CHAPTER 2

NAVIGATION

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

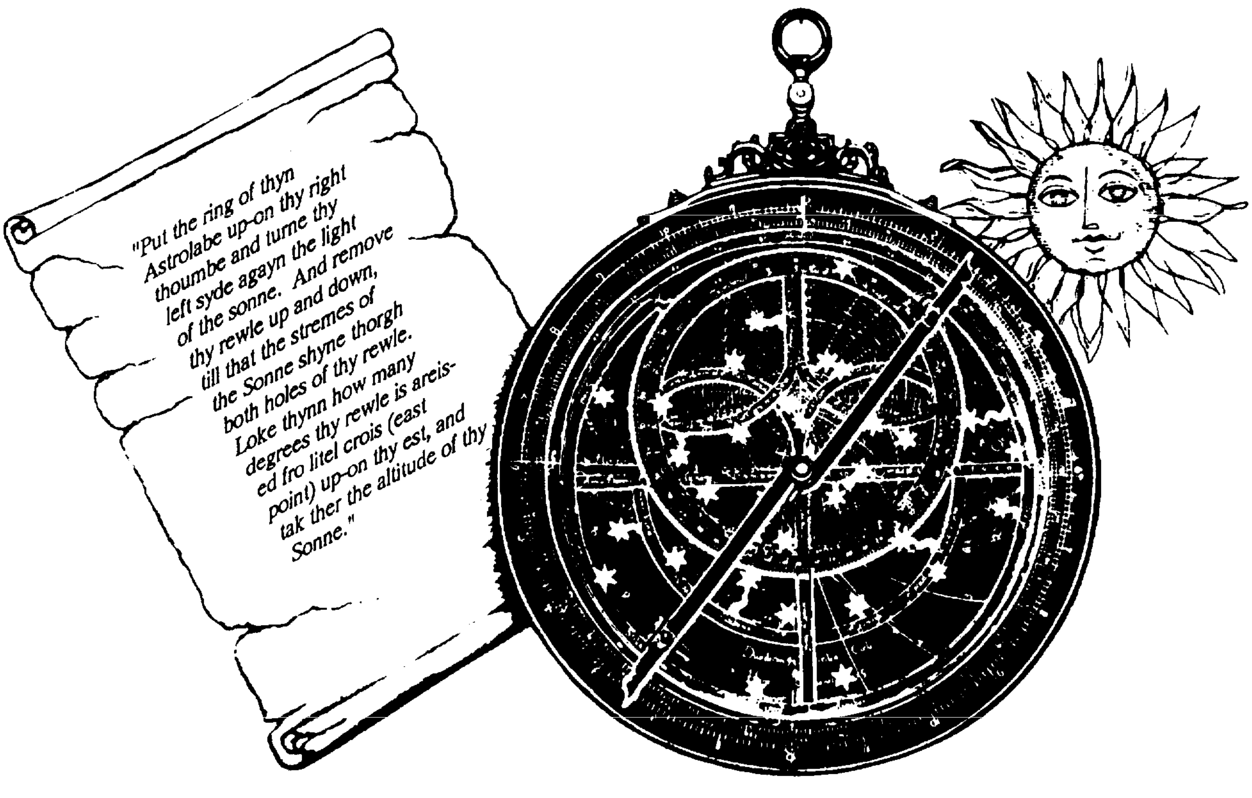
- Need for continued motion. A ship can stop and resolve any uncertainty of motion or wait for more favorable conditions if necessary. Most aircraft must keep going.

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

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

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

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



"Put the ring of thyn Astrolabe up-on thy right thoumbe and turne thy left syde agayn the light of the sonne. And remove thy rewle up and down, till that the stremes of the Sonne shyne thorgh both holes of thy rewle. Loke thynn how many degrees thy rewle is areised fro litel crois (east point) up-on thy est, and tak ther the altitude of thy Sonne."

Figure 2-1.-The ancient astrolabe.

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

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

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

METHODS OF NAVIGATION

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

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

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

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

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

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

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

EARTH'S SIZE AND SHAPE

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

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

Great Circles and Small Circles

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

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

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

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

Latitude and Longitude

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

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

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

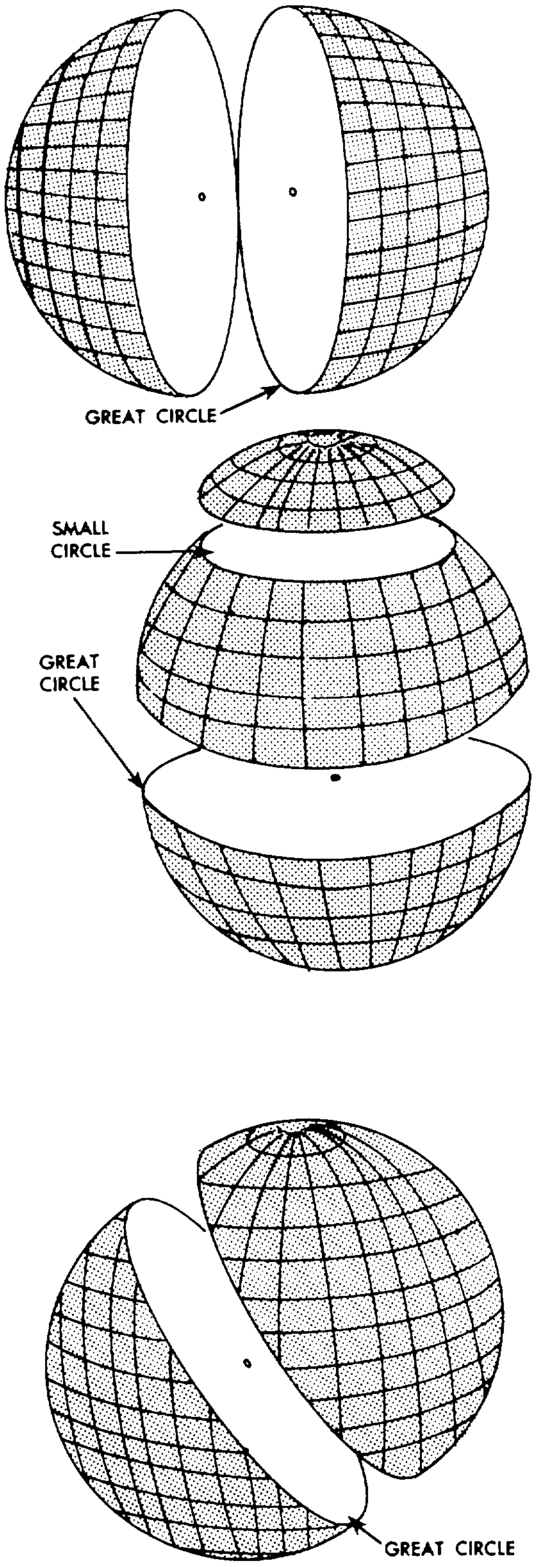


Figure 2-2.-A great circle is the largest circle in a sphere.

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

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

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

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

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

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

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

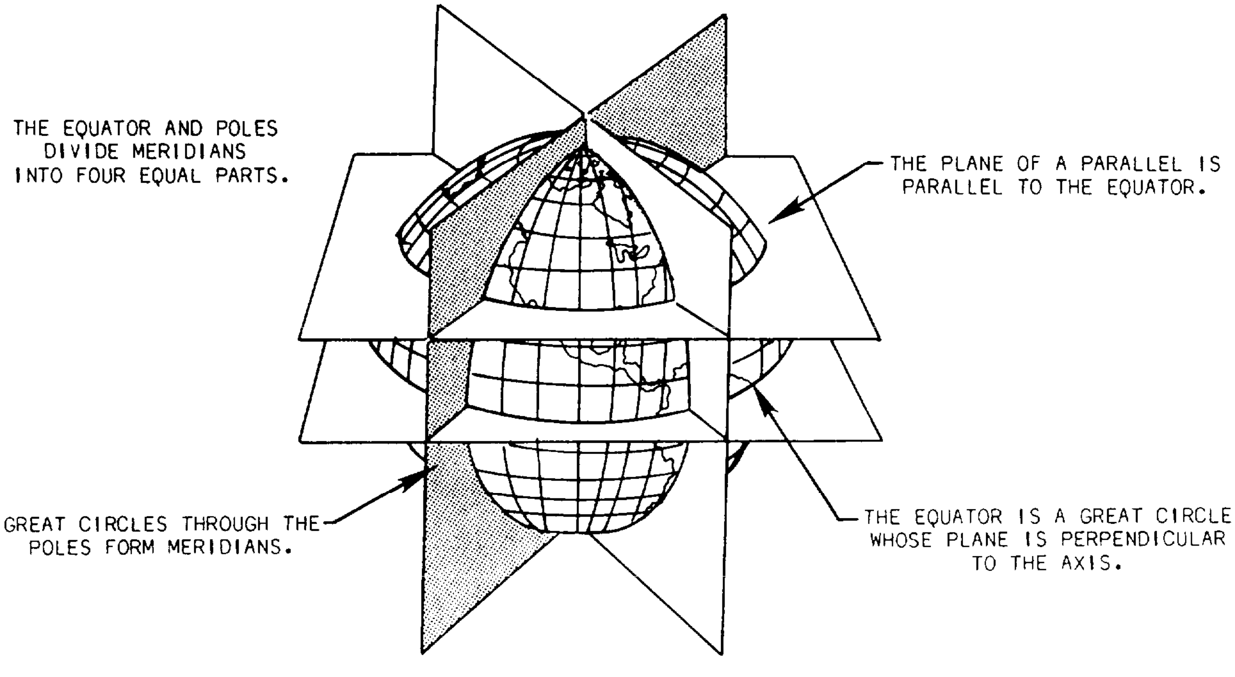


Figure 2-3.-Planes of the earth.

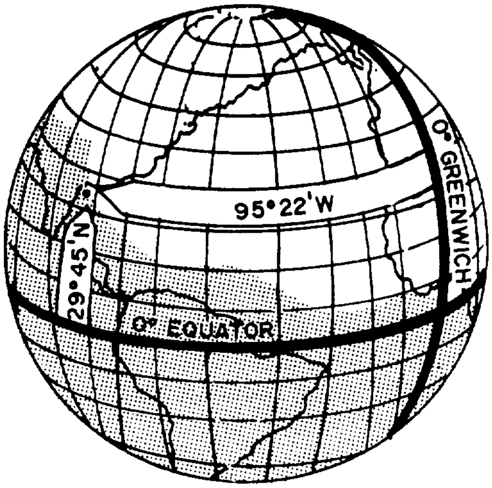


Figure 2-4.-Latitude is measured from the equator; longitude from the prime meridian.

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

Distance

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

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

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

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

This means that 1 nautical mile equals 1.15 statute miles.

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

Direction

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

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

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

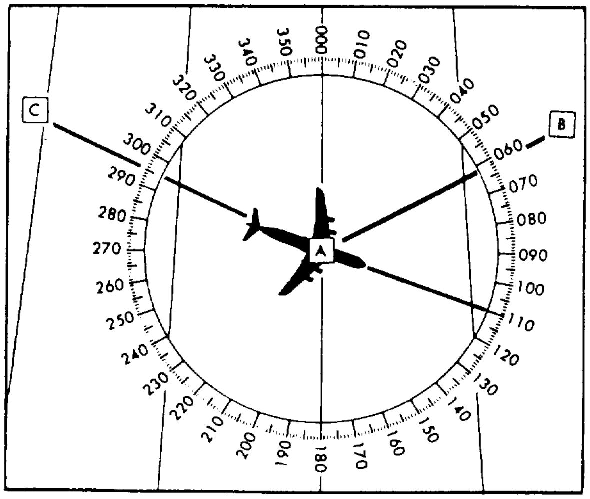


Figure 2-5.-Numerical system used in air navigation.

- Course is the intended horizontal direction of travel.

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

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

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

DEAD RECKONING

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

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

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

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

ELECTRONIC ASSISTED NAVIGATION

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

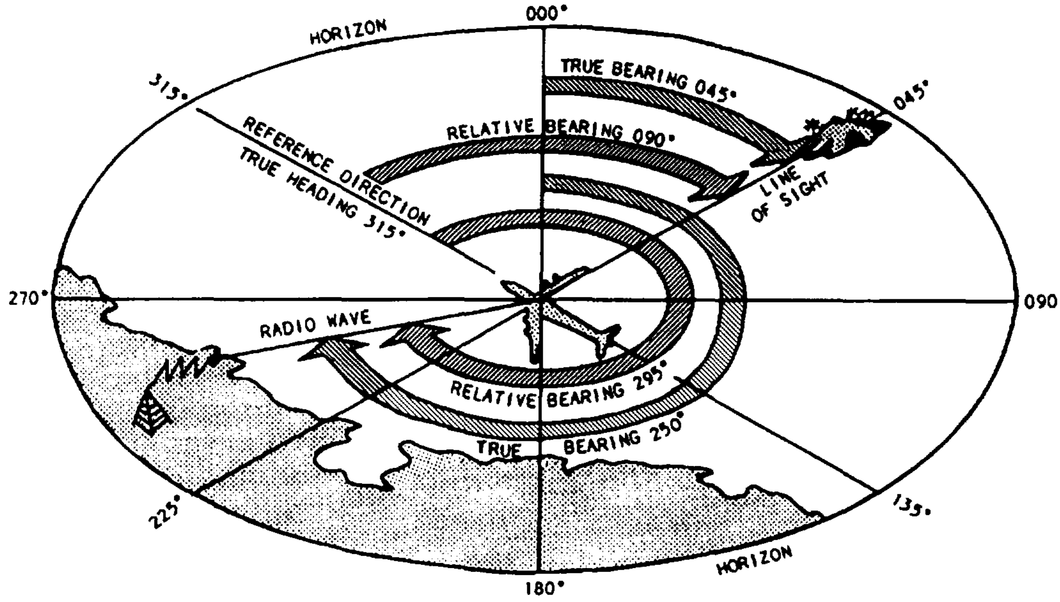


Figure 2-6.-Measuring true and relative bearing.

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

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

AIRBORNE NAVIGATION SYSTEMS

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

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

ALTITUDE AND ALTIMETERS

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

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

Standard Datum Plane

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

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

Figure 2-7.-Standard lapse rates.

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

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

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

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

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

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

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

Pressure Altimeter

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

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

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

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

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

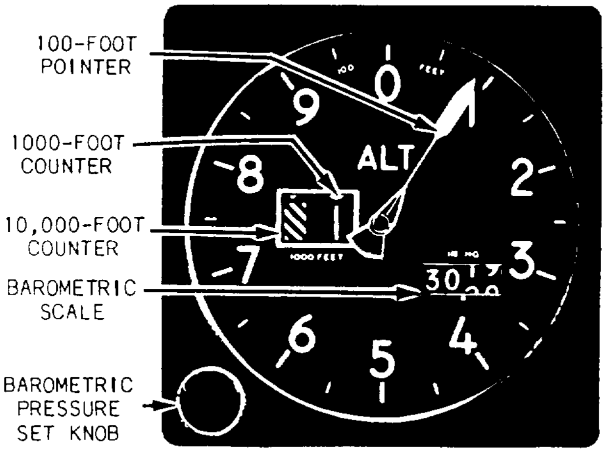

INDICATED ALTITUDE IS 1,090 FEET

Figure 2-8.-Counter-pointer altimeter.

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

CAUTION

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

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

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

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

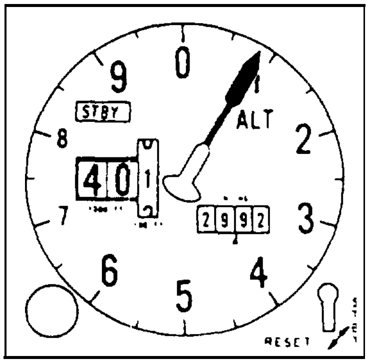


Figure 2-9.-Counter-drum-pointer altimeter.

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

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

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

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

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

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

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

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

Absolute (Radar) Altimeter

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

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

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

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

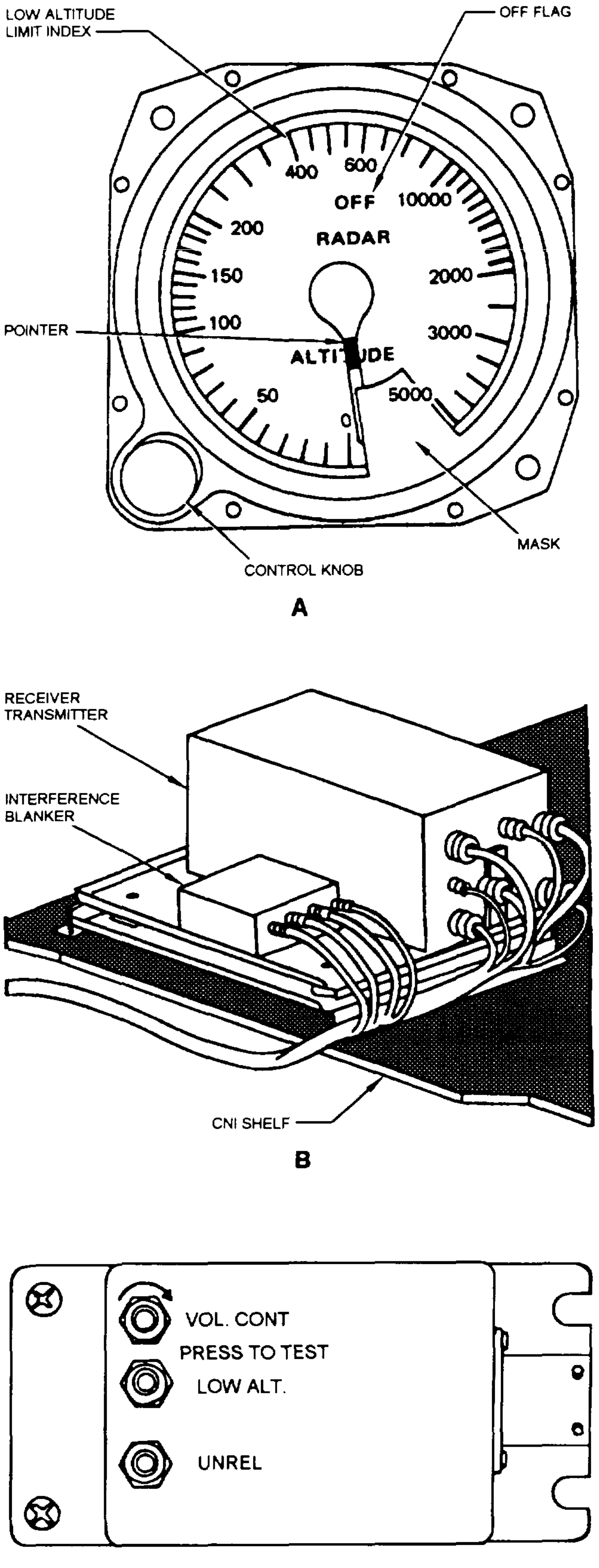


Figure 2-10.-AN/APN-194(V) components. A. ID-1760A/APN-194(V). B. RT-1042/APN-194 (V), MX-9132A/APN-194(V). C. BZ-157A.

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

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

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

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

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

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

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

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

RADAR ALTIMETER WARNING SET

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

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

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

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

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

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

AUTOMATIC DIRECTION FINDER (ADF)

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

Major Components

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

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

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

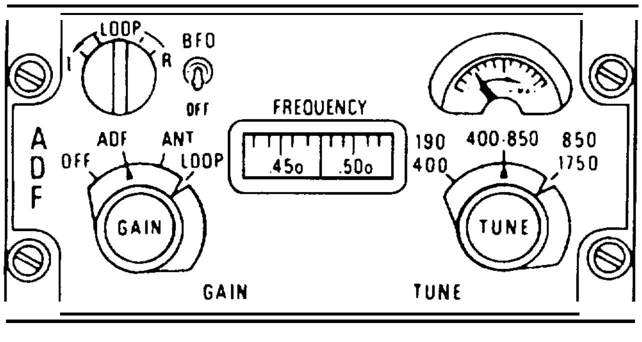


Figure 2-11-Direction finder control panel C-6889/ARN-83.

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

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

Functional Description

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

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

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

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

TACTICAL AIR NAVIGATION (TACAN)

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

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

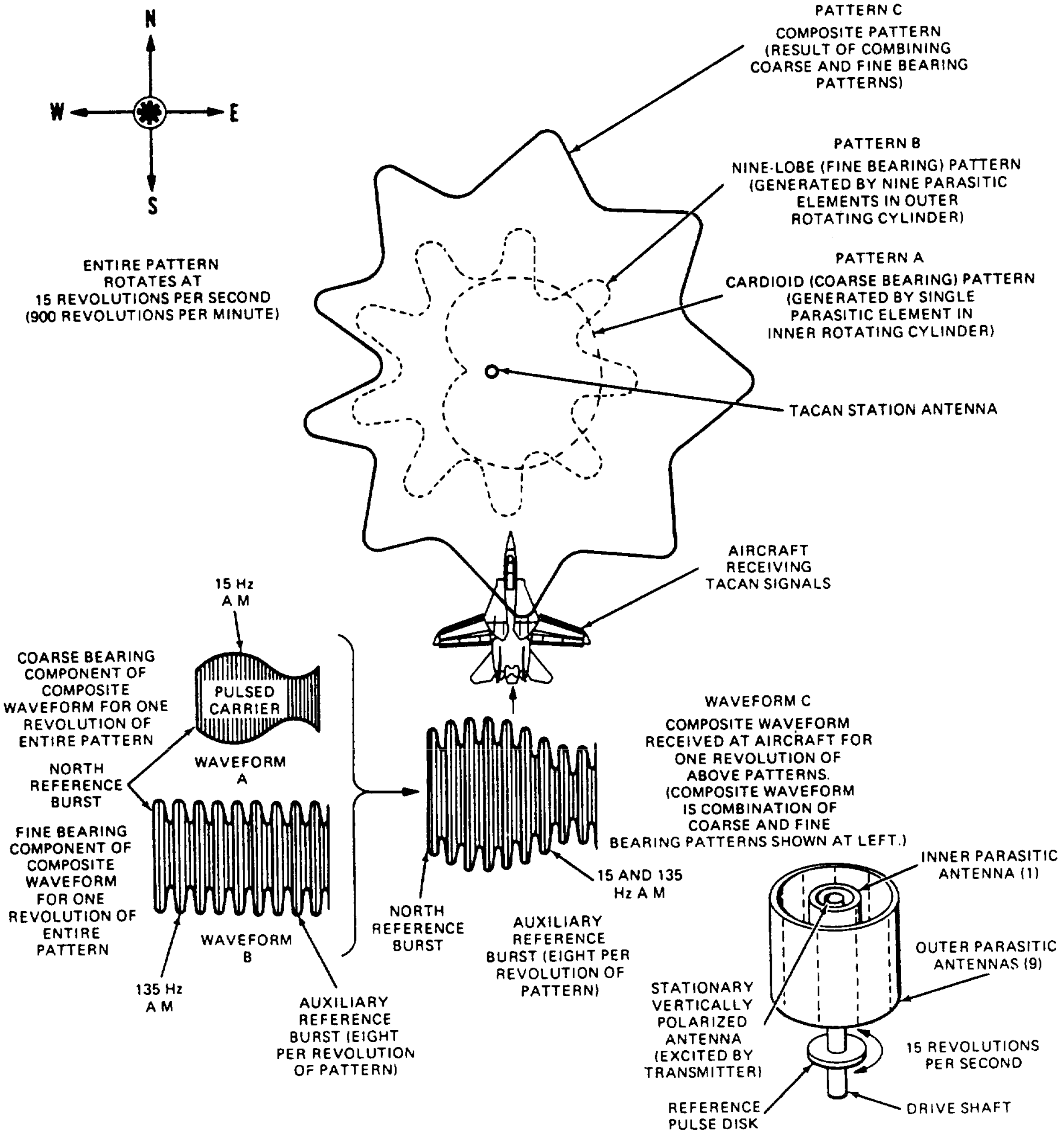


Figure 2-12.-Typical TACAN station bearing antenna and radiation pattern.

Major Components

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

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

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

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

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

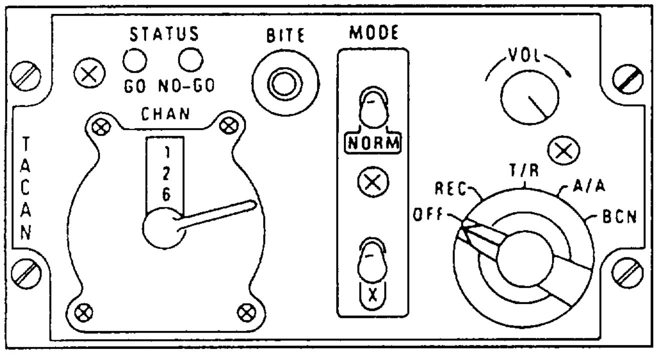


Figure 2-13.-TACAN control panel C-9054/ARN-84(V).

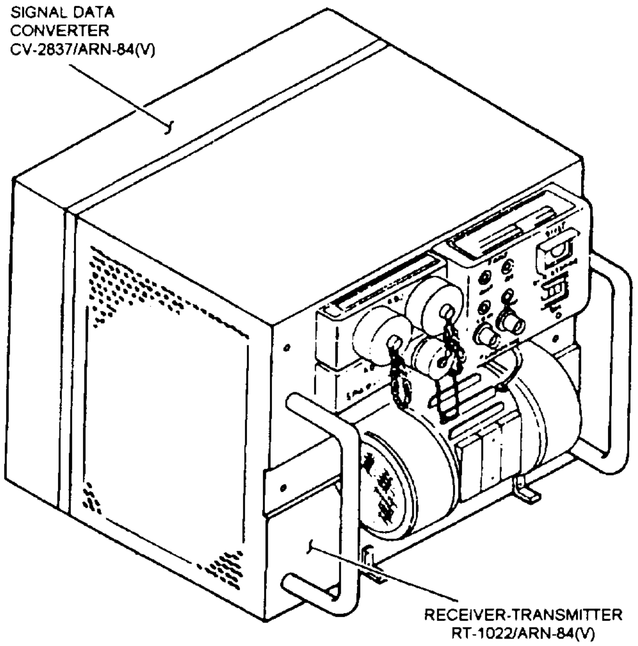


Figure 2-14.-TACAN receiver transmitter and signal data converter.

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

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

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

Operation

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

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

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

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

Self-Test

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

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

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

LONG RANGE NAVIGATION (LORAN)

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

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

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

Major Components

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

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

System Functions

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

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

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

OMEGA

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

Theory of Operation

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

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

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

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

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

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

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

Components

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

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

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

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

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

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

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

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

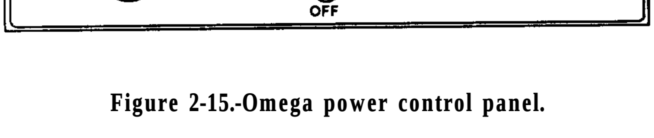


Figure 2-15.-Omega power control panel.

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

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

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

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

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

DOPPLER

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

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

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

Theory of Operation

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

Major Components

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

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

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

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

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

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

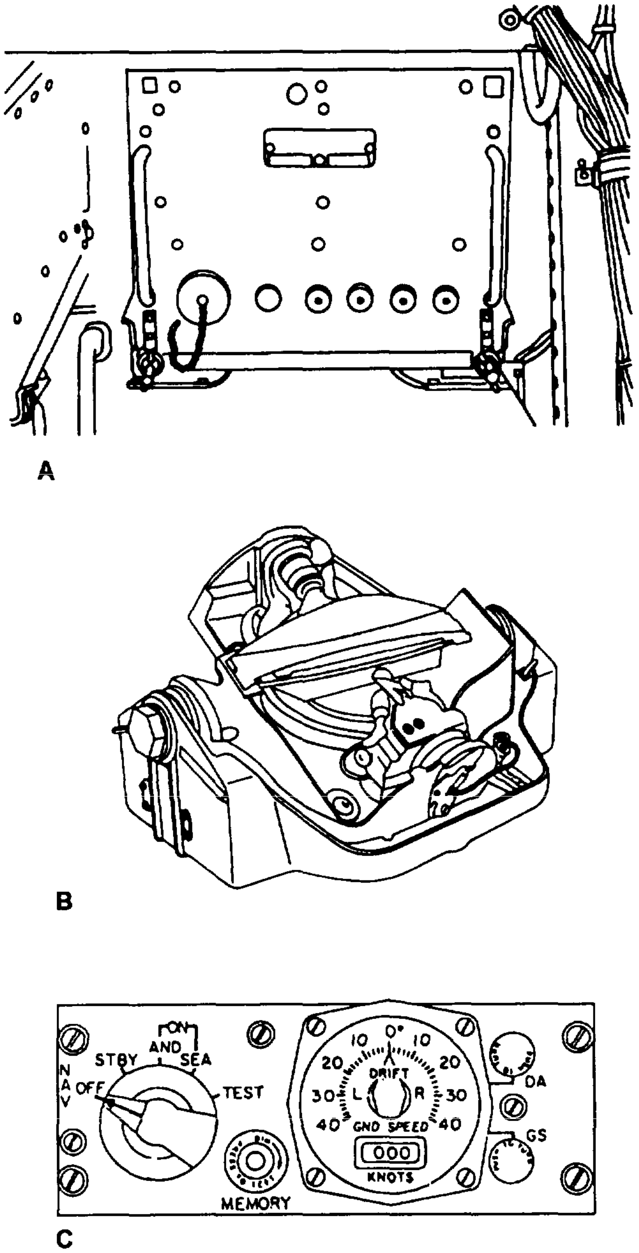


Figure 2-16.-AN/APN-153(V) components. A. RT-680A/APN-153(V). B. AS-1350/APN-153(V). C. C-4418A/APN-153(V).

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

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

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

REVIEW QUESTIONS

Q1. What is the definition of direction?

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

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

Q4. What is the definition of absolute altitude?

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

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

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

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

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

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

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