



**NONRESIDENT
TRAINING
COURSE**



Aviation Electricity and Electronics—Radar

NAVEDTRA 14339

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PREFACE

About this course:

This is a self-study course. By studying this course, you can improve your professional/military knowledge, as well as prepare for the Navy-wide advancement-in-rate examination. It contains subject matter about day-to-day occupational knowledge and skill requirements and includes text, tables, and illustrations to help you understand the information. An additional important feature of this course is its reference to useful information to be found in other publications. The well-prepared Sailor will take the time to look up the additional information.

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CHAPTER 1

RADAR

Possibly one of the greatest inventions to come out of World War II is the radar unit. The term *radar* is derived from the words **R**adio **D**etection **A**nd **R**anging. Radar refers to electronic equipment used to detect the presence of objects and to determine their direction, altitude, and range by means of reflected electromagnetic energy. The development of radar into highly complex systems, as it is known today, is the accumulation of many years of developments and refinements contributed by many people of many nations. While the development of radar dates back many years, the general principles used in the past still apply today.

FUNDAMENTALS OF RADAR

LEARNING OBJECTIVE: Identify the fundamental characteristics of radar to include range, velocity, range measurements, azimuth, and accuracy. In addition, recognize the factors that affect radar performance to include pulsewidth, peak power, beamwidth, receiver sensitivity, and atmospheric conditions.

The word radar applies to electronic equipment used to detect the presence of objects. Radar determines an object's direction, altitude, and range by using reflected electromagnetic energy. The characteristics of radar discussed in this section include the range, azimuth, resolution, and accuracy. Also, some of the factors that affect radar performance will be discussed.

RANGE

Radar measurement of range, or distance, is possible because radiated radio frequency (RF) energy travels through space in a straight line at a constant speed. However, the straight path and constant speed are altered slightly by varying atmospheric and weather conditions.

VELOCITY

RF energy travels at the speed of light, about 186,000 statute miles per second, 162,000 nautical miles per second, or 300 million meters per second. Radar timing is expressed in microseconds (μs); the

speed of radar waves is given as 328 yards or 984 feet per microsecond. One nautical mile is equal to about 6,080 feet. This means that it takes RF energy about 6.18 microseconds to travel 1 nautical mile.

RANGE MEASUREMENT

The pulse radar set determines range by measuring the elapsed time during which the emitted pulse travels to the target and returns. Since two-way travel is involved, a total time of 12.36 microseconds per nautical mile will elapse between the start of the pulse from the antenna and its return from the target. The range in nautical miles can be found by measuring the elapsed time during a round trip radar pulse (in microseconds) and dividing this quantity by 12.36 as shown below:

$$\text{Range} = \frac{\text{elapsed time}}{12.36}$$

Minimum Range

Radar duplexers alternately switch the antenna between the transmitter and receiver so that one antenna can be used for both functions. The timing of this switching is critical to the operation of the radar and directly affects the minimum range of the radar system. A reflected pulse will not be received during the transmit pulse and subsequent receiver recovery time. Therefore, any reflected pulses from close targets that return before the receiver is connected to the antenna will be undetected.

The minimum range of capability of pulse radar is determined by the time of the transmitter pulse, or pulsewidth (PW), plus the recovery time of the duplexer and the receiver. The minimum range (in yards) at which a target can be detected is equal to the PW (in microseconds) plus the recovery time, divided by 2 and multiplied by 328 yards. Stated as a formula:

$$\begin{aligned} \text{Minimum range} &= \text{PW} + \text{recovery time}/2 \times 328 \text{ yd} \\ &= (\text{PW} + \text{recovery time}) \times 164 \text{ yd} \end{aligned}$$

Targets closer than these ranges cannot be seen because the receiver is inoperative for the period of time necessary for a signal to travel this distance. An

increase in recovery time caused by a bad TR tube in the duplexer not only increases minimum range but can also decrease the receiver sensitivity.

Maximum Range

The higher the frequency of a radar wave, the greater the attenuation due to the weather effects. Gases and water vapor that make up the atmosphere absorb energy from the radiated pulse. Frequencies below 3,000 MHz are not appreciably attenuated under normal conditions, while frequencies above 10,000 MHz are highly attenuated. Attenuation of the transmitted pulse results in a decrease in the ability of the radar to produce useable echoes at long ranges. A usable echo is defined as the smallest signal that a receiver-indicator is able to detect, amplify, and present so that the observer can visually distinguish it from noise signal on a radar indicator.

At lower frequencies, higher transmitter power can be developed more easily. Also, there is greater refraction and diffraction (bending of the waves). Therefore, lower radar frequencies are better suited for extremely long-range search radar conditions.

The maximum range of a pulse radar system depends upon transmitted power, pulse repetition frequency (PRF), and receiver sensitivity. The peak power of the transmitted pulse determines what maximum range that the pulse can travel to a target and still return as a usable echo. Sufficient time must be allowed between transmitted pulses for an echo to return from a target located at the maximum range of the system.

AZIMUTH (BEARING)

The azimuth or bearing of a target is its clockwise angular displacement in the horizontal plane with respect to true north as distinguished from magnetic north. This angle may be measured with respect to the heading of an aircraft containing the radar set; in this case, it is called "relative bearing." The angle may be measured from true north, giving true bearing, if the system contains stabilization equipment. The angle is measured by using the directional characteristics of the unidirectional antenna and determining the position of the antenna when the strongest echo is received from the target.

Radar antennas are constructed of radiating elements and reflectors. Some types use a director element to produce a narrow beam of energy in one direction. The pattern produced in this manner permits

the beaming of maximum energy in a desired direction. The transmitting pattern of an antenna is also its receiving pattern. An antenna can be used to transmit energy, receive reflected energy, or both.

RESOLUTION

The range resolution of a radar system is the minimum resolvable separation, in range, of two targets of the same bearing. Range resolution is a function of the width of the transmitted pulse, the type and size of the targets, and the characteristics of the receiver and indicator. With a well-designed system, sharply defined targets on the same bearing should be resolved if their ranges differ by the distance the pulse travels in one-half of the time of the pulsewidth (164 yards per microsecond of PW). For example, if a radar set has a pulsewidth of 5 microseconds, the targets would have to be separated by more than 820 yards before they would appear as two blips on the indicator. The formulas for range resolution and minimum target separation are listed below.

$$\text{Range resolution} = \text{PW} \times 328 \text{ yd}$$

$$\text{Minimum target separation} = \text{PW} \times 164 \text{ yd}$$

The azimuth resolution is the ability to separate targets at the same range but on different bearings, and is a function of the antenna beamwidth and range of the targets. Antenna beamwidth may be defined as the angular distance between the half-power points of an antenna's radiation pattern. (Half-power points are those points at which the transmitted power is one-half the maximum value that is radiated along the lobe center.) Two targets at the same range, in order to be resolved as being two targets instead of one, must be separated by at least one beamwidth. Strong multiple targets appearing as one target can often be resolved by azimuth (bearing) by reducing the gain of the receiver until only the strongest portions of the echoes appear on the indicator.

ACCURACY

The accuracy of a radar unit is a measure of its ability to determine the correct range and bearing of a target. The degree of accuracy in azimuth is determined by the effective beamwidth and is improved as the beamwidth is narrowed. On a plan position indicator (PPI), the echo begins to appear when energy in the edge of the beam first strikes the target. The echo is strongest as the axis of the beam crosses the target, but the echo continues to appear on the scope as long as any part of the beam strikes the target. The target appears

wider on the PPI than it actually is, and the relative accuracy of the presentation depends in a large measure on the width of the radar beam and the range of the target.

The true range of a target is the actual distance between the target and the radar unit, as shown in (fig. 1-1). In airborne radar, the true range is called the slant range. The term *slant range* indicates that the range measurement includes the effect of difference in altitude.

The horizontal range of a target is a straight-line distance (fig. 1-1) along an imaginary line parallel to the earth's surface. This concept is important to the radar observer because an airborne target, or the observer's aircraft, need only to travel represented by its horizontal range to reach a position directly over its target. For example, an aircraft at a slant or true range of 10 miles and at an altitude of 36,000 feet above the radar observer's aircraft possesses a horizontal range of only 8 miles.

FACTORS AFFECTING RADAR PERFORMANCE

Many factors or elements affect the operating performance of a radar system. Some of these factors or elements are pulsewidth, peak power, beamwidth, receiver sensitivity, antenna rotation, and atmospheric conditions. Other key factors are the maintenance upkeep and the operator's knowledge of the radar system. The ability to keep the system operating at peak efficiency will also influence the overall capabilities and limitations of the unit.

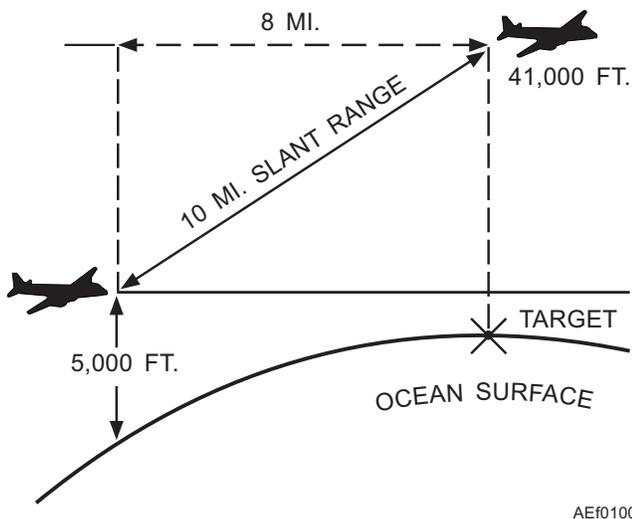


Figure 1-1.—Slant range versus horizontal range.

Pulsewidth

Pulsewidth or pulse duration is the time interval between specific points on the leading edge and trailing edge of a pulse, shown in figure 1-2. The longer the pulsewidth, the greater the range capabilities of the radar. This is due to the greater amount of RF energy present in each pulse. In addition, consider the fact that narrow bandpass receivers can be used, thus reducing the noise level. An increase in pulsewidth, however, increases the minimum range and reduces the range resolution capabilities of the system.

Peak Power

The peak power of a radar unit is its useful power, which is the maximum power of a pulse of RF energy from the radar unit's transmitter, shown in figure 1-2. The range capabilities of the radar will increase with an increase in peak power. Doubling the peak power (a 3-dB gain) will increase the range capabilities by roughly 25 percent.

Beamwidth

The beamwidth is specified in degrees between the half power points in the radiation pattern. The effective beamwidth of a radar system is not a constant quantity, because it is affected by the receiver gain (sensitivity) and the size and range of target.

The narrower the beamwidth, the greater the concentration of energy. The more concentrated the beam, the greater the range capabilities for a given amount of transmitted power.

Receiver Sensitivity

The sensitivity of a receiver is a measure of the ability of the receiver to amplify and make useable a very weak signal. Increasing sensitivity of the receiver increases both the detection ranges of the radar and the radar's ability to detect smaller targets. Sensitive



Figure 1-2.—Pulse of RF energy.

receivers are easier to jam; however, the interference will be more apparent on the indicator.

Antenna Rotation

The more slowly the antenna rotates the greater the detection range of the radar. Thus, an antenna that is not rotating would afford the greatest range in the direction it is pointing, within the limits of the radar. For tactical reasons, it is best not to stop the antenna from rotating and point the antenna beam at the target, except momentarily, and then only to gain information on the composition of the target.

Atmospheric Conditions

Several conditions within the atmosphere can adversely affect radar performance. Normally, the path of radar signals through the atmosphere, whether the paths are direct or reflected, are slightly curved. These signals travel through the atmosphere at speeds that depend upon temperature, atmospheric pressure, and the amount of water vapor present in the atmosphere. Generally, the higher the temperature, the lower the atmospheric pressure; and the smaller the content of water vapor, the faster the signal will travel.

The bending of radar waves due to a change in density of the medium through which they are passing is termed *refraction*. The bending that occurs is indicated by the difference in the index of refraction from one substance to another. The density of the atmosphere changes at a gradual and continuous rate; therefore, the index of refraction changes gradually with increased height.

The temperature and moisture content of the atmosphere normally decreases with height above the surface of the earth. Under certain conditions, the temperature may first increase with height and then begin to decrease. Such a situation is called “temperature inversion.” More important, the moisture content may decrease more rapidly with height just above the sea. This effect is called “moisture lapse.”

Either temperature inversion or moisture lapse, alone or in combination, can cause a large change in the refraction index of the atmosphere. The result is a greater bending of the radar waves passing through the abnormal condition. The increased bending in such a situation is referred to as “ducting,” and may greatly affect radar performance. The radar horizon may be extended or reduced, depending on the direction in which the radar waves are bent. The effect of ducting is illustrated in figure 1-3.

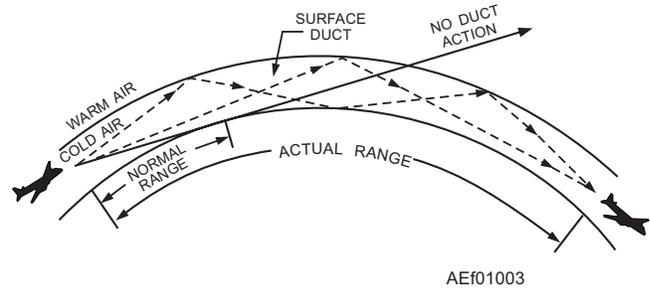


Figure 1-3.—Ducting effect on a radar wave.

Water droplets and dust particles diffuse radar energy through absorption, reflection, and scattering. This leaves less energy to strike the target so the return echo is smaller. The overall effect is reduction in the useable range. Useable range varies widely with weather conditions. The higher the frequency of the radar system, the more it is affected by weather conditions such as rain and or clouds.

- Q1-1. What does the acronym radar mean?
- Q1-2. What is the speed of electromagnetic energy when it travels through air?
- Q1-3. What is the minimum range for a radar system with a pulsewidth of 10.5 μs , which has a recovery time of 0.5 μs ?
- Q1-4. What is the range of target when the elapsed time for the radar pulse to travel to the target and return is 370.8 microseconds?
- Q1-5. What factors determine the minimum range of a pulse radar system?
- Q1-6. The maximum range of a pulse radar system depends upon what three factors?
- Q1-7. Define range resolution of a radar system.
- Q1-8. What effect is achieved by increasing the length of a pulsewidth?
- Q1-9. What term is used to describe the situation in which atmospheric temperature first increases with altitude and then begins to decrease?
- Q1-10. The bending of radar waves due to a change in density of the medium through which they are passing is known by what term?

RADAR CONSTANTS AND TRANSMISSION METHODS

LEARNING OBJECTIVE: Identify basic constants associated with radar and the three major transmission methods.

Although all radar systems operate on the same basic principles, each varies according to its function. Certain constants are associated with any radar. These constants are chosen for a particular radar system, depending on its tactical use, the accuracy required, the range to be covered, the physical size of the system, and the energy transmission methods incorporated.

CARRIER FREQUENCY

Carrier frequency is the frequency at which the electromagnetic energy is transmitted. The principal

factors influencing the selection of a carrier frequency are the desired directivity of the radiated beam, the desired physical size of the antenna, and the generation and reception of RF energy. The antenna should be highly directive to permit the determination of direction and to concentrate the transmitted energy so that a greater amount of it is useful. The higher the carrier frequency, the shorter the wavelength; hence the smaller the antenna system. For example, the carrier frequency for a radar set intended for airborne use has to be fairly high (usually on the order of 10,000 MHz) so that a small reflector can be used. Some ground radar systems use frequencies so low that they must have antenna reflectors more than 100 feet long to attain the desired directivity.

The range of frequencies designated for radar are divided into bands. Table 1-1 lists the frequency ranges and typical usage for each of the bands.

Table 1-1.—Radar frequency bands.

Band Designation	Frequency Range	Typical Usage
A	0 - 250 MHz	Very long range surveillance
B	250 MHz - 500 MHz	Very long range surveillance
C	500 MHz - 1 GHz	Very long to long range surveillance
D	1 GHz - 2 GHz	Long range surveillance, enroute traffic control
E	2 GHz - 3 GHz	Moderate range surveillance, terminal traffic control, long range weather
F	3 GHz - 4 GHz	Long range tracking
G	4 GHz - 6 GHz	Long range tracking, airborne weather
H	6 GHz - 8 GHz	Long range tracking, airborne weather
I	8 GHz - 10 GHz	Short range tracking, missile guidance, marine radar, airborne intercept
J	10 GHz - 20 GHz	High resolution mapping, satellite altimetry (Note: 18 GHz to 27 GHz little use due to H ² O absorption)
K	20 GHz - 40 GHz	Very high resolution mapping, airport surveillance (Note: 18 GHz to 27 GHz little use due to H ² O absorption)
L	40 GHz - 60 GHz	Experimental
M	60 GHz - 100 + GHz	Experimental

PULSE SHAPE AND WIDTH

In typical pulse radar, the shape and width of the RF pulse influences minimum range, range accuracy, and maximum range. The ideal pulse shape would resemble a square wave having very sharp vertical leading and trailing edges.

The factors that determine the minimum range of a system will be discussed first. Since the receiver cannot receive target reflections while the transmitter is operating, it should be evident that a narrow pulse is necessary for short ranges. A sloping trailing edge extends the width of the transmitter pulse, although it may add very little to the total power generated. Therefore, along with a narrow pulse, the trailing edges should be as near vertical as possible.

A sloping leading edge also affects minimum range as well as range accuracy since it provides no definite point from which to measure elapsed time. Using a starting point at the lower edge of the pulse's leading edge will increase minimum range. Using a starting point high up on the slope will reduce the accuracy of range measurements at short ranges.

Maximum range is influenced by pulsewidth and pulse repetition frequency (PRF). Since a target reflects only a very small part of the transmitted power, the greater the transmitted power, the greater the strength of the echo that is received by the radar system. Thus, a transmitted pulse should quickly rise to its maximum amplitude, remain at this amplitude for the duration of the desired pulsewidth, and immediately return to zero to begin the process once again. Figure 1-4 shows the effects of different pulse shapes.

PULSE REPETITION FREQUENCY

Sufficient time must be allowed between the transmitted pulse for an echo to return from any target located within the maximum workable range of the system. Otherwise, succeeding transmitted pulses may obscure the reception of the echoes from the more distant target. This necessary time interval fixes the

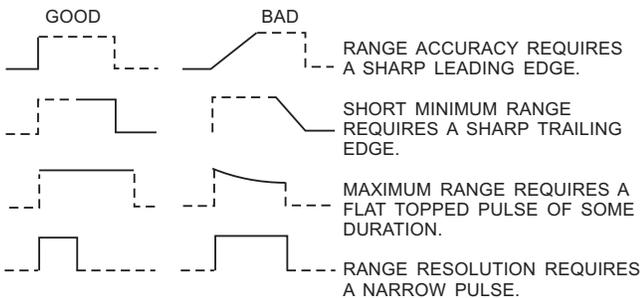


Figure 1-4.—Pulse shapes and effects.

highest frequency that can be used for the pulse repetition. Both maximum and minimum pulse repetition frequencies for any radar set depends on the tactical application required of the system. To reach great distances, the radar must be capable of radiating plenty of power during the transmission of the pulse, and the rest cycle or waiting time must be long enough to allow the radiated pulse to travel well beyond the maximum range of the radar and then return. The time from the beginning of one pulse to the start of the next pulse (this includes the pulse and the waiting time for the return of the same pulse) is the pulse repetition time (PRT), which is the reciprocal of the pulse repetition frequency; that is,

$$PRT = 1/PRF.$$

From this relationship it can be seen that a radar set having a pulse repetition frequency of 400 pulses per second has a pulse repetition frequency of 1/400 second, or 2,5000 μ s. This indicates that as far as PRF is concerned, the maximum range of a radar is the distance a pulse can travel to a target and back in 2,500 μ s. To be useful, radar range expressed in time must be converted to radar range expressed in miles. Since RF energy travels at a constant velocity of 162,000 nautical miles per second (186,000 statute miles), a transmitted pulse will travel 1 nautical mile in 6.18 μ s. Remember that the pulse, to indicate a target 1-mile away, must travel a mile to the target and a mile back to the receiver. The pulse travels a radar mile, which is out to the target and back, and requires 12.36 μ s.

As a general rule, the PRF determines the maximum range of the radar unit. As previously mentioned, the time interval between the transmitted pulse and the return echo from the maximum workable range of a radar determines the highest PRF that can be used by the radar. If the maximum workable range of a radar unit is 200 miles, then the pulse repetition time (PRT) is 2,472 μ s (200 x 12.36 μ s). See figure 1-5. To

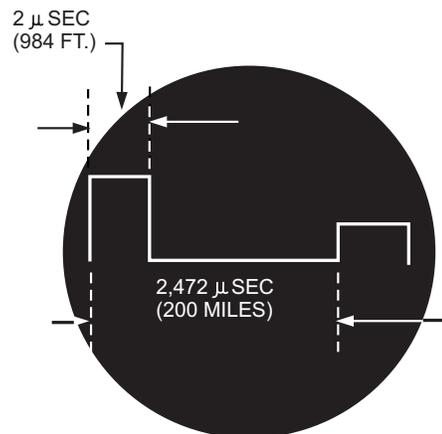


Figure 1-5.—Pulsewidth, pulse repetition time, and range.

obtain this, a PRF of $1 / 2,472 \mu\text{s}$, or approximately 405 pulses per second (PPS) is necessary.

If, for some reason, the pulse of energy should travel farther than 200 miles and be reflected, it would return to the radar after the next pulse is transmitted. An echo from a target 250 miles out would appear at the 50-mile point on an indicator. How can the operator determine if the indication is from a target 50-miles away or from a target 250-miles away that was reflected by the prior pulse? To eliminate ambiguous targets, the operator can use a lower PRF. A PRF of 200 PPS will give a PRT of $5,000 \mu\text{s}$ and a range of about 400 miles; that is, a pulse can travel out approximately 400 miles and return before the next pulse is transmitted. However, a sweep of only 200 miles is used on the indicator since that is the normal workable range. During the additional time, the sweep is blanked out. Any echo returning after $2,472 \mu\text{s}$ and up to $5,000 \mu\text{s}$ is not displayed. The PRF must not be made too low. The speed of the antenna rotation also has an effect on the minimum PRF. The radar beam strikes a target for a relatively short time during a revolution of an antenna. If the antenna rotates at 20 revolutions per minute, it completes a revolution every 3 seconds. During this time the transmitter has fired 600 times if the PRF is 200 PPS. If the beamwidth is 1 degree during its 1 degree of rotation, there will be less than two pulses sent out and echoes returned from a target.

$$\frac{600 \text{ pulses per revolution}}{360 \text{ degrees per revolution}} = 1 \frac{2}{3} \text{ pulse per degree}$$

A sufficient number of pulses of energy must strike the target to return an echo that will be useful at the receiver. If the target is very narrow, the pulse may miss it entirely; and if it is very large, much of it will not show up on the scan.

POWER OUTPUT

Although PRF determines the maximum range of radar, it should be understood that it is also dependent on the power output of the radar system. The radar must radiate enough power so that the received echo signal at the maximum range will have a power level at least equal to the electronic noise in the receiver.

The generating and amplifying of RF energy at extremely high frequencies and very high power levels is primarily determined by the physical construction of the generating device. Some of high power RF generating devices used are the magnetron and klystron. In general these have low interelectrode

capacitance, low transit time, and the ability to handle very high levels of RF power.

In considering power requirements, distinction must be made between the two kinds of output powers. These powers are peak power, which is the power during the transmission of the pulse, and average power, which is the average power over the pulse repetition, illustrated in figure 1-6. While the peak power can be very high, the average power may be very low because of the great differences between pulsewidth and pulse repetition time.

Pulse repetition time is used to figure average power because it defines the total time from the beginning of one pulse to the beginning of the next pulse. Average power (P_{avg}) can be figured as follows:

Where: P_{avg} = average power

P_{pk} = peak power

PW = pulsewidth

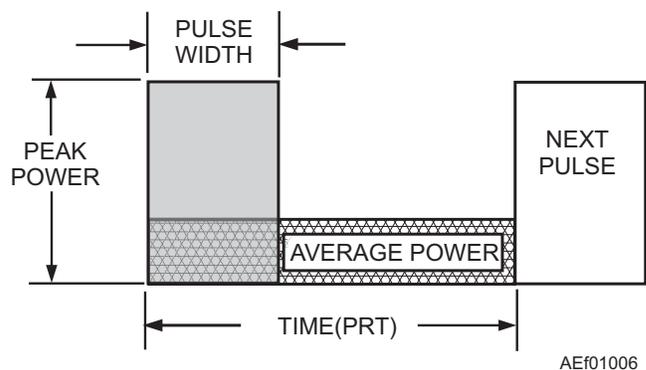
PRT = pulse repetition time

$$P_{avg} = P_{pk} \times PW / PRT$$

Because $1/PRT$ is equal to PRF, the formula may be written as follows:

$$P_{avg} = P_{pk} \times PW \times PRF.$$

The product of pulsewidth (PW) and pulse repetition frequency (PRF) in the above formula is known as the duty cycle of a radar system. The duty cycle is the ratio of the time on PW to the Pulse



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Figure 1-6.—Pulse energy content.

Repetition Time (PRT), as shown in figure 1-7. The duty cycle is used to calculate both the peak power and average power of a radar system. The formula for duty cycle is shown below:

$$\text{Duty cycle} = \text{PW} \times \text{PRF}$$

Since the duty cycle of a radar is usually known, the most common formula for average power is expressed below:

$$P_{avg} = P_{pk} \times \text{duty cycle}$$

Transposing the above formula gives us a common formula for peak power:

$$P_{pk} = P_{avg} / \text{duty cycle}$$

Peak power is usually calculated more often than average power because most measuring devices measure average power directly. An example is shown below:

$$P_{avg} = 10 \text{ kW}$$

$$\text{PW} = 10 \text{ } \mu\text{s}$$

$$\text{PRF} = 1000 \text{ PPS}$$

Before figuring P_{pk} , you must calculate duty cycle as follows:

$$\text{duty cycle} = \text{PW} \times \text{PRF}$$

$$\text{duty cycle} = 10 \text{ } \mu\text{s} \times 1000 \text{ PPS}$$

$$\text{duty cycle} = 0.01$$

Now that you have calculated duty cycle, P_{pk} can be calculated as follows:

$$P_{pk} = P_{avg} / \text{duty cycle}$$

$$P_{pk} = 10 \text{ kW} / 0.01$$

$$P_{pk} = 1,000,000 \text{ watts or } 1 \text{ MW}$$

RADAR DETECTING METHODS

Radar systems are divided into categories based on their energy transmission method. Although the pulse method is the most common method of transmitting RF

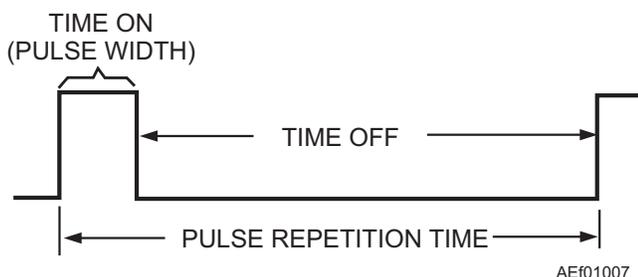


Figure 1-7.—Duty cycle.

energy, two other methods are occasionally used in special applications. These are the continuous wave (CW) method and the frequency modulation (FM) method.

Continuous Wave

The continuous wave (CW) method uses the Doppler effect to detect the presence and speed of an object moving towards or away from the radar. The system is unable to determine the range of the object or to differentiate between objects that lie in the same direction and are traveling at the same speed. It is usually used by fire control systems to track fast-moving targets at close range.

Frequency Modulation

With the frequency modulation (FM) method, energy is transmitted as radio frequency waves that continuously vary, increasing and decreasing from a fixed reference frequency. Measuring the difference between the frequency of the returned signal and the frequency of the radiated signal will give an indication of range. The system works well with stationary or slow-moving targets, but is not suited for locating moving objects. It is used in aircraft altimeters that give a continuous reading of how high the aircraft is above the earth.

Pulse Modulation

With the pulse modulation method, depending on the type of radar, energy is transmitted in pulses. The time interval between transmission and reception is computed and converted into a visual indication of range in miles or yards. Pulse radar systems can also be modified to use the Doppler effect to detect a moving object. Since this method does not depend on the relative frequency of the returned signal or on the motion of the target, it has major advantages over continuous wave or frequency modulation.

Q1-11. A very high radar antenna indicates what type of frequency?

Q1-12. Radar frequency ranges are divided into sections referred to by what term?

Q1-13. The ideal radar pulse shape should have what characteristics?

Q1-14. What part of a radar pulse affects its range accuracy?

Q1-15. What is the reciprocal of PRF?

- Q1-16. What two RF generating devices have low interelectrode capacitance, low transit time, and the ability to handle very high levels of RF power?
- Q1-17. What is the duty cycle of a radar system that has an average power of 2 Megawatts and a peak power of 200 Megawatts?
- Q1-18. What radar transmission method does not depend on target motion or relative frequency of the returned signal?

BASIC PULSE RADAR SYSTEM

LEARNING OBJECTIVE: Identify the general components and functions of a basic airborne pulse radar unit.

Aircraft radar systems, like other complex avionics systems, are composed of several major subsystems and many individual circuits. Basically, all radar systems operate in a similar manner. Since the majority of radars used today are some variation of a pulse radar system, the units that will be discussed in this section will be those used in pulse radar.

BLOCK DIAGRAM OF A PULSE RADAR SYSTEM

Although modern radar systems are highly complicated, you can understand their operation by using a simplified block diagram of a pulse radar system, shown in figure 1-8A. Figure 1-8B shows the timing relationship of waveforms in a typical radar set. The timing trigger pulses are applied to both the transmitter and the indicator. When a trigger pulse is applied to the transmitter, a short burst, or pulse, of RF energy is generated. This energy is conducted along a transmission line to the radar antenna, from which it is radiated into space. If the transmitter energy strikes one or more reflecting targets in its path, some of the transmitted energy is reflected back to the antenna. Echo pulses from three reflecting targets at different ranges are illustrated in the part of the figure 1-8B labeled "Echo pulses." The corresponding receiver output signal is also shown.

The initial and final pulses in the receiver output signal are caused by the energy that leaks through the transmit-receive (TR) device when a pulse is being transmitted.

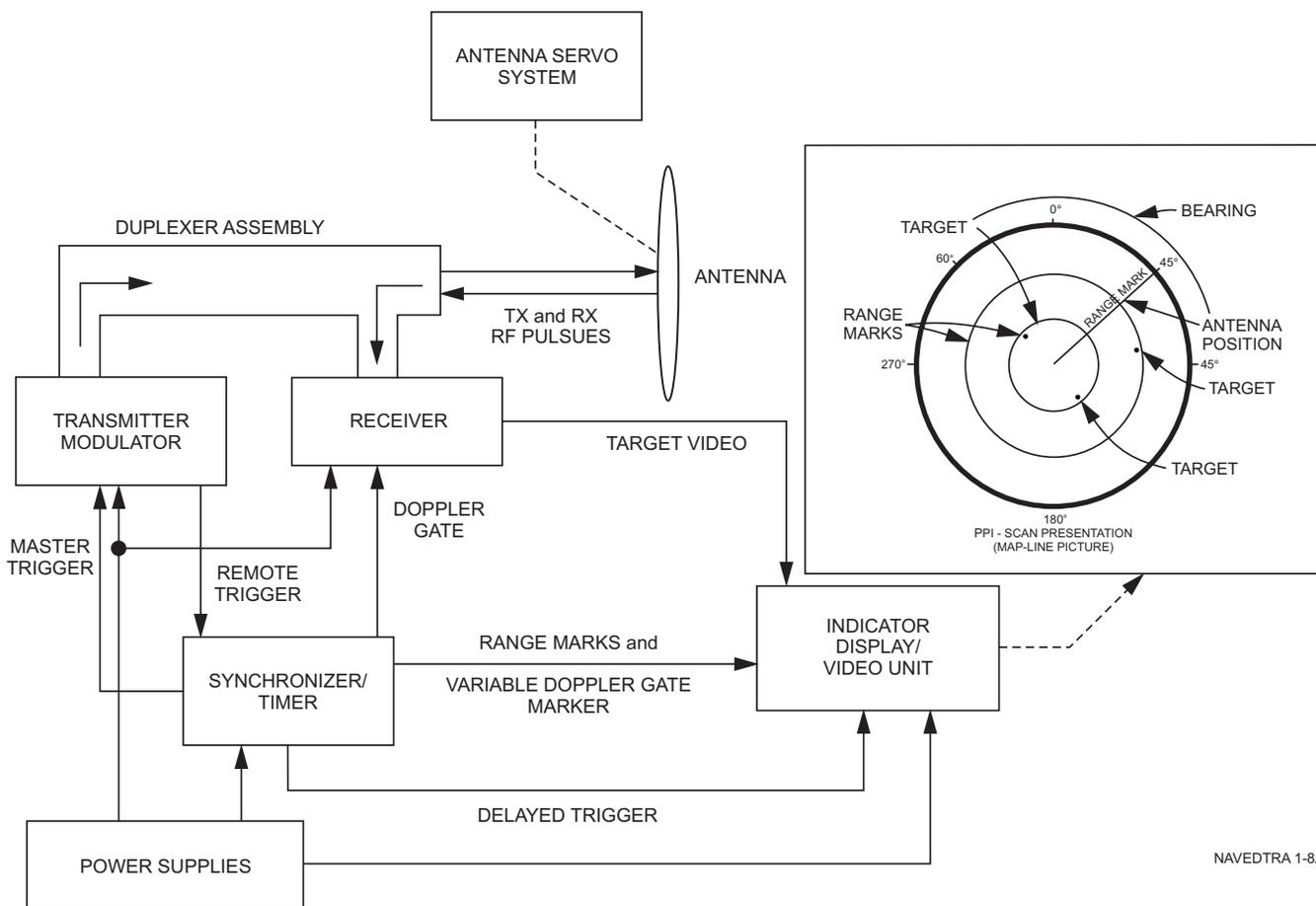


Figure 1-8A.—Block diagram of a pulse radar system with signal flow.

NAVEDTRA 1-8A

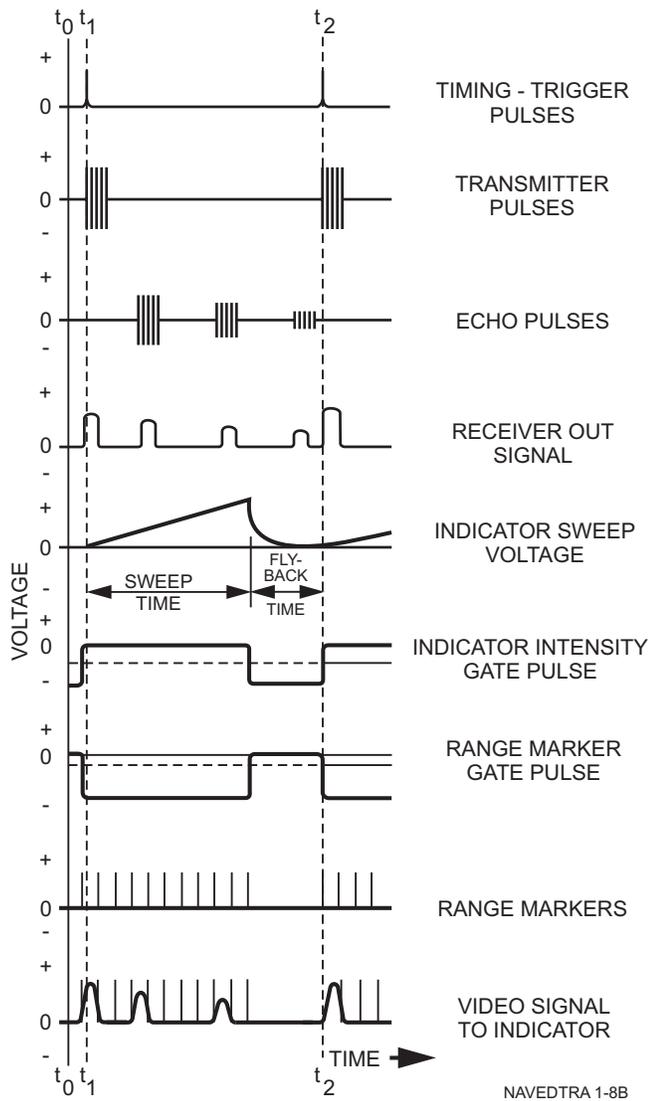


Figure 1-8B.—Typical time relationship of waveforms.

The indicator sweep voltage (fig. 1-8B) is initiated at the same time that the transmitter is triggered. By delaying the timing trigger pulse fed to the indicator sweep circuit, it is possible to initiate the indicator sweep after a pulse is transmitted. (It is also possible to initiate the indicator sweep before a pulse is transmitted.)

Note in figure 1-8B that the positive indicator intensity gate pulse (applied to the cathode-ray tube control grid) occurs during the indicator sweep time. As a result, the cathode-ray tube trace occurs only during the sweep time and is eliminated during the flyback (retrace) time. The negative range marker gate pulse also occurs during the indicator sweep time. This negative gate pulse is applied to a range mark generator, which produces a series of range marks.

The range marks are equally spaced and last only for the duration of the range marker gate pulse. When the range marks are combined (mixed) with the receiver output signal, the resulting video signal applied to the indicator may appear as shown in figure 1-8B, and graphically depicted in figure 1-8A.

Synchronizer

The synchronizer or timer circuitry supplies the pulses of the proper timing to other component parts of the radar. It insures that all circuits operate in a definite time relationship with each other and that the interval between the transmitted pulses is of the proper length. Radar systems may be classified as either self-synchronized or externally synchronized systems. In a self-synchronized system, the timing trigger pulses are obtained from the transmitter. Also, the repetition rate of the timing trigger pulses is determined by the repetition rate of the modulator (or transmitter) pulses. In an externally synchronized system, the timing trigger pulses are obtained from a master oscillator. The master oscillator may be a sine-wave oscillator, a stable (free-running) multivibrator, or a blocking oscillator. In an externally synchronized radar system, the repetition rate of the timing trigger pulses from the master oscillator determines the pulse repetition rate of the transmitter.

Trigger pulses for the timer (synchronizer) are also frequently used to produce gate pulses. When applied to the indicator, these gate pulses perform the following functions:

1. Initiate and time the duration of the indicator sweep voltage.
2. Intensify the CRT electron beam during the sweep period so that the echo pulses may be displayed.
3. Gate a range mark or range marker generator so that range marker signals may be superimposed on the indicator presentation. (The terms *marks* and *markers* are normally interchangeable.) The range marker generator is discussed in the following paragraphs.

In a weapons systems radar that requires extremely accurate target-range data, a movable range marker maybe used. The range marker is obtained from a range marker generator and may be a movable range gate or range step. When a PPI-scope is used, a range circle of adjustable diameter is used to measure range accurately. In some cases, you obtain range readings

from the movement of the range marker by turning a calibrated control dial. In other cases, the range marker may be used as a range gate for automatic range tracking. In this case there may be no direct range readout, or the readout may be a voltmeter calibrated in range and to which range voltage, equivalent to range marker position, is applied. This discussion describes the operation of three types of range markers (generators): the range gate generator; the range marker generator; and the range step generator.

The **range gate generator**, used in conjunction with a blocking oscillator, generates a movable range gate. Figure 1-9 shows a simplified block diagram of a typical radar synchronizer that includes a range gate generator. The indicator is a B-scope with the range deflection voltages applied to the vertical plates. The PRF is controlled by a master oscillator, or

multivibrator, whose output is coupled to a thyatron trigger.

The range gate circuit receives its input pulse from the trigger thyatron and generates a delayed range gate pulse. The delay of this pulse from t_0 is dependent on the position of the target in range when tracking, or on the manual positioning of the range volts potentiometer by the operator when in the search mode. The range gate triggers the range strobe multivibrator, whose output is amplified and sent to the blocking oscillator. This oscillator sharpens the pulses, as shown in figure 1-9. The range gate selects the target to be tracked and, when in track mode, brightens the trace or brackets the target (depending on the system) to indicate which target is being tracked.

The **range marker generator** is used in conjunction with an astable multivibrator to generate

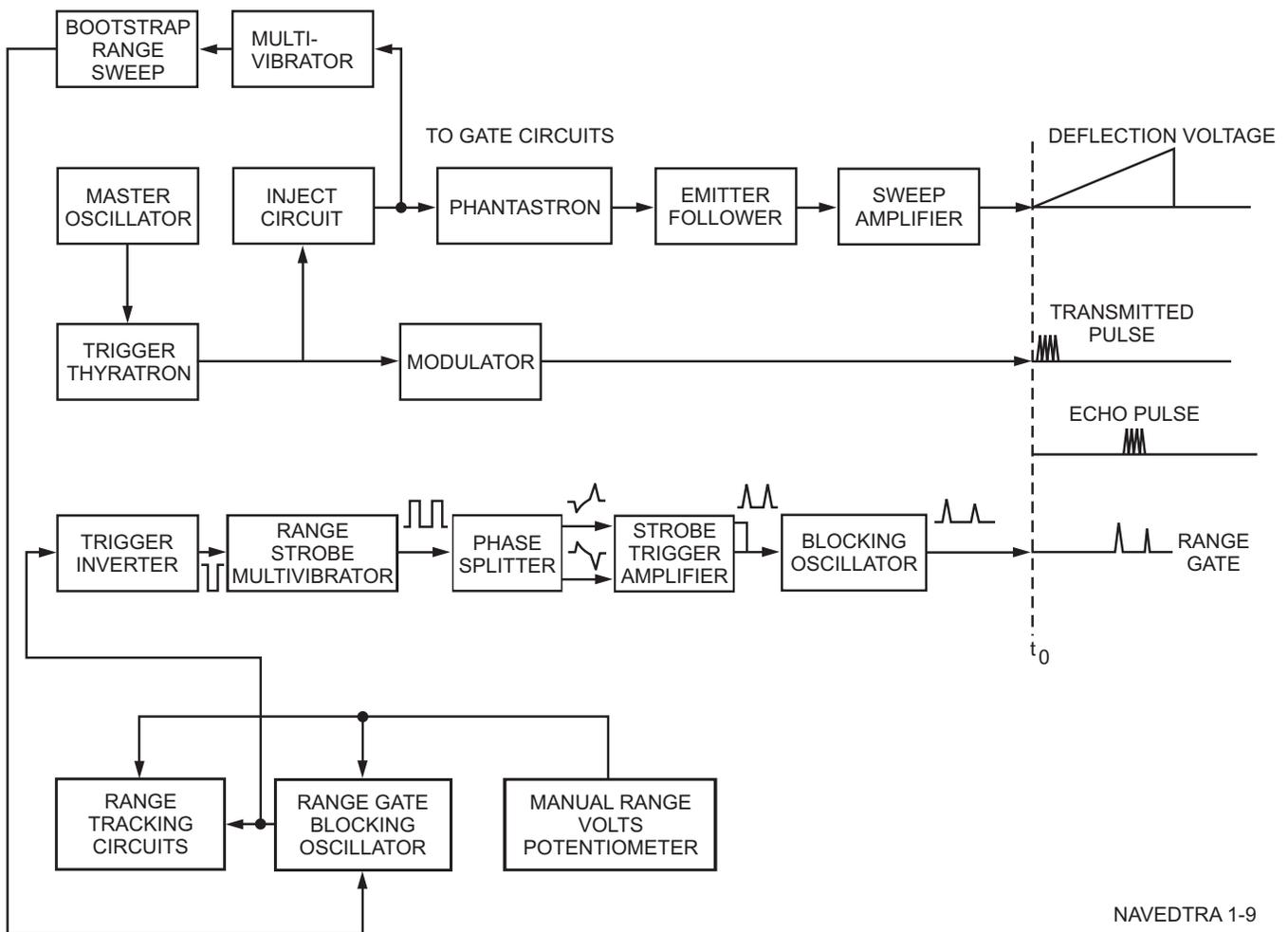


Figure 1-9.—Synchronizer with range gate generator.

fixed range marks. Figure 1-10 is a block diagram of a typical range marker generator. This generator consists of a ringing oscillator Q1611-Q1612, an emitter follower Q1613, a countdown multivibrator Q1616-Q1617, and a pulse-forming amplifier Q1614. Generation of the marks starts at the ringing oscillator, which is excited into operation by incoming trigger pulses. Once in operation, it produces a sinusoidal output, which is synchronized to the trigger pulses. This sinusoidal output is then applied to the emitter follower. This provides interstage buffering by isolating the ringing oscillator from the countdown multivibrator. The output coupling circuit of the emitter follower shifts the average output level to zero (ground) and clips the negative going portions of the signal. This allows only the positive half of each sine wave to reach the countdown multivibrator. The countdown multivibrator receives a high-frequency positive trigger corresponding to a fixed interval. This input drives the countdown multivibrator to develop a negative pulse train. The period of the pulse train is controlled by the range marks select switch. This negative output is applied to the pulse-forming amplifier, where it is reshaped and passed on to a marker mixer. The output of a range marker generator can be applied directly to one of the deflection plates on an A-scope. In this case, range marker pulses appear simultaneously with the radar echo signals, and permit estimation of target range. In B-scope and PPI-scope applications, the output of the range marker generator is applied to a video mixer. In this case, radar echo signals are combined with marker signals before being applied to the grid of the CRT.

The **range step generators**, used in conjunction with an astable multivibrator, generate a movable range step. Figure 1-11, view A, shows the schematic diagram and waveforms of a typical range step generator. The range step generator consists of a sawtooth voltage generator Q1, a negative clipper CR1, and a limiting amplifier. Diode CR1 is frequently referred to as a pickoff diode. The position of the range step along the indicator time base is controlled by

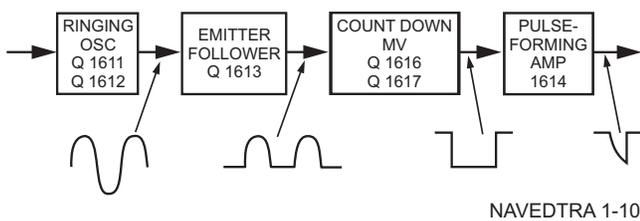


Figure 1-10.—Range Marker Generator.

potentiometer R3. When the range step coincides with the leading edge of a target echo pulse, the target range can be read directly from a calibrated range dial associated with R3. Between times t_0 and t_1 (fig. 1-11, view B), the base of transistor Q1 is at ground potential (zero volts). As a result, Q1 conducts and the Q1 collector voltage (E_1) equals Q1 collector-supply voltage (V_{cc}) minus the voltage drop across the load resistor R1. The horizontal dashed line across the E_1 waveform indicates the E_{R3} voltage (fig. 1-11, view A) at the adjustable tap of potentiometer R3. Since E_1 is less than E_{R3} between times t_0 and t_1 , the anode of the negative clipper CR1 is less positive than the CR1 cathode, and CR1 does not conduct. Hence the CR1 cathode voltage (E_2) equals E_{R3} , the voltage at the R3 tap. Between times and the base of transistor Q1 is driven below cutoff. As a result, Q1 ceases to draw collector current. When no collector current flows in Q1, the capacitor C1 charges through the Q1 load resistor R1, and the collector voltage of Q1 rises exponentially toward the Q1 collector-supply voltage (V_{cc}).

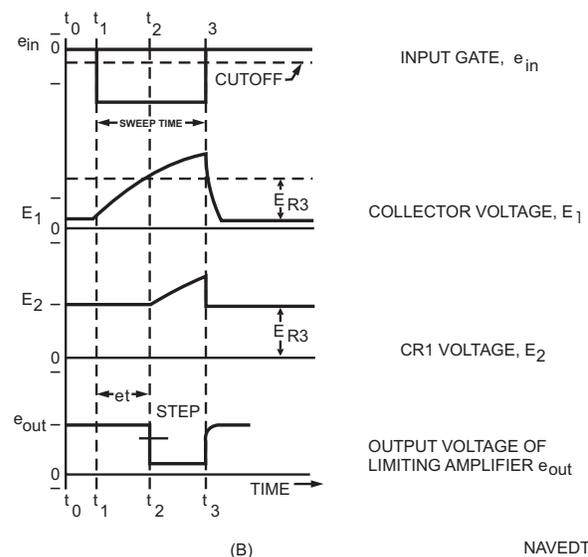
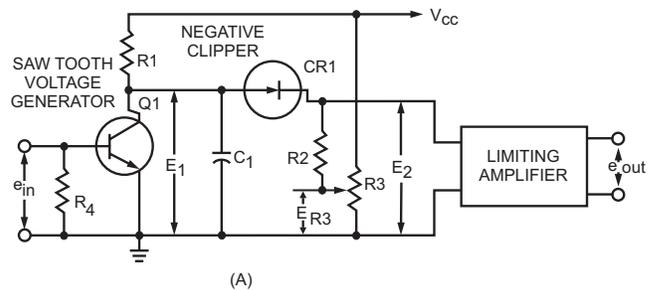


Figure 1-11.—Range step generator with pickoff diode. (A) Schematic diagram; (B) waveforms.

At time t_2 , E_1 exceeds E_{R3} , and diode CR1 conducts. If the CR1 anode resistance is small, the CR1 cathode voltage (E_2) practically equals E_1 between times t_2 and t_3 . Following time t_3 the base of Q1 returns to ground potential, and Q1 again conducts. As a result, capacitor C1 discharges through Q1, and the Q1 collector voltage decays exponentially toward its initial value. As soon as E_1 becomes less than E_{R3} , CR1 no longer conducts, and the CR1 cathode voltage again equals E_{R3} . When the E_z waveform is amplified and limited by the limiting amplifier, the amplifier output-voltage (e_{out}) waveform appears, as shown in figure 1-11, view B. Note that a nearly vertical edge (step) appears in the e_{out} waveform the instant CR1 begins to conduct (time t_2). By varying the setting of the R3 tap, you can vary the instant at which CR1 conducts. You can therefore control the position of the range step by adjusting the setting of R3. If a linear relationship is to be established between the delay of the step (t) and the voltage at the R3 tap (E_{R3}), the Q1 sawtooth collector voltage must be linear. The e_{out} waveform is applied to the vertical deflection plates of a cathode-ray tube. Only the portion of the e_{out} waveform that occurs between times t_1 and t_3 is displayed on the CRT screen. Remember, the indicator trace is blanked out during the flyback (retrace) time.

Modulator

The modulator receives the trigger from the synchronizer and generates a very high dc pulse to drive the transmitter. The Pulse Forming Network (PFN) contained within the modulator, as depicted in figure 1-12, determines the voltage level and width of the pulse. The PFN is a series of inductors and capacitors that produces the nearly rectangular pulse. The peak power of the transmitted (RF) pulse depends on the amplitude of the modulator pulse. A basic radar modulator consists of four parts:

1. A power supply.
2. A storage element (a circuit element or network for storing energy).

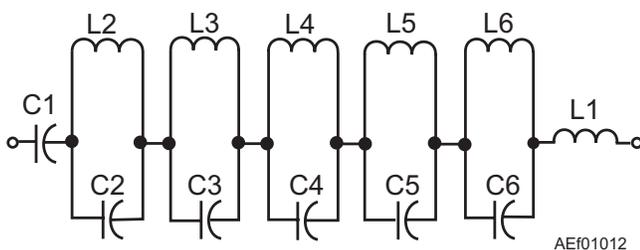


Figure 1-12.—Pulse forming network.

3. A charging impedance (to control the charge time of the storage element and to prevent short circuiting of the power supply during the modulator pulse).
4. A modulator switch (to discharge the energy stored by the storage element through the transmitter oscillator during the modulator pulse).

Transmitter

The transmitter is turned on for the duration of time of the voltage pulse from the modulator. Its output is a pulse of high power RF energy, which occurs at the rate, and the width of the pulse from the modulator. One type of high power RF generator is the magnetron. A cutaway view of a magnetron is shown in figure 1-13.

A magnetron is a diode whose anode is made of a series of resonant cavities. An external magnetic field between the cathode and plate is perpendicular to the electric field. As the electrons are emitted from the cathode, the magnetic field causes them to spiral past the cavities of the plate before they are collected. As the electrons pass the cavities, they cause them to oscillate at resonant frequency determined by the size of the magnetrons cavities.

A major disadvantage of the magnetron is the pulse-to-pulse frequency variation because its frequency stability is dependent on the combination of the magnetic and electrical fields, either of which is subject to variations over short periods of time. Another disadvantage is the physical consideration. The cathode and anode are included in the frequency determining system, and are a compromise between desired power output and required size.

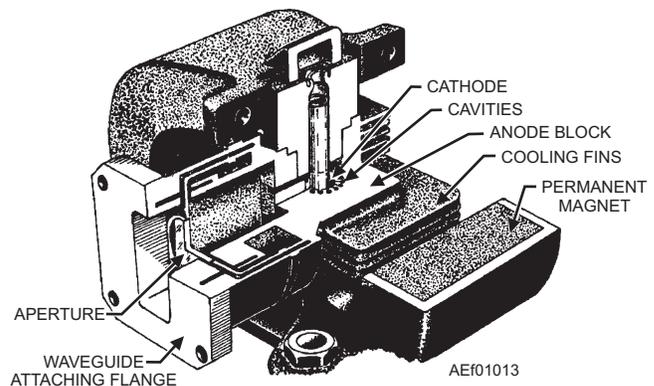


Figure 1-13.—Cutaway view of a typical radar magnetron.

These disadvantages can be overcome by the use of a klystron, shown in figure 1-14. In the klystron the cathode and collector are separated from the frequency determining fields and can be designed independently of the RF section to handle the desired power. The klystron is simply a power amplifier and has no influence on the frequency determining system.

The klystron shown has three cavities, which must be tuned to the desired transmit frequency. Notice that an external RF generator is coupled to the input cavity. A large negative pulse placed on the cathode turns on the klystron. The negative pulse comes from the modulator and causes a cloud of electrons to be emitted. The cloud of electrons is formed into a beam by placing a magnetic focusing coil around the klystron (not shown), which keeps the electrons in a tight group and away from the sidewalls of the tube. The RF pulse applied to the input cavity causes the cavity to oscillate at the RF frequency. RF fields act upon the electrons that are accelerated by the cathode pulse across the input and middle cavities. Some electrons are accelerated, some are decelerated, and others are unaffected in the movement of the electron beam towards the collector, causing what is referred to as "bunching." The bunching is at the RF frequency that causes succeeding cavities to oscillate at the same frequency, accelerating the bunching process. The

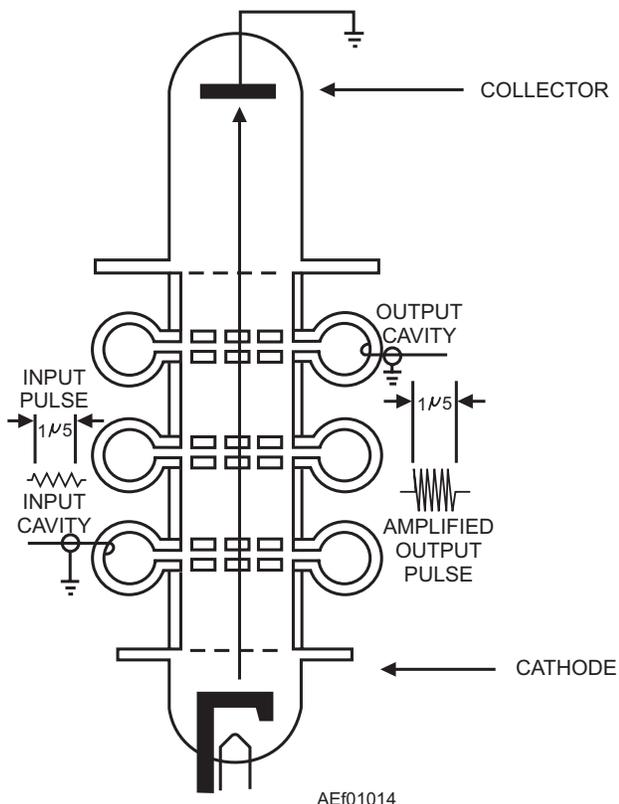


Figure 1-14.—Basic three-cavity klystron.

design of klystron is such that maximum bunching at the RF frequency occurs at the last cavity giving up maximum power to the cavity, which is coupled into a waveguide as output power to an antenna.

Klystron amplification, power output, and efficiency can be greatly improved by the addition of intermediate cavities between the input and output cavities of a klystron. Additional cavities serve to velocity-modulate the electron beam and produce an increase in the energy available at the output for transmission.

Duplexer

Whenever a single antenna is used for both transmitting and receiving, as in a typical radar system, problems arise. A means of keeping the high-transmitted power from damaging the receiver, and a means of keeping the low power received energy from being dissipated in the transmitter is another. Both of these problems are solved by the use of a duplexer. A duplexer is essentially an electronic switch that permits a radar system to use a single antenna, for both transmit and receive. The duplexer must transfer the antenna connection from the receiver to the transmitter during the transmitted pulse, and back to the receiver during the return (echo) pulse.

An effective radar duplexer must meet the following four requirements:

1. During the period of transmission, the switch must connect the antenna to the transmitter and disconnect it from the receiver.
2. The receiver must be completely isolated from the transmitter during the transmission of the high-power pulse to avoid damage to sensitive receiver components.
3. After transmission, the switch must rapidly disconnect the transmitter and connect the receiver to the antenna. For targets close to the radar to be seen, the switch must be extremely rapid.
4. The switch should absorb an absolute minimum of power both during transmission and reception.

Receiver

Looking again at the radar block diagram (fig. 1-8A), you can see that the received signal is routed through the duplexer to the receiver. The function of a receiver in a radar system is to receive and detect radar

returns. The transmitter and antenna generates and radiates bursts of RF energy, which travels out into space and hits distant targets. A portion of the RF energy is reflected back to the antenna. The receiver mixes this reflected RF energy with RF energy from a local oscillator to produce a lower frequency called the intermediate frequency (IF). This type of receiver is referred to as a superheterodyne receiver, shown in figure 1-15.

The IF frequency is more desirable when working with high frequency RF because it is much easier to build circuitry to handle the lower frequency. The IF amplifier amplifies the intermediate frequency, and the target information is removed by the detector and displayed on the various radar indicators.

The following discussion examines the components that make up a radar receiver. The local oscillator generates a RF frequency that is 30 MHz above the transmit signal. This signal is then applied to a signal mixer along with the received frequency, which also produces a 30 MHz difference signal.

The AFC mixer controls the frequency through the use of a discriminator. The AFC circuitry controls the frequency by mixing portions of the transmitter frequency with the local oscillator frequency. The output of the AFC mixer is directed into a discriminator, which maintains the frequency of the local oscillator at a frequency of 30 MHz above the transmitter frequency. The purpose of the AFC circuitry is to maintain a constant 30 MHz IF frequency out of the signal mixer. For example, if the transmitter frequency changes from 3000 MHz to 3010 MHz, the AFC circuit would detect the change and shift the

frequency of the local oscillator from 3030 MHz to 3040 MHz. The difference would remain at 30 MHz. The 30 MHz IF frequency is important because it affects the overall receiver sensitivity.

The IF amplifier/detector section of a radar determines the gain, signal-to-noise ratio, bandwidth, and converts the IF pulses to video pulses to be applied to the indicators. Typical IF amplifier usually contains from three to ten amplifier stages. The IF amplifier has the capability to vary both the bandpass and the gain of the receiver. Normally, the bandpass is as narrow as possible without affecting the actual signal energy. The most critical stage of the IF amplifier section is the input or first stage. The quality of this stage determines the noise figure of the receiver and the performance of the entire receiving system with respect to detection of small objects at long ranges. Gain and bandwidth are not the only considerations in the design of the first IF stage. Another consideration is noise generation. Noise generation in this stage must be low. Noise generated in the input IF stage will be amplified by succeeding stages and may exceed the echo signal in strength.

The function of the detector within the receiver is to convert the IF pulses into video pulses, from there video pulses are applied to various indicators. A more in-depth discussion of radar receiver circuitry can be found in NEETS, Module 18, *Radar Principles*.

Indicators

Target information must be made available for quick analysis by the radar operator for radar to be useful. After echoes have been received and detected in the receiver section of the radar, they are ready for display. Indicators are triggered to initiate a sweep at the time the transmitter produces its output. As the indicator sweep passes over the viewing screen, the received targets or echoes are shown by a bright spot or blip on the screen. The distance from the start of the sweep to the blip is the actual range to the object or target. At this point the signal is amplified to a level where it can be properly displayed. The exact time required for the transmitted RF burst to travel to the target and for its echo to return is measured. One half of this total elapsed time measurement represents target range. A few examples of radar display indicators are the Plan Position Indicator (PPI), Range Height Indicator (RHI), and Amplitude Indicator (A-scope).

The PPI is the most common indicator used for radar displays. These types display the direction and range of the target. The PPI presentation is practically

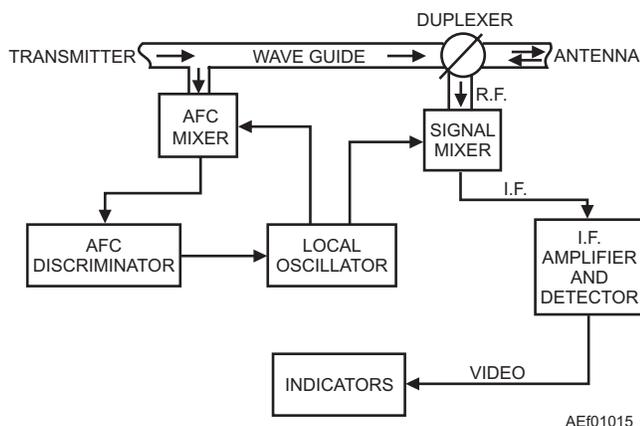


Figure 1-15.—Radar receiver block diagram.

an exact replica of the region scanned by the radar antenna. Distance along the radial sweep line represents target range. Rotation of the radial sweep line, synchronized with the antenna's rotation, produces a circular display.

When echo signals are applied to the control grid (or cathode) of the PPI CRT during the sweep period, the brightness of portions of the radial sweep line is increased. An increase in the brightness of portions of the PPI radial sweep line results in a map-like presentation, as shown in figure 1-16.

Another indicator used in radar is the RHI, sometimes called an E-scope. It is used with height finding search radars to obtain altitude information. The E-scope displays targets in elevation above the earth in kilometers or feet versus range in kilometers or nautical miles. The sweep is displayed as an angle that represents the elevation angle of the antenna. The start of the sweep is synchronized with the transmitted pulse. Targets are indicated by increasing the intensity of the CRT sweep. Radar circuitry uses target range and antenna angle to calculate target height above the earth, as shown in figure 1-17.

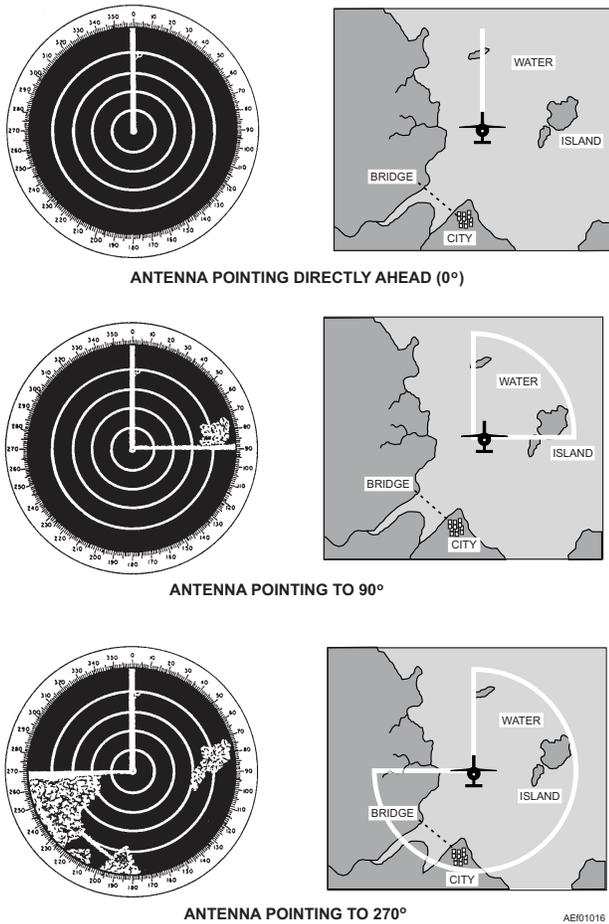


Figure 1-16.—PPI presentation.

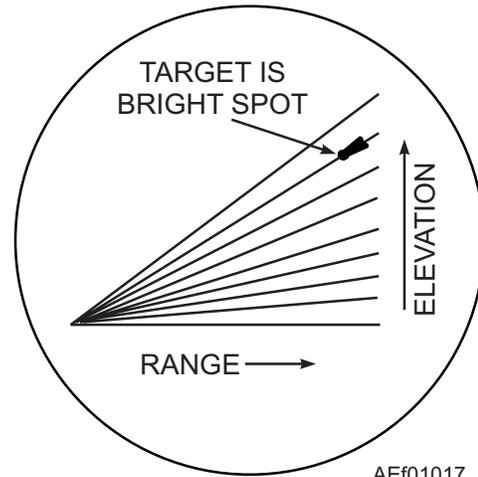


Figure 1-17.—RHI presentation.

The last indicator to be discussed is the A-scope, shown in figure 1-18, which is normally used in weapons control radar systems. This type of display shows echo signal strength as vertical deflection. Range is displayed on the horizontal axis. The sweep starts at the left side of the scope with each transmitted radar pulse, and travels to the right at a constant speed across the face of the CRT. Echo returns cause a vertical deflection on this horizontal sweep at the proper range. The amplitude of this vertical deflection is directly proportional to the intensity of the echo.

Antenna

Antenna characteristics are discussed in detail in NEETS, Module 10, *Introduction to Wave-Generation, Transmission Lines, and Antennas*, and in Module 11, *Microwave Principles*. The antenna is designed to be

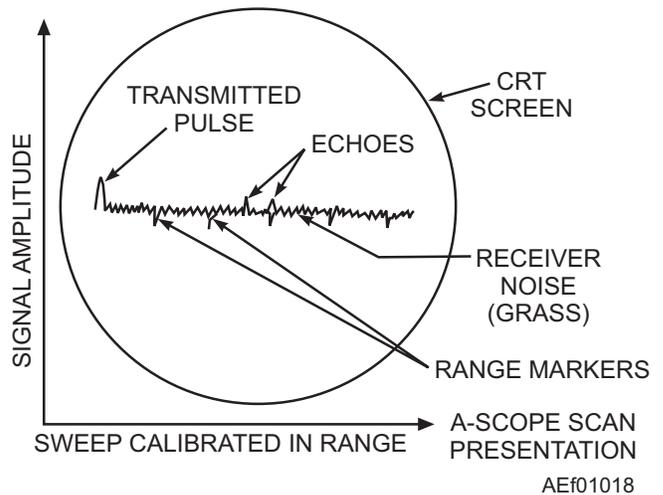


Figure 1-18.—A-scope presentation.

directive for transmission and reception of signals to provide directional information and signal gain. It is a radiator for the transmitter and receptor for the echo. The RF energy reflected from a target (echo) is applied to the receiver, via the wave guide and duplexer where received signals are amplified and converted to video and then applied to the indicators for display.

A servo system is used to position a radar antenna and supply target information to associated weapons systems. The system can be operated in a search mode or track mode of operation. The search mode provides a scan pattern, which is used to locate targets. In the track mode of operation, the function of the antenna servo system is to position the antenna based on the video output of the radar system. The positioning is such that the antenna will follow the movement of the target.

POWER SUPPLY

A single block in the diagram represents the power supply; however, one power supply may not meet all the requirements of a radar unit. The distribution of the physical components of the system may be such as to make it impossible to place all the power supply circuits into one physical unit. Thus, different supplies may be needed to meet the various requirements of the system and must be designed accordingly. Essentially, the power supply converts the voltage supplied from the aircraft's electrical system to voltages and currents utilized by multiple electronic circuits for proper operation of the unit.

- Q1-19. What is the purpose of radar synchronizer?*
- Q1-20. What are the two synchronization classifications for a basic pulse radar system?*
- Q1-21. What are the two high-powered RF generators used in transmitters of pulse radar systems?*
- Q1-22. Adding additional intermediate cavities between the input and output of a klystron has what affect on power output?*
- Q1-23. What is a duplexer and what is its purpose in a radar system?*
- Q1-24. What type of receiver mixes incoming signals with the receiver's local oscillator signal to produce an intermediate frequency?*
- Q1-25. What is the purpose of the AFC circuitry within the receiver?*

- Q1-26. What function does the detector perform within the receiver?*
- Q1-27. What are the three types of radar indicators?*
- Q1-28. The PPI provides what type of presentation?*
- Q1-29. What are the nine major components that make up a typical pulse radar system?*

SEARCH RADAR SYSTEM

LEARNING OBJECTIVE: Recognize the components of the search radar systems AN/APS-130(V)1 and AN/APS-130B(V)1.

The AN/APS-130 radar set used in the EA-6B aircraft is an airborne, multi-mode search radar system. It provides long- and short-range ground mapping and navigation update. It is made up of a combined antenna receiver unit, which includes all antenna drive units, a transmitter-modulator unit, reference signal generator, the radar set control, azimuth range indicator, displays for the pilot and the ECMO 1, and the power supply.

The antenna scan function is performed by the antenna-receiver via the scan power drive assembly, with reference and timing signals from the reference signal generator (RSG), relative bearing from the Analog-Digital Converter CV-2434/AYA-6, and pitch and roll stabilization command from the Course Attitude Data Transmitter T-1073/A via the radar control panel (RCP). The antenna pitch function is provided by the pitch power drive assembly.

Outputs from the antenna-receiver are applied to the RSG, which processes the radar video and generates sweeps that are used by the direct view storage tube in the pilot's horizontal display (PHD) and the cathode-ray tube in the direct view radar indicator to provide visual radar presentations to the pilot and ECMO 1.

The RADAR SLEW controls permit use of the navigation update mode by enabling the pilot or ECMO 1 to slew range and azimuth cursors on the PHD or DVRI and to enter radar cursor intersection position data into the tactical computer (TC).

Built-in test (BIT) permits an evaluation of each component of the search radar and provides the operator with a GO or NO-GO indication of the status of each.

The APS-130 search radar system includes the following equipment:

- Reference Signal Generator (RSG)
O-1778/APS-130
- Radar Transmitter T-1396/APS-130
- Radar Set Control (RCP) C-10535/APS-130
- Cursor Control C-7588A/APQ-129
- Azimuth Range Indicator IP-1342/APS-130 or
IP-1342B/APS-130
- Azimuth Elevation Range Indicator
IP-1060A/APQ-148
- Antenna-Receiver AS-3325/APS-130
- Power Supply PP-6574/APQ-148

O-1778/APS-130 REFERENCE SIGNAL GENERATOR (RSG)

The Reference Signal Generator O-1778/APS-130 (RSG) provides a crystal-controlled clock and digital timing loop to generate PRF trigger, sweep triggers, range markers, and precision range line signal. Figure 1-19 provides the physical location of the RSG in the aircraft and a visual representation of the unit. The RSG provides for vertical and horizontal sweeps, intensity gates, and video for the DVRI and PHD during all modes of operation of the DVRI and PHD. The BIT

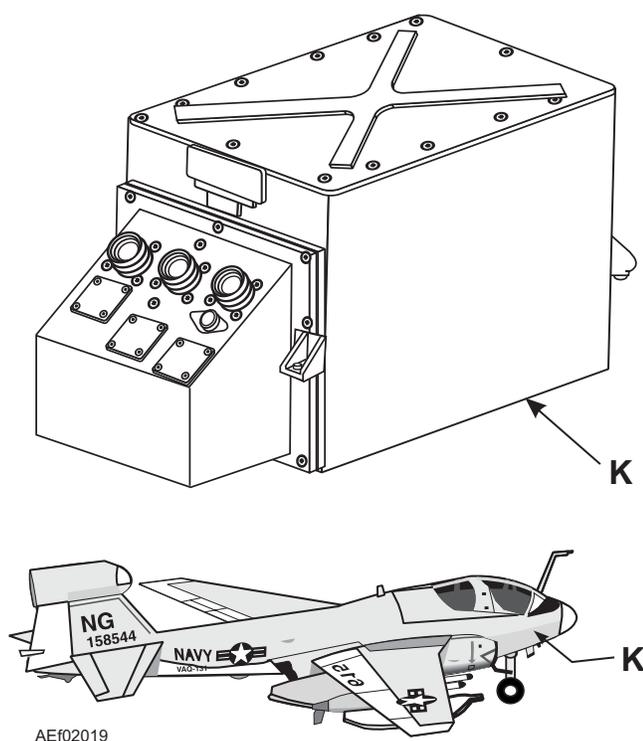


Figure 1-19.—O-1778/APS-130 Reference Signal Generator (RSG) position in aircraft.

capability, which is selectable on the radar control panel, verifies the operation. The BIT capability, which is selectable on the radar control panel, verifies the operation of the RSG.

The RSG is divided into the following functional groups: synchronization and timing group, precision range line (PRL) generation group, video selection mixing group, sweep group, and bit group.

The synchronization and timing group receives inputs from the antenna receiver (A/R) and radar control panel (RCP), and provides timing and control signals for the operation of the radar set.

The PRL generation group receives inputs from the analog digital-digital analog converter (ADDAC) and provides the PRL range markers, the pulldown signal, and the sweep start trigger.

The video selection and mixing group combines video with azimuth and range markers for processing by the azimuth range indicator (DVRI) and azimuth elevation range indicator (PHD). Range and azimuth marker brightness signals from the RCP and display control panel (DCP) control the brightness signals from the RCP and display control panel (DCP) control the brightness (intensity) of the range and azimuth markers that are mixed with the video signals.

The sweep group demodulates azimuth, vertical, and horizontal synchro information, provides selection and scaling for the plan position indicator (PPI) horizontal and vertical sweeps, generates timing signals that relate to azimuth, and generates intensity gates and intensity compensation sweeps that control the presentation of video returns.

The BIT group provides an operational status indication to the RCP. The three major output of the BIT group supplied to the RCP are used to monitor functionally all RSG circuits.

T-1396/APS-130 RADAR TRANSMITTER

Figure 1-20 shows the T-1396/APS-130 Transmitter and its position within the aircraft. The radar transmitter/modulator (T/M) provides high-energy microwave pulses of fixed width and fixed repetition rate, and whose RF frequency can be continuously adjusted for radiation by the antenna receiver. The T/M generates high-voltage negative pulses of required amplitude at a pulsewidth and repetition frequency determined by the system. The pulses are stepped up to an amplitude required to fire the magnetron. When the magnetron fires, it generates

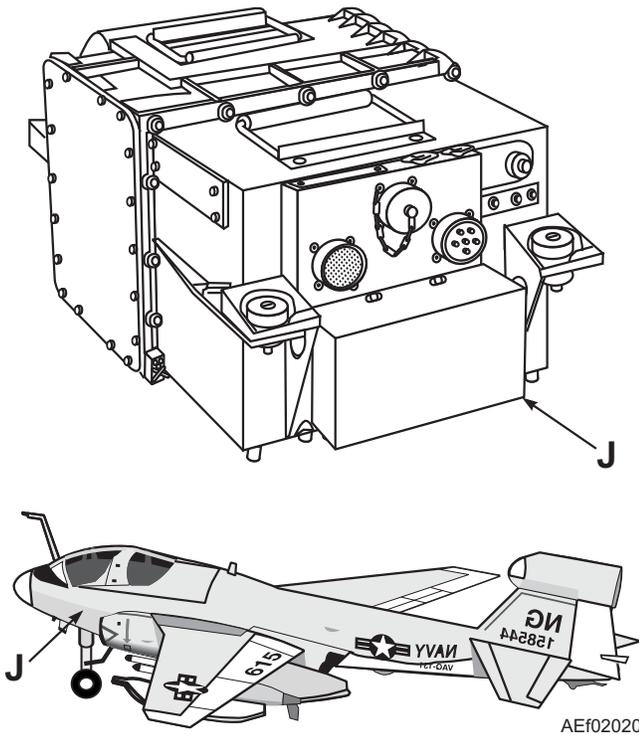


Figure 1-20.—T-1396/APS-130 Transmitter location in aircraft.

high-energy RF power that is applied to the wave guide section for transmission to the antenna/receiver antenna for radiation. The T/M is divided into four functional groups: power supply group, modulator group, transmitter group, and BIT group.

C-10535/APS-130 RADAR SET CONTROL (RCP)

The Radar Set Control C-10535/APS-130 (RCP) is at the ECMO 1 station on the forward right pedestal. It provides all the manual controls for coordinating functions of the search radar, for adjusting the DVRI display, and for selections and displaying the results of BIT. A detailed description of the controls and indicators shown in figure 1-21 follows:

1. **MAG FREQ.** The MAG FREQ indicator is a three lamp indicator that monitors the magnetron operating frequency range and displays whether the magnetron is operating in HIGH, MID, or LOW frequency range.

2. **TILT.** The TILT is a rotary control knob adjustable over 270° with a locking device and detent position. It adjusts the tilt (pitch) angle from 12° tilt down to 4° tilt up.

3. **RNG MKR.** The RNG MKR is a rotary control knob adjustable over 312°. It varies the brightness level of the DVRI range markers.

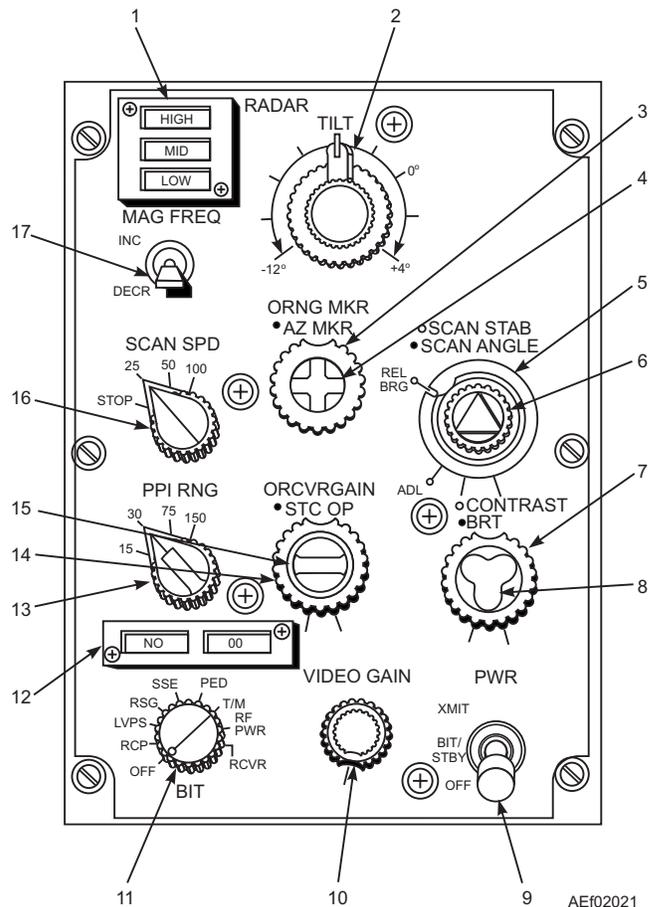


Figure 1-21.—Radar Control Panel - Controls and Indicators.

4. **AZ MKR.** The AZ MKR is a rotary control knob adjustable over 312°. It varies the brightness level of the DVRI azimuth markers.

5. **SCAN STAB.** The SCAN STAB is a two-position rotary selected switch that allows selection of either of two antenna stabilization references. In the ADL position, the antenna scan is stabilized about the aircraft datum line (ADL). The DVRI display will be centered about the ADL. In the REL BRG position, the antenna scan is stabilized about the azimuth cursor, which may be positioned at any point from 0° to ± 55° relative bearing with respect to the ADL. The DVRI display will be centered about the azimuth cursor position.

6. **SCAN ANGLE.** The SCAN ANGLE is a rotary control knob adjustable over 320° that provides a means of adjusting the antenna scan angle for any value from ± 10° to ± 55° about the selection scan stabilization center.

7. **CONTRAST.** The CONTRAST is a rotary control knob adjustable over 312°, which controls the DVRI video amplifier gain.

8. **BRT.** The BRT is a rotary control knob adjustable over 312° , which sets the brightness level of the DVRI raster.

9. **PWR.** The PWR is a three position lever-locked switch (without RAMEC P-27-82 installed) and a three position, detented, lever-locked switch (with RAMEC P-27-82 installed) that controls the application of aircraft power to the radar set. In the OFF position, the radar is completely de-energized, and the raster does not appear on the DVRI. In the BIT/STBY position, low-voltage power is applied to all WRAs and to tube filaments. The BIT function is enabled, high voltage is not applied to the transmitter, and raster and markers appear on the DVRI. In the XMT position, high voltage is applied to the transmitter after a 5-minute time delay, making the radar completely operational. The DVRI will display raster, markers, and video.

10. **VIDEO GAIN.** The VIDEO GAIN is a rotary control knob adjustable over 312° , which allows the operator to enhance the displayed characteristics of a simple target or a group of targets.

11. **BIT.** The BIT is a nine-position rotary selector switch that allows selection of component BIT status signals to be monitored. The positions are:

- OFF - No bit status signal is monitored.
- RCP - Radar Control Panel BIT status is monitored.
- LVPS - Low Voltage Power Supply BIT status is monitored.
- RSG - Reference Signal Generator BIT status is monitored.
- SSE - Antenna/Receiver scan servo electronics BIT status is monitored.
- PED - Antenna/Receiver pedestal BIT status is monitored.
- T/M - Transmitter/Modulator BIT status is monitored.
- RF PWR - Antenna/Receiver rf power BIT status is monitored.
- RCVR - Antenna/Receiver BIT status is monitored.

12. **NO/GO.** The NO/GO consists of two lamps that illuminate to indicate to the operator when there is a BIT failure.

13. **PPI RNG.** The PPI RNG is a four-position rotary selector switch that permits the selection of different PPI sweep ranges from the DVRI and PHD. The selector positions are:

- 15—Selects 15 nmi PPI sweep range.
- 30—Selects 30 nmi PPI sweep range.
- 75—Selects 75 nmi PPI sweep range.
- 150—Selects 150 nmi PPI sweep range.

14. **RCVR GAIN.** The RCVR GAIN is a rotary control knob adjustable over 312° that, in conjunction with the BRT and CONTRAST controls, provides adjustment of the receiver gain to intensify the targets presented on the DVRI and PHD display.

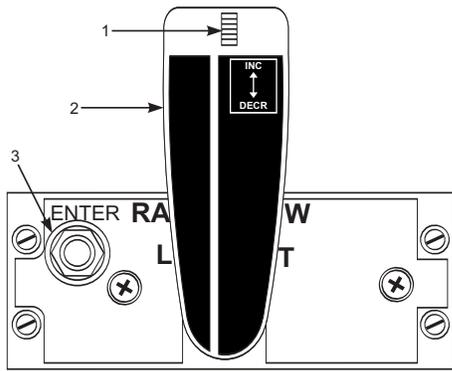
15. **STC DP.** The STC DP is a rotary control knob adjustable over 312° that provides a means of reducing the gain level of video returns from close-in targets in order to prevent blooming.

16. **SCAN SPD.** The SCAN SPD is a four-position rotary selector switch that provides a means of selecting the antenna scan speed. The positions are OFF, 25, 50, and 100. The OFF position holds the antenna at the selected SCAN STAB position. The 25 position selects the 25° /second antenna speed, the 50 position selects the 50° /second antenna speed, and the 100 position selects the 100° /second antenna speed.

17. **MAG FREQ-INC/DECR.** The MAG FREQ-INC/DECR is a three-position toggle switch spring-loaded to the center (OFF) position. When the INC position is selected, it increases the magnetron frequency; and when the DECR position is selected, it decreases the magnetron frequency.

C-7588A/APQ-129 CURSOR CONTROL

The Cursor Control C-7588A/APQ-129 (fig. 1-22), also known as the slew control, is used to check or update the precomputed target or navigation data while operating the search radar in search mode. Two slew control(s) permits the slewing of range and azimuth cursors on the pilot's horizontal display (PHD), Radar Display Indicator IP-691A/APQ-129, or on the radar operator's direct view range indicator (DVRI). Each slew control provides manually controlled signals for updating of target coordinates. Repositioning of range and azimuth lines at the PHD and DVRI provides visual verification of target coordinates updating. During updating, the ECMO 1 slew control has priority for all inputs.



1. RANGE SLEW THUMBWHEEL
2. AZIMUTH SLEW STICK
3. ENTER SWITCH

AEf02022

Figure 1-22.—Cursor Control C-7588A/APQ-129 (Front View).

IP-1342 or IP-1342A/APS-130 AZIMUTH RANGE INDICATOR

The Azimuth Range Indicator IP-1342/APS-130 (fig. 1-23) (direct view radar indicator) (DVRI) presents ECMO 1 with a depressed center PPI display, ground map-like presentation of the terrain ahead of the aircraft, along with a display of range and azimuth cursors. The angular width and the range of the display are selectable on the RCP. A fixed azimuth ring is provided for direct measurement of relative bearing of the azimuth cursor. The DVRI is functionally divided into the following groups: intensifying group, video group, indicator group, and power supply group. Figure 1-24 provides a description of indicators on the DVRI.

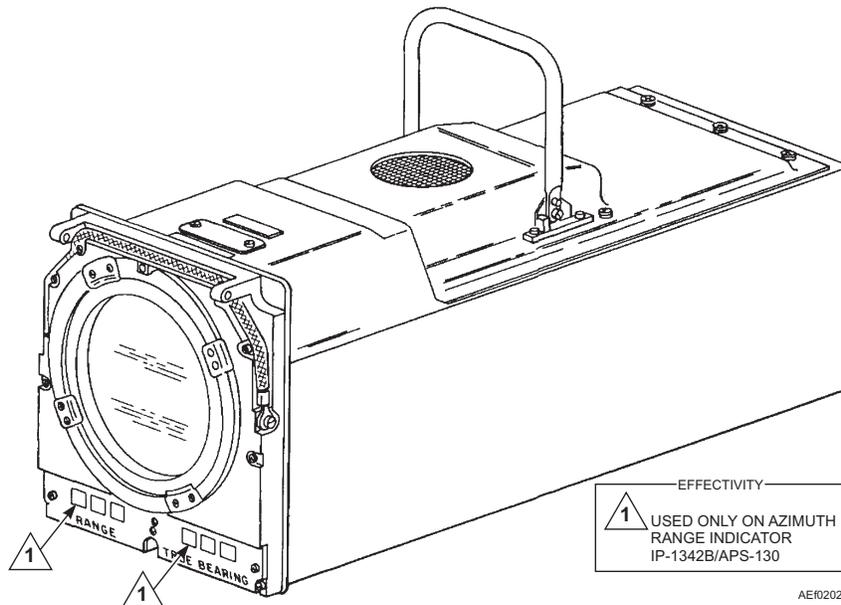
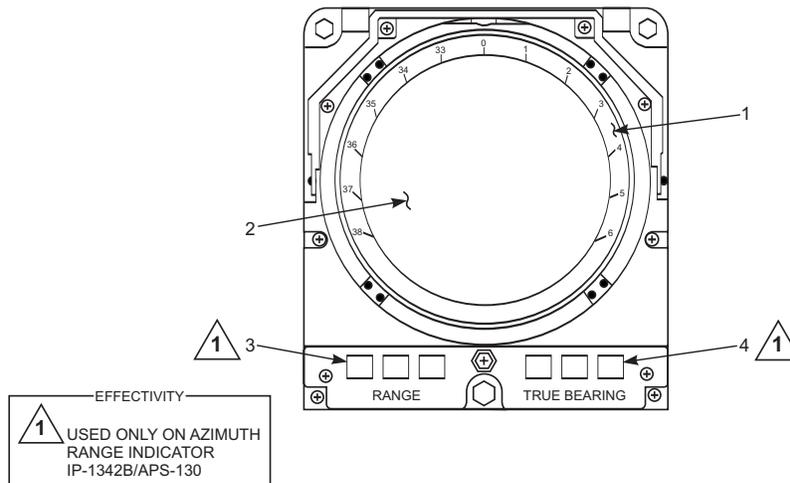


Figure 1-23.—Azimuth Range Indicator IP-1342/APS-130 and IP-1342B/APS-130.



1. Fixed Relative Bearing Compass
2. Cathode Ray Tube (CTR)
3. RANGE
4. TRUE BEARING

AEf02024

Figure 1-24.—Azimuth Range Indicator - Location of Indicators.

IP-1060A/APQ-148 AZIMUTH ELEVATION RANGE INDICATOR

The Azimuth Elevation Range Indicator IP-1060A/APQ-148 (pilot’s horizontal display) (PHD) relays to the pilot a duplicate display of the DVRI presentation of the terrain ahead of the aircraft. The angular width and the range of the display are selected on the RCP. The PHD also includes electromechanical indicators that permits the pilot to determine aircraft heading and relative drift corrected steering. A Direct View Storage Tube (DVST) is used to provide a display that may be viewed in broad daylight.

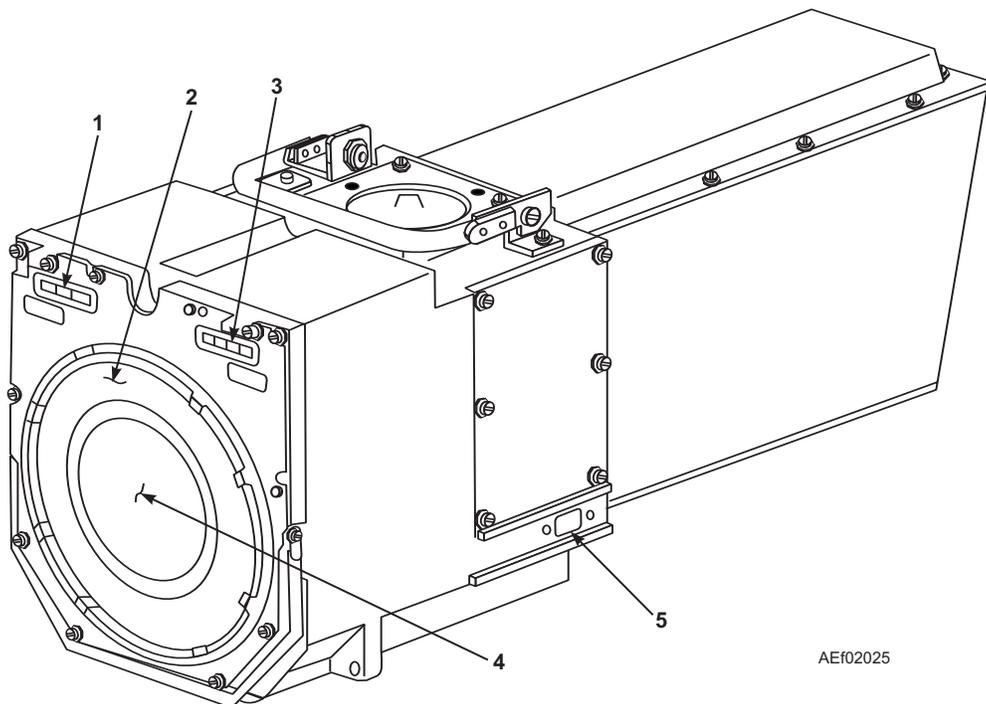
The PHD itself has no operating controls, however, the front panel does contain indicators described in table 1-2 and shown in figure 1-25.

AS-3325/APS-130 ANTENNA-RECEIVER

The Antenna-Receiver AS-3325/APS-130 (A/R) is a pitch-and-roll stabilized unit that provides the means of radiating energy from the T/M and of receiving reflected microwave energy. The A/R is in the nose of the fuselage, with the antenna dish and front feed horn on a scan column. Attached to the bottom of the scan column is the search receiver electronics unit. Toward

Table 1-2.—Indicators

INDICATOR	FIGURE 1-25 INDEX NO.	INDICATION FUNCTION
Time	1	Command heading is indicated by position of movable pointer on compass rose.
Compass rose and pointer	2	True heading of aircraft is indicated by position of movable compass: rose under fixed painter at top center of DVST screen.
RANGE	3	Displays ground range to a selected target in nautical miles (not used in APS-130).
Direct View Storage Tube (DVST)	4	Displays radar and test pattern information.
ELAPSED TIME meter on right side	5	Indicates total accumulated time (in hours) that the prime power has been applied to the PHD.



AEf02025

Figure 1-25.—PHD Indicators.

the top rear of the scan column is the scan and stabilization electronics unit. Access to the A/R is gained by raising the nose radome (fig. 1-26).

The scan power drive assembly develops the necessary drive power to drive the antenna alternately in a clockwise and counterclockwise direction to perform the scanning function. The assembly contains a motor tachometer and a cooling fan.

Scan drive excitation power is applied to the motor section of the motor-tachometer. The polarity of the input determines the direction of rotation of the motor tachometer, and thus of the antenna scan. To make certain that the antenna scan rate is maintained at the desired speed, the scan tach feedback, which represents the actual speed of the antenna scan, from the tachometer portion of the motor-tachometer is fed back to the scan electronics amplifier assembly. The electronics amplifier assembly is part of the scan and

stabilization electronics assembly, where the scan tach feedback is summed with the desired scan rate.

A capacitor (C1) provides the proper phase-shift angle between the fixed-phase and control-phase windings angle between the fixed-phase and control-phase windings of the motor-tachometer. The cooling fan, powered by the 115 Vac, 400 Hz, 3-phase power, provides the necessary cooling of the scan power drive assembly.

The pitch power drive assembly develops the necessary drive power to drive the antenna in the direction necessary to correct the antenna position due to aircraft deviation from the horizontal. The assembly contains a motor-tachometer and a brake clutch.

The pitch drive excitation power is applied to the motor section of motor-tachometer. The polarity of the input determines the direction of rotation of the motor-tachometer, and thus of the antenna. To make

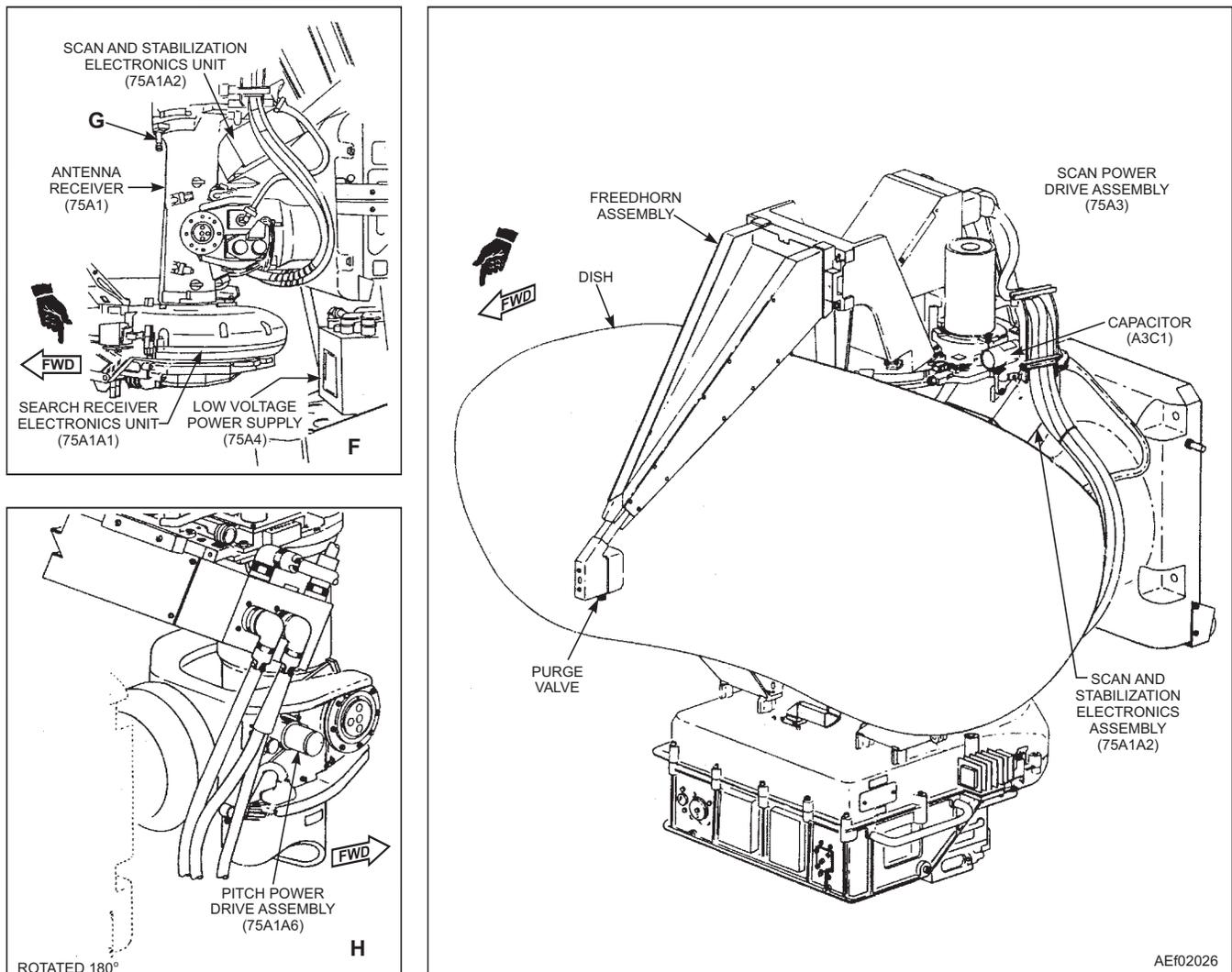


Figure 1-26.—AS-3325/APS-130 Antenna-Receiver.

certain that the antenna maintains constant corrective speed, the pitch tach feedback from the tachometer portion of the motor-tachometer is fed back to the pitch electronics amplifier.

The pitch electronics amplifier is part of the scan and stabilization electronics assembly, where the pitch tach feedback is either summed or subtracted from the pitch error signal to maintain proper pitch corrective speed. A capacitor (A6C1) provides the proper phase-shift angle between the fixed-phase and control-phase windings of the motor-tachometer.

The BIT switch on the RCP has positions marked SSE, PED, RF PWR, and RCVR that provide go/no-go checks and fault isolation of the components of the A/R.

PP-6574/APQ-148 POWER SUPPLY

The power supply PP-6574/APQ-148 (low-voltage power supply) (LVPS) controls the application of aircraft power (115 Vac, 400 Hz, three-phase and 28 Vdc) supplied to the radar, and rectifies, regulates, and supplies all low-voltage power to the search radar WRAs. Selection of LVPS on the radar control panel BIT switch provides a GO/NO-GO check of the LVPS. Cold plate heat exchangers are used with forced air cooling provided by the aircraft environmental control system to satisfy the cooling requirements of the LVPS. See figure 1-27.

Q1-30. What are the four positions on the SCAN SPD rotary switch on the C-10535/APS-130 Radar Set Control?

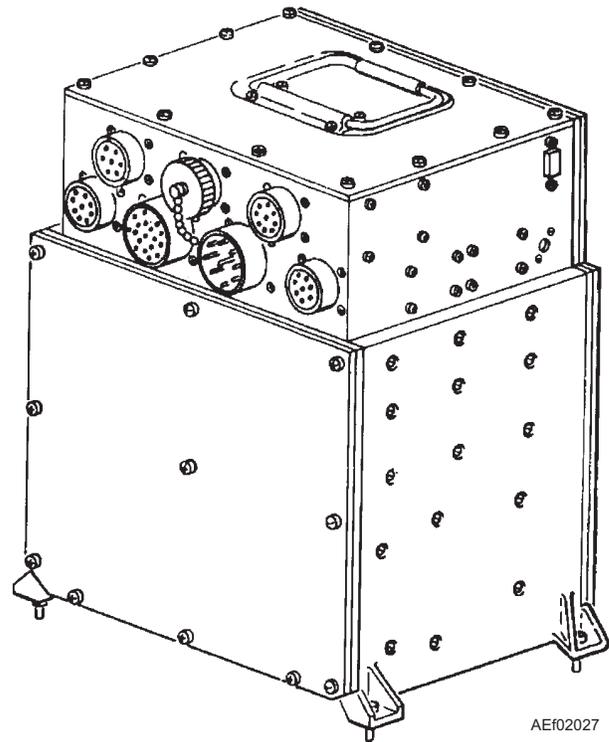


Figure 1-27.—PP-6574/APQ-148 power supply.

- Q1-31. What are the four functional groups of the T-1396/APS-130 Transmitter?*
- Q1-32. What position is the DVRI located in?*
- Q1-33. The CV-2434 Analog-Digital Converter is a major component of what radar system?*
- Q1-34. During update mode, what slew control has priority for all inputs?*

CHAPTER 2

IDENTIFICATION FRIEND OR FOE (IFF) SYSTEMS

INTRODUCTION

With the destructive power of modern weapon systems and the speed of modern weapon delivery systems, it is not always practical to wait until a detected radar target has been identified by visual means before preparing for battle. Therefore, a means of identifying friendly targets from enemy targets at long range is necessary. It was this need that brought about the advent of the IFF system. The IFF system provides automatic identification friend or foe (IFF) of an air or surface vehicle to all IFF interrogator-equipped aircraft, ships, and ground forces within the operating range of the system. IFF systems also provide other information, such as type of craft, squadron, side number, mission, and aircraft altitude.

GENERAL THEORY OF OPERATION

LEARNING OBJECTIVE: Recognize general operating principles, components, characteristics,

and maintenance concepts of typical airborne IFF systems.

IFF completes the identification process in three basic steps: (1) challenge, (2) decode, and (3) reply. A simplified block diagram of a typical IFF system is shown in figure 2-1. The system is comprised of an interrogator (challenging unit) and a transponder (reply unit). The interrogator interfaces physically with the radar system in which its operations (transmissions and receptions) are synchronized. When radar contacts of interest are interrogated, the transponder unit of the interrogated aircraft replies to the challenges and provides the proper coded response, which, in turn, indicates the challenged contact is friendly. Responses not incorporating the proper identification codes are interpreted as coming from hostile units. All naval aircraft contain a transponder set; however, an interrogator set is installed only in platforms that have a need to interrogate and identify aircraft from a distance for tactical purposes.

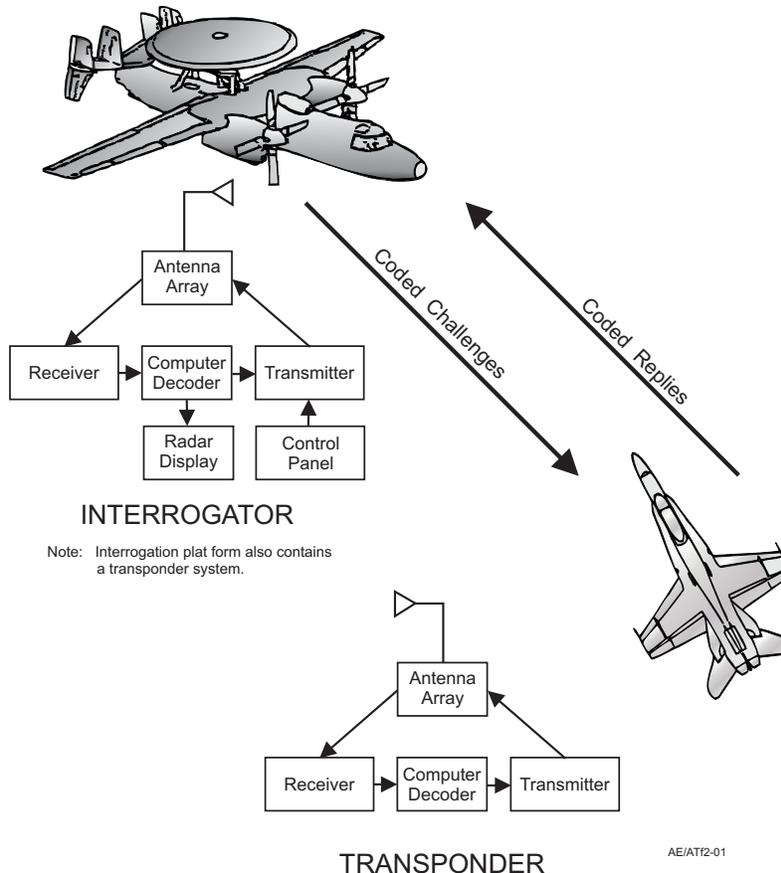


Figure 2-1.—IFF system block diagram.

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INTERROGATION (CHALLENGE)

The interrogator is a pulse-type transmitter that is triggered by the coder synchronizer. The coder synchronizer is synchronized to the radar system so that reception of the IFF response and radar echo signals cannot occur simultaneously. The output (challenge signal) of the interrogator is different for different modes of IFF operation. As long as the aircraft transponder is operating in the correct mode, it will receive these interrogation signals and will transmit back to the interrogator the proper coded reply pulses. The IFF reply pulses are sent via the coder synchronizer to a display indicator, which is part of the challenging units radar system. The coded replies from a friendly craft normally appear as dashed lines just beyond the target blip, as shown in figure 2-2.

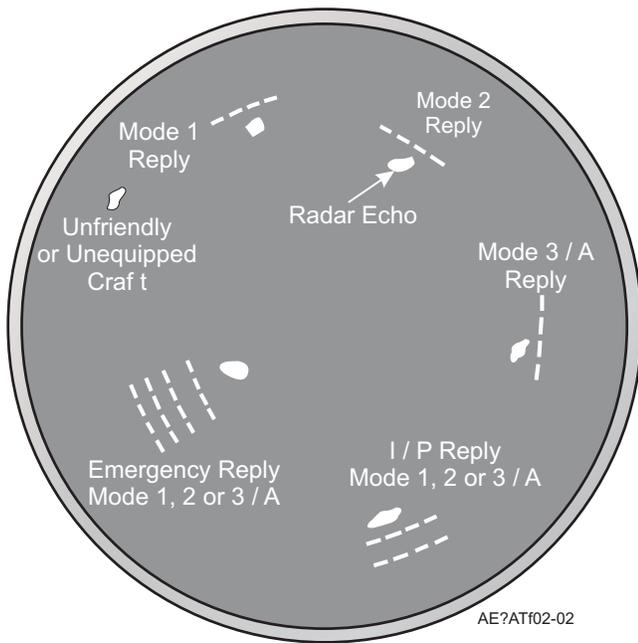


Figure 2-2.—Typical radar display showing several IFF responses.

Interrogation Modes and Codes

There are presently five modes of IFF operation used by naval aircraft; an additional mode is available for loop testing. These modes are designated as Modes 1, 2, 3/A, C, Mode 4 (A or B) and Test. Modes 1, 2, 3/A, and C, and Test use two interrogation pulses, $0.8 \pm 0.1 \mu\text{s}$ wide with pulse spacing as shown in table 2-1.

Table 2-1.—IFF Pulse Spacing

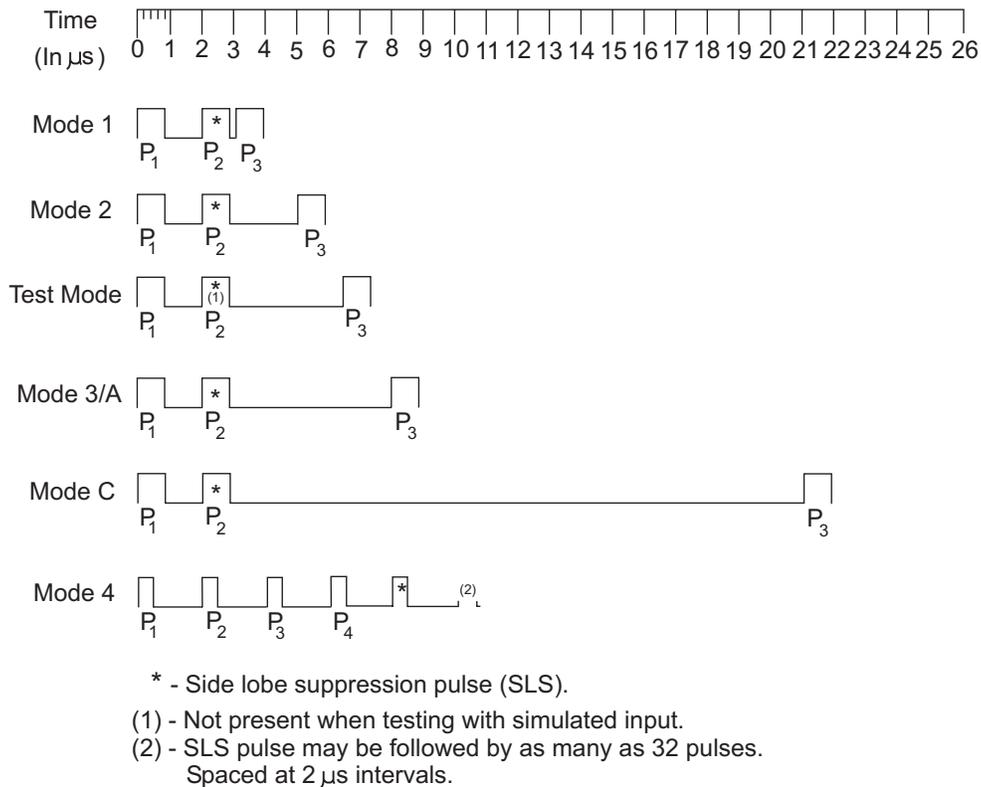
MODE	SPACING
1	2.9 to 3.1 μs
2	4.8 to 5.2 μs
3/A	7.8 to 8.2 μs
C	20.8 to 21.2 μs
TEST	6.3 to 6.7 μs

Each mode of operation obtains a specific type of information from the craft that is being challenged. Modes 1 and 2 are exclusively used by the military as tactical modes for mission and identification purposes. Mode 3/A is the standard air traffic control mode used by military and civilian air traffic control stations. It is used in conjunction with the automatic altitude-reporting mode (Mode C), which reports the aircraft's altitude as provided by the onboard air data computer. Mode 4 is a military encrypted mode, which is classified and requires the use of a transponder computer. Only interrogators and transponders using the same encrypted codes can communicate with each other. Additionally, you can use system testing to check for proper system operation when completing a loop test.

Interrogation Pulse Characteristics

The interrogation pulse characteristics for the various modes of IFF operation are shown in figure 2-3. These pulses are transmitted at a frequency of 1030 MHz, and are recognized by the transponder through pulsewidth and spacing. Modes 1, 2, 3/A, C, and Test use two interrogation and one side-lobe suppression (SLS) pulse, each respectively $0.8 \mu\text{s}$ wide. The side-lobe suppression pulse occurs at $2 \mu\text{s}$ after the leading edge of the first interrogation pulse in each case. The SLS pulse allows the transponder to accept the main lobe and to reject minor lobe signals from interrogating stations. This ensures proper operation of the system.

Mode 4 interrogation pulses consist of four pulses plus a SLS pulse. Each pulse is between 0.4 and $0.6 \mu\text{s}$ wide, and occurs in multiples of $2.0 \mu\text{s}$ intervals from the leading edge of the first pulse. The four pulses may be followed by as many as 32 additional pulses spaced as close as $2 \mu\text{s}$ apart. The fifth pulse, which is the SLS pulse for Mode 4, is spaced $8 \mu\text{s}$ from the leading edge of the first interrogation pulse used.



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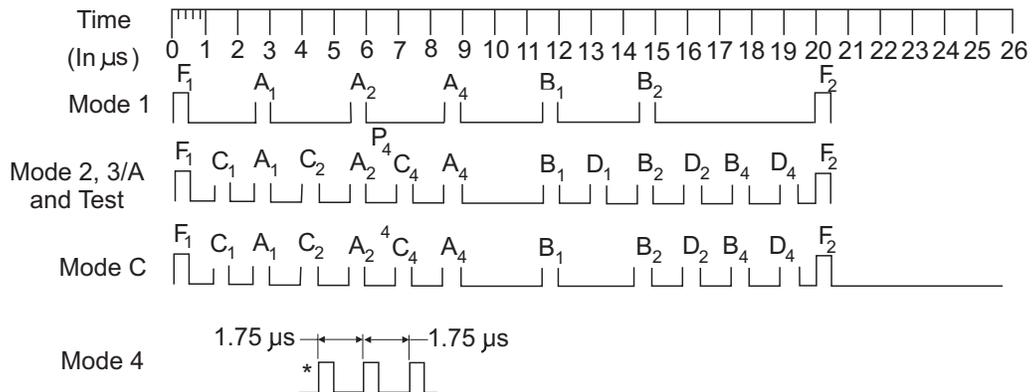
Figure 2-3.—IFF interrogator pulse characteristics.

TRANSPONDER (REPLY)

The IFF transponder is a receiver/transmitter combination, which automatically replies to coded challenges when Mode decoding is satisfactory. The receiver section identifies the interrogation Mode by decoding the spacing between P_1 and P_3 (for Modes 1, 2, 3/A, C, and Test) and comparing P_2 (SLS) with the main lobe pulses P_1 and P_3 . If the SLS control pulse is at least 9 dB less than P_1 or P_3 , the interrogator pulse train

is evaluated and decoded as being in a main lobe, which automatically keys the transmitter section to send a prearranged reply signal at a frequency of 1090 MHz. If not, it is evaluated and decoded as being in a side lobe, and the transponder system disables any reply response to such an interrogation.

Modes 1, 2, 3/A, and Test IFF replies use selective-identification-function (SIF) encoding. SIF/IFF codes are octal numbers that consist of three binary bit positions. A standard SIF reply (fig. 2-4) has



* Reply occurs between 200 and 270 μs after a mode 4 trigger

Note:

F_1 and F_2 pulses are reply framing pulses.

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Figure 2-4.—IFF transponder reply pulse characteristics.

provisions for four octal characters (A, B, C, and D) and is bounded by two framing (bracket) pulses (F₁ and F₂). The seventh bit position, between bit position A and B, is designated X. Bit position X is not part of any octal character and is logical 0 in any standard reply.

Mode 1 uses only octal characters A (A₄-A₂-A₁) and two least significant bit positions of character B (B₂-B₁) to represent a code range from 00 to 73 (rendering 32 possible combinations). Modes 2 and 3/A use all four octal characters (A, B, C, D) to represent a code range from 0000 to 7777 (4,096 possible combinations are capable). Mode 1 is set by two pushbutton switches or thumbwheels (depending on the model of IFF system being used), Mode 3/A is set by four switches, while Mode 2 (four switches) is preset prior to flight by maintenance personnel. Mode C reply uses the same standard format as a SIF reply, except that bit position D₁ is not used, which allows for a total of 2,048 possible codes. Mode 4 replies are generated by the transponder computer and sent to the transponder receiver/transmitter for RF transmission as three-pulse, time-coded reply. A valid Mode 4 exists if the Mode 4 reply rate and transmission are satisfactory. Mode 4 reply pulse coding is accomplished by crypto equipment and is classified information. This information can be found in technical manuals for the KIT-1/TSEC equipment.

The operation of the interrogated aircraft's transponder (mode of operation and specific codes,

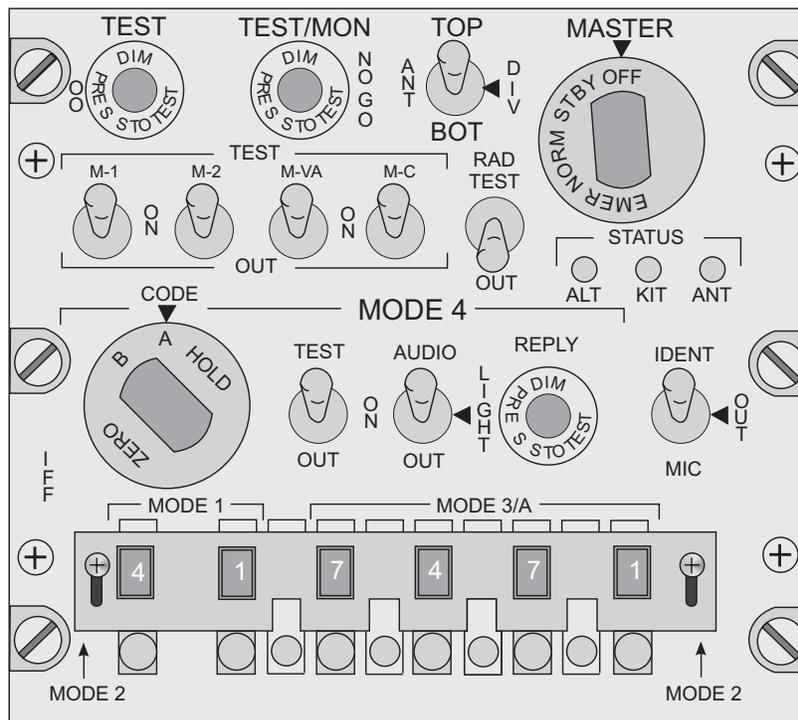
etc.) are controlled by a panel (depending on IFF system) similar to the one shown in figure 2-5. This panel contains switches, code selectors, lights, and operational modes.

MASTER Control Switch

The MASTER control switch is a four position rotary switch used to select the operating condition. In the STBY position, power is applied to the IFF coder, but interrogations are inhibited. In the NORM position, the transmitter-receiver is enabled for normal sensitivity. In the EMER position, the IFF coder transmits emergency replies to interrogations in Modes 1, 2, or 3/A. The Mode 3/A emergency reply includes code 7700. With EMER selected, Mode 4 is enabled regardless of the position of the Mode 4 switch, and Mode C continues to function normally if selected. To select the EMER position, pull the control outward and rotate to the EMER position.

IDENT/OUT/MIC Switch

The IDENT/OUT/MIC switch is a three-position toggle switch that is spring-loaded to return to the OUT position, which controls the transmission of the Identification of Position (IP) pulse. It is used in conjunction with Modes 1, 2, and 3/A to identify a specific friendly aircraft among other friendly aircraft that reply with the correct code. When the switch is



AE/ATf02-04

Figure 2-5.—Typical IFF transponder set control box.

momentarily set to the IDENT position, the IFF coder adds an identification of position response to Modes 1, 2, and 3/A for 15 to 30 seconds. In the MIC position, the identification of position function is activated for 15 to 30 seconds whenever the microphone switch is actuated. In the OUT position, the IDENT reply is disabled.

Modes 1, 2, and 3/A Code Selectors

Four eight-position push-button switches are provided for selection of Modes 2 and 3/A, while Mode 1 has one eight-position and one four-position push-button switch for selection of a particular code to be transmitted. The Mode 2 reply code setting is set by the maintenance person prior to flight by loosening the Mode-2 screws on the front panel of the transponder receiver/transmitter and sliding the plate up. The proper code is then set by using the four Mode 2 push-button switches. The plate is then returned to its normal position and the screws are retightened.

Mode-Selector Test Switches and Lights

Four three-position toggle switches, labeled "M-1," "M-2," "M-3/A," and "M-C", are used for selecting the proper mode of operation. Placing anyone of the switches to ON selects that mode for transmission. By placing the switch to OUT, it de-selects the mode of operation; and by placing the switch to TEST, it initiates the built-in test (BIT) operation for that mode. As a result, a Mode 1, 2, 3/A, or C test enable signal is applied to the bit control circuits in the transponder-transmitter, which enables generation of a test signal of proper parameters. If the parameters are found satisfactory, the TEST GO indicator light will illuminate on the transponder receiver/transmitter control panel. An error causes the TEST/MON NO-GO indicator light to illuminate, indicating a malfunction has occurred.

RAD TEST/OUT Switch

The RAD TEST/OUT switch is a two-position toggle switch that is spring-loaded to the OUT or (down) position. When RAD TEST is selected, the system responds to TEST mode interrogations from a test set during ground maintenance testing.

Mode 4 Operation

The Mode 4 controls and indicator light are grouped across the center of the control panel. The

MASTER rotary switch controls transponder operation in Mode 4 as well as in the other modes of operation. Mode 4 will operate normally, when selected, in either the NORM or EMER position. The Mode 4 function will be inoperative in either the STBY or OFF position. With the transponder functioning, Mode 4 operation is selected by placing the 3-position Mode 4 TEST-ON-OUT toggle switch to ON. Placing the switch to OUT disables Mode 4 operation, and placing it to TEST enables the BIT operation.

The Mode 4 CODE control selects either of the two (A or B) Mode 4 codes that are stored in the classified transponder computer. The rotary switch has two additional positions, HOLD and ZERO. At a designated daily time and/or prior to the day's mission, maintenance personnel electronically load the Mode 4 codes into the transponder computer. The present code period is placed in position A, and the code for the succeeding code period is placed in position B. Both code settings will automatically zeroize when power is turned off or lost after the landing gear interlock switch supplies a ground signal to the computer. Activating the HOLD function will retain the code settings. This is normally done while the aircraft is landing, and before power is removed from the transponder. Place the Mode 4 CODE control to HOLD, and release. Allow transponder power to remain on for at least 15 seconds, and then turn it off. The code setting will be retained when aircraft power is turned off.

With aircraft power on and the MASTER rotary switch in any position except OFF, both code settings can be zeroized at any time by placing the CODE switch to the ZERO position. Both code settings will also be zeroized if the HOLD function has not been properly actuated before the MASTER switch is turned to OFF. (Inadvertent selection of OFF is prevented by switch design, which requires that the rotary knob be pulled out before it can be turned to OFF.) When the CODE switch is placed in the A position, the aircraft transponder will respond to Mode 4 interrogations from an interrogator using the same code setting as that set into the aircraft's code A position. In the B position, interrogations from an interrogator using the same code setting as that set into the aircraft's code B position will be answered. The changeover time from code A to code B use is operationally directed.

The Mode 4 AUDIO/LIGHT/OUT switch selects the aircraft indication for Mode 4 replies. In the LIGHT position, the Mode 4 REPLY lamp will light when a correct Mode 4 reply is transmitted. In the AUDIO position, an IFF transponder caution tone will be heard

in the pilot's headset if an unidentified Mode 4 interrogation is received. In the OUT position, both light and audio indications are inoperative.

Transponder Special Reply Functions

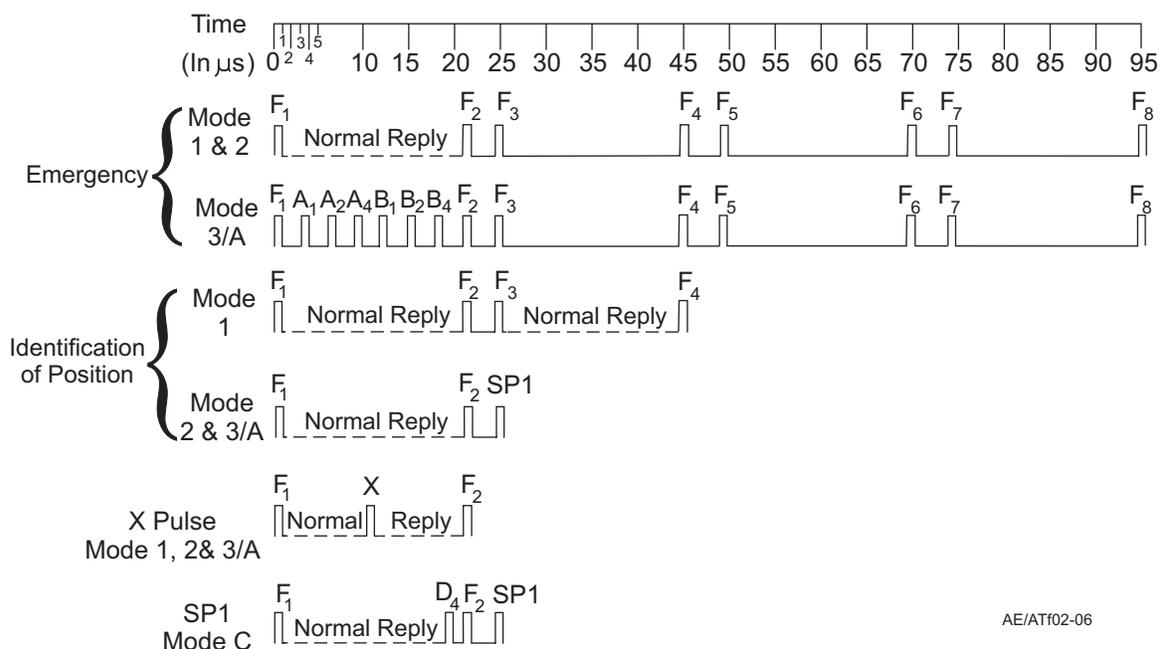
The transponder may transmit replies in four special modes: the emergency mode; the identification of position (I/P) mode; the X-pulse mode, which is used in Modes 1, 2, and 3/A; and the altitude special position identification (SPI) used with Mode C replies. Mode 4 is not affected by the special reply functions. Refer to figure 2-6 for the special replies generated for these special features.

EMERGENCY REPLY.—Setting the MASTER selector switch to EMER controls the emergency mode of operation of the transponder. This condition is initiated when the operator has an onboard emergency or has ejected from the aircraft. The emergency function affects the operation of Modes 1, 2, and 3/A. In Modes 1 and 2, the reply pulse train containing the code in use is transmitted once for each interrogation pulse received, followed by three sets of framing pulses and no information pulses. For each interrogation pulse received in Mode 3/A, one reply pulse train containing the code 7700 (regardless of the Mode 3 control dial settings) is transmitted, followed by three sets of framing pulses and no information pulses. The framing pulses are spaced in the same manner as Modes 1 and 2. During the emergency function the IFF transponder system replies to interrogations in Modes 1, 2, and 3/A automatically, regardless of which mode is enabled on the receiver/transmitter. By referring back to figure 2-2,

the interrogating source radar screen should show four display bars or markers behind the target instead of just one row as in normal operation.

IDENTIFICATION OF POSITION (I/P).—The I/P function is controlled by the IDENT/OUT/MIC switch and affects the operation of Modes 1, 2, and 3/A. Upon radio request from an interrogating source, the I/P operation is selected by placing the transponders IDENT-OUT-MIC switch momentarily to IDENT, which forces the reply into an I/P format. In Mode 1, the reply pulse train containing the code in use is transmitted twice, instead of once, for each interrogation pulse received. In Modes 2 and 3/A, the reply pulse train containing the code in use is transmitted once, followed by a special position indicator (SPI) pulse for each interrogation pulse received. The result of the extra pulse train in Mode 1 and the SPI pulse in Modes 2 and 3 can be seen in figure 2-6. At the interrogating source radar screen, an IFF reply display with an I/P reply is differentiated from standard IFF reply displays by two display bars or markers appearing behind the target, as shown in figure 2-2. This mode is useful when the desired aircraft is in the vicinity of other aircraft using the same coding.

X-PULSE.—The X-pulse appears following the initial framing pulse in the normally unused position of Modes 1, 2, and 3/A. It can only be obtained by modifying the controls. When modified, all replies in Modes 1, 2, and 3/A will include this pulse, along with the normally selected information reply pulses, between the two framing pulses. To date, the use of this pulse has been used to identify “special” status, such as an unmanned or experimental aircraft.



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Figure 2-6.—Special reply pulse characteristics.

SPECIAL POSITION IDENTIFICATION (SPI) PULSE.—The SPI pulse is generated whenever a D₄ pulse is used in a Mode C reply. This pulse is in the same position as the initial framing pulse of a second reply train, F₃. The SPI mode is used with Mode C replies to assist the operator at the challenging station to segregate aircraft above or below an altitude of approximately 31,000 feet.

IFF MAINTENANCE CONCEPTS

IFF systems are designed for rapid recognition of hardware failures, ease in replacement of the unit, accuracy of fault isolation, and ease of board and module replacement and repair. Built-In-Test (BIT) circuits are used to verify system readiness and perform fault isolation to the failed Weapons Replaceable Assembly (WRA).

Corrective maintenance consists of troubleshooting, removal, and replacement of WRAs. The BIT features are used to perform fault isolation to failed WRA in most cases. External confidence checks are performed using the AN/APM-424(V)2 (Star Wars Gun) transponder test set, shown in figure 2-7. This test set performs a radiated test on the aircraft transponders system to verify proper operation of Modes 1, 2, 3/A, C, and 4. When a failure in the transponder system occurs, the test set displays a coded digit to assist the operator in fault isolation of the system.

- Q2-1. *What does the acronym IFF stands for?*
- Q2-2. *What are the three basic steps in the identification process of a typical IFF system?*
- Q2-3. *True or False. All naval aircraft contain an interrogator system.*
- Q2-4. *What is the pulse spacing of Mode 1?*
- Q2-5. *Of the six modes of IFF operation, which one is used by military and civilian aircraft control stations?*

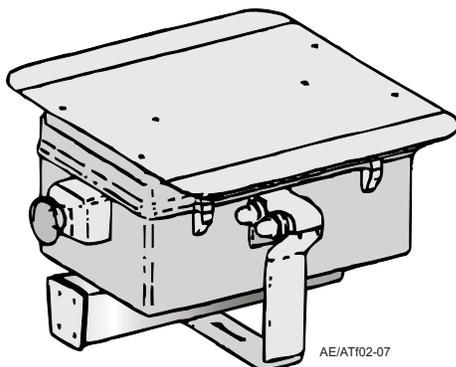


Figure 2-7.—AN/APM-424(V)2 transponder test set.

- Q2-6. *What mode IFF is the military encrypted mode?*
- Q2-7. *What is the transmission frequency of the interrogator?*
- Q2-8. *In a typical IFF/SIF system, what total number of codes can be selected in Mode 2?*
- Q2-9. *The Identification of Position (I/P) pulse is used for what purpose?*
- Q2-10. *What mode of IFF is set prior to takeoff by maintenance personnel?*

TRANSPONDER AND INTERROGATOR SETS

LEARNING OBJECTIVE: Recognize the components of the Transponder Set AN/APX-72, Interrogator Set AN/APX-76(V), and Transponder Set AN/APX-100(V).

Components of Transponder Set AN/APX-72, Interrogator Set AN/APX-76, and Transponder Set AN/APX-100(V) are discussed here.

TRANSPONDER SET AN/APX-72

The AN/APX-72 transponder set generates and transmits a 1090 MHz reply signal only upon receipt and successful validation of an interrogation signal. Although the IFF transponder system is capable of responding to interrogations in any of the five modes of operation, it responds only if the operator has manually enabled a particular mode. The five major components of the AN/APX-72 are discussed here.

RF TRANSMISSION LINE SWITCH SA-1769/A. The RF transmission switch (fig. 2-8)

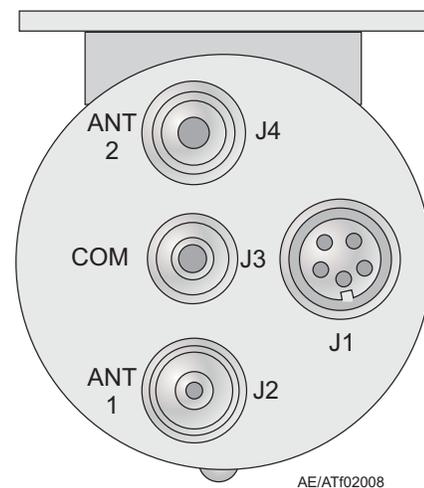


Figure 2-8.—SA-1769/A RF transmission line switch.

couples interrogations and replies between two UHF L-band antennas and the transponder set. The switching between the antennas operates at approximately 38 Hz. This switching action prevents the antenna system from being blanked out during aircraft maneuvers.

TRANSPONDER SET CONTROL C-6280/APX-72. The IFF control box (fig. 2-9) contains controls and indicators used for system operation and manual testing. Reply codes for Modes 1 and 3/A are selected with panel-mounted thumbwheel switches. These codes can be inserted or changed during flight, while Mode 2 and Mode 4 codes must be preset before takeoff.

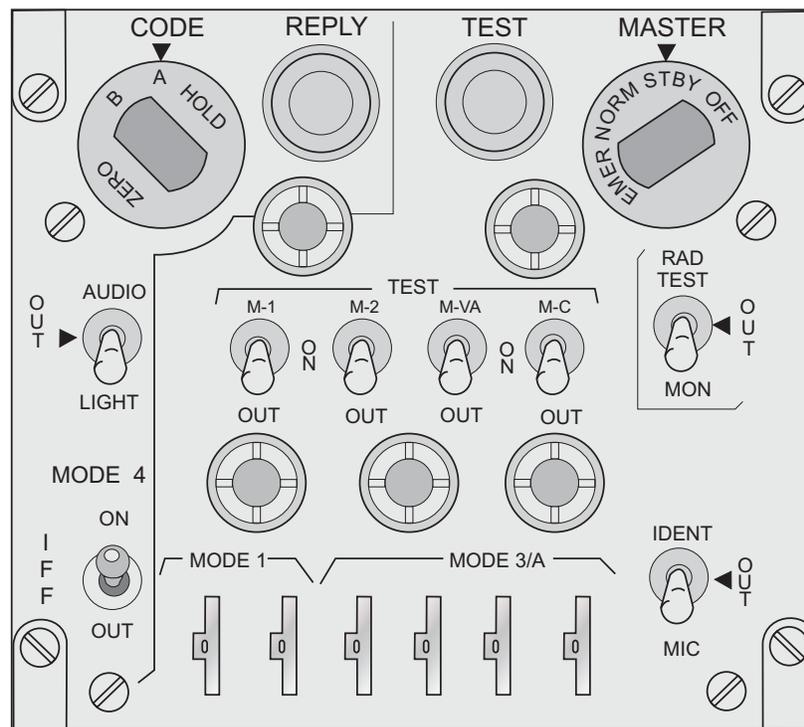
RECEIVER/TRANSMITTER RT-859/APX-72. The receiver/transmitter (fig. 2-10) will transmit a reply when RF interrogations are received from an IFF interrogator. The unit receives coded interrogations at 1030 MHz and transmits code replies at 1090 MHz. The transponder is capable of operating in five modes and superimposing special signals on the mode replies. Thumbwheel switches mounted on the front panel are used to preset code for Mode 2 operation prior to flight.

TRANSPONDER TEST SET TS-1843/APX. The test set (fig. 2-11) provides on-ground or in-flight transponder system test capability. During normal operation it routes interrogations and reply pulses between the receiver/transmitter and the line switch. During manual test mode it generates interrogation test

pulse pairs when Mode 1, 2, 3/A or C tests are enabled. These tests are selected from the transponder set control. Transponder reply codes are monitored and evaluated by the transponder test set. When the reply code pulses fall within specified limits, a monitor go signal is established, which causes the TEST monitor indicator on the control box to light. When reply code pulses do not meet proper specifications, a NO GO condition exists and causes the TEST monitor indicator to stay dark, indicating an error has occurred.

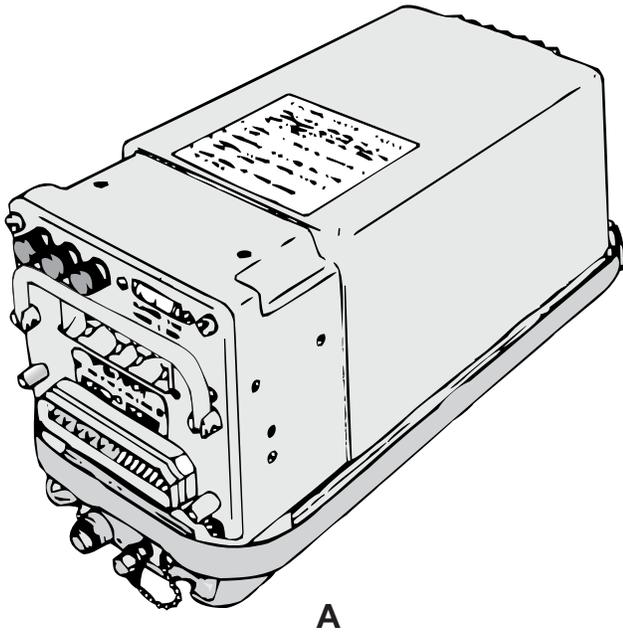
COMPUTER KIT-1/TSEC. The transponder computer, figure 2-12, allows the IFF transponder to respond to Mode 4 interrogations. When enabled, the transponder computer decodes Mode 4 interrogations. If the interrogation contains the correct code, a coded Mode 4 reply is generated and routed to the transmitter-receiver for transmission. Mode 4 operating codes are classified and are inserted in the computer with an electronic keying device prior to takeoff.

- Q2-11. *Where are Modes 1 and 3/A selected on the AN/APX-72 transponder set?*
- Q2-12. *What part of the APX-72 system provides for ground or in-flight transponder testing capability?*
- Q2-13. *The AN/APX-72 generates a signal of what frequency when interrogated?*

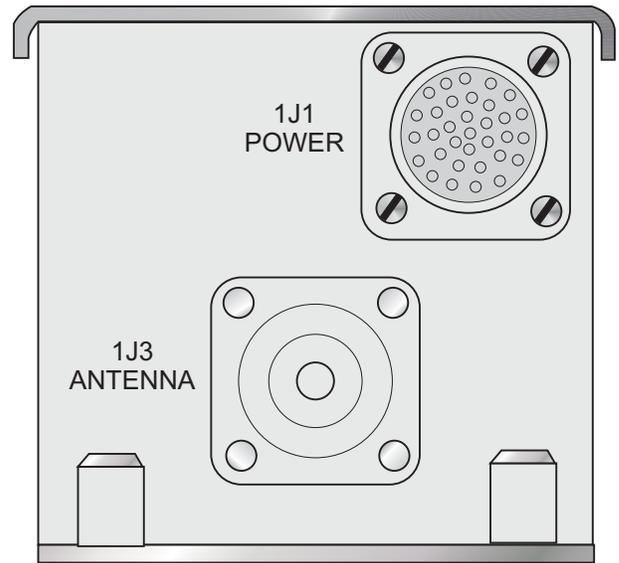


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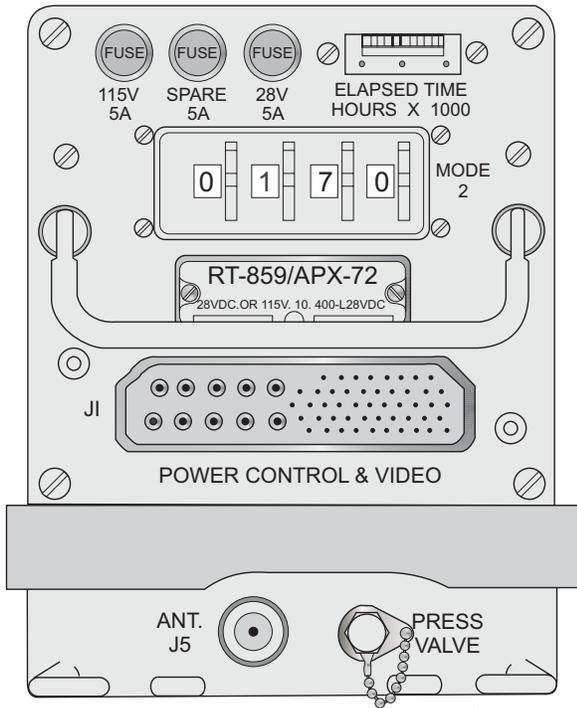
Figure 2-9.—C-6280/APX-72 transponder set control.



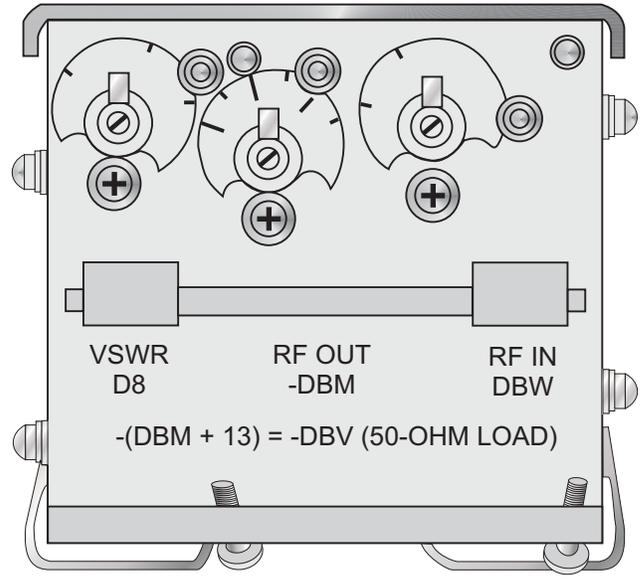
A



FRONT VIEW



B



REAR VIEW

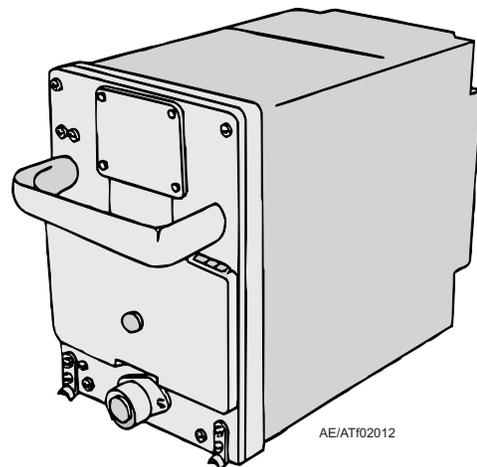
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Figure 2-10.—RT-859/APX-72 receiver/transmitter.

Figure 2-11.—TS-1843/APX test set.

INTERROGATOR SET AN/APX-76(V)

The interrogator system works in conjunction with the radar unit. The system transmits (interrogations) at 1030 MHz to transponders of airborne or surface crafts. Coded replies are received at 1090 MHz from the target transponders and processed by the receiver/transmitter, which is the major component of the IFF interrogator set. Upon receipt of coded reply signals the system



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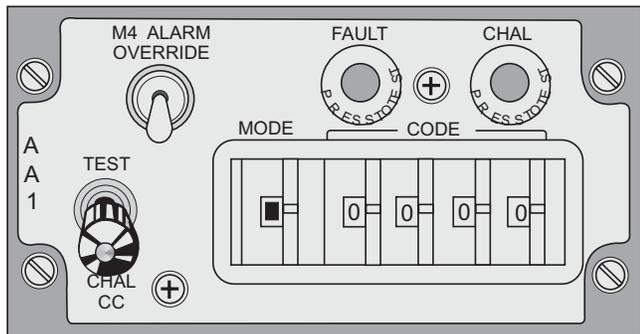
Figure 2-12.—KIT-1/TSEC transponder computer.

determines whether the target is friendly, hostile, or unknown. The IFF interrogator set is capable of providing challenges in five different modes (1, 2, 3/A, and C) and classified mode 4 (code A and B). In addition, the system incorporates interrogation sidelobe suppression (ISLS) and receiver (RSLs) functions to provide a narrow bandwidth. This permits selective aircraft interrogation in a narrow sector of the aircraft path and also aids in anti-jamming. Additionally, the IFF interrogator system includes a self-checking performance monitoring and fault isolation capability.

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

INTERROGATOR SET CONTROL PANEL C-7383/APX-76(V). The interrogator control panel, often referred to as the control box (fig. 2-13), provides selection of interrogation modes (1, 2, 3/A, 4A, or 4B) or STANDBY, and allows for SIF reply codes for Modes 1, 2, and 3/A operation. A momentary two-position toggle switch (TEST/CHAL CC) allows for loop testing the system, or to provide correct code challenge. The loop testing allows for the interrogation of the onboard transponder set by the IFF interrogator. Correct code challenge enables interrogations for which IFF display pulses are generated if the received SIF reply code is identical to the code switch settings. There are two indicators (FAULT and CHAL) that indicate the operating status of the system. The Mode 4 alarm may be overridden by using the toggle switch M4 ALARM OVERRIDE.

RECEIVER/TRANSMITTER RT-868/APX-76(V). The receiver/transmitter (fig. 2-14) is capable of transmitting challenges in five different modes (1, 2, 3/A, C and 4). It converts these modes to modulation pulses, and then uses these pulses to modulate the internally generated 1030 MHz carrier to provide IFF interrogation pulses. Coded replies from target



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Figure 2-13.—C-7383/APX-76(V) interrogator control box.

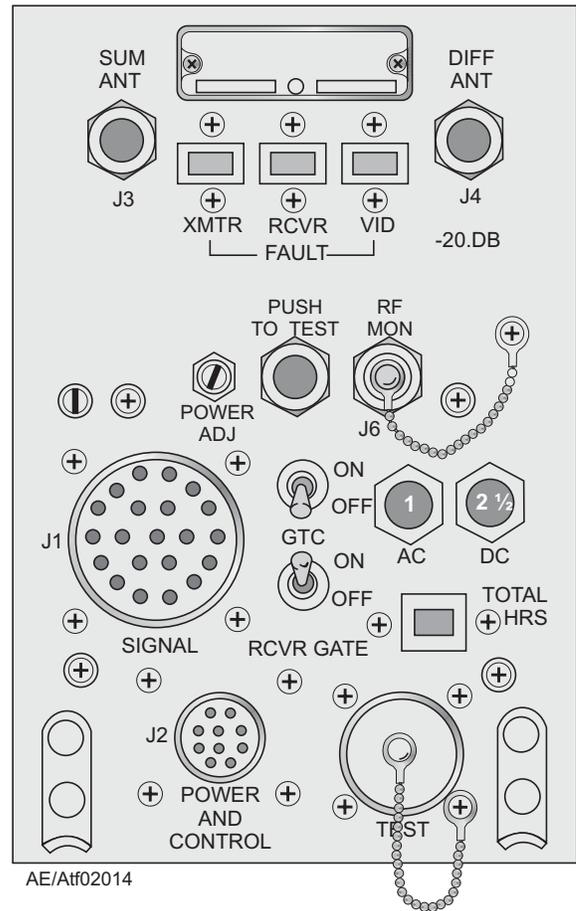
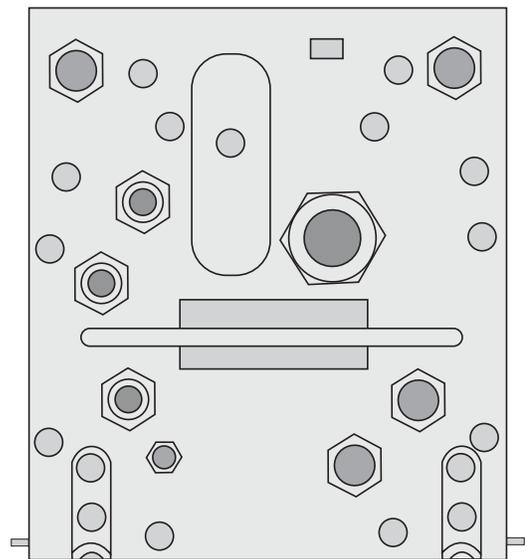


Figure 2-14.—RT-868/APX-76(V) receiver/transmitter.

transponders are received and used to determine target nature (friendly, hostile, or unknown). The propagation delay between challenge pulses and receipt of coded replies provides a means of determining target range.

SWITCH-AMPLIFIER SA-1568/APX-76(V). The switch-amplifier (fig. 2-15) switches the



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Figure 2-15.—SA-1568/APX-76(V) switch-amplifier.

interrogator's RF output from the sum antenna channel to the difference antenna channel for the duration of the ISLS pulse. During this time, the output is amplified by 4 to 7 dB. This amplification provides the required antenna output characteristics. Additionally, the unit contains internal performance monitoring circuits that perform self-tests for each challenge period. If a malfunction is determined, the unit will generate an interrogator switch-amplifier fault signal.

ELECTRONIC SYNCHRONIZER SN-416/APX-76(V). The synchronizer (fig. 2-16) contains performance monitoring circuits that check the timing triggers and pre-triggers, gates, and a test video. If any of these signals are incorrect, the synchronizer generates a fault signal, which causes the FAULT flag indicator to go red. The synchronizer fault is also applied to the fault indicator circuit. The fault indicator circuit also receives status inputs from the interrogator receiver/transmitter, switch-amplifier, and the interrogator computer (KIR-1/TSEC). If any of the inputs reflect a NO-GO status, the fault indicator circuit generates a fault indication signal to light the FAULT indicator lamp on the interrogator control.

COMPUTER KIR-1/TSEC. The interrogator computer is used for Mode 4 security and decoding for secure operation. Mode 4 A or B codes are loaded prior to flight by maintenance personnel, who use special electronic keying devices.

Q2-14. The interrogator works in conjunction with what other aircraft system?

Q2-15. What component of the interrogator set is used to select SIF reply codes for Modes 1, 2, and 3/A?

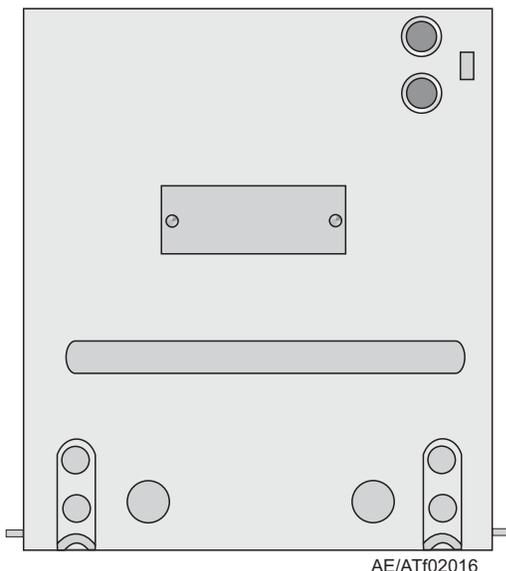


Figure 2-16.—SN-416/APX-76(V) synchronizer.

Q2-16. What component monitors the timing triggers, pre-triggers, gates, and test video and causes the fault indicator lamp on the interrogator control to illuminate when a fault has been detected within the system?

TRANSPONDER SET AN/APX-100(V)

The AN/APX-100 transponder set generates and transmits a 1090 MHz reply signal only upon receipt and successful validation of an interrogation signal similar to the AN/APX-72 transponder. This system uses two antennas (upper and lower) to receive interrogation signals. After the two antennas receive the signal they are routed through the RF distribution subassembly to the top and bottom receivers respectively. Each of the transponders' receivers convert the RF signal into two separate video signals. Both videos are then compared in the diversity processor, and the stronger of the two signals is used to provide the coder assembly with digital pulses. The decision made by the processor as to which is the stronger video is indicated to the RF distribution subassembly so that it may cause the transmitted reply to be radiated from the same antenna. The coder assembly decodes the digital pulses by using a digital delay line, which identifies the spacing between the pulses and recognizes the interrogation mode that has been received. For all modes, with the exception of Mode 4, settings of the switches on the control panel cause a reply train in the appropriate mode to be encoded by the coder assembly and sent to the modulator.

If decoding identifies the interrogation received as Mode 4 and the control panel has enabled Mode 4, the signal is sent to the Mode 4 module where it is then passed to the transponder computer. The resulting Mode 4 reply is then returned to the IFF transponder and then sent to the modulator. If the IFF transponder is unable to respond to the Mode 4 interrogations, an audio tone will be generated in the pilot's headset and the IFF caution light will illuminate. The modulator/transmitter subassembly generates the RF reply pulses. These pulses are routed by the RF distribution subassembly to the upper or lower antenna depending upon the diversity decision made by the processor.

The transponder set comes in two configurations. One is of the panel (or console) mounted construction; while the other is a rack (electronic bay) mounted that requires a remote, panel mounted control, and a MT-4811, electrical mounting base. These components are discussed briefly in the following text.

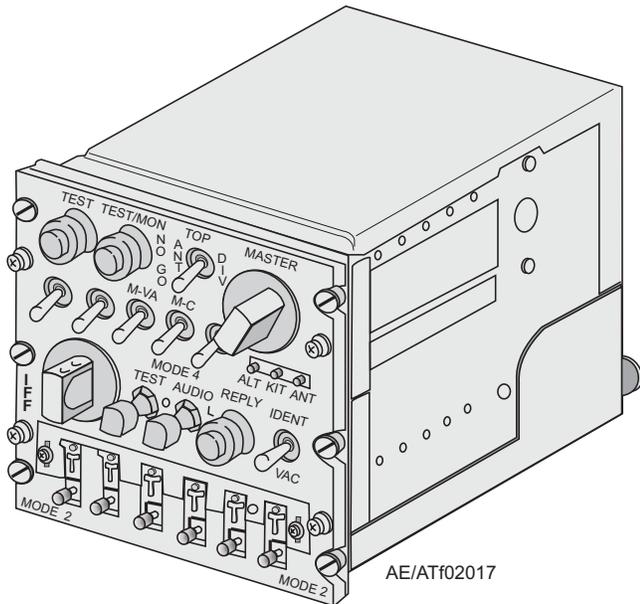


Figure 2-17.—RT-1248/APX-100 receiver/transmitter.

RECEIVER/TRANSMITTER RT-1248/APX-100.

The IFF transponder set RT-1248/APX-100 (fig. 2-17) is of the panel-mounted configuration and consists of a receiver/transmitter/control contained in a single

weapon replaceable assembly. The system receives, decodes, and replies to interrogation by challenging aircraft, ships, or shore installations. Modes of interrogation include aircraft identification, flight status, and altitude. The transponder responds to normal IFF challenges or SIF challenges. When operated in conjunction with the KIT-1/TSEC computer, the IFF transponder set will receive interrogations and transmit replies in secure Mode 4.

RECEIVER/TRANSMITTER RT-1157/APX-100.

The RT-1157/APX-100 is referred to as the rack-mounted configuration, which consists of three separate assemblies, as shown in figure 2-18. The system has the same operating characteristics as the RT-1248/APX-100, but was designed for use in different aircraft platforms. The major difference with this system is that the control box is located away from the receiver/transmitter.

ANTENNA AS-3557/A.

The AS-3557/A (fig. 2-19) is a dual element blade antenna used for the IFF and VHF/UHF communication systems. The IFF system uses the L-band elements of the upper and lower forward communication antennas. Figure 2-20 displays where these antennas are typically located on the

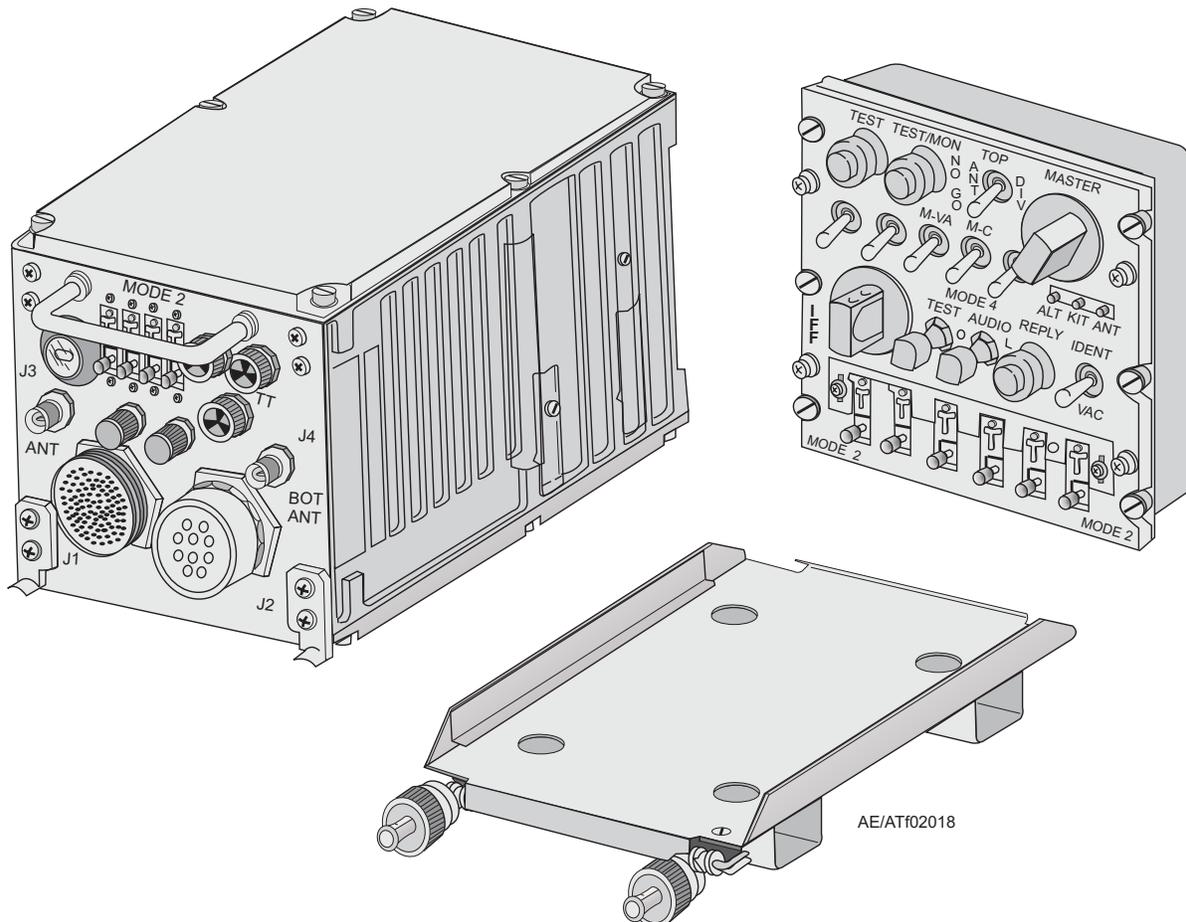


Figure 2-18.—RT-1157/APX-100 receiver/transmitter.

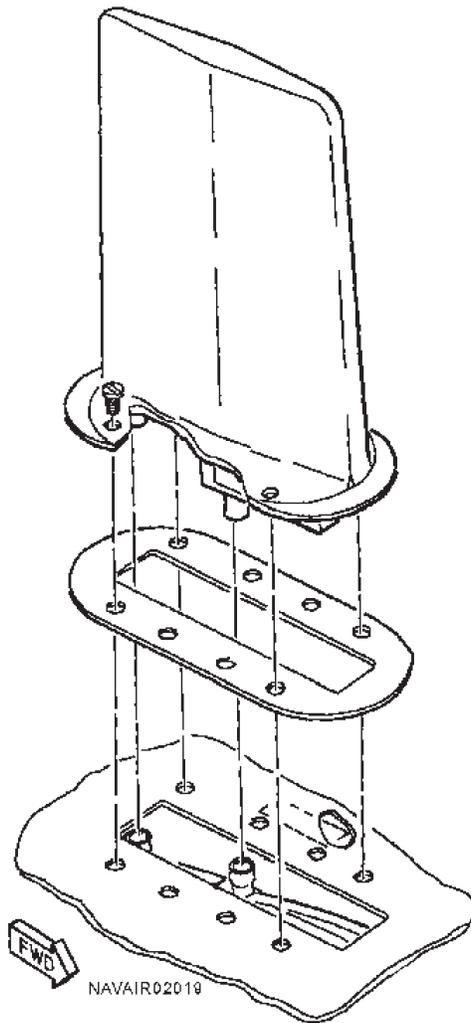


Figure 2-19.—Antenna AS-3557/A.

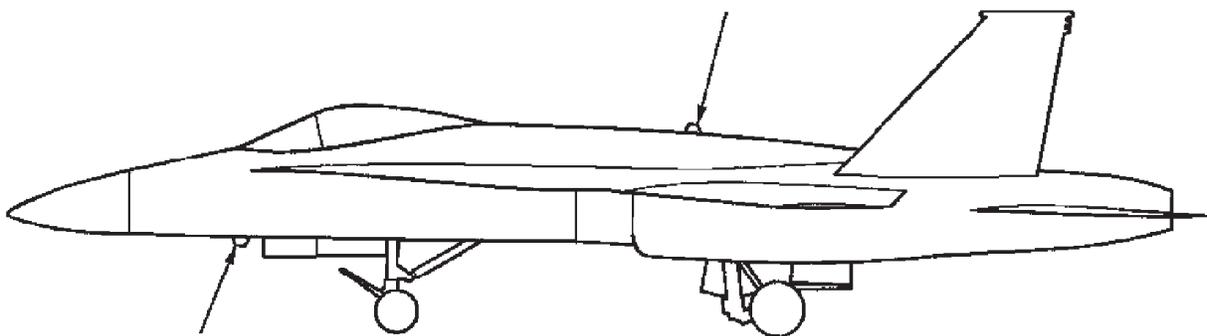


Figure 2-20.—Typical IFF antenna position on F/A-18A/B/C/D.

aircraft. The ANT SEL-IFF switch on the ANT SEL control panel assembly controls the antenna selection. Setting ANT SEL-IFF switch to BOTH enables diversity (automatic antenna selection) operation. Diversity operation compares signal strength received from both antennas and selects the antenna that has the greater signal strength. Selecting UPPER or LOWER forces the IFF system to operate on the antenna selected.

- Q2-17. The APX-100 transponder set is available in what number of configurations?
- Q2-18. To respond to Mode 4 interrogations, the IFF transponder set system requires what additional components?
- Q2-19. What APX-100 system is referred to as the rack-mounted configuration?

APPENDIX I

GLOSSARY

- ALTITUDE**—The vertical distance of an aircraft or object above a given reference, such as ground or sea level.
- AMBIGUOUS RETURNS**—Echoes that exceed the PRT of a radar and appear at incorrect ranges.
- ANTENNA**—A conductor or set of conductors used to radiate RF energy into space or to collect RF energy from space, or to do both.
- ANTENNA BEAMWIDTH**—Width of a radar beam measured between half-power points.
- ANTENNA SYSTEM**—Routes RF energy from the transmitter, radiates the energy into space, receives echoes, and routes the echoes to the receiver.
- A-SCOPE (A-SCAN)**—In radar, a display in which targets appear as vertical displacements from a line representing the time base. Target distance is represented by the horizontal distance from one end of the time base. Amplitude of the vertical deflection is a function of the signal intensity.
- ASSEMBLY**—A number of parts or subassemblies, or any combination thereof, joined together to perform a specific function.
- AVERAGE POWER**—Output power of a transmitter as measured from the start of one pulse to the start of the next pulse.
- AZIMUTH**—Angular measurement in the horizontal plane in a clockwise direction.
- BANDWIDTH**—The difference between the highest usable frequency of a device (upper frequency limit) and the lowest usable frequency of the device (lower frequency limit) measured at the half-power points.
- BEAM**—See LOBE.
- BEAMWIDTH**—The width of an electromagnetic beam, measured in degrees, on an arc that lies in a plane along the axis of propagation, between points of equal field strength. It may be measured in the horizontal or vertical plane.
- BEARING**—An angular measurement of the direction of an object from a reference direction, such as true north.
- BEARING RESOLUTION**—Ability of a radar to distinguish between targets that are close together in bearing.
- BIT**—Built-in-test.
- BLIP**—See PIP.
- BLOCK DIAGRAM**—A diagram in which the major components of an equipment or a system are represented by squares, rectangles, or other geometric figures, and the normal order of progression of a signal or current flow is represented by lines.
- CARRIER FREQUENCY**—The frequency of an unmodulated transmitter output.
- CATHODE**—(1) In an electron tube, the electrode that is the source of current flow. The general name for any negative electrode.
- CATHODE-RAY TUBE (CRT)**—An electron tube that has an electron gun, a deflection system, and a screen. This tube is used to display visual electronic signals.
- CAVITY**—A space totally enclosed by a metallic conductor and supplied with energy in such a way that it becomes a source of electromagnetic oscillations. The size and shape of the enclosure determine the resonant frequency.
- CIRCUIT**—The complete path of an electric current.
- CLUTTER**—Confusing, unwanted echoes that interfere with the observation of desired signals on a radar indicator.
- DECIBEL (dB)**—A dimensionless unit for expressing the ratio of two values of power, current, or voltage. Normally, used for expressing transmission gains, losses, levels, and similar quantities.
- DETECTOR**—A mixer or converter in a superheterodyne receiver.

- DIRECTIONAL ANTENNA**—An antenna that radiates most effectively in only one direction.
- DOPPLER EFFECT**—The apparent change in frequency or pitch when a sound source moves either toward or away from a listener. In radar, the change in frequency of a received signal caused by the relative motion between the radar and the target.
- DOPPLER FREQUENCY**—The difference between transmitted and reflected frequencies; caused by the Doppler effect.
- DUCTING**—Trapping of an RF wave between two layers of the earth's atmosphere or between an atmospheric layer and the earth.
- DUPLEXER**—A switch or tube that permits the use of a single antenna for both transmission and reception. The dual function of the duplexer is to prevent absorption of transmitter energy by the receiver system (thereby protecting the receiver), and to prevent absorption of any appreciable portion of the received echo signal by the transmitter.
- DUTY CYCLE**—In a transmitter, ratio of time on to time off.
- ECHO**—The reflection of the original sound wave as it bounces off a distant surface. The RF signal reflected back from a radar target.
- ELECTRON**—The elementary negative charge that revolves around the nucleus of an atom.
- ENCRYPT**—To convert from one system of communication to another.
- EXTREMELY HIGH FREQUENCY**—The band of frequencies from 30 gigahertz to 300 gigahertz.
- EXTREMELY LOW FREQUENCY**—The band of frequencies up to 300 hertz.
- FREQUENCY (f)**—The number of complete cycles per second existing in any form of wave motion, such as the number of cycles per second of an alternating current.
- FREQUENCY MODULATION (FM)**—Angle modulation in which the modulating signal causes the carrier frequency to vary. The amplitude of the modulating signal determines how far the frequency changes, and the frequency of the modulating signal determines how fast the frequency changes.
- FREQUENCY SPECTRUM**—In a radar, the entire range of frequencies contained in an RF pulse or signal.
- HERTZ (Hz)**—A unit of frequency equal to one cycle per second.
- HETERODYNING**—The process of mixing two frequencies across a nonlinear device. The process of mixing the incoming signal with the local oscillator frequency. This produces the two fundamentals and the sum and difference frequencies.
- HIGH FREQUENCY**—The band of frequencies from 3 megahertz to 30 megahertz.
- IF AMPLIFIER**—Usually a narrow bandwidth IF amplifier that is tuned to one of the output frequencies produced by the mixer.
- IFF**—Identification friend or foe. A system using radar transmission to which equipment carried by friendly forces automatically responds by emitting unique characteristic series of pulses, thereby distinguishing themselves from enemy forces.
- INDICATOR**—Equipment in radar that provides a visual presentation of target position information.
- INTERMEDIATE FREQUENCY (IF)**—A lower frequency to which an RF echo is converted for ease of amplification.
- INTERROGATION**—The triggering of one or more transponders by transmitting a radio signal or combination of signals.
- INTERROGATOR**—Also called challenger. A radio transmitter used to trigger a transponder.
- KILO**—A prefix meaning one thousand.
- KLYSTRON**—A multicavity microwave electron tube that uses velocity modulation.
- LOBE**—An area of greater signal strength in the transmission pattern of an antenna.
- LOW FREQUENCY**—The band of frequencies from 30 kHz to 300 kHz.
- MAGNETRON**—An electron tube that provides a high power output. Theory of operation is based on interaction of electrons with the crossed electric and magnetic fields in a resonant cavity.
- MEDIUM FREQUENCY**—The band of frequencies from 300 kHz to 3 MHz.
- MEGA**—A prefix meaning one million; also MEG.

- MICRO**—A prefix meaning one-millionth.
- MIL**—The diameter of a conductor equal to 1/1000 (.001) inch.
- MILLI**—A prefix meaning one-thousandth.
- MIXER**—In radar, a circuit that combines the received RF signal with a local-oscillator signal to effectively convert the received signal to a lower IF frequency signal.
- MODULATOR**—In radar, a component that produces a high-voltage pulse that turns the transmitter on and off.
- NAUTICAL MILE**—The length of a minute of arc of a great circle of the earth (6,076 ft).
- NAUTICAL RADAR MILE**—See RADAR MILE.
- NOISE**—In radar, erratic or random deflection or intensity of the indicator sweep that tends to mask small echo signals.
- OCTAL**—A number system with a base number of eight.
- PEAK POWER**—The maximum value of the transmitted pulse.
- PIP (BLIP)**—On a CRT display, a spot of light or a baseline irregularity representing the radar echo.
- PPI-SCAN (PPI DISPLAY)**—A radar display in which range is indicated by the distance of a bright spot or pip from the center of the screen and the bearing is indicated by the radial angle of the spot.
- POWER SUPPLY**—A unit that supplies electrical power to another unit. It changes ac to dc and maintains a constant voltage output within limits.
- PULSE**—Signal characterized by a steep rise from and decay toward an initial level.
- PULSE-FORMING NETWORK (PFN)**—An LC network that alternately stores and releases energy in an approximately rectangular wave.
- PULSE MODULATION**—A form of modulation in which one of the characteristics of a pulse train is varied.
- PULSE-REPETITION FREQUENCY (PRF)**—The rate, in pulses per second, at which the pulses occur.
- PULSE-REPETITION RATE (PRR)**—Same as PULSE-REPETITION FREQUENCY (PRF).
- PULSE-REPETITION TIME (PRT)**—Interval between the start of one pulse and the start of the next pulse; reciprocal of pulse-repetition frequency.
- PULSEWIDTH**—Duration of time between the leading and trailing edges of a pulse.
- RADAR**—An acronym for **RA**dio **D**etecting **A**nd **R**anging.
- RADAR ALTIMETER**—Airborne radar that measures the distance of the aircraft above the ground.
- RADAR BEAM**—The space in front of a radar antenna where a target can be effectively detected or tracked. Defined by areas that contain half or more of the maximum power transmitted.
- RADAR MILE**—Time interval (12.36 microseconds) for RF energy to travel out from a radar to a target and back to the radar; radar nautical mile.
- RADIO FREQUENCY (RF)**—Any frequency of electromagnetic energy capable of propagation into space. The frequencies that fall between 3 kilohertz and 300 gigahertz used for radio communications.
- RANGE**—The length of a straight line between a radar set and a target.
- RANGE-HEIGHT INDICATOR**—A radar display on which slant range is shown along the X axis and height along the Y axis.
- RANGE MARKER**—A movable vertical pulse on an A-scope or a ring on a PPI scope used to measure the range of an echo or to calibrate the range scale.
- RANGE RESOLUTION**—Ability of a radar to distinguish between targets that are close together.
- RECEIVER**—Equipment that converts electromagnetic energy into a visible or an audible form. In radar, a unit that converts RF echoes to video and/or audio signals.
- RECEIVER SENSITIVITY**—The degree to which a receiver can usefully detect a weak signal. The lower limit of useful signal input to the receiver.
- RECOVERY TIME**—In a radar, the time interval between the end of the transmitted pulse and the time it takes for recovery to a specified relation between receiving sensitivity or the received signal and the normal value.

RELATIVE BEARING—Bearing of a target measured in a clockwise direction from “dead ahead” of a ship or plane.

RESONANT CAVITY—A space, normally enclosed by an electrical conductive surface, in which oscillatory electromagnetic energy is stored, and whose resonant frequency is determined primarily by the geometry of the enclosure.

RETURN—The RF signal reflected back from a radar target; echo.

SET—A unit or units and the assemblies, subassemblies, and parts connected or associated together to perform a specific function.

SIDE LOBE SUPPRESSION (SLS)—Allows the transponder to accept the main lobe and to reject minor lobe signals from the interrogator set.

SLANT RANGE—See RANGE.

STATUTE MILE—5,280 feet.

SUPERHETERODYNE RECEIVER—A type of receiver that uses a mixer to convert the RF echo to an IF signal for amplification.

SUPERHIGH FREQUENCY—The band of frequencies from 3 gigahertz to 30 gigahertz.

SYNCHRONIZER—A circuit that supplies timing signals to other radar components.

SYSTEM—A combination of sets, units, assemblies, subassemblies, and parts joined together to form a specific operational function or several functions.

TARGET—In radar, a specific object of radar search or detection.

TARGET RESOLUTION—The ability of a radar to distinguish between two or more targets that are close to each other.

TRANSMITTER—Equipment that generates and amplifies an RF carrier, modulates the RF carrier with intelligence, and radiates the signal into space.

TRANSPONDER—A radio transmitter-receiver that transmits identifiable signals automatically when the proper interrogation is received.

TREMENDOUSLY HIGH FREQUENCY—The band of frequencies from 300 gigahertz to 3,000 gigahertz.

ULTRAHIGH FREQUENCY—The band of frequencies from 300 megahertz to 3 gigahertz.

VELOCITY—The rate at which a disturbance travels through a medium.

VERY HIGH FREQUENCY—The band of frequencies from 30 megahertz to 300 megahertz.

VERY LOW FREQUENCY—The band of frequencies from 3 kilohertz to 30 kilohertz.

WATT—The unit of electrical power that is the product of voltage and current.

WAVEGUIDE—A rectangular, circular, or elliptical metal pipe designed to transport electromagnetic waves through its interior.

WAVELENGTH—The distance, usually expressed in meters, traveled by a wave during the time interval of one complete cycle. It is equal to the velocity divided by the frequency.

APPENDIX II

REFERENCES USED TO DEVELOP THIS NONRESIDENT TRAINING COURSE (NRTC)

Although the following references were current when this Nonresident Training Course was published, their continued currency cannot be assured. When consulting these references, keep in mind that they may have been revised to reflect new technology or revised methods, practices, or procedures. Therefore, you need to ensure that you are studying the latest references.

Chapter 1

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Aviation Electronics Technician 3, NAVEDTRA 14028, Naval Education Training Professional Development Technology Center, Pensacola, FL

Radar Fundamental Course Pulsed Radar, Pulsed Radar, NWSTC, Kansas City, MO

Chapter 2

Technical Manual, Organizational Maintenance, Principles of Operation Communication Systems, Navy Model F-14D Aircraft, NAVAIR 01-F14AAD-2-2-12, Commander, Naval Air Technical Services Facility, Philadelphia, PA, 1 December 1995.

Technical Manual, Organizational Maintenance, Principles of Operation Communication Systems, Navy Model F-14A and F-14B Aircraft, NAVAIR 01-F14AAA-2-2-12, Commander, Naval Air Technical Data and Engineering Service Command, San Diego, CA, 1 March 2000.

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NAVAIR Technical Manuals, SH-60F ETM Update CD ROM, A1-H60CD-60F-000, Commanding Officer, Naval Air Technical Data and Engineering Service Command, San Diego, CA, 04 August 1999.

APPENDIX III

ANSWERS TO REVIEW QUESTIONS CHAPTERS 1 AND 2

CHAPTER 1

- A1-1. Radio Detection and Ranging.*
- A1-2. Approximately the speed of light or 186,000 statute miles per second.*
- A1-3. 1,804 yards.*
- A1-4. 30 nautical miles.*
- A1-5. The pulsewidth of the transmitted pulse and the recovery time of the duplexer and the receiver.*
- A1-6. Transmitted power, pulse repetition frequency (PRF), and receiver sensitivity.*
- A1-7. Range resolution of a radar system is the minimum resolvable separation in range of two targets at the same bearing.*
- A1-8. The longer the pulsewidth, the greater the range capabilities of the radar.*
- A1-9. Temperature inversion.*
- A1-10. Refraction.*
- A1-11. A low carrier frequency.*
- A1-12. Bands.*
- A1-13. A square wave with very sharp leading and trailing edges.*
- A1-14. The leading edge.*
- A1-15. PRT.*
- A1-16. Magnetron and klystron.*
- A1-17. 0.01.*
- A1-18. Pulse modulation radar.*
- A1-19. Provides proper timing pulses to components of the radar system.*
- A1-20. Self-synchronized or externally synchronized.*
- A1-21. Magnetron and klystron.*
- A1-22. An increase in the power available at the output.*
- A1-23. An electronic switch that permits the use of one antenna for both transmit and receive functions.*
- A1-24. Superheterodyne.*
- A1-25. To maintain a constant IF frequency out of signal mixer.*
- A1-26. Converts IF pulses into video pulses, which are applied to radar indicators.*
- A1-27. PPI, RHI, and A-scope.*

- A1-28. A map-like presentation of the region scanned.*
- A1-29. Antenna, antenna servo system, duplexer, transmitter, receiver, modulator, power supplies, synchronizer, and indicators.*
- A1-30. OFF, 25, 50, 100.*
- A1-31. Power supply group, modulator group, transmitter group, and BIT group.*
- A1-32. ECMO 1.*
- A1-33. The APS-130.*
- A1-34. ECMO 1.*

CHAPTER 2

- A2-1. Identification Friend or Foe.*
- A2-2. Challenge, decode, and reply.*
- A2-3. False.*
- A2-4. 2.9 to 3.1 μ s.*
- A2-5. Mode 3/A.*
- A2-6. Mode 4.*
- A2-7. 1030 MHz.*
- A2-8. 4,096.*
- A2-9. It is used to identify a specific friendly aircraft among other friendly aircraft that reply with the same code.*
- A2-10. Mode 2.*
- A2-11. By thumbwheel switches on the front of the control box.*
- A2-12. The Transponder Test Set TS-1843/APX.*
- A2-13. 1090 MHz.*
- A2-14. The radar.*
- A2-15. C-7383/APX-76(V) control box.*
- A2-16. Electronic Synchronizer SN-416/APX-76(V).*
- A2-17. The system comes in two configurations.*
- A2-18. Transponder Computer KIT-1/TSEC.*
- A2-19. Receiver/Transmitter RT-1157/APX-100.*

ASSIGNMENT 1

Textbook Assignment: "Radar," chapter 1, pages 1-1 through 1-24, and "Identification Friend or Foe (IFF) Systems," chapter 2, pages 2-1 through 2-13.

- 1-1. The acronym radar is derived from what words?
1. Ranging, detection, and receiving
 2. Radiation, detection, and radio
 3. Radio, detection, and ranging
 4. Radiation, detection, and ranging
- 1-2. Radar uses what form of energy to detect the presence of objects?
1. Sound waves
 2. Visible light
 3. Infrared radiation
 4. Electromagnetic energy
- 1-3. RF energy travels through air at approximately what speed?
1. 186,000 statute miles per second
 2. 162,000 nautical miles per second
 3. 300 million meters per second
 4. Each of the above
- 1-4. What is the time required for two-way travel of an RF pulse if the target is 15 miles from the radar unit?
1. 927.0 μs
 2. 270.8 μs
 3. 185.4 μs
 4. 92.7 μs
- 1-5. An increase in recovery time of a radar set will cause which of the following results?
1. Decrease in minimum range and an increase in receiver sensitivity
 2. Increase in minimum range and decrease in receiver sensitivity
 3. Decrease in both minimum range and receiver sensitivity
 4. Increase in both minimum range and receiver sensitivity
- 1-6. A radar set has a pulsewidth of 3 μs . In order for the operator to see two separate blips that are directly on the same line of bearing, what minimum distance must separate the targets?
1. 37.08 yards
 2. 55 yards
 3. 492 yards
 4. 984 yards
- 1-7. A pulse radar's range resolution is a function of the transmitted pulsewidth, while azimuth resolution is a function of what?
1. Antenna beamwidth
 2. Receiver sensitivity
 3. Peak transmitted power
 4. Peak half-power points
- 1-8. In order for two targets at the same range to appear as two targets instead of one target on the radar's indicator, what minimum distance must separate the two targets?
1. 164 yards
 2. 620 yards
 3. One beamwidth
 4. One-half of the pulsewidth
- 1-9. Refer to figure 1-1. Which of the following statements is correct concerning the slant range as used to indicate a target's distance from an observing radar?
1. Altitude difference is included in the slant range and is the same as horizontal range
 2. The straight-line distance is the ratio of slant range to altitude
 3. Horizontal range is always greater than the slant range measurement
 4. Altitude difference must be considered if horizontal range is to be computed
- 1-10. The maximum power of a RF transmitted pulse is referred to by what term?
1. Duty cycle
 2. Average power
 3. Beamwidth
 4. Peak power
- 1-11. Radar performance is affected by which of the following factors?
1. Prevailing atmospheric conditions
 2. The quality of maintenance performed on the equipment
 3. The operator's knowledge of the equipment's capability
 4. Each of the above

- 1-12. Although high-frequency energy from a transmitter travels essentially in a straight line and a constant speed, refraction and speed change are known to occur. Which of the following atmospheric conditions cause this to happen?
1. Temperature only
 2. Pressure only
 3. Vapor content only
 4. Temperature, pressure, and vapor content
- 1-13. Which of the following conditions is formed by a temperature inversion and/or by a moisture lapse that may extend or reduce the range of radar?
1. Ionization
 2. Ducting
 3. Fraction-of-index
 4. Surface wave
- 1-14. The elapsed time between the start of one transmitted pulse and the start of the next is known as which of the following terms?
1. PRT
 2. PRF
 3. 1/PRF
- 1-15. In addition to certain power considerations, the output pulse of a radar transmitter should possess which of the following characteristic shapes in order to present nearby targets on an indicator?
1. Narrow with a sloping trailing edge
 2. Narrow and square
 3. Wide and square
 4. Wide with slow rise in the leading edge
- 1-16. Generally, the maximum range of pulse type radar is determined by what element?
1. Modulation intensity
 2. Wavelength of transmitted energy
 3. Pulse repetition frequency
 4. Antenna radiation pattern
- 1-17. The PRF of a radar must be low enough to eliminate ambiguous targets, but high enough that the antenna's speed of rotation does not interfere with what factor?
1. Target reception
 2. Transmitter power
 3. The transmitted frequency
 4. Range notch circuitry
- 1-18. A radar set with a PRF of 2,000 PPS and an antenna rotation of 20 rpm produces what maximum number of pulses per degree?
1. 2.7
 2. 11.1
 3. 14.4
 4. 16.6
- 1-19. Which of the following statements is correct concerning peak power and average power of a pulsed radar system?
1. Average power expended is always greater than peak power
 2. Average power should approximate peak power to obtain maximum range
 3. Peak power is expended during the transmission of a pulse, and average power is the power expended over the pulse repetition time
 4. Average power is the power expended during the transmission of the pulse, and peak power is the power expended over the pulse repetition time
- 1-20. Which of the following formulas expresses the duty cycle of a radar set?
1. PRF/PW
 2. PW x PRF
 3. Peak Power x PW/PRT
 4. Peak Power x Average Power
-
- QUESTIONS 1-21 THROUGH 1-23 PERTAIN TO A PULSE RADAR SET THAT HAS THE FOLLOWING CHARACTERISTICS:
- $P_{pk} = 500 \text{ kW}$, $PW = 3.5 \mu\text{s}$, and duty cycle = 0.0014.
- 1-21. What is the PRT of this radar set?
1. 1,000 μs
 2. 1,250 μs
 3. 2,500 μs
 4. 4,000 μs
- 1-22. What is the P_{avg} of this radar set?
1. 207 W
 2. 358 W
 3. 600 W
 4. 700 W
- 1-23. What is the PRF of this radar set?
1. 200 PPS
 2. 300 PPS
 3. 400 PPS
 4. 490 PPS

- 1-24. Which of the following methods of transmitting RF energy uses the Doppler principle for radar detection?
1. Pulse modulation
 2. Continuous-wave
 3. Phase modulation
 4. Frequency modulation
- 1-25. Frequency-modulated radars transmit a wave that is continuously varying from a fixed reference frequency. When frequency modulation is used, how is the target detected?
1. Comparing the frequency of the signal that is presently being transmitted with the received frequency that has been reflected from the target
 2. Comparing the magnitude of the pulses that have been transmitted at one frequency with the magnitude of the reflected pulses at a second frequency
 3. Measuring the velocity of the received energy and comparing it with the velocity of the energy being transmitted
 4. Measuring the Doppler shift that has occurred in the returning signal
- 1-26. Continuous-wave radar, which employs the Doppler effect, is best suited in detecting which of the following targets?
1. Stationary or slow moving targets
 2. Fast moving targets
 3. Targets with a high degree of bearing resolution
 4. Targets with a high degree of range resolution
- 1-27. Which of the following components of a radar system determines the timing for all components of the radar?
1. Automatic tracker
 2. Synchronizer
 3. Receiver
 4. Transmitter
- 1-28. What is the purpose of the modulator in a typical pulse radar system?
1. To establish the pulse repetition period
 2. To establish the number of times the transmitter will fire per second
 3. To supply high voltage, rectangular pulses to drive the transmitter
 4. To supply high voltage, rectangular pulses to drive the synchronizer
- 1-29. What modulator circuitry determines the voltage level and width of the pulse generated?
1. The transforming network
 2. The RC differentiator
 3. The range mark generator
 4. The pulse forming network
- 1-30. Which of the following tubes should be used as the power amplifier in a radar transmitter?
1. Magnetron
 2. Klystron
 3. Tetrode
 4. Cathode-ray
- 1-31. The process whereby some electrons are accelerated, some are decelerated, and others are unaffected in the movement of the electron beam towards the collector end of a klystron is referred to by what term?
1. Ionic agitation
 2. Bunching
 3. Heterodyning
 4. Beam oscillation
- 1-32. What is the primary function of radar duplexing system?
1. To prevent the formation of standing waves in the waveguide system
 2. To increase the effective range of the radar
 3. To increase the antenna directivity
 4. To permit the use of one antenna for transmission and reception
- 1-33. A defective duplexer will likely cause damage to which of the following radar components?
1. The waveguide
 2. The magnetron
 3. The receiver
 4. The power amplifier tube
- 1-34. Because of the difficulty in amplifying high-frequency signals received in most radar receivers, it is necessary to generate an intermediate-frequency signal by a process referred to by which of the following terms?
1. Heterodyning
 2. Demodulation
 3. Spin modulation
 4. Discrimination

- 1-35. The intermediate frequency is produced in what stage of a microwave receiver?
1. Signal mixer
 2. Local oscillator
 3. IF amplifier/detector
 4. AFC discriminator
- 1-36. What section of a radar receiver usually determines the overall bandwidth?
1. Signal mixer
 2. Local oscillator
 3. IF amplifier/detector
 4. AFC discriminator
- 1-37. The IF amplifier stages of a radar receiver determines which of the following receiver characteristics?
1. The gain
 2. Signal-to-noise ratio
 3. Converts IF pulses to video pulses
 4. All of the above
- 1-38. Which of the following radar displays provides a map-like presentation that is practically an exact replica of the region scanned by the radar antenna?
1. RHI
 2. PPI
 3. A-scope
 4. B-scope
- 1-39. On a RHI display, what is represented by the vertical axis?
1. Range only
 2. Azimuth only
 3. Elevation
 4. Range and Azimuth
- 1-40. On an A-scope presentation, what is displayed on the horizontal axis?
1. Range only
 2. Azimuth only
 3. Range and Azimuth
 4. Elevation
- 1-41. Which component provides a crystal-controlled clock and digital timing loop to generate PRF trigger, sweep triggers, range markers, and precision range line signal?
1. PPD
 2. RSG
 3. PHD
 4. RCP
- 1-42. The Radar Set Control C-10535/APS-130 (RCP) is located at which of the following stations?
1. ECMO 1
 2. ECMO 2
 3. Pilot
 4. Co-Pilot
- 1-43. What are the four ranges on the PPI RNG rotary switch on the RCP?
1. OFF, 15, 60, 120
 2. 15, 30, 75, 150
 3. 10, 25, 50, 250
 4. 25, 50, 75, 100
- 1-44. How many slew controls are there with the APS-130 radar system?
1. 5
 2. 3
 3. 2
 4. 4
- 1-45. The Azimuth Elevation Range Indicator IP-1060A/APQ-148 is located at what station?
1. ECMO 1
 2. Pilot
 3. Co-Pilot
 4. TACCO 1
- 1-46. In a typical IFF system, what component is referred to as the challenging unit?
1. The radar system
 2. The synchronizer
 3. The transponder
 4. The interrogator
- 1-47. In a typical IFF system, what component is referred to as the responding unit?
1. The radar system
 2. The synchronizer
 3. The transponder
 4. The interrogator
- 1-48. What IFF mode of operation is used to report altitude information?
1. Mode 2
 2. Mode C
 3. Mode 3/A
 4. Mode 4

- 1-49. Which of the following modes of IFF operation is the military encrypted mode?
1. Mode 1
 2. Mode C
 3. Mode 3/A
 4. Mode 4
- 1-50. What is the transmission frequency of the interrogator?
1. 1030 MHz
 2. 1060 MHz
 3. 1090 MHz
 4. 1120 MHz
- 1-51. Which of the following modes are used strictly by the military as tactical modes for mission and identification purposes?
1. 1 and 2
 2. 2 and 3/A
 3. 3/A and 4
 4. C and 4
- 1-52. What is the pulse spacing of Mode 3/A?
1. 2.9 to 3.1 μ s
 2. 4.8 to 5.2 μ s
 3. 7.8 to 8.2 μ s
 4. 20.8 to 21.2 μ s
- 1-53. What is the pulse spacing of Mode 2?
1. 2.9 to 3.1 μ s
 2. 4.8 to 5.2 μ s
 3. 7.8 to 8.2 μ s
 4. 20.8 to 21.2 μ s
- 1-54. What is the pulse spacing of Mode 1?
1. 2.9 to 3.1 μ s
 2. 4.8 to 5.2 μ s
 3. 7.8 to 8.2 μ s
 4. 20.8 to 21.2 μ s
- 1-55. What is the transmission frequency of the transponder?
1. 1030 MHz
 2. 1060 MHz
 3. 1090 MHz
 4. 1120 MHz
- 1-56. A standard SIF reply is bound by a total of how many framing pulse(s)?
1. One
 2. Two
 3. Three
 4. Four
- 1-57. In a typical IFF system, what total number of combinations of codes can be selected in Mode C?
1. 4
 2. 32
 3. 2048
 4. 4096
- 1-58. In a typical IFF system, what total number of combinations of codes can be selected in Mode 1?
1. 4
 2. 32
 3. 2048
 4. 4096
- 1-59. What is the total number of possible codes available in Mode C IFF?
1. 2048
 2. 2465
 3. 4096
 4. 4930
- 1-60. Which of the following IFF codes are set prior to flight by maintenance personnel?
1. 1 and 3/A
 2. 2 and 3/A
 3. 2 and 4
 4. 1 and 4
- 1-61. Mode 4 codes are loaded into the transponder computer by which of the following means?
1. Electronically
 2. Mechanically
 3. Physically
 4. Hydraulically
- 1-62. The emergency function affects which of the following IFF mode(s)?
1. 4 only
 2. 2 and 4 only
 3. 1, 2, and 3/A
 4. 1, 3/A, and C
- 1-63. The I/P function is used for which of the following purposes?
1. Emergencies
 2. Aircraft using identical coding
 3. Drones
 4. Altitude information above 45,000 feet

- 1-64. The X-pulse special reply function is used for which of the following purposes?
1. Emergencies
 2. Helicopters
 3. Timing
 4. Unmanned or experimental aircraft
- 1-65. When is the SPI pulse present in the reply pulse train in Mode C?
1. When a D4 pulse is present
 2. When a D4 pulse is not present
 3. When a F2 pulse is present
 4. When a F2 pulse is not present
- 1-66. Which of the following components of the APX-72 system contains controls for selection of Modes 1 and 3/A?
1. TS-1843/APX
 2. RT-859/APX-72
 3. C-6280/APX-72
 4. KIT-1/TSEC
- 1-67. Which of the following APX-72 system components provides for ground or in-flight transponder testing capability?
1. TS-1843/APX
 2. RT-859/APX-72
 3. C-6280/APX-72
 4. KIT-1/TSEC
- 1-68. Which of the following components of the APX-72 system allow the transponder to respond to Mode 4 interrogations?
1. TS-1843/APX
 2. RT-859/APX-72
 3. C-6280/APX-72
 4. KIT-1/TSEC
- 1-69. What component of the interrogator set determines the delay between the challenge pulse and receipt of the coded replies for determining target range?
1. Receiver/Transmitter RT-868/APX-76(V)
 2. Switch Amplifier SA-1568/APX-76(V)
 3. Electronic Synchronizer SN-416/APX-76(V)
 4. Interrogator Computer KIR-1/TSEC
- 1-70. What component of the interrogator set contains performance monitoring circuits that perform self-tests during each challenging period?
1. Receiver/Transmitter RT-868/APX-76(V)
 2. Switch Amplifier SA-1568/APX-76(V)
 3. Electronic Synchronizer SN-416/APX-76(V)
 4. Interrogator Computer KIR-1/TSEC
- 1-71. The interrogator set works in conjunction with which of the following systems?
1. Inertial
 2. Loran
 3. Global Positioning
 4. Radar
- 1-72. The AN/APX-100 system contains what number of antenna(s)?
1. One
 2. Two
 3. Three
 4. Four
- 1-73. What number of major configurations exist for the AN/APX-100 system?
1. One
 2. Two
 3. Three
 4. Four
- 1-74. What electronic circuit compares both videos in the AN/APX-100 system to determine the stronger signal?
1. Coder assembly
 2. Digital converter
 3. Diversity processor
 4. Antenna coupler