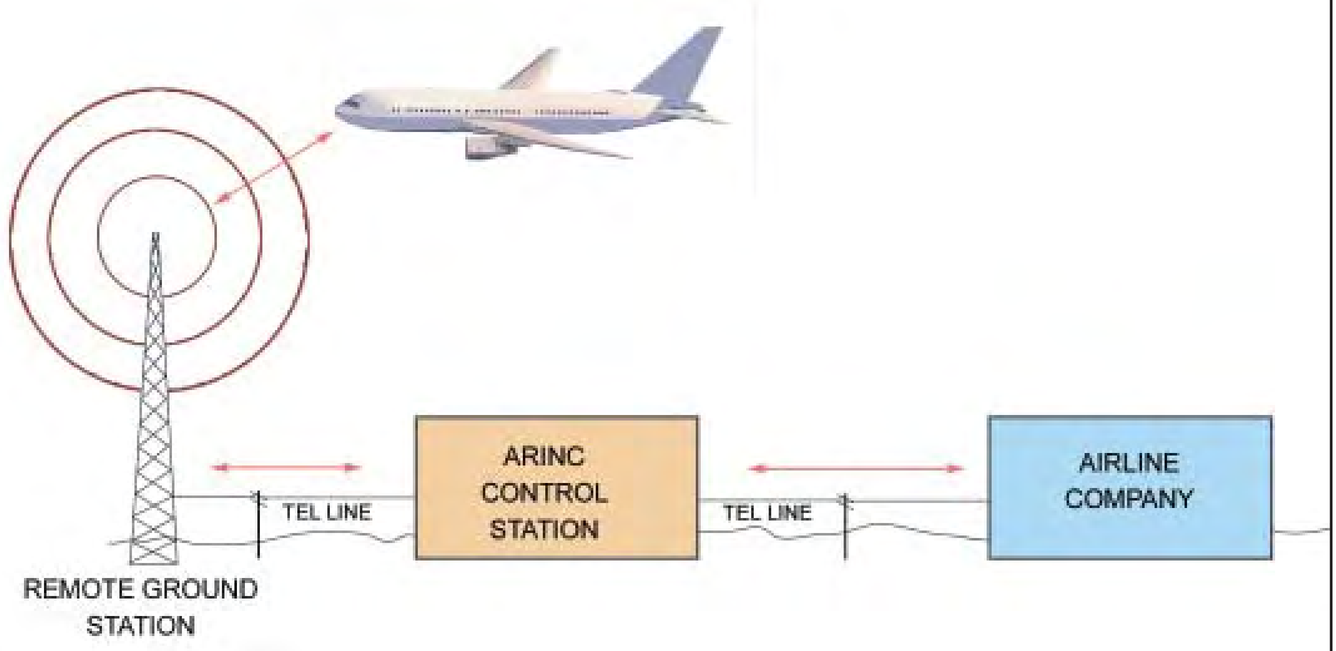
## How Selcal Code is Generated

| TONE | FREQUENCY (HZ) |
|---|---|
| A | 312.6 |
| B | 346.7 |
| C | 384.6 |
| D | 426.6 |
| E | 473.2 |
| F | 524.8 |
| G | 582.1 |
| H | 645.7 |
| J | 716.1 |
| K | 794.3 |
| L | 881.0 |
| M | 977.2 |
| P | 1083.9 |
| Q | 1202.3 |
| R | 1333.5 |
| S | 1479.1 |




**A Selcal code consists of four tones taken from the 16 audio frequencies shown at the left. In this example, the code is AB-CD. As seen in the diagram, they are sent in two pairs. A and B are mixed together (312.6 and 346.7 Hz) and transmitted for one second. After a .2-second interval the second pair is sent; C and D, or 384.6 and 426.6 Hz. (The technique is similar to touch-tone dialing for telephones.) Because the tone signals are audio in the voice range, they can be detected by a conventional VHF or HF communications transceiver.**

## Selcal Ground Network




**When Selcal must operate on VHF, where maximum range is about 200 miles, it is done through a network of remote ground stations. The airplane, always within range of some ground station, transmits and receives Selcal messages through an ARINC control station (in the U.S.). ARINC relays the message to the airline company. The link between stations is usually through telephone lines.**

**Selcal over oceanic routes is done on HF, where range from airplane to ground may be several thousand miles. The future of Selcal will be satcom; the airplane will communicate with satellites for relay to the ground.**

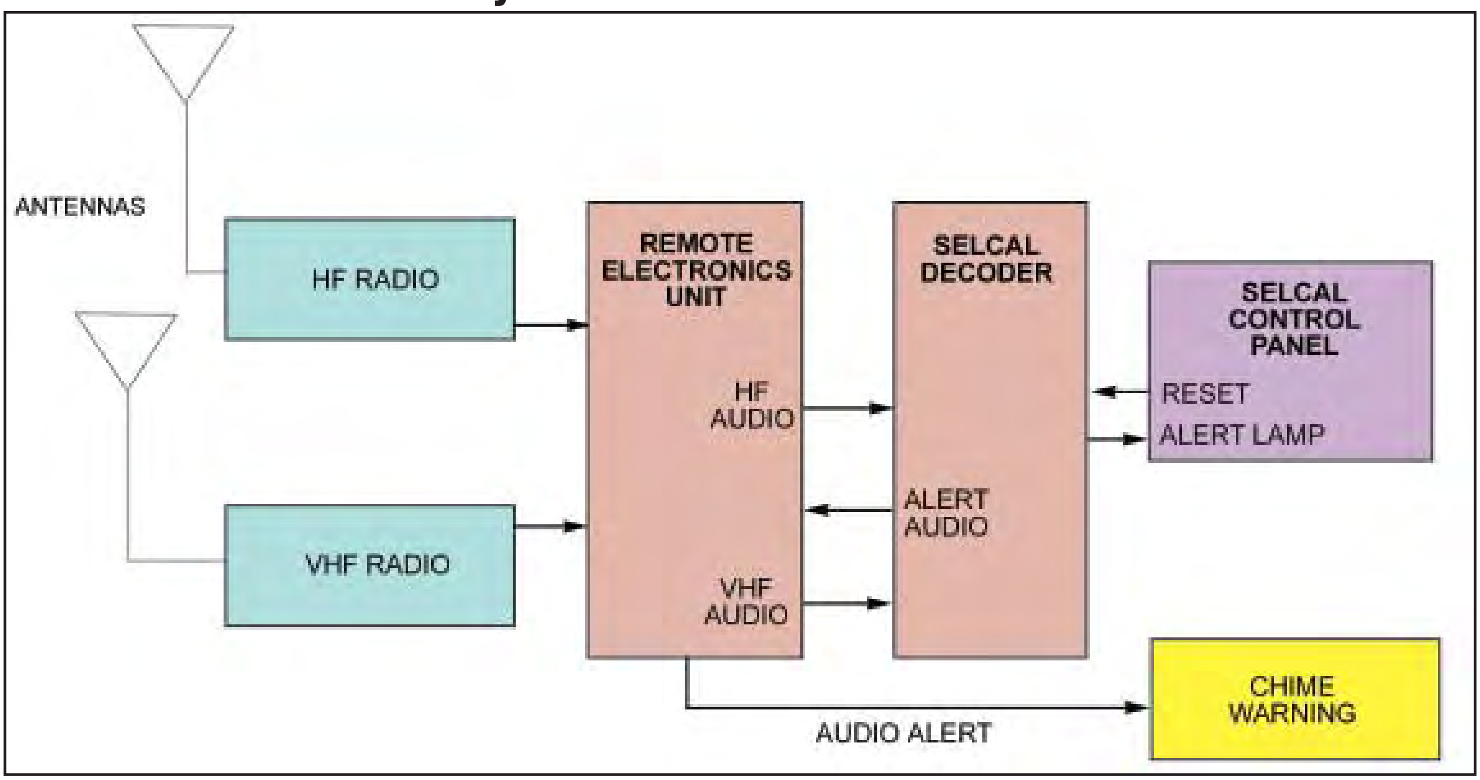
**VHF**. Selcal also operates with VHF radios, used by aircraft flying within a country or continent. Not only does Selcal reduce pilot workload, but extends the communication distance of VHF. If an airline company in Denver, for example, wants to talk to one of its airplanes in flight over Chicago, this is far beyond the range of VHF. Instead, the message is sent, through a telephone line to a network of ground stations. A VHF groiund station near the aircraft transmits to the airplane, and the pilot is signalled. He replies on VHF to the ground station and the message reaches the airline company through the network.

**Coding.** Selcal is based audio tones, as shown in the illustration. Each airplane has a code of four letters set into the Selcal decoding unit aboard the airplane. The code is entered into the flight plan to controllers can address it.

Although there are nearly 10,000 possible four-letter codes, they are in short supply. The demand is so high that more than one aircraft may be assigned the *same* Selcal code. To avoid answering a call intended for another airplane, identical codes are assigned in widely separated parts of the world. There is also an attempt to assign the same code to airplanes with different HF channel assignments.

It is important to warn pilots that it's possible to receive a Selcal alert not intended for them. This can be corrected by the pilot by clearly identifying his flight to the ground station.

## Selcal Airborne System




**Block diagram of Selcal system. Signals are received and from ground stations through the aircraft HF and VHF transceiver. They are processed by the Remote Electronics Unit and sent to the Selcal decoder for delivery to the pilot (on a screen or printer).**

**An incoming signal with the correct code illuminates a green panel light in the Selcal Control Panel and sounds a chime (aural alert).**

**A single system is shown here, but many aircraft have dual Selcal installations.**

Chapter 10

# ILS

## Instrument Landing System

The ILS is responsible for the ability of airliners and other aircraft to reach their destination more than 95 percent of time in bad weather. The system improves safety to such a degree that most airlines will not operate into airports without an ILS. In the business world, many corporations will not base their airplanes at airports without an ILS.

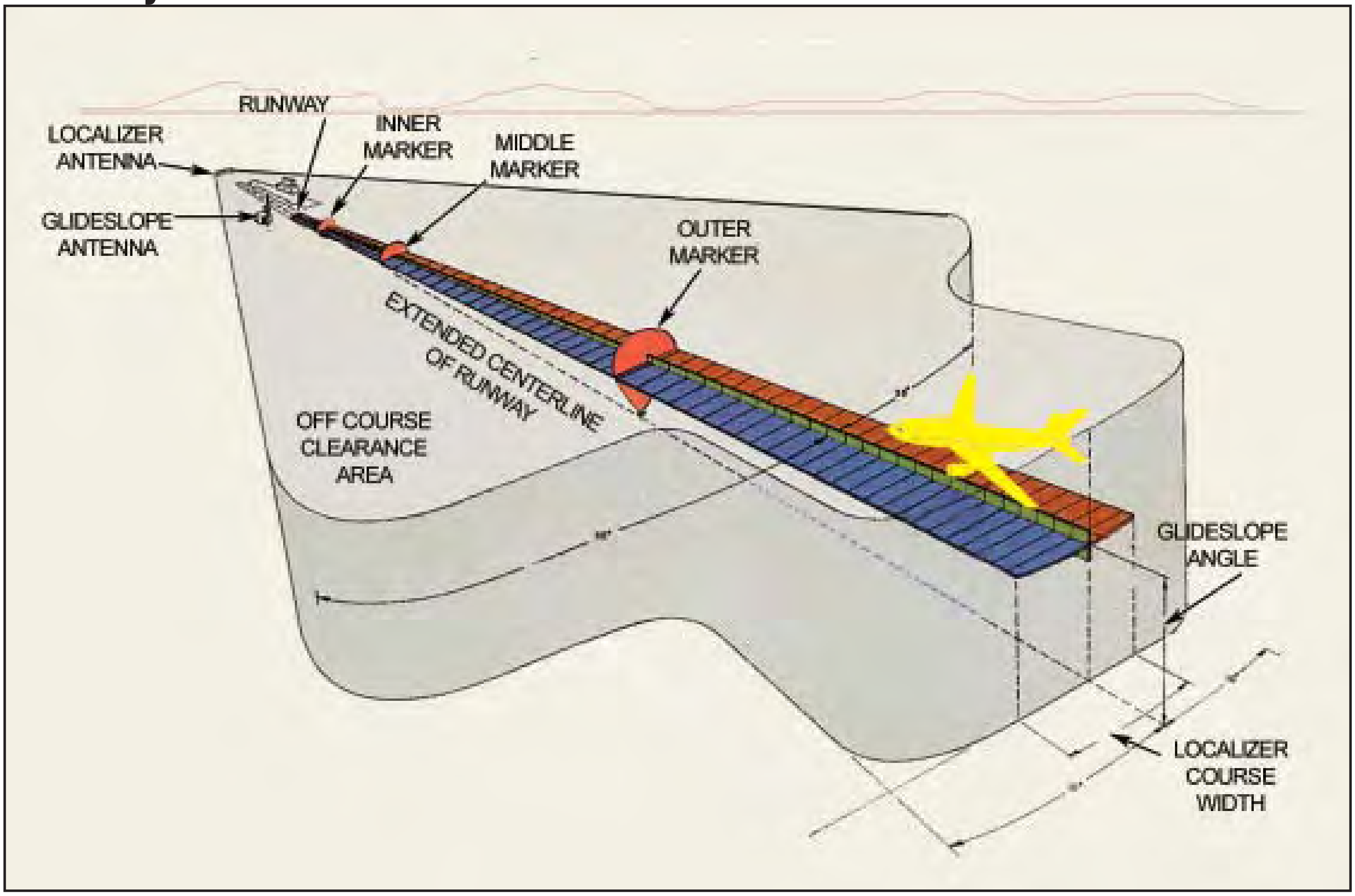
The ILS isn't only for bad weather. While descending into an airport at night at a brightly lighted city, pilots see a "black hole" where the runway surface should be. But a descent along an ILS glideslope clears all obstacles brings the airplane safely within feet of the touchdown zone. That guidance is also needed on bright summer days when an airport is hidden in haze.

Another benefit of ILS is that it provides a "straight in" approach. As airplanes become heavier and faster, there is more danger in maneuvering close to the ground at low airspeed. A 70-ton airliner cannot nimbly bank and turn through the right angles of an airport traffic pattern. But flying the ILS, the airplane "stabilizes" on the approach 30 or 40 miles from the airport and flies straight "down the slot."

**An array of antennas launches the localizer signal near the end of an ILS runway. The beams are beamed toward an airport runway at the right and reach out to about 50 miles.**

Airport Systems Int'l

# ILS System




**A three-dimensional path leads an airplane to the runway threshold at upper left. After intercepting the localizer (right), the airplane receives left-right guidance. At the outer marker the airplane begins a descent on the glideslope. At the middle marker the pilot decides whether there is sufficient visibility to land, or perform a missed approach.**

## ILS Components

The ILS consists of more than a half-dozen systems, both aboard the airplane and on the ground. Each ILS fits in a category, depending how low the airplane may fly---known as "minimums"--- before seeing the runway and deciding to land. Even a few dozen feet have great impact on airline operations. If the ceiling, for example, is 150 feet and ILS minimums require a descent no lower than 200 feet, the airplane may have to fly to an alternate airport, deal with hundreds of unhappy passengers, miss connecting flights and disrupt schedules over the country. Similar problems face the overnight express industry (Fed Ex, Airborne, etc.). But with sufficient investment in avionics, training, maintenance and ground facilities, airplanes are unable to land at their destination only four or five days a year! (In the US, this usually happens when a low pressure area with clouds, fog and rain cover the East Coast.

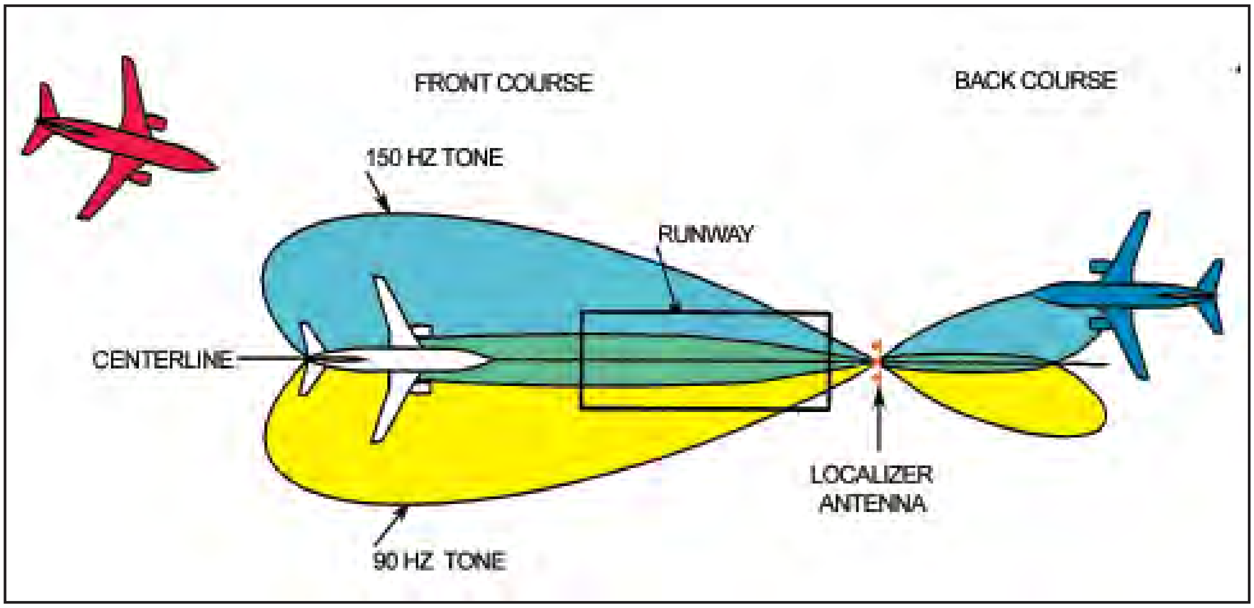
## ILS Categories

Because avionics in the airplane and ground stations must be equal to the ILS to be flown, consider the major divisions. The categories are based on ceiling and visibility at the airport when the airplane arrives. For ILS operations they are known as "Decision Height" (DH) and RVR (Runway Visual Range).

**Decision Height.** When the airplane descends to decision height (shown on an instrument approach chart) the pilot must decide whether to continue and land, declare a missed approach or go to an alternate airport. To continue the approach, he must be in a position to land (without excessive maneuvering) and see the approach lights or other visual component on the surface.

**RVR (Runway Visual Range).** Visibility is usually estimated by a weather observer and stated in miles. But the person may be more than mile from where the

# ILS: Two Audio Tones on a Carrier




The localizer antenna focuses the radio carrier into two narrow lobes, shown here as blue and yellow. The blue lobe is modulated with a 150 Hz tone; the yellow lobe by a 90 Hz tone. If the airplane flies along the center of the overlapping (green) area, the pilot sees a centered ILS pointer.

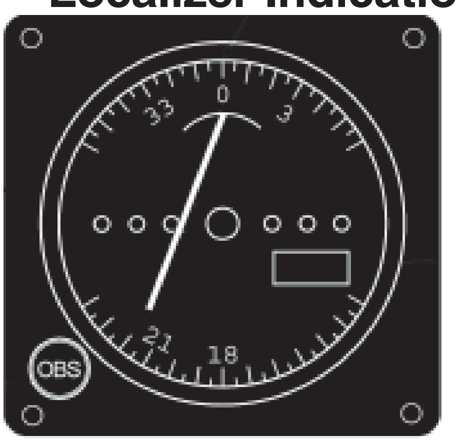
An ILS receiver does not measure the difference in *strength* of the two radio lobes. Rather, the receiver compares the *difference* in strength between the two audio tones. This is known as "DDM," for difference in depth of modulation.

Many localizer antennas also launch signals off their back end (to the right in this illustration) and form a "back course." This can be used for limited guidance, but in simple localizer receivers, the needle indications are reversed; the pilots flies *away* from the needle to get back on course (known as "reverse sensing"). Because this is confusing to the pilot, most localizer receivers have a back course switch ("BC")" to keep the same sensing as on the front course.

Back courses are present at all localizers, but should never be flown unless there is a published procedure. Also, there is no glideslope with a back course approach.

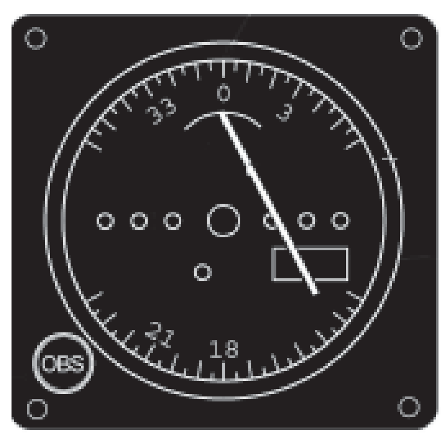
Many localizer displays use the blue and yellow colors shown in the above illustration. The trend, however, is not to use these colors on an instrument because they don't provide useful information. The needle provides all the guidance.

# Localizer Indications




The localizer needle indicates "fly left" to intercept the centerline of the localizer course. When tuned to a localizer frequency, the OBS (omnibearing selector) is disabled. Most pilots, however, set it to the localizer course as a reminder. This example is Runway 36 (the same as 0 or 360 degrees).


WIth the needle centered, the airplane is on an extended centerline of the runway. The same indicator is used for VOR navigation, but when a localizer frequency is selected, the needle become four times more sensitive. This achieves the higher accuracy required for an ILS approach.




The needle indicates "fly right" to get on the localizer course.

The overall width of a localizer course is usually 5 degrees. Thus, a needle deflecting full right or full left indicates the airplane is 2.5 degrees off the centerline.

## Chapter 14

# Transponder

A transponder ("transmitter-responder") receives a signal from a ground station (an "interrogation") and automatically transmits a reply. Transponders were developed for the military at a time when radar could locate airplanes but couldn't tell the friendlies from the enemy. The reply of a transponder provides that information; the airplane's ID, altitude and other data.

When first introduced, transponders were called= "IFF," for Identification, Friend Or Foe." The term is still used, but mostly by the military. In civil aviation, it is in a system called SSR, for "Secondary Surveillance Radar." It is *secondary* because primary radar simply sends a signal from the ground that reflects from the metal surface of the airplane and receives an echo called a "skin return."

In the airline world the transponder is labeled "ATC, " referring to Air Traffic Control.

. **Squawk.** When a pilot is instructed by ATC to set his transponder to a code (say, 1234), the controller says:

"Squawk 1234."

The pilot selects the code on the control panel that causes his airplane's ID to appear on the radarscope. Sometimes a controller may need to verify the ID, in which case he asks the pilot to "Ident." The pilot responds by pressing an ID button on the transponder, which causes his target on the ground radar to "bloom," creating a circle of light that clearly indicates the location of the airplane.

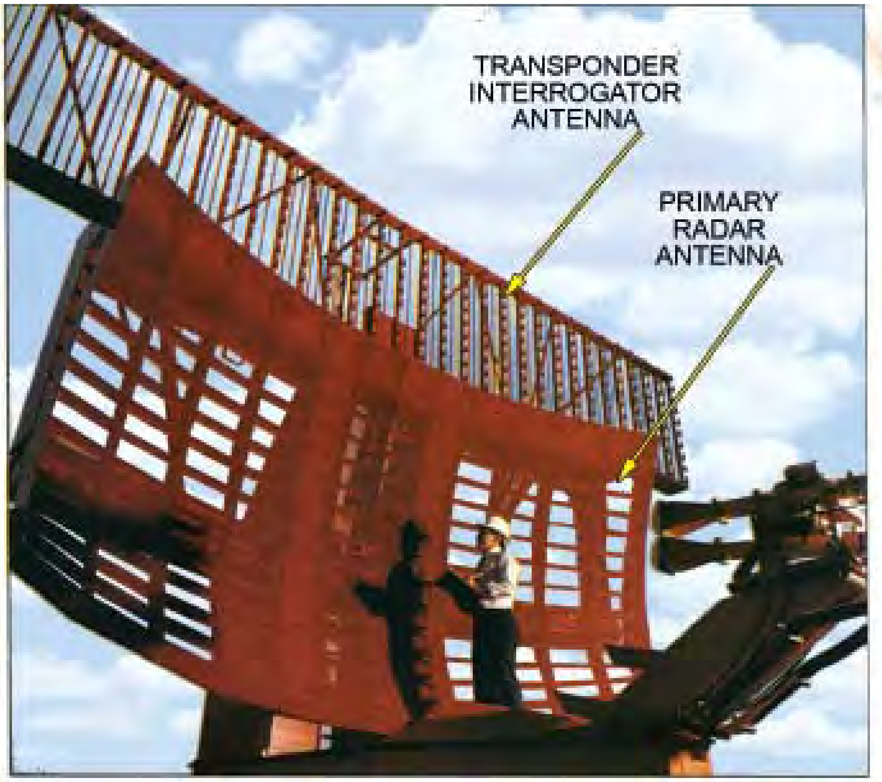
The word "squawk" goes back to World War II when the British, to keep their new transponder secret,

### Control-Display Unit


**Transponder control head. The transponder is "squawking" an identification code of "1045, " which is the Mode A function. Also transmitted is altitude, the Mode C function. The ident button is pressed only when requested by the controller. The standby (STBY) position keeps the transponder hot, but prevents replies. This reduces clutter on the radar screen while the airplane taxis on the ground at an airport. As the airplane lifts off, the pilot turns the knob to Mode C (which activates ID and altitude replies).**

**Note "ATC" at the upper right. This term is used for the transponder in large and airline aircraft.**

## Transponder Interrogator




(Westinghouse)

**The aircraft transponder sends to, and receives from, the top section of a surveillance radar known as a "beacon interrogator."**

**The larger antenna below it is the older primary radar, which sends out a pulse and picks up the signal reflected from the skin of the aircraft. Because skin returns are weak, difficult to see and carry no information other than the range and bearing of the aircraft, they are used only as a back-up.**

**The beacon interrogator on top, on the other, hand, picks up a signal that's strengthened thousands of times by the aircraft transponder. Besides a bright display, the image on the radar screen carries data such as aircraft ID, transponder code and ground speed.**

**The surveillance radar shown above is an ASR---airport surveillance radar---that covers up to about 60 miles from the airport. To the pilot, this is "approach control" or "Tracon" (terminal radar approach control).**

**During cross-country flight, airplanes receive longer range coverage from "en route" radars of larger size and power.**

called it "Parrot." It survives to this day in the military; when a (British) controller wants a pilot to turn off his transponder, he says, "Strangle your parrot!"

The word "parrot" also explains why controllers today ask the pilot to "Squawk" a transponder code.

**Grand Canyon**. Transponders came into widespread use after a mid-air collision between two airliners over the Grand Canyon in 1956. A DC-7 and a Constellation requested permission from ATC to fly off course so passengers could enjoy the view. Flying outside controlled airspace (on a sunny day) the airplanes collided with the loss of 128 lives. The disaster began an overhaul of the ATC system (and created the FAA). With an ability to put strong targets and flight data on the radar screen, transponders became a key component in the air traffic system.

## Two Systems: ATCRBS and Mode S

**ATCRBS.** The transponder improved air traffic control for a half-century, operating under the name, ATCRBS, for Air Traffic Control Radiobeacon System." But it began showing its age as the aircraft popu-

## Panel- Mount Transponder (Mode S)


**A Mode S transponder for General Aviation, the Bendix/ King KT-73. Its controls and displays include:**

**IDENT BUTTON. The pilot presses the button when air traffic control requests "Ident." The reply light (R) illuminates for several seconds while the reply transmits.**

**The same Reply Light also blinks when the transponder answers interrogations from the ground.**

**FLIGHT LEVEL. The altitude of the airplane, as reported by the transponder in hundreds of feet. Thus, "072" on the display is 7200 feet (add two zeroes).**

**ID CODE. The squawk code assigned by ATC under the older transponder system (ATCRBS). It is dialed in by four knobs along the bottom of the panel.**

**FUNCTION SELECTOR. This turns the transponder on, displays the flight ID code and tests all lighted segments of the display. The Ground position disables most transponder functions because they are not needed on the ground. A large number of airplanes on the airport surface would clutter radar displays. The pilot switches, shortly after take-off to Alt (altitude) to resume normal transponder operation. The Alt position reports ID and altitude.**

**The "VFR" button at the bottom right automatically sets the transponder to 1200. This code is selected when the airplane is not on an instrument flight plan and is flying under visual flight rules (VFR).**

lation grew and more airplanes operated out of fewer airports.

There are several limitations on ATCRBS. First, it wastes space in the radio spectrum. When the radar interrogator on the ground sweeps around, it interrogates all airplanes within range---and all airplanes reply. The controller cannot obtain a reply only from the airplane it needs to contact.

Also, when radar sends a beam, it sweeps across the airplane, making 20 or more interrogations in one pass. Only one interrogation and reply are required; additional replies only limit the capacity of the system.

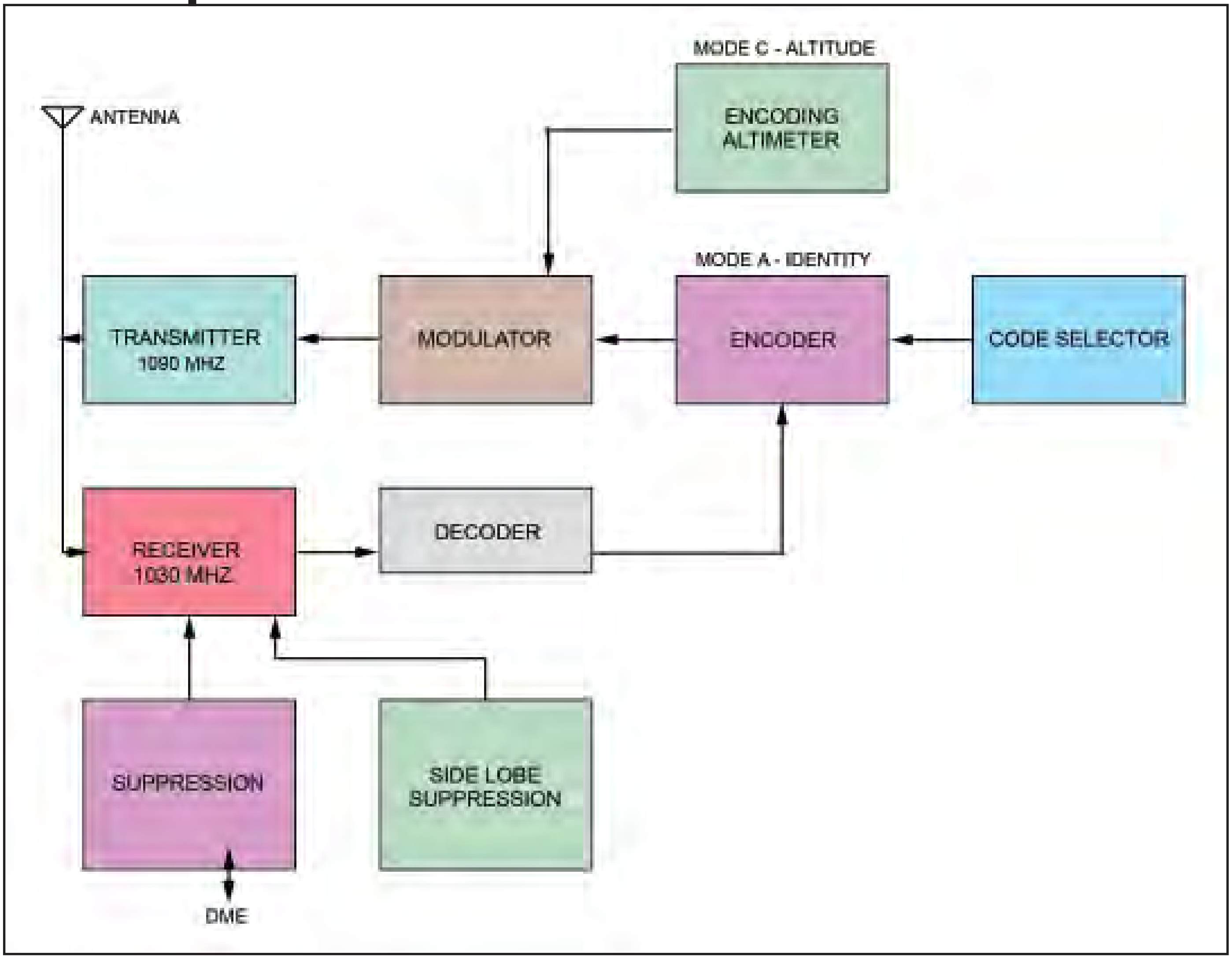
Another shortcoming is "synchronous garble," which is two replies happening at the same time. Let's say two airplanes are on the same line north of the radar site; one at 20 miles, the other at 30 miles. Because they are both struck by the same radar interrogation, they reply nearly at the same time. The two replies move along the same line back to the radar antenna and interfere with each other. To the controller, the targets appear confused or "garbled."

Another limit for the ATCRBS transponder is in the collision avoidance system (TCAS). As described in the chapter on TCAS, two aircraft approaching each other must fly an escape maneuver that keeps them apart; for example, to avoid a collision, one flies up, the other flies down. That maneuver must be coordinated by the transponder, but ATCRBS cannot provide this function.

**Mode S**. The answer to these problems came as a completely new transponder known as Mode S (S for Select). It means "selective addressing," which enables a controller to request a specific airplane to reply, not the whole fleet. This greatly reduces the number of unnecessary signals filling the air.

A requirement of Mode S is that it does not rapidly obsolete the ATCRBS transponder. The two must

# Transponder




The transponder is a transmitter-receiver with these major building blocks:

RECEIVER
Interrogations from the ground station are picked up by the antenna on a frequency of 1030 MHz. The pulses are applied to the decoder.
DECODER
Measuring incoming pulses, the decoder identifies the type of interrogation. If they are recognized they are passed on to the encoder.
ENCODER
The encoder creates the pulse train which contains the reply.
ENCODING ALTIMETER
After converting barometric pressure (based on 29.92 inches of mercury) to electrical signals, the encoding altimeter sends altitude information to the encoder for the Mode C repy.
CODE SELECTOR
The pilot dials in the 4-digit transponder code, which is sent to the encoder.

MODULATOR
Pulses that form the reply are amplified in the modulator and applied to the TRANSMITTER for transmission on 1090 MHz.
SIDE LOBE SUPPRESSION
The radar signal from the ground contains a main lobe and several side lobes. If the transponder replies to a side lobe, the radar operator will see the airplane at the wrong position. The side lobe suppression circuit prevents the transponder from replying if it senses reception of a side lobe.
SUPPRESSION
There is a chance that other transmitters aboard the airplane might interfere with the transponder. This usually caused by the DME. which operates close in frequency. To avoid interaction, the transponder receiver is suppressed when the DME transmits. The DME receiver is also suppressed when the transponder is transmitting.

# Ch 16

# GPS/Satnav


Rockwell

**A typical GPS satellite weighs nearly 1800 pounds and is powered by a combination of solar panels (in the light) and ni-cad batteries (in the dark). Because precise time is essential, each satellite carries four atomic clocks that keep time accurate to one second in 80,000 years. The overall width of the satellite, including solar panels, is about 19 feet.**

**The satellite continuously broadcasts the GPS signal through 12 rod-like (helical) antennas, shown in the illustration as pointing "To Earth."**

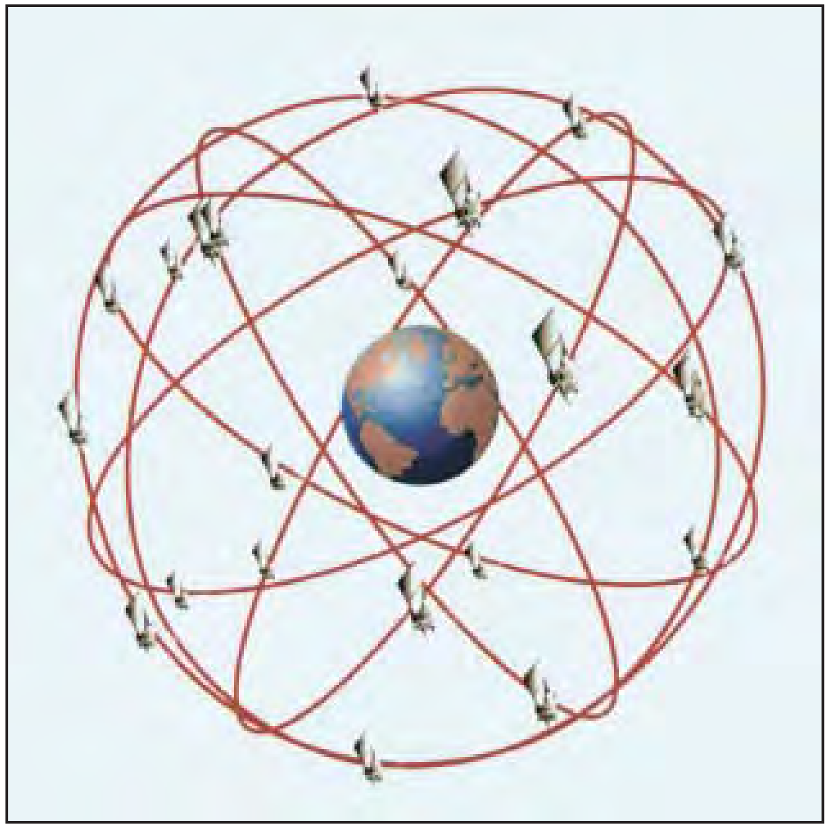
Satnav---satellite navigation---will replace nearly every other form of radionavigation. It meets or exceeds the accuracy, reliability and global coverage of land-based systems. Satnav is also supported by world aviation agencies to eliminate the high cost of servicing thousands of VOR, ILS, NDB and other ground stations.

The benefits of satnav will multiply as GPS, a U.S. system, is joined in coming years by Europe's Galileo. To avoid obsoleting the huge avionics investment in old aircraft, however, today's land-based stations will continue to operate well into the 21st Century.

**Satnav.** In the 1980's, the captain of a trans-atlantic flight between Sweden and New York walked back to the passenger cabin. He was approached by a man who said, "Captain, I believe we are 10 miles off course."

The captain looked at him and replied, "You're probably right." He had noticed the man holding a portable GPS. The airliner was navigating by the most advanced system known; the ring laser gyro. (Three of them, in fact, for redundancy.) The laser gyro is guaranteed not to exceed an error of 1 mile per hour-

# **GPS Constellation:** "Space Segment"



**Number of satellites in orbit..........24**
**(21 active and 3 spares)**
**Height above earth...........11,000 n miles**
**Orbital planes..................................6**
**Time to complete one orbit.......12 hours**
**(circles the earth twice a day)**

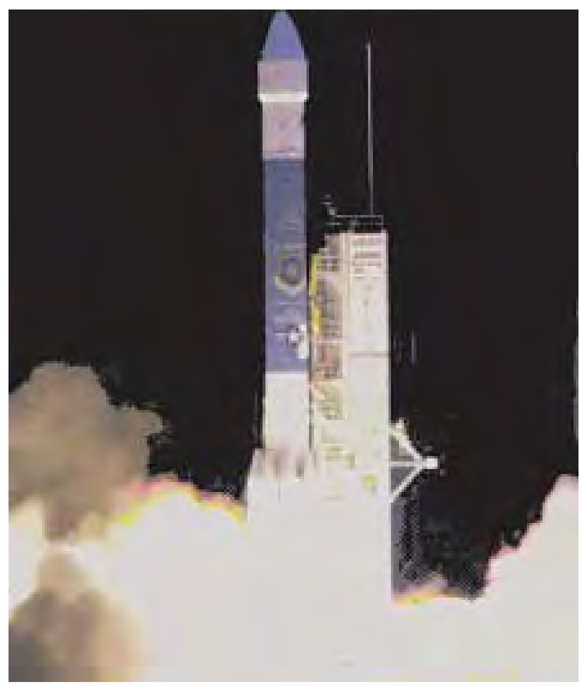
**There are six paths, or "planes," around the earth, each with six satellites. To an observer on earth, they appear to rise at the horizon, cross the equator, then descend below the opposite horizon. Over most of the earth, at least five or more satellites are available for navigation at any time.**

--meaning that after a 4-hour flight across an ocean, the airplane would be no more than 4 miles off either side of its assigned track. That passenger's pocket GPS not only knew the aircraft position within less than 100 meters, but held that accuracy throughout the trip (updating once per second).

Radionavigation for nearly 100 years sent out signals to be detected by an airborne receiver. But by the 1960's the microcomputer introduced digital signal processing. Instead of transmitting simple tones or timing pulses, a satellite could encode large amounts of data and broadcast it over the earth's surface. This data could then control the accuracy and performance of even the most inexpensive GPS receiver.

This places the costliest components---like precision timing generators---aboard the satellites, not in the receiver. Each GPS satellite carries at least two atomic clocks, which measure time by the motion in atomic particles of the elements rubidium or cesium. When the Galileo satellites appear, they will add yet another technology; the "maser," a cousin to the laser. In the maser, radio waves are driven to a high state of energy, then allowed to fall to a lower level. During the fallback, they produce oscillations which are extremely accurate timing references.

## Launch Vehicle



**GPS satellite is launched by Delta II rocket at Cape Kennedy. Although satellites are usually rated for a life of 7.5 years, many have operated 11 years.**

two after being turned on. With a 12-channel parallel system, the receiver performs a quick "sky search".

### Satnav Terms and Service

Some major terms and acronyms to describe satnav systems:

**GNSS: Global Navigation Satellite System**. The international term to describe navigation based on satellites. When GNSS describes a precision instrument approach, it is called **GLS** (the LS meaning landing system).

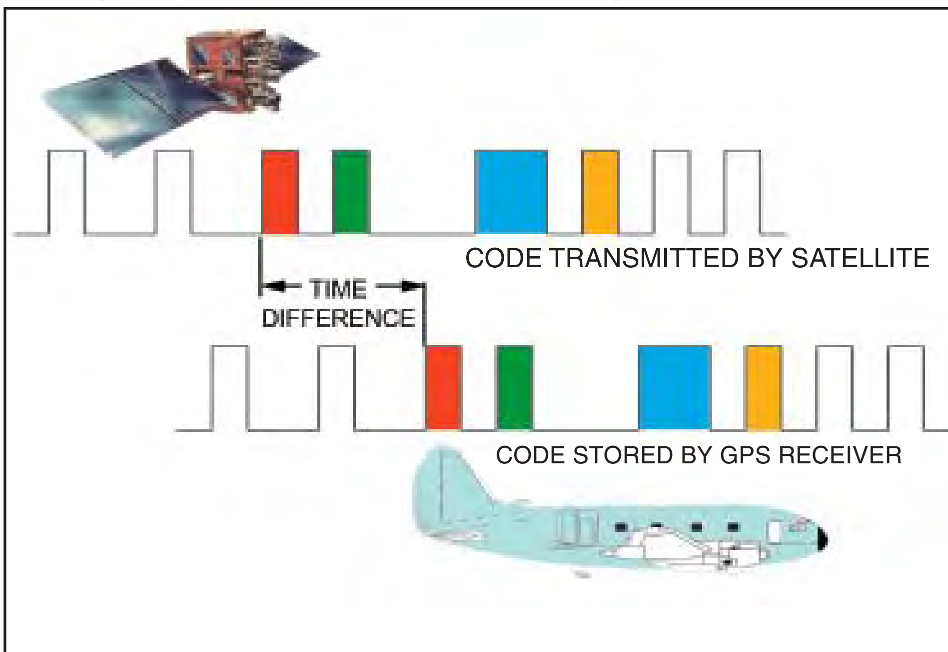
**SA: Selective Availability.** Because GPS began as a system for the U.S. Dept. of Defense, the highest accuracy was reserved for the military. The signal available to civil users was degraded by "SA," which limited receivers to about 100-meter accuracy.

In the year 2000, Selective Availability was turned off and accuracy improved by about five times.

## Panel-Mount GPS Receiver


**A GPS receiver used in IFR (instrument flight rules), like this Bendix-King KLN-94, must update its navigation database regularly. This can be done in two ways. A database card is inserted into the slot, or the dataloader jack connected to a PC. Updates may be obtained over the Internet.**

## Airplane Measures Time to Compute Distance to Satellite

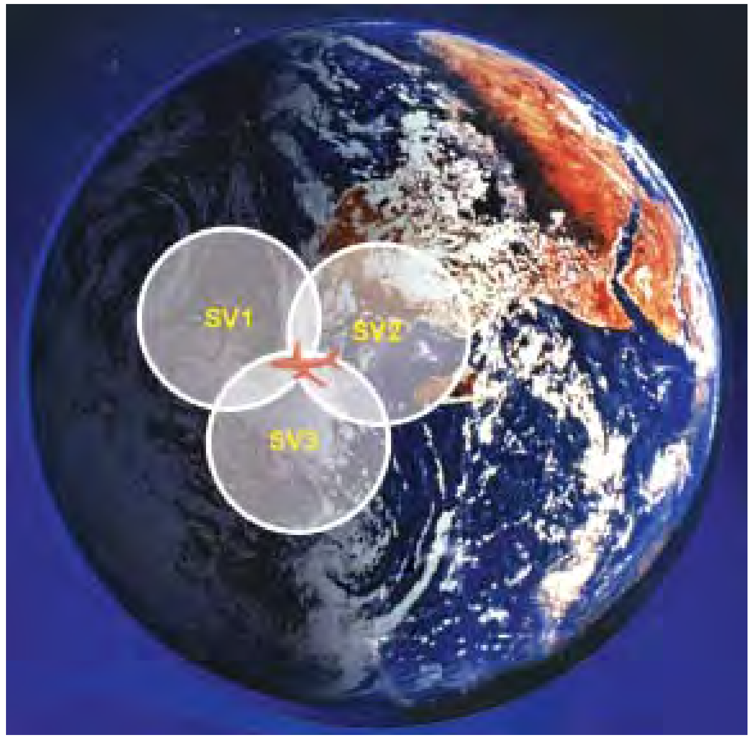



**1. The signal from the satellite is transmitted as a pulse code. Each satellite sends a unique identification, as represented by red, green and blue pulses.**

**2. The receiver in the airplane already knows the code patterns sent by every satellite. It searches until it locates a satellite signal that matches a stored pattern.**

**The satellite message also tells the receiver the time the signal was transmitted. By comparing this time with the time of arrival at the receiver, a time difference is calculated. This is multiplied by the speed of light and the answer is distance.**

## Finding Position




**When only one signal is received, the airplane may be located anywhere on the surface of a sphere (or "bubble"), with the satellite (SV1) at its center. After receiving a second satellite (SV2) the spheres intersect and narrow the position. With SV3, the position is further refined. It takes a fourth satellite to obtain latitude, longitude and altitude, which is a 3-dimensional fix.**

**Receiving a fourth satellite is required for correcting the clock in the GPS receiver. That enables a low-cost clock to keep sufficiently accurate time for the distance-solving problem.**

**SPS: Standard Positioning Service** This service is intended for civil users and is located on L1, one of two existing GPS channels. More channels will be added in the future.

**C/A Code: Coarse/Acquisition Code.** This is the code transmitted on the civil channel, L1. It is "coarse" because it has the least accuracy.

**PPS: Precise Positioning Service.** Provides the greatest accuracy for military users and operates on the two existing GPS channels, L1 (shared with civil) and L2 (military only). It uses the "P Code," which is encrypted and available only to qualified users.

**Propagation Corrections**. The advantage of two channels, L1 and L2, is reducing propagation error. As satellite signals move toward earth, they pass through the ionosphere, which lies from about 60 miles to 200 miles above earth. Although radio signals move at close to the speed of light, higher frequencies move faster through the ionosphere, which introduces error. By measuring different GPS frequencies, L1 and L2, the receiver computes the "propagation" error and removes it.

The military removes the error because it is able to receive both L1 and L2. However, future satellites will add a civil code to L2, enabling any civil receiver to solve the error. Later, civil aviation will receive a third civil frequency, L5.

### PRN Code

Each satellite transmits a unique identity known as a "pseudorandom" code. The term "pseudo" usually means "false" but in GPS it means "uncorrected. It is called "random" because the GPS signal resembles random noise.

The atomic clocks aboard satellites are extremely precise, however, they do drift in time. The error is measured by ground stations, but this is not used to correct satellite time. Atomic clocks are not easily reset while in orbit. It is more practical to develop a time correction factor based on the error and send it to the GPS receiver. The receiver stores the correction factors for all satellites in orbit and applies them while developing a position fix. For maximum timing accuracy, at least four satellites should be received.

**Position-fixing**. Determining aircraft position is similar to "triangulation." The receiver draws lines of position from several satellites, and locates the airplane where they intersect. One way to visualize this is to imagine each satellite surrounded by a large bubble. When the airplane measures distance from a satellite, the receiver places the airplane somewhere on the *surface* of the bubble. For example, if the range is 15,000 miles, the airplane may be anywhere on the bubble and still be at 15,000 miles.

Next, assume the receiver measures 18,000 miles to another satellite, placing the airplane on the surface

Chapter 17

# EFIS

## Electronic Flight Instrument System

Along with digital electronics and GPS navigation, the Electronic Flight Instrument System changed the face of the flight deck. The term EFIS originally described an airline system (that first rolled out with the Boeing 767 in 1981) but today it identifies electronic instruments for aircraft of all sizes.

EFIS is often called the "glass cockpit" because TV screens replace mechanical and electromechanical instruments. Dozens of old "steam gauges" are now replaced by an EFIS display that is rapidly changing from about a half-dozen separate screens to "wall-to-wall" glass.

Six large EFIS screens span across the main instrument panel. This is the flight deck of a B-757, first airliner to adopt electronic flight instruments. Although these displays are CRT's, newer aircraft use LCD flat panels ing system) by keeping two needles centered; one for the localizer to remain on the runway centerline, the other a glideslope for vertical guidance. In a series of experiments by NASA, the "highway in the sky" was developed. The pilot aims the airplane at a rectangle (or hoop) on the screen and flies through it. Additional hoops appear in the distance; if the pilot keeps flying through them (like threading a needle), the airplane remains on the localizer, glideslope or other 3-dimensional path.

The original technology for EFIS was the heavy glass cathode ray tube. Flat panel LCD's of the 1970's were not ready for aviation; they were monochrome, had narrow viewing angles and low resolution. Driven by the large market in portable PC's, the technology advanced rapidly and all new EFIS systems are flat panel.

There is much retrofitting of old aircraft to replace their electromechanical instruments with EFIS. It's happened in most major transport aircraft in "derivative" models, usually shown by a "dash number;" for example; the Boeing 737-100 first rolled out in 1967 with conventional instruments. It is now up to 737-900, with recent generations equipped with EFIS.

## Transition from Electromechanical to EFIS

**This EFIS screen is a "Primary Flight Display" and combines many early instruments into a single screen. The top half was once the artificial horizon. One of the first improvements was the addition of "command" bars--the V-shape near the middle of the screen. Driven by the flight control system (autopilot), the bars helped guide the pilot fly manually or enabled him to observe commands of the autopilot. At this stage, the instrument was called an "ADI," for attitude director indicator.**

**When EFIS appeared, all the same functions were pictured on a video screen. This called for a new name, EADI, for electronic attitude director indicator. At the same time, several other instruments were added to the image; air speed indicator, altimeter, vertical speed indicator and others.**

**The lower half of the screen was once the horizontal situation indicator (HSI). When the electromechanical instrument is shown on an EFIS screen it is known as an EHSI, the "E" is for electronic.**

**When the two major flight instruments---ADI and HSI---are placed one above the other and connected to the autopilot, they are known as a "flight director."**

**The trend in EFIS, however, is to combine those instruments onto one screen, as shown here, and call it a "Primary Flight Display."**

**The system in the illustration is the Honeywell Primus EPIC, a flat panel measuring 8-in by 10-in.**

# Three-Screen EFIS


L3 Communications

The future of instrument panels is shown in this “Smartdeck” by L3 Communications. It is “wall-to-wall” glass, with three 10.5-inch panels that display information once required by three separate instruments.

Panels like these are usually interchangeable, with their function determined by how their software is programmed. This permits “reversionary modes,” meaning that any display on one panel can be switched over to another.

The panels are arranged as Primary Flight Displays for captain (left) and first officer (right). In the center is the multifunction display. Because the multifunction display typically displays engine instruments and warnings it is also called EICAS, for engine instrument and crew advisory system.

The Primary Flight Display is mainly for controlling the attitude of the airplane and for navigating.

### Primary Flight Display

| | |
|---|---|
| Attitude | Engine Power |
| Heading | Selected Heading |
| Altitude | Selected Course |
| Airspeed | Autopilot/Flight Director |
| Vertical Speed | Navigation |
| Lateral/Vertical Path | Timer |

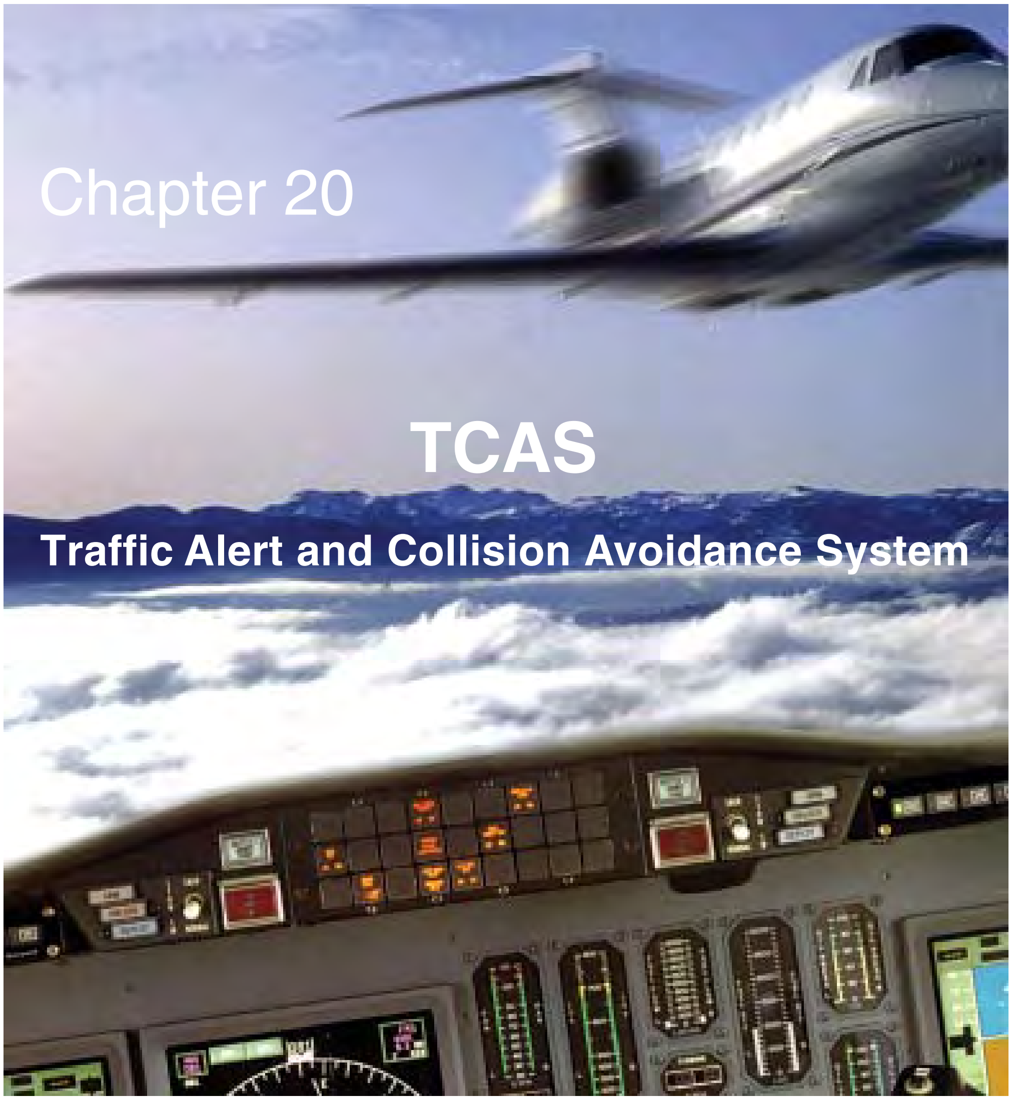
### Multifunction Display

| | |
|---|---|
| Radio Management | Charts |
| Aircraft Systems | Runway Diagrams |
| Engine Instruments | Wind Direction/Speed |
| Checklists | Ground Track |
| Moving Map | Caution/Warning |
| Flight Plan | Geographic Overlays |
| Terrain | Lightning/Weather |
| Datalink (Traffic/Weather) | Traffic Information |

# Chapter 20

# TCAS

## Traffic Alert and Collision Avoidance System



Honeywell

Keeping aircraft safely separated had been the task of air traffic control since the 1930's when pilots radio'ed position reports by voice. This was followed primary surveillance based on radar "skin returns," then secondary surveillance using transponder interrogation and reply. But as airplanes began cruising near Mach 1 and air traffic multiplied, so did the threat of the "mid-air."

The search for a workable anti-collision system persisted for 50 years. Early experimental systems required costly atomic clocks, complex antennas and techniques borrowed from electronic warfare. Progress was slow until, in 1956, two airliners collided over the Grand Canyon on a sunny day. Closing at about 900 miles per hour, the pilots would have to see the other airplane at four miles, decide on the correct response, then maneuver off the collision course. All this would have to happen in 15 seconds. As a resultof the accident, the U.S. Congress brought pressure on the FAA to develop an anti-collision system, and for airlines to install it at an early date.

During the 1960's, the transponder was spreading through aviation and researchers decided to abandon earlier technology and adopt the transponder as a building block in a new anti-collision system. After trying several variations, the TCAS system (Traffic Alert and Collision Avoidance System) was chosen as a world standard and it's now in widespread use everywhere, with scaled-down versions for business and light aircraft. In Europe the system is known as ACAS, for Airborne Collision Avoidance System, but all systems follow the standard adopted the International Civil Aviation Organization (ICAO).

While the transponder is a major component, the foundation is the TCAS processor. It performs one of the most intensive and rapid computations aboard the aircraft, executing software for collision logic. It must acquire, track and evaluate dozens of aircraft up to about 40 miles away---then issue commands on how to avoid a collision---all within seconds.

The road to TCAS was not entirely smooth. As

# TCAS Symbols on a Radar Display


Bendix-King

**If an airplane has an EFIS or radar display, it can show TCAS information. The weather radar control panel is at the top, with a button at top left for activating the TCAS display.**

**Besides TCAS symbols on the display, there are voice announcements. If a threat advisory (TA) appears on the display, the voice says, "Traffic, Traffic." If it turns into a resolution advisory (RA), the voice gives a command to climb or descend.**

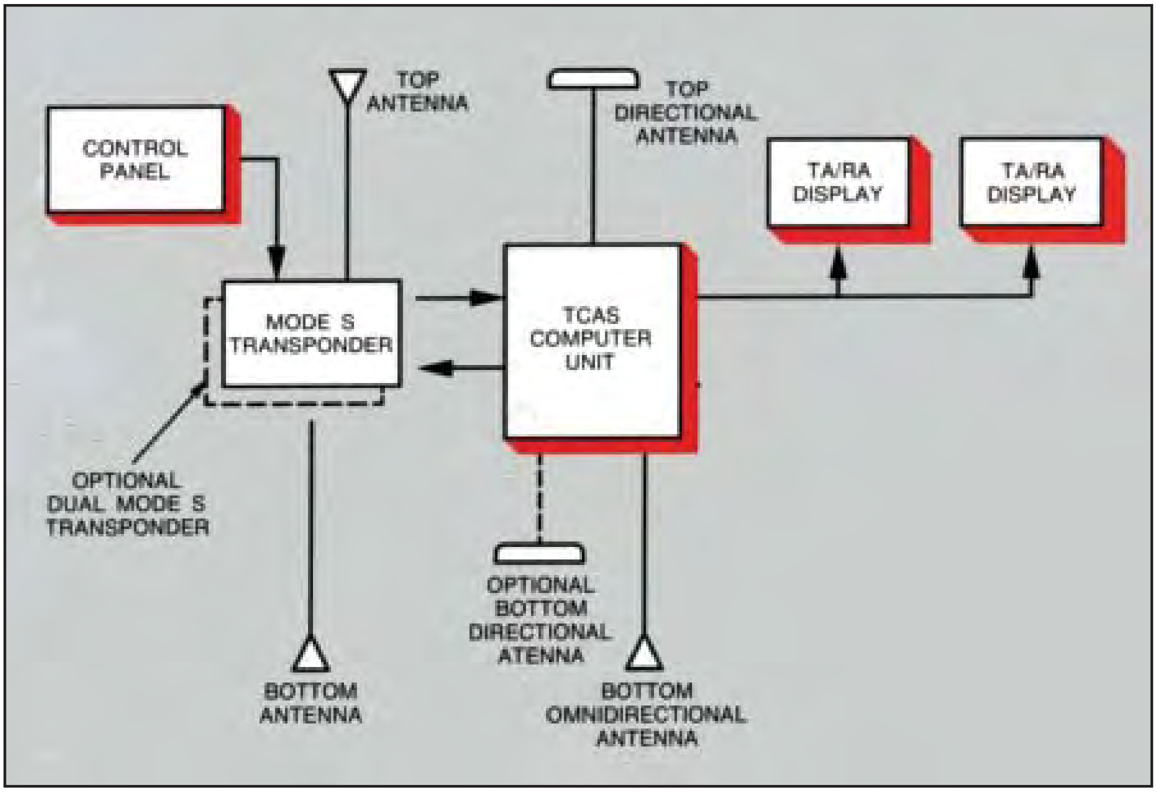
the first systems were fitted to aircraft, pilots complained about false alarms (and shut them off). It mostly happened near crowded terminals and at low altitude. The technical committee responsible for TCAS responded with software upgrades ("Changes") that address each complaint. The performance of TCAS is now so effective, the FAA ruled that if a pilot receives a clearance from a controller that conflicts with TCAS, the pilot must obey the TCAS. In 2002 a pilot ignored that procedure and caused a mid-air collision 35,000 feet over Europe between an airliner and a cargo plane. Air traffic control had instructed the pilot to descend, while TCAS advised him to climb. All 69 people perished in the collision. Both aircraft had fully functioning TCAS.

## Basic Operation

Once every second, the transponder of TCAS airplane automatically transmits an interrogation. This is similar to the interrogations sent out by air traffic surveillance radar and the frequencies are the same.

If another airplane is within range, its transponder replies to the interrogation. The first airplane measures the time between interrogation and reply to de-

## TCAS System




Honeywell

**Major functions of a TCAS II system. It requires a Mode S transponder to enable two closing aircraft to communicate and determine which direction to fly (up or down) to avoid a collision. The transponder often uses a top and bottom antenna on the aircraft to assure full coverage above and below.**

**The computer processes large amounts of information; transponder replies of other aircraft, target tracking, threat assessment, visual and aural advisories, escape maneuvers and coordinating maneuvers between closing aircraft.**

### Traffic and Resolution Advisories

If a collision is possible, TCAS delivers two kinds of warnings

•**Threat Advisory (TA**). This is the less serious of the two. It means another aircraft might be 45 seconds from the closest point of approach (CPA). The pilot sees the TA on a display (shown in the illustration) and becomes aware of the threat.

•**Resolution Advisory (RA)** With this warning the conflict is rapidly growing more serious. The threat aircraft could now be 30 seconds from closest point of approach. TCAS issues a Resolution Advisory, which commands the pilot to climb, descend, remain level or observe a vertical restriction, as shown.

**TCAS I and TCAS II**

There are two versions of TCAS, for large and small aircraft. The full system, TCAS II, is required aboard airliners and large transports with 31 or more seats. In TCAS II, the full collision logic is provided to generate the two types of warnings; TA (threat advisory) and RA (resolution advisory).

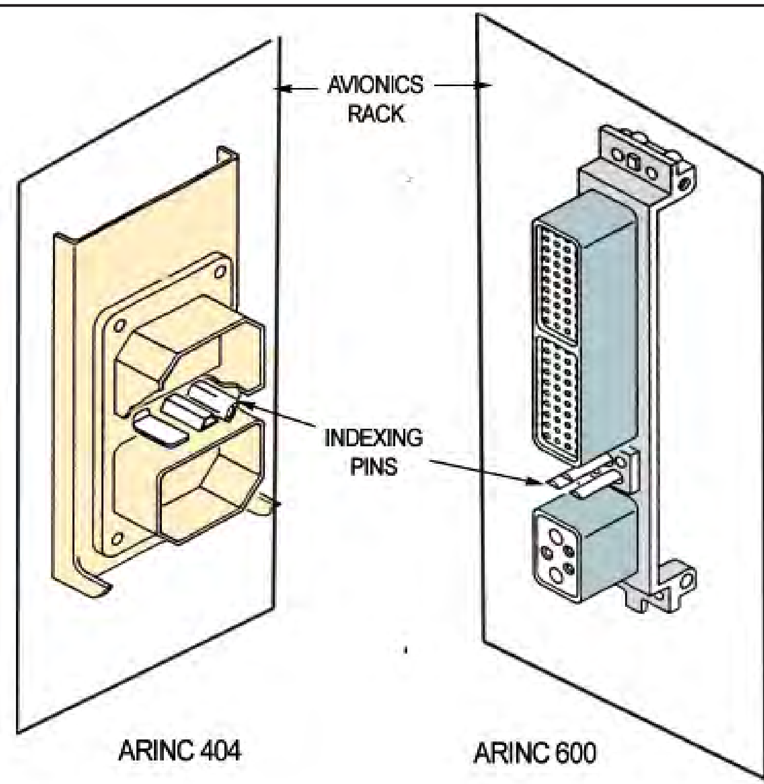
TCAS I is a scaled-down system that issues only TA's (threat advisories). Otherwise, everything is much the same as TCAS II; the symbols, warnings and displays. Lower in cost, TCAS I is designed for corporate, business and light aircraft.

The added complexity of TCAS II is in the collision logic for developing the evasive commands, a more elaborate antenna system, the need for a Mode S transponder and a method of air-to-air communication known as "datalink."

**Coordinating Climb and Descend**

When TCAS issues a Resolution Advisory (RA) it instructs the pilot how to avoid a collision by flying up or down. Obviously, if both aircraft fly toward each other and perform the same =escape maneuver (both fly up, for example) they would collide. This is prevented by "coordination interrogations" transmitted by each aircraft once per second. These are regular transponder signals on 1030 and 1090 MHz, but now used as a datalink to exchange information between aircraft.

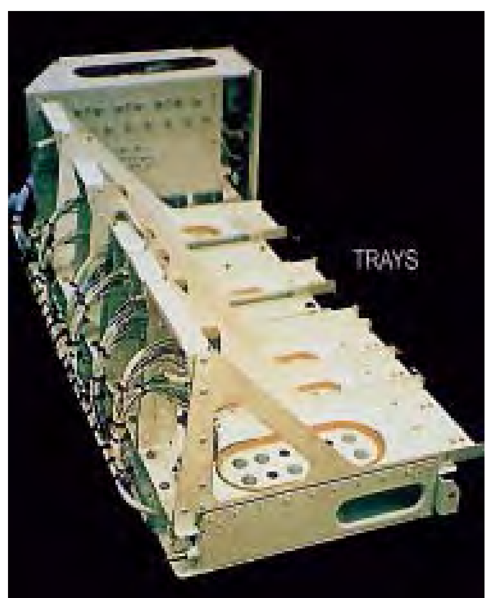
# Indexing Pins Prevent Error




**Different avionic LRU's (line replaceable units) are often housed in cabinets of the same size---which could cause installation error. To prevent it, a connector has an indexing pin at an angle that matches only one LRU. Unless all pins line up with connector holes, the radio cannot be pushed in. To prevent damage, however, avoid forcing a radio into the rack.**

US Technical

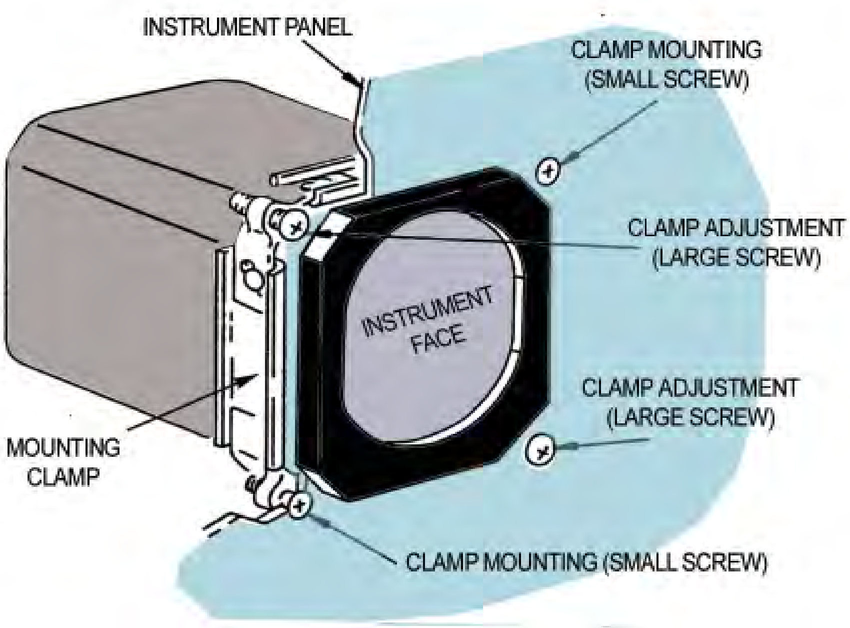
**ARINC trays are designed with variations to accommodate different cooling, connector and radio sizes. The black knobs, which lock in the equipment, have a mechanism which cannot be overtightened and damage the connectors.**




Barry

**Several ARINC trays are often mounted together to form a "rack" (sometimes called an "equipment cabinet").**

# Instrument Mounting



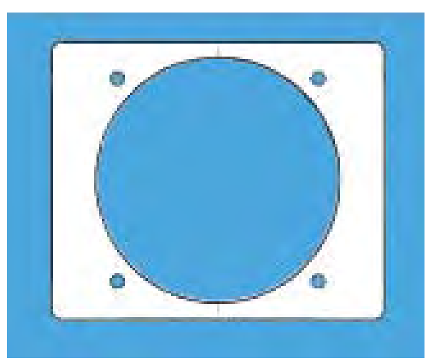

**Instruments like this 3-inch rectangular are often held by a mounting clamp behind the panel. The clamp is slid over the case and two sets of screws are adjusted. Two screws have large heads labelled "Clamp Adjustment". They tighten the clamp around the case. The other pair, labelled "Clamp Mounting," hold the clamp to the back of the instrument panel.**

**Round instruments are installed in similar fashion with a round clamp. However, there are only two screws; one to tighten the clamp on the instrument, the other to hold the clamp to the panel.**

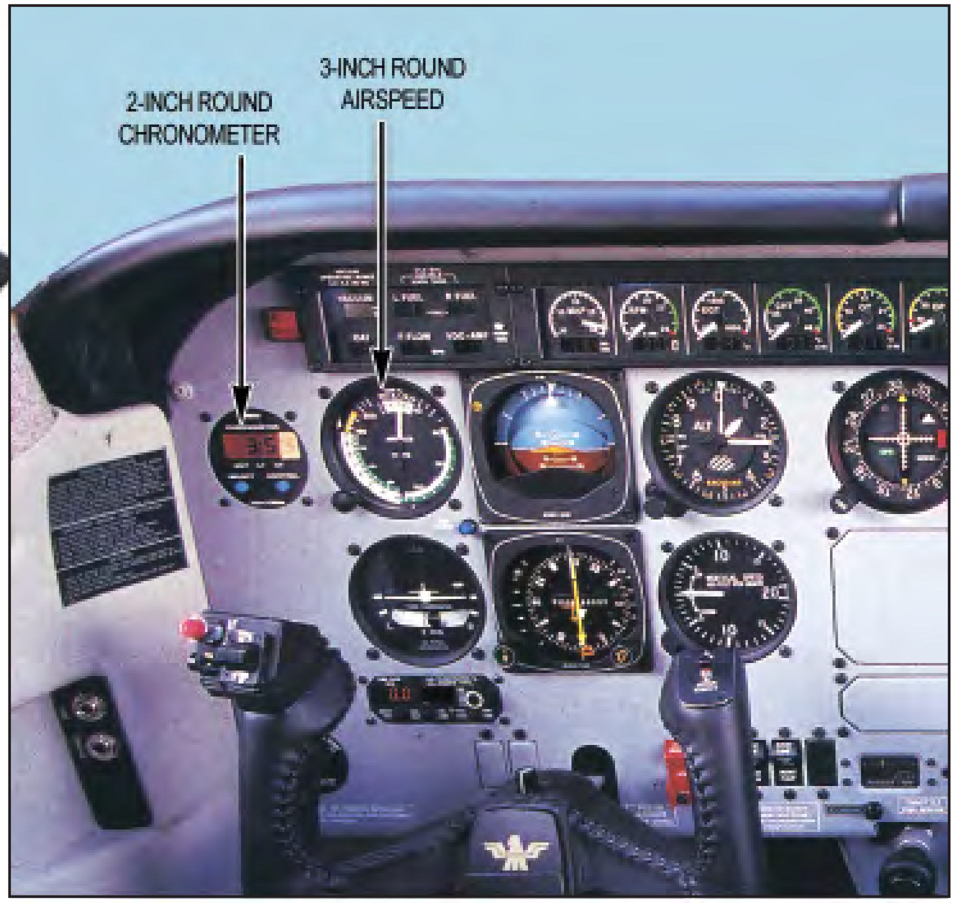
**Some instruments have tapped holes on their cases and need no clamps. Check the manufacturer's literature on using the correct screws. If too long, they can penetrate the case and damage the instrument,**

**Instrument screws are often made of brass, especially when mounting a magnetic compass. As a non-magnetic metal, brass will not cause deviation in the compass.**


**Some instrument cases are fitted with mounting studs, as in this Dynon EFIS display. Four holes are drilled in the instrument panel according to the template (below) supplied by the manufacturer. The large hole receives the instrument case.**



# Round Instruments: 2- and 3-inch

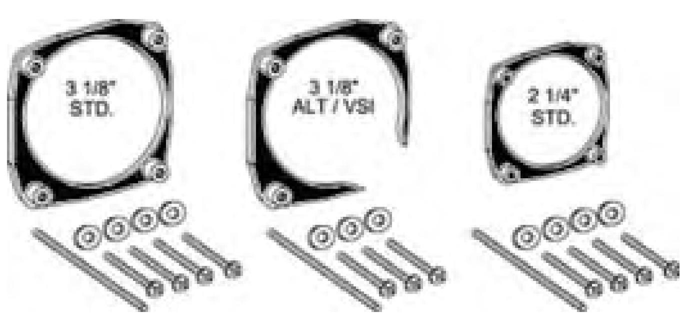



Many flight instruments in General Aviation mount in round holes. The two main sizes are 2- and 3-inch diameters (actually 2-1/4 and 3-1/8-inches).

An example of each is shown in this Mooney panel; a 2-inch chronometer and a 3-inch airspeed indicator.

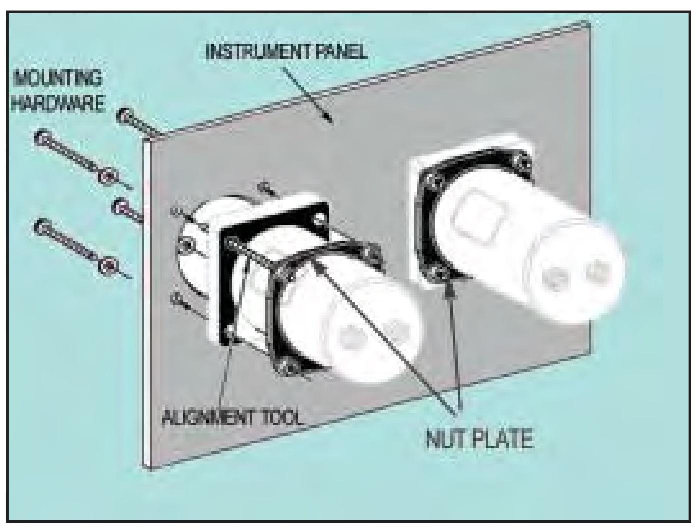
The instruments are held to the panel by four screws, as seen around the instrument face. The screws are held behind the panel by threaded fasteners ("grasshopper nuts"). Because the fasteners are easily lost during installation, there are mounting kits like the one shown below to simplify the job.

## Instrument Mounting Kit




Edmo

"Nut rings" make the installation job easier.They come in standard 2- and 3-inch sizes. There are two versions of the 3-inch; note the one in the center, "ALT/VSI" which has a cut-out at the lower right. This allows space for the altimeter knob after the instrument is installed. ALT is for altimeter, which has a knob adjusted by the pilot (for barometer setting). VSI (vertical speed indicator) has a small screw adjustment for zero'ing the needle.




A nut plate is installed by sliding it onto the back of the instrument. To make it match holes in the panel with holes in the nut plate, the installer inserts an alignment tool through one hole, as shown. It's removed when all holes line up, and mounting screws can be inserted.

# Chapter 27

# Antenna Installation

A light aircraft that occasionally flies on instruments ("light" IFR) typically has these antennas:

| | |
|---|---|
| Com 1 | DME |
| Com 2 | GPS |
| VOR | ADF Loop/ |
| Localizer | ADF sense |
| Glideslope | Marker Beacon |
| Transponder | Emergency Locator |

For low IFR (low ceilings, extended flight in clouds) a well-equipped General Aviation airplane may add antennas for:

Weather detection (Stormscope)
Traffic detection (TCAS I)
Datalink for weather (XM radio, WSI)
Antenna for emergency handie-talkie

Airliners and corporate aircraft carry most of the above, plus antennas for:

Weather radar
TCAS II (collision avoidance)
Satcom (satellite communication)
Radar altimeter
Passenger telephone and entertainment

Not mentioned above is Loran, a popular navigation system that rapidly declined with the arrival of GPS. Loran does not cover the world and suffers interference from precipitation. Loran, however, is still aboard many light aircraft---which means there is a need for replacement antennas. The installation of a Loran antenna is the same as that described for a VHF com.


**Antennas by HR Smith for high-performance aircraft are encased in thermosplastic composite material to resist rain erosion, impact, chemicals and temperature changes.**

In 1971, a system known as Omega provided world-wide long-range navigation. But with the rise of GPS, Omega lasted only until 1997, when its eight global stations were taken off the air. Omega antennas were difficult to install because the airplane had to be "skin-mapped"---tested all over to find an electrically

# Antennas for Airline,Corporate and Military Aircraft

VHF Com, will operate at 100 watts. Has internal duct for hot air de-icing. Used on Boeing, Lockheed and Douglas.

VHF Com with low profile. Has filter to prevent VHF interference to GPS receiving antenna.

Glideslope antenna rated for Cat III (instrument) landing. Used on Gulfstream, Regional Jet, others.

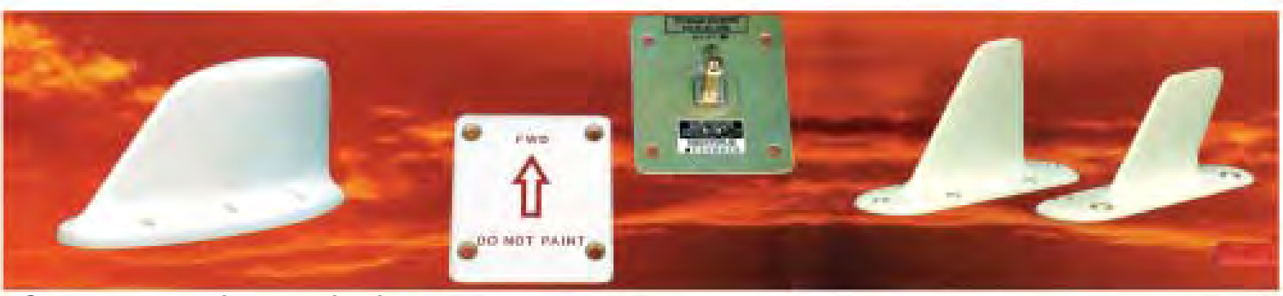
UHF com antenna for military aircraft covers 180-400 MHz. Rated to 70,000 ft and 35 G's

TCAS (collision avoidance) antenna determines direction of target. Arrow shows antenna mountng direction.

Directional antennas for TCAD (collision avoidance) system. Mounts on top and bottom of fuselage.

GPS models may look the same but some have built in preamplifiers to overcome losses in long cable runs

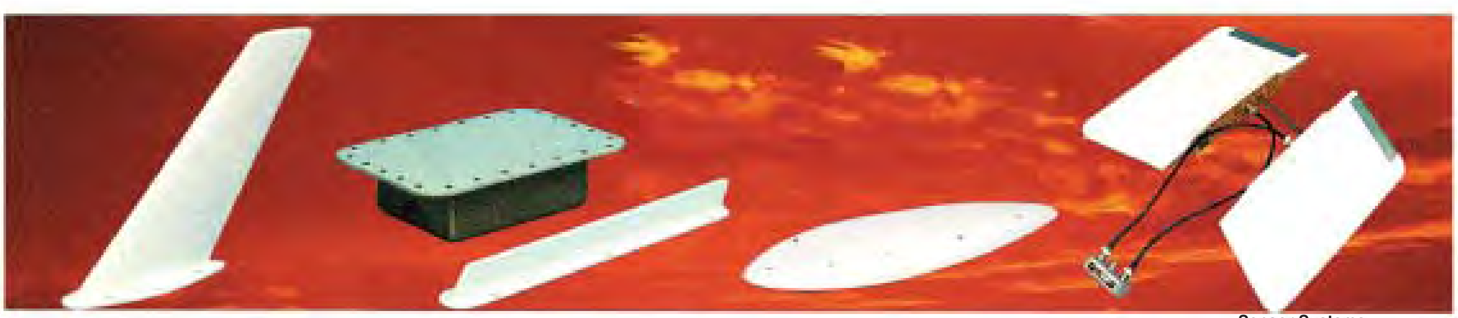
This amplified GPS antenna is aboard Boeing aircraft for GPS reception in multimode receivers.




Satcom antenna for operating in Aero-L and Aero-C bands of INMARSAT satellite. It is a low-gain antenna for moving data on 1.5-1.6 GHz.

Outside and underside views of radio altimeter antenna. Operating on 4200-4400 MHz, it is flush-mounted on belly of aircraft.

Antennas for passenger radiotelephone service operating on 830-900 MHz.



Sensor Systems

VHF-FM com antenna for 140-180 MHz (outside the aviation bands). Provides communications with non-aviation services.

Two different marker beacon antennas (75 MHz). Top one is a flush-mount used on the Boeing 747. Bottom one is low-profile, used on the Boeing 737 and Pilatus.

ADF antenna contains both loop and sense antennas for automatic direction finder. Applications include several Boeing, Douglas and Airbus airliners.

Two blades, known as a "balanced loop," mount on rudder fin to provide VOR, localizer and glideslope reception.

quiet place that would not interfere with the Omega signal.

**Hostile environment**. Aircraft antennas operate under the worst conditions. Sitting on the ramp in Arizona on a summer day, they bake in over 100 degrees F. After the airplane takes off and reaches altitude 15 minutes later, antennas are chilled to 50 degrees F below zero and buffeted by winds over 500 kts. If the airplane flies in clouds at or near the freezing level, ice may form on the antenna. And it's not the *weight* of the ice, but the change in antenna shape that causes "flutter," a vibration that can break the structure. As if that weren't enough, the antenna is mounted on an aluminum fuselage which flexes as the airplane pressurizes. Add such hazards as fluid sprayed on the airplane for de-icing or hydraulic oil in the belly and you can see why antennas require rugged construction and follow-up maintenance.

What goes wrong? Despite the hostile environment, most problems (antenna-makers say) result from poor installation. Materials used by every reputable antenna maker are tested and well-proven. It's the

## How to Read an Antenna Spec Sheet

First, consider the type of aircraft. Catalogs often divide them into such categories as General Aviation, Commercial (business jets), air transport (airline) and military. These categories are divided into type of service; communications, navigation, transponder, DME and others.

In the example shown here, we are seeking a communication antenna for a business jet. Looking down the list of specifications (see numbers in red);

**1. Frequency.** The aviation "com" band extends from 118 to 137 MHz. The band is also called "VHF" or "VHF com."

**2. VSWR.** Meaning "Voltage Standing Wave Ratio," VSWR indicates antenna efficiency. The lower the first number (2), the higher the efficiency. Manufacturers produce antennas with a VSWR usually less than 3.0:1.

**3. Polarization.** VHF com antennas operate with "vertical" polarization, which helps concentrate signals toward the horizon, rather than angling up to space.

**4. Radiation Pattern.** "Omnidirectional" sends signals in every direction, a requirement because the ground station may be anywhere.

**5. Impedance.** The AC electrical load of the antenna. 50 ohms is standard in aviation. The cable feeding the antenna is also 50 ohms, which produces a correct match to the antenna.

**6. Power.** The amount of radio-frequency power that can be handled by the antenna. Light aircraft transmitters generate about 5 to 10 watts. A transmitter for an airliner or business jet may run 25 watts.

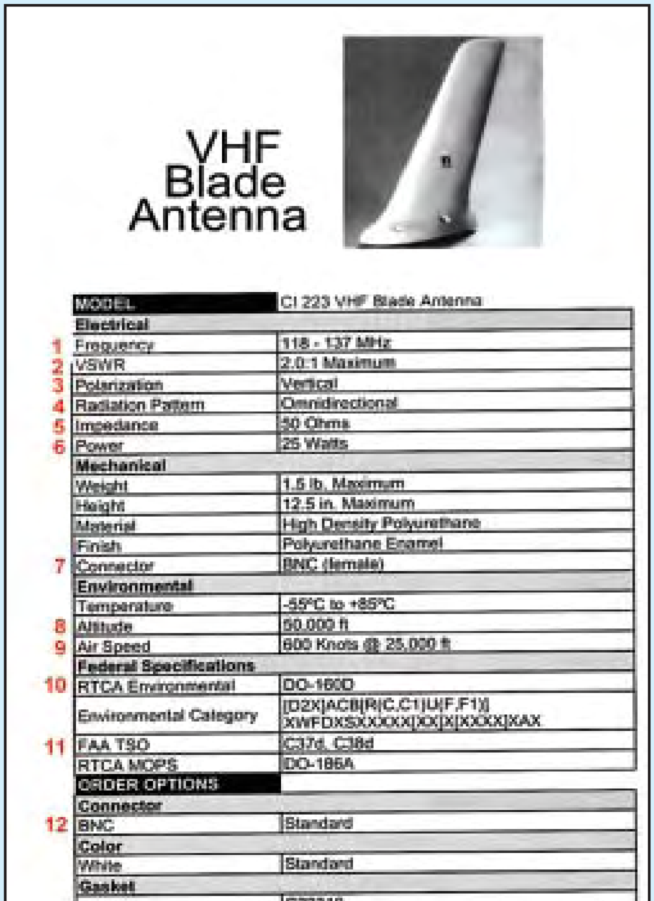
**7. Connector.** Many antenna connectors are the "BNC" (bayonet) type, but be sure the coaxial cable is also fitted with a BNC connector. TNC is also used.

**8. Altitude.** Rated to 50,000 feet, this antenna can operate at altitudes flown by a business jet. (The highest altitude for air traffic control is 60,000 feet.)

**9. Air speed.** The antenna can operate at 600 knots at 25,000 feet. This is accomplished by the "blade" design, which is stronger than narrow whips or rods for slower aircraft. Any requirement above 600 knots would be for military, or aircraft flying at supersonic speeds

**10,11 Certifications**. These ratings mean the antenna will meet environmental and performance standards for this application.

**12. BNC** The antenna accepts the common BNC connector used on most coaxial antenna cables.


VHF Blade Antenna

| | | |
|---|---|---|
| | MODEL | CI 223 VHF Blade Antenna |
| | **Electrical** | |
| 1 | Frequency | 118 - 137 MHz |
| 2 | VSWR | 2.0:1 Maximum |
| 3 | Polarization | Vertical |
| 4 | Radiation Pattern | Omnidirectional |
| 5 | Impedance | 50 Ohms |
| 6 | Power | 25 Watts |
| | **Mechanical** | |
| | Weight | 1.5 lb. Maximum |
| | Height | 12.5 in. Maximum |
| | Material | High Density Polyurethane |
| | Finish | Polyurethane Enamel |
| 7 | Connector | BNC (female) |
| | **Environmental** | |
| | Temperature | -55°C to +85°C |
| 8 | Altitude | 50,000 ft |
| 9 | Air Speed | 600 Knots @ 25,000 ft |
| | **Federal Specifications** | |
| 10 | RTCA Environmental | DO-160D |
| | Environmental Category | [D2X]ACB[R(C,C1)U(F,F1)] XWFDXSXXXXX[XX]X[XXXX]XAX |
| 11 | FAA TSO | C37d, C38d |
| | RTCA MOPS | DO-186A |
| | ORDER OPTIONS | |
| | **Connector** | |
| 12 | BNC | Standard |
| | **Color** | |
| | White | Standard |
| | **Gasket** | |
| | | C22310 |

Comant

installer's responsibility to provide a good location, a secure mounting, a seal against weather and a low-resistance electrical ground to the airframe---all factors covered in this chapter.

### Selecting an Antenna

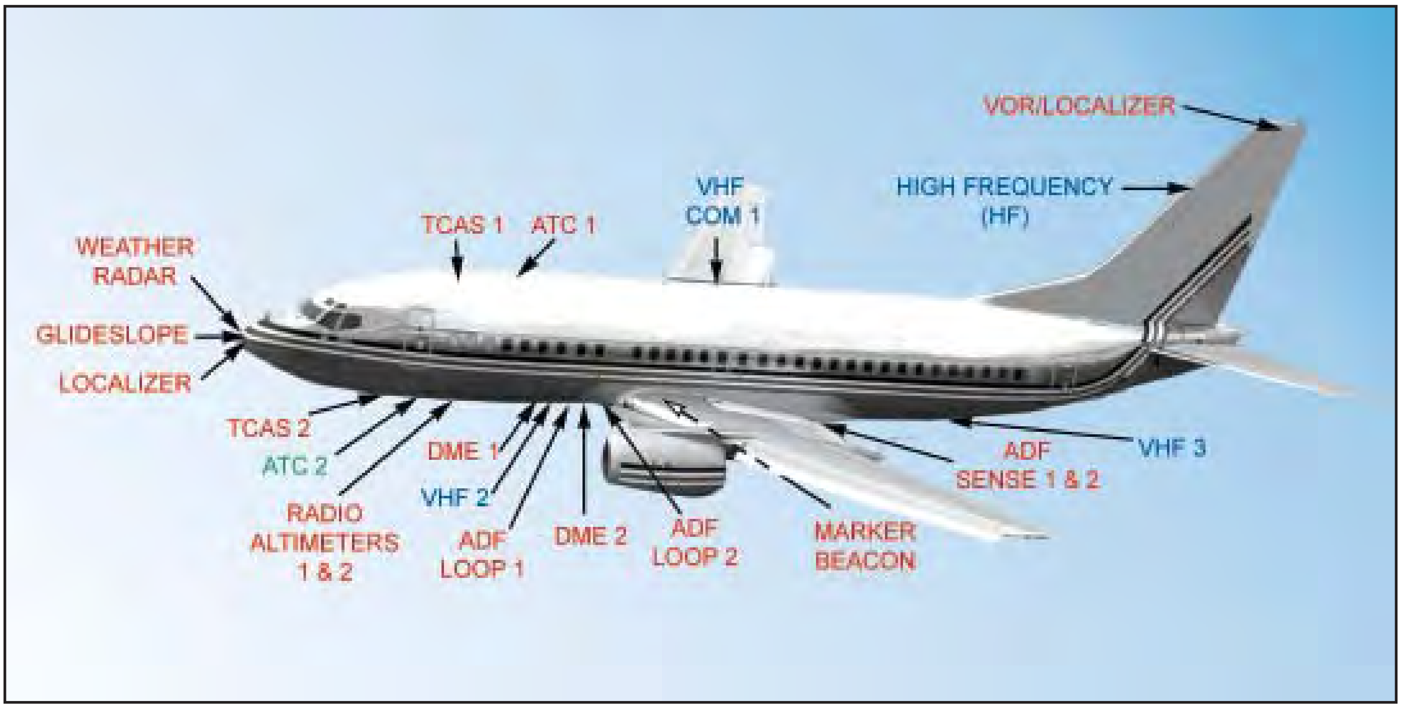
Catalogs on antennas are filled with engineering terms; *isotropic radiator, dB gain, VSWR, impedance,* and more. It is not difficult, however, to choose the right antenna for the job, so long as you select a model from a reputable antenna manufacturer---for example, Comant, Dorne & Margolin, Sensor Systems, RAMI and HR Smith---the antenna should perform as described for its category (airline, military, general aviation, etc.). An explanation of important antenna terms is shown in the table.

An antenna with a "TSO" (Technical Standard Order) assures the antenna was tested to the limit of its specifications. The TSO is not a legal requirement for many installations, but antenna makers obtain this certification as a mark of quality. Business and airline operators usually require it.

Major specifications to know are shown in the table, "How to Read an Antenna Spec Sheet." Consider other details in selecting an antenna:

**Speed.** A dividing line between antennas depends on the speed of the aircraft. For General Aviation look

## Airline Antenna Locations




**Shown above is a Boeing 737. Antennas divide into three categories, often known as CNI, for Communication, Navigation and Interrogation. Navigation antennas are shown in red, communications in blue. The two interrogation antennas (green) are for ATC, which is the airline term for "transponder."**

**Most antennas are dual installations because safety requires two or more radios for each function. Where possible, they are placed at top and bottom of the fuselage for greatest reliability.**

**The two radar altimeters must be at the bottom because they measure the few feet between the airplane belly and runway during a low-visibility landing (Category 2 ILS and higher).**

**In the nose are three antennas protected against weather by a plastic radome. The glideslope antenna in small aircraft is usually on the tail (as part of the VOR antenna). In large aircraft, however, the glideslope antenna is usually in the nose. During an approach, large aircraft pitch up at a high angle of attack, which could cause its wings and fuselage to block glideslope signals arriving from the ground. Putting the glideslope in the nose eliminates that problem.**

**New airline models add several more antennas; GPS for navigation and satellite (for voice and data).**

# Chapter 29

# Test and Troubleshooting

## TCAS Ramp Testing

**Tests to verify and certify a TCAS (Traffic Alert and Collision Avoidance System) can be done outside the airplane. The ramp tester, an IFR Systems TCAS-201, communicates with the airplane via radio signals and simulates different collision conditions. Without connecting directly into airplane systems it measures signal power, frequency, interrogations and replies. The tester is programmable to perform ten different collision scenarios.**

The first step in troubleshooting an avionics problem is when the pilot describes the complaint to the technician, or fills out a squawk sheet. The quality of these reports often means the difference between a quick fix or wasted hours looking for trouble.

The typical pilot squawk is often brief, such as "My number 1 com doesn't work." This gives few clues and is only the starting point to ask questions to narrow the problem. The pilot knows much more than he thinks---if the technician asks well-placed questions.

Here are suggestions to make the diagnosis go faster. Frame your questions to learn the conditions surrounding the failure (we'll use the com as an example):

Does the problem affect *both* transmit and receive?

Does the problem happen in all directions?

Does it occur over both high and low terrain?

If there are two navcoms, are both transmitters affected?

Is communicating distance affected by the weather?

Is the problem worse during taxi and takeoff, then improves while cruising?

Have you tried a different microphone?

When was the most recent repair to any avionics equipment?

Answers to specific questions like these can narrow down the faulty area.

### Technical Terms

Be certain you and the pilot are talking about the same thing. For example, one pilot said "My speaker doesn't work,"---but pointed to his *microphone*. To

# Index