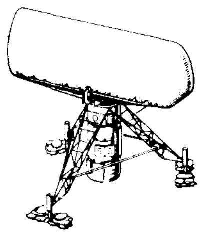


LESSON 2. LOPAR ACQUISITION RADAR

MMS Subcourse No 150 . . . . **Nike Radars and Computer**

Lesson Objective . . . . **To give you a general knowledge of the purpose, capabilities, and basic functions of major units of the LOPAR on a block diagram level.**

Credit Hours . . . . **Four**

TEXT

1. PURPOSE.

a. The low power acquisition radar (LOPAR) is a complete microwave range and direction sensing system. The functions of the LOPAR system are to locate, interrogate, and designate targets in the area defended by the improved Nike Hercules air defense guided missile system. A chain of improved Nike Hercules systems is capable of defending all approaches to an extensive area. In a permanent installation, the Army Air Defense Command Post (AADCP) is the next higher command center. Each battery control area is linked to AADCP through fire unit integration facilities (FUIF) equipment. In a transportable installation, the battery is also linked through FUIF equipment to the AADCP. In either of these installations, each improved Nike Hercules system is tactically monitored and controlled by the AADCP. When the improved Nike Hercules is employed as an individual defense unit, the LOPAR system can be operated independently to provide surveillance of air traffic in the surrounding defense area. However, should the improved Nike Hercules be used as a unit of an integrated air defense system, the LOPAR system receives target identification information from AADCP. This information is linked to the LOPAR system through FUIF and is displayed on a plan position indicator (PPI) in the trailer mounted director station.

b. The LOPAR system is capable of detecting targets and defining their coarse slant range and azimuth, as illustrated in figures 1 and 2, when the targets lie within the transmitted RF beam. The beam consists of pulsed RF energy focused into a radiation pattern by the LOPAR antenna. Target detection is accomplished by continuously rotating the beam through 360 degrees in azimuth while elevation is scanned between 2 degrees and 22 degrees. The maximum elevation position is sufficient to detect targets in excess of their ceiling

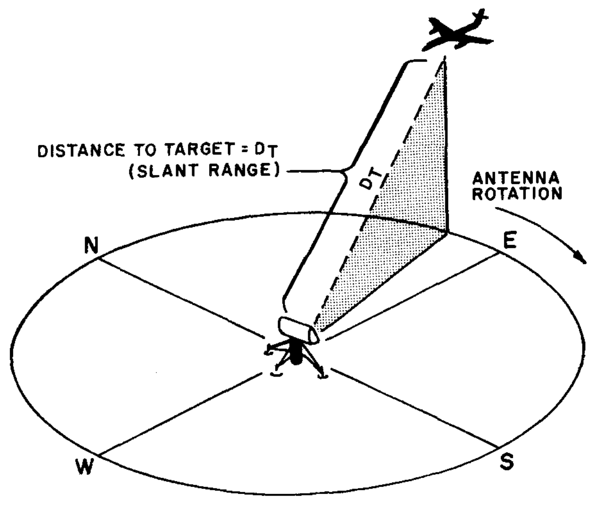


Figure 1. Meaning of Slant Range.

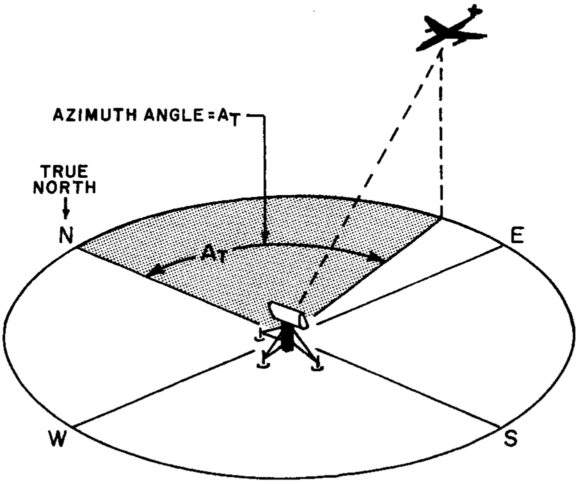


Figure 2. Meaning of Azimuth.

capabilities. LOPAR, as all radars in the Nike system, determines range by measuring the time required for pulses of RF energy to travel from the radar transmitter to the target and be reflected to the receiver. Transmission of RF energy is in short pulses followed by a long listening or receiving period. Since the RF energy travels at 161,500 nautical miles per second, precise timing is necessary for accurate range determination. The time interval for RF energy to travel 2 miles, indicating the reflecting object is 1 mile away, can be calculated as follows: T = 2/C.

Where:

T = time

C = velocity of light

2 represents a round trip nautical mile

$$T = \frac{2 \text{ miles}}{161{,}500 \text{ nautical miles per second}}$$

$$T = 12.4 \times 10^{-6} \text{ seconds per mile}$$

At the instant RF energy is transmitted from the LOPAR, a radial trace starts at the center of a cathode ray tube (CRT) in the presentation system and progresses outward, forming a radial line (sweep) on the face of the CRT (figure 3). The RF return (echo) is processed into a video pulse which produces an intensified spot on the radial sweep. The distance the video pulse appears from the start of the sweep indicates time, thus range of the object causing the echo. The sweep ends prior to the next transmitted pulse. Azimuth is determined by rotating the radial sweep through 360 degrees in sync with the rotating antenna. Since the antenna radiates and receives in a highly directional pattern, the area covered by transmission and reception is confined to the direction the antenna is pointed at any instant. The video display indicates objects at the instantaneous azimuth of the antenna. Through simultaneous presentation of acquisition video signals and certain mark signals on CRT indicators, the LOPAR system allows rapid designation of selected targets to the target tracking radar (TTR). These signals represent coarse slant range and azimuth information. When a designated target is within the range of the TTR, target coarse slant range and azimuth position data are electrically transferred from the LOPAR system to the TTR system. The TTR antenna will rotate to the target azimuth and the TTR range unit will slew to the target

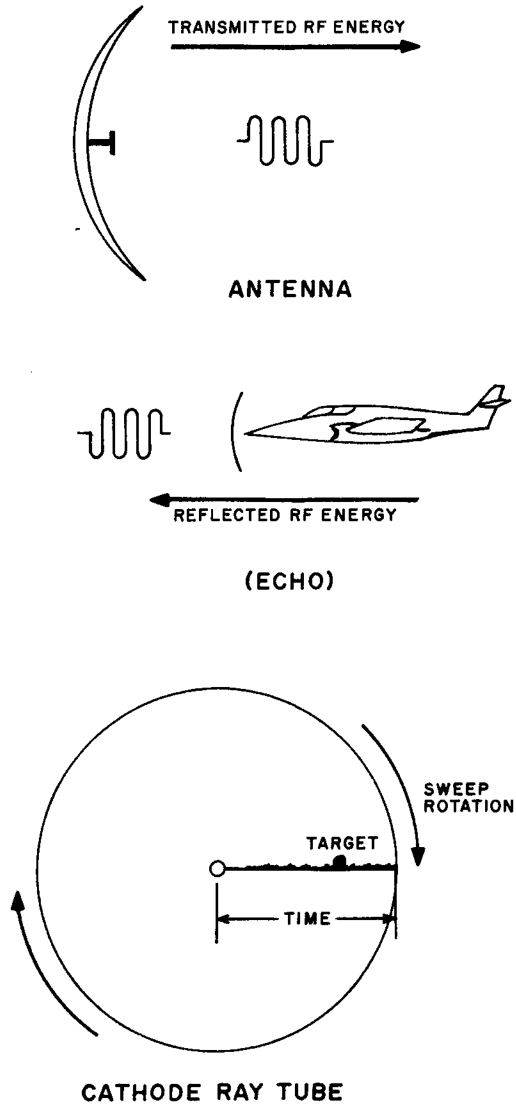


Figure 3. Range and Azimuth Display.

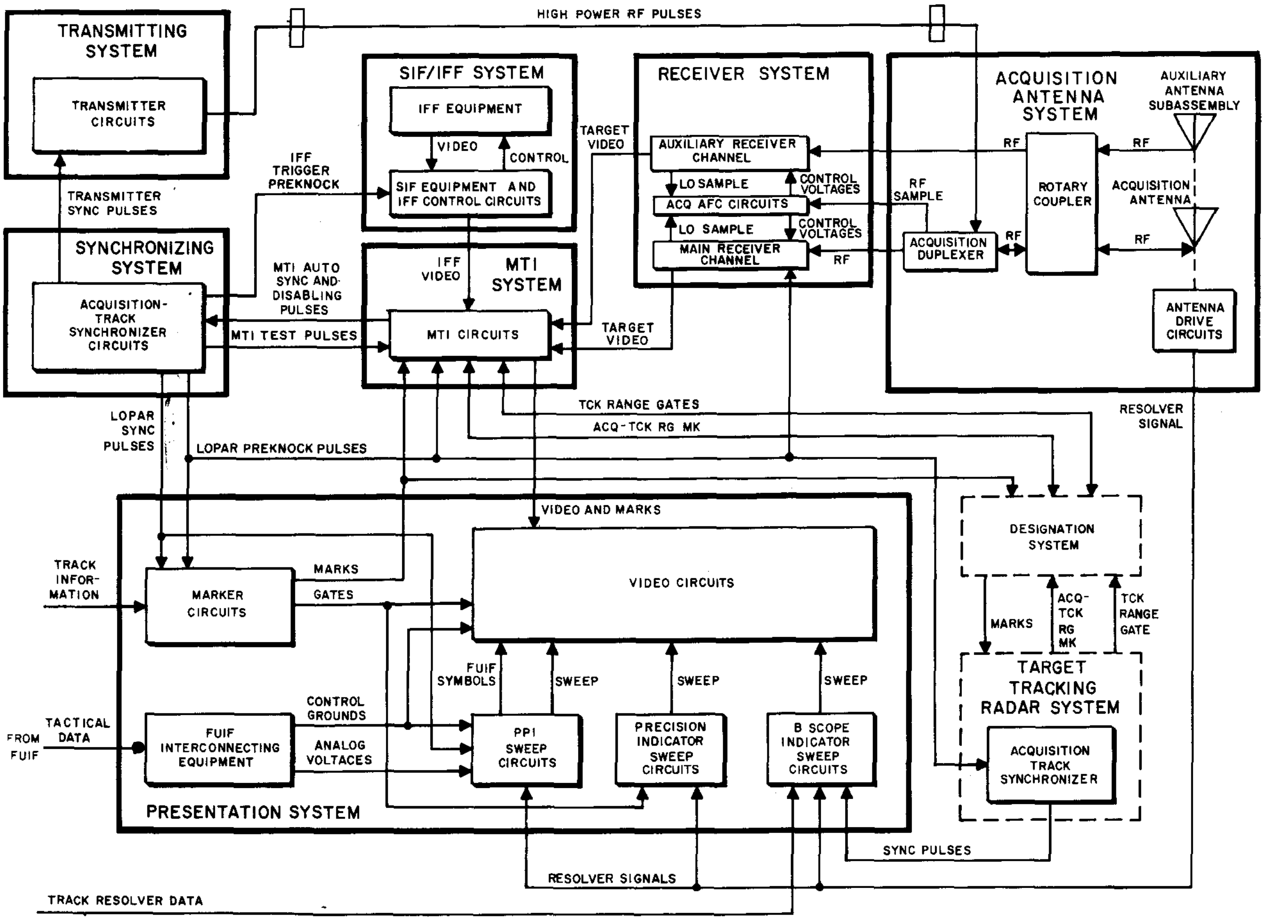


Figure 4. LOPAR system - block diagram.

range. The target fine range, azimuth, and elevation angle will be determined by TTR and supplied to the computer. Since the range capability of the LOPAR system is greater than that of the TTR, sufficient time is allowed for evaluation of the target, its designation to the TTR, and the launching of one or more missiles.

2. **MAJOR UNITS.**

a. **General.** The LOPAR system is functionally divided into seven systems as illustrated in figure 4. This paragraph will give a general discussion of these seven systems and succeeding paragraphs will present a more detailed discussion of each system.

b. **Synchronizing system.** Synchronization is extremely important in any electronic equipment and this is certainly true of all radars in the Nike system. These are pulse modulation type radars that determine range by measuring the time required for the transmitted RF energy to strike the target and be reflected to the receiver. The acquisition synchronizing system synchronizes the operation of the complete LOPAR system. Synchronization is produced by timing pulses generated in the acquisition-track synchronizer circuits. The synchronizer may be free running, but for proper operation of the moving target indicator (MTI) system, it is synchronized by the MTI auto sync and disabling pulse. The synchronizing circuits provide four different pulses at a constant rate and time sequence for distribution to the six associated systems. As illustrated in figure 4, the four pulses are: LOPAR preknock, MTI test pulse, transmitter sync, and LOPAR sync. The LOPAR preknock pulse initiates the operation of the receiver, MTI, presentation, and selective identification facility/identification friend or foe (SIF/IFF) systems. In addition, the LOPAR preknock pulse triggers an identical acquisition-track synchronizer in the TTR system. When triggered, this second synchronizer generates the preknock and sync pulses used by the TTR system. The transmitter sync pulse triggers and times the operation of transmitter circuits in the transmitting system. The LOPAR sync pulse (fig 4) synchronizes the operation of selected circuits in the presentation system. The MTI test pulse is used in the adjustment and operation of the MTI system, while the MTI auto-sync and disabling pulse synchronizes the acquisition-track synchronizer circuits with the MTI system.

c. **Transmitter system.** The transmitter system produces RF pulses that are radiated into space. This system consists of the transmitter circuits and associated power supplies and control circuits. The transmitter circuits use transmitter sync pulses and high voltage direct current (DC) inputs to generate high power pulses of RF energy (fig 4). When transferred to the antenna, these pulses are formed into a beam for radiation into space.

d. **Antenna system.** The antenna system receives RF energy pulses from the transmitter through a duplexer, waveguide, and a rotary coupler (fig 4), then shapes and radiates the energy in the form of a transmitted beam. After transmission, the antenna receives both target reflections and reflections from other objects in the path of the radiated beam. The antenna system includes the units that drive the antenna in azimuth and elevation. The resolver signals furnish azimuth position information to sweep circuits in the presentation system (fig 4) and to the B-scope indicator sweep circuits in the target tracking radar.

e. **Receiving system.** The receiving system receives reflected RF energy (echoes) from the antenna (fig 4) and converts it into video signals. The target video signals are processed by the moving target indicator circuits, then sent to the presentation system for display on appropriate indicators. Since the transmitter is prone to "shift" or change frequency, the receiver system employs an automatic frequency control (AFC) to insure that the receiver circuits are tuned to the frequency of the transmitted RF pulse. The AFC circuits accomplish this by sampling the frequency of the transmitted energy (fig 4). If the transmitted frequency has changed, the AFC circuits will sense the amount and direction (increase or decrease) of frequency shift. The AFC circuits will then send appropriate control voltages to the receiver in order to make the necessary tuning adjustments to receive the reflected energy.

f. **Moving target indicator system.** The function of the MTI system is to reduce video interference from fixed objects. This system consists of the MTI circuits and the associated power supplies and control circuits. The MTI circuits use the video from the receiving system (fig 4) and electronically distinguish between moving target video and fixed target video (clutter). As a result, the MTI circuits provide the presentation system with improved target video displays on CRT indicators. As illustrated in figure 4, the MTI circuits also generate an automatic sync and disabling pulse that is used to accurately time the circuits in the acquisition-track synchronizer.

g. **Presentation system.** The presentation system is a means of providing a visual display of all targets within the range of the LOPAR system. In addition, the presentation system provides a means of displaying the slant range and azimuth of any selected target and of applying target video and position data to the B-scope indicator. As illustrated in figure 4, the presentation system consists of the marker circuits, planned position indicator sweep circuits, precision indicator sweep circuits, B-scope indicator sweep circuits, video circuits, and FUIF interconnecting equipment. The marker circuits provide signals to form gates and marks for the video circuits. The video circuits, in turn, enable the display of target video on three cathode ray tube indicators as intensified portions of the sweep. The PPI, PI, and B-scope indicators are synchronized with the acquisition antenna position by the resolver signals. The PI sweep circuits and the B-scope indicator sweep circuits provide display voltages for expanding a portion of the PPI presentation. The PI expansion, which is centered around the selected target area, allows the acquisition operator to determine target slant range and azimuth more accurately before transferring this information to the TTR. The B-scope, located in the TTR, allows the track operators to observe an expanded portion of the target area and shows the track antenna position relative to the selected target. The FUIF interconnecting equipment electrically ties the presentation system, through a data link, to FUIF equipment. This data link allows coordination of all air defense activities in an area controlled by the Army Air Defense Command Post (AADCP). The FUIF equipment controls the generation of FUIF video symbols on the presentation system which, in turn, develops and displays the symbol video.

h. **SIF/IFF system.** The selective identification feature/identification friend or foe system supplements the LOPAR system by enabling additional target information to be furnished to the presentation system. Moreover, when the LOPAR system is employed in an individual defense unit, the SIF/IFF system is the source of local target identification; however, when the LOPAR is part of an integrated defense system, the LOPAR presentation system receives target identification information through FUIF equipment linked to the AADCP.

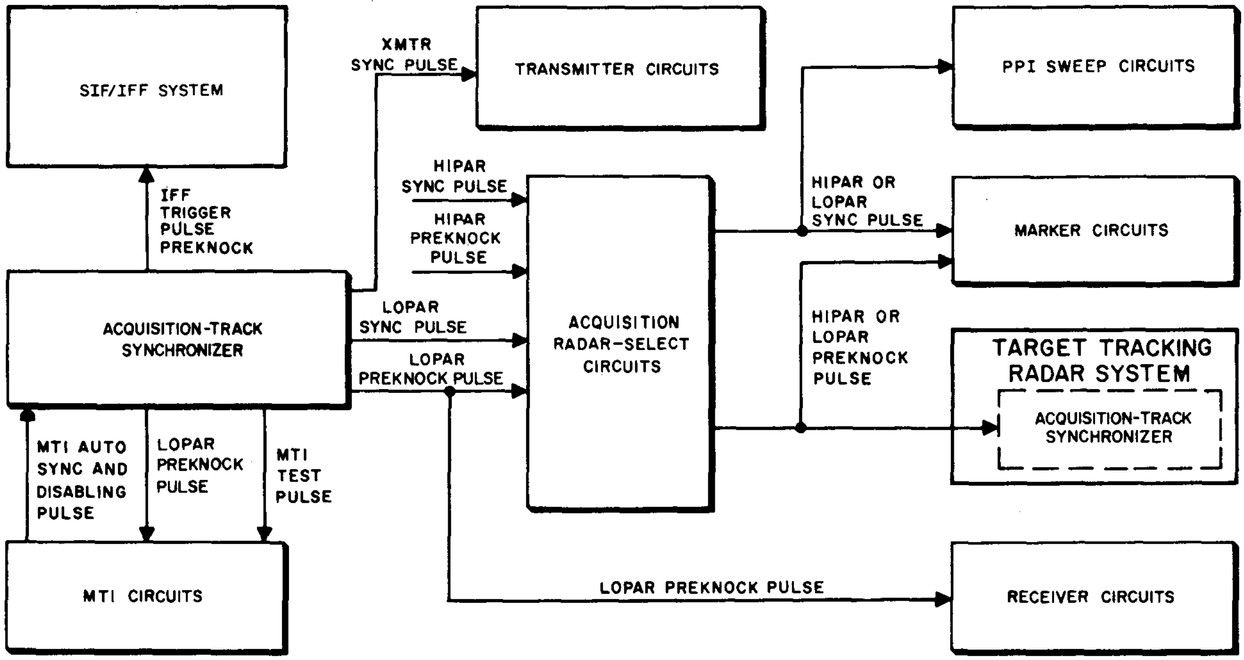


Figure 5. LOPAR synchronizing system - block diagram.

Basically, the SIF/IFF system consists of three parts: the IFF equipment, the IFF control circuits, and the SIF equipment (fig 4). The IFF equipment, although not a basic part of the LOPAR system, is provided as auxiliary equipment which can be used in conjunction with the LOPAR operation. The IFF control circuits, an integral part of the LOPAR system, provides a means for remote control of the IFF equipment. The SIF equipment is then added to the IFF equipment in order to increase the number of IFF codes and to permit rapid code changes. When IFF equipment is provided, it may be operated by the IFF control circuits in synchronization with the LOPAR system in interrogating a target. The response of the target is received by the SIF/IFF system and then appropriately displayed by the presentation system.

3. ACQUISITION SYNCHRONIZING SYSTEM.

a. **Purpose**. The synchronizing system, shown in figure 4, provides accurately timed pulses that synchronize the operation of the LOPAR system and the TTR system. Although identical acquisition-track synchronizers are used in both the LOPAR and TTR systems, the LOPAR synchronizer produces the timing pulses (LOPAR preknock) that trigger or synchronize the acquisition track synchronizer in the TTR system (fig 5). Therefore during LOPAR operation, the TTR system is synchronized with the LOPAR system. Although the LOPAR acquisition track synchronizer can be free running, it is normally triggered by the timing pulse (composite MTI auto sync and disabling pulse) from the MTI circuits (fig 5).

b. **Block diagram analysis**. The LOPAR synchronizing system (fig 5) consists of pulse generating circuits, in the acquisition track synchronizer, and external distribution circuits. The acquisition track synchronizer, located in the director station group of the trailer mounted director station, receives one input pulse and produces five output pulses at a constant repetition rate. As illustrated in figure 5, the input pulse is the composite MTI auto sync and disabling pulse from the MTI circuits. The output pulses are LOPAR preknock, LOPAR sync, transmitter sync, IFF trigger pulse, and MTI test pulse. These pulses, illustrated in figure 6 are discussed in (1) through (5) below.

(1) LOPAR preknock pulse. The LOPAR preknock, triggered by the MTI auto sync pulse, is a positive 40-volt, 1-microsecond pulse (fig 6) which occurs at a repetition rate of 500 pulses per second. This pulse has a steep leading edge and is in time coincidence with the MTI auto sync pulse. As illustrated in figure 5, the LOPAR preknock triggers the receiver and MTI circuits and supplies a trigger pulse (IFF trigger) to the SIF/IFF system. In addition, LOPAR preknock triggers the acquisition track synchronizer of the TTR system and the marker circuits. As illustrated in figure 6, LOPAR preknock occurs 23.5 microseconds before the LOPAR sync and transmitter sync pulses. Pretriggering is required to stabilize the system prior to the LOPAR

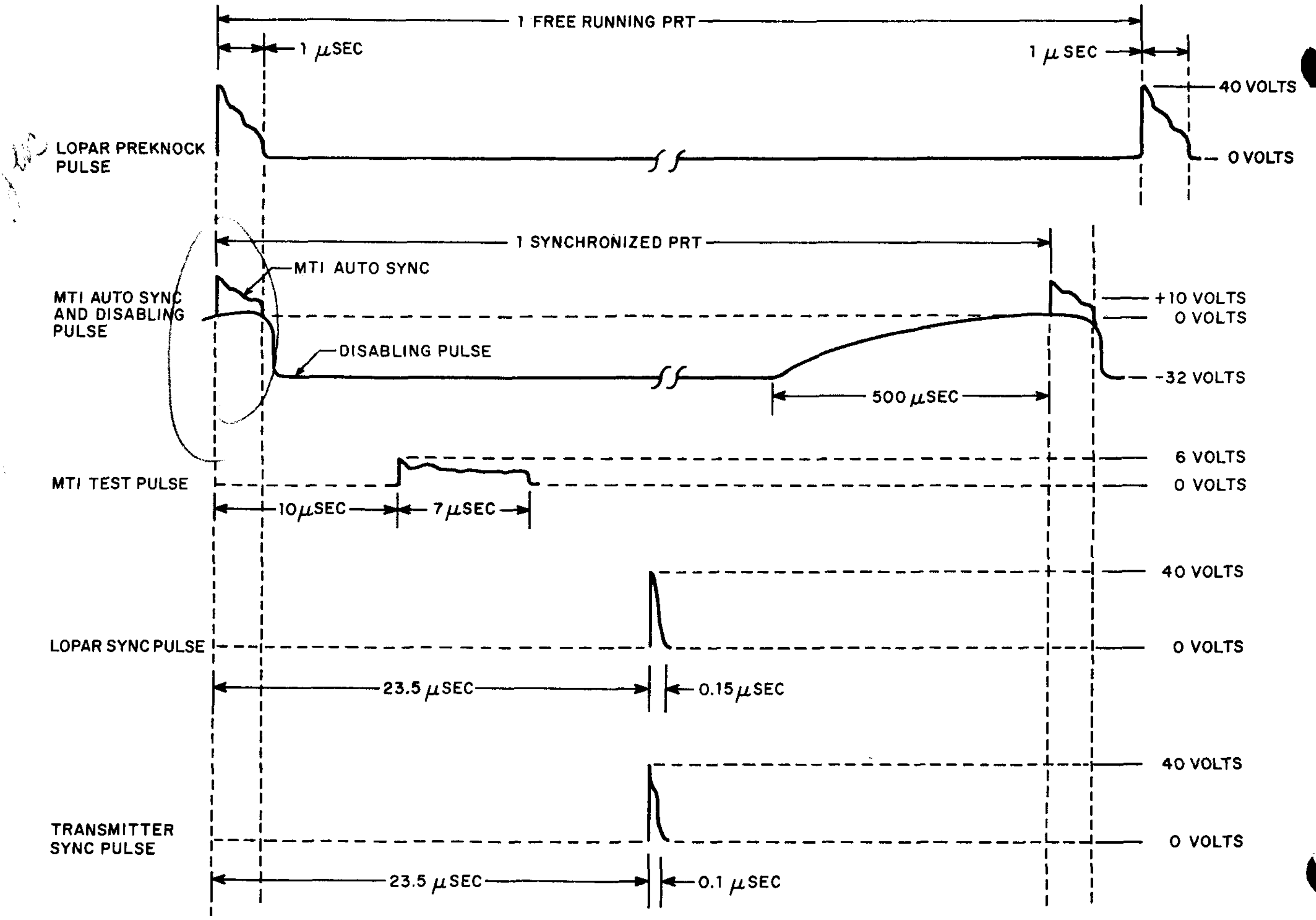


Figure 6. LOPAR synchronizing system - ideal waveforms in time sequence.

sync pulse which triggers the LOPAR system into operation.

(2) LOPAR sync pulse. The LOPAR sync, a positive 40-volt, 0.15-microsecond pulse, occurs once each pulse repetition time (PRT) and is always 23.5 microseconds after preknock. As illustrated in figure 5, when the acquisition radar-select circuits are conditioned for LOPAR synchronization, the LOPAR sync pulse triggers the PPI sweep circuits and the marker circuits.

(3) Transmitter sync pulse. The transmitter sync, a positive 40-volt, 0.1-microsecond pulse, is in time coincidence with the LOPAR sync pulse (fig 6). This narrow pulse triggers the acquisition trigger amplifier in the transmitter circuits. The transmitter, in turn, produces a burst of RF energy in time coincidence with each transmitter sync pulse. Once each PRT, this RF energy burst is coupled to the antenna for transmission into space.

(4) MTI test pulse. The MTI test pulse, a positive 6-volt, 7-microsecond pulse, occurs 10 microseconds after the leading edge of each LOPAR preknock pulse. As illustrated in figure 6, this time delay effectively places the test pulse between the LOPAR preknock and LOPAR sync pulses. The MTI circuits use the test pulse to generate an internally used automatic gain control (AGC) voltage and for internal checks and adjustments of the MTI circuits.

(5) Composite MTI auto sync and disabling pulse. The MTI auto sync and disabling pulse is a composite pulse consisting of a positive 10-volt auto sync pulse and a negative 32-volt disabling pulse (fig 6). The auto sync pulse is developed by circulating each LOPAR preknock from a blocking oscillator in the acquisition track synchronizer through an MTI delay line and returning the delayed pulse (MTI auto sync) to the blocking oscillator within the synchronizer. This allows the blocking oscillator to synchronize itself at a pulse

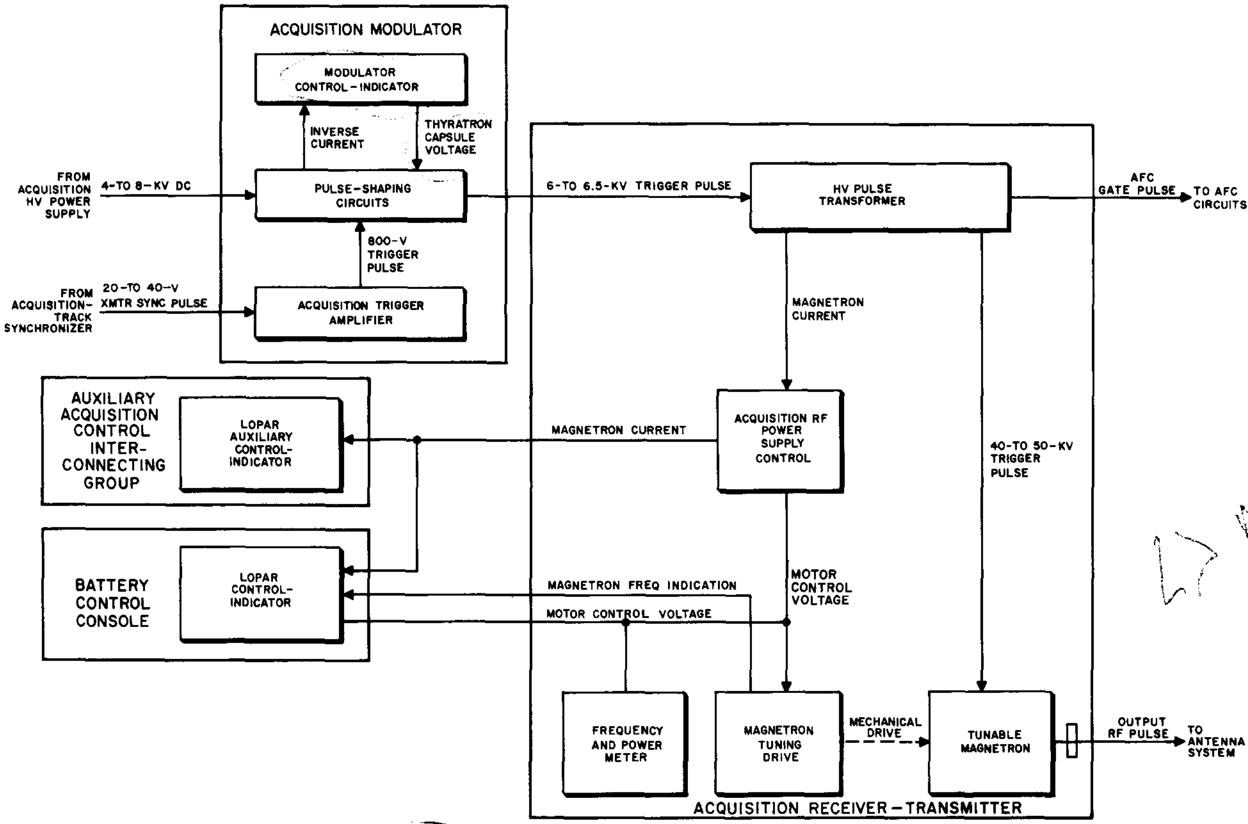


Figure 7. Acquisition transmitter circuits - block diagram.

repetition time equal to the delay time of the MTI delay line. However, the blocking oscillator's free running PRT must be longer than the MTI delay time. This type synchronization is required for proper MTI operation. The MTI auto sync pulse (fig 6), developed from each LOPAR preknock pulse, has a steep leading edge and a time duration of 1 microsecond. It is used to trigger the blocking oscillator into conduction. The disabling pulse, which consists of a steep negative-going leading edge, a relatively flat portion, and a positive-going exponential trailing edge of 500 microseconds is used to hold the blocking oscillator cutoff during listening time. The auto sync pulse and the disabling pulse are combined in the MTI circuits for application as a composite timing feedback pulse to the acquisition-track synchronizer. The application of a feedback pulse causes the synchronizer to be accurately synchronized with the operation of the MTI circuits.

(6) Acquisition radar select circuits. When a high power acquisition radar (HIPAR) system is used with the radar course directing central (RCDC), the presentation system and TTR system can be synchronized by the HIPAR system. As illustrated in figure 5, the acquisition radar-select circuits provide a means of selecting preknock and sync pulses from either the LOPAR or HIPAR system. Selection of these pulses permit video from the HIPAR or LOPAR system to be displayed on the presentation system.

4. ACQUISITION TRANSMITTING SYSTEM.

a. **Purpose.** The transmitter system produces RF energy pulses in the S-band frequency range. (Refer to appendix at the end of lesson 2 for freq. band designators.) As illustrated in fig 4, the pulse repetition freq. (PRF) is determined by the transmitter sync pulse produced by the acquisition synchronizing system.

b. **Block diagram analysis.** As illustrated in figure 7, the transmitter system consists of the acquisition modulator, high voltage pulse transformer, magnetron, and various control and measuring circuits. These circuits are located in the acquisition modulator and antenna-receiver-transmitter group at the LOPAR antenna and in the auxiliary acquisition control interconnecting group and the battery control console inside the trailer mounted director station.

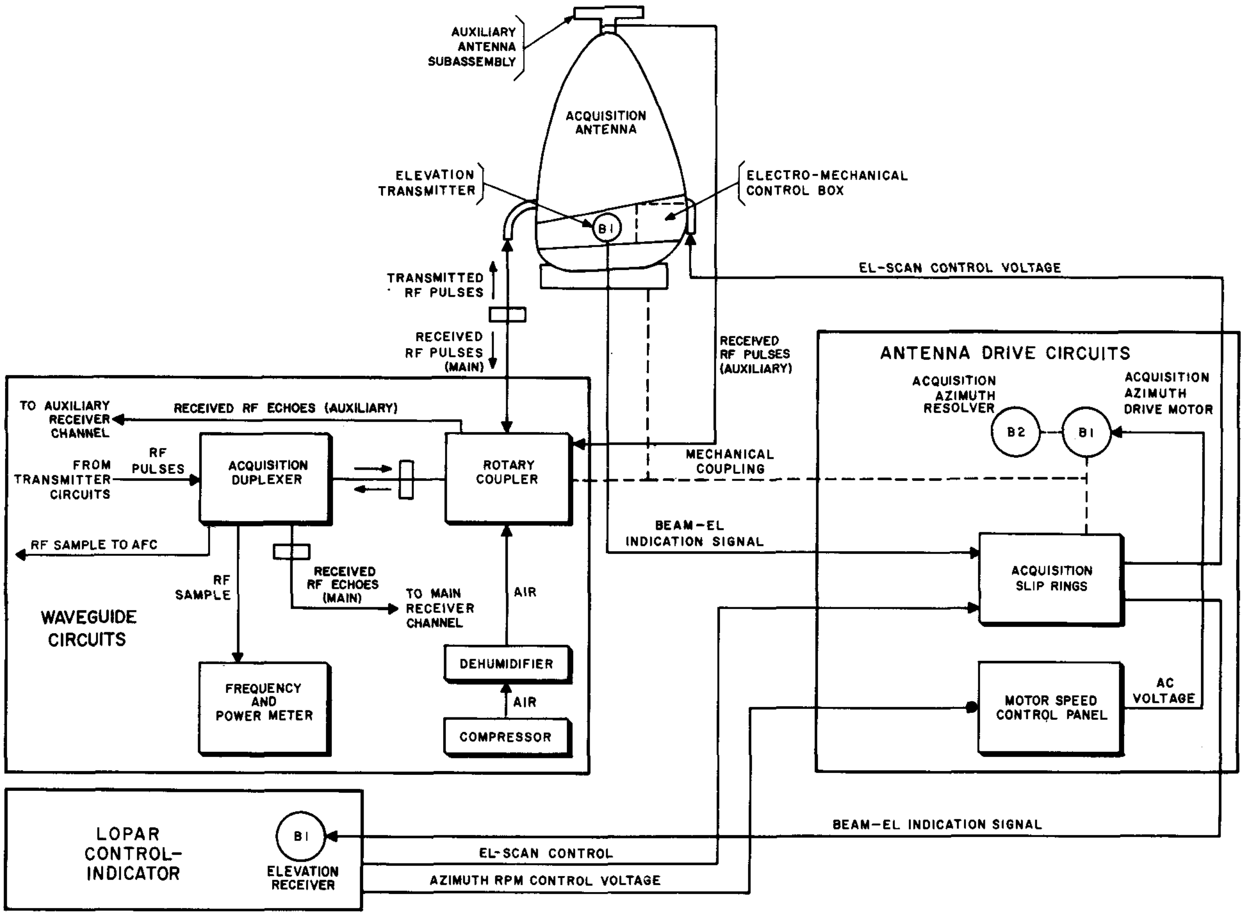


Figure 8. Antenna system - block diagram.

(1) Acquisition trigger amplifier. As illustrated in figure 7, the transmitter sync pulse from the acquisition track synchronizer is applied as a trigger to the acquisition trigger amplifier in the modulator. The trigger amplifier then amplifies and widens the transmitter sync into an 800-volt, 2 microsecond output pulse. The 800-volt trigger output pulse, coincident with each transmitter sync pulse, is then sent to the pulse shaping circuits in the modulator.

(2) Acquisition modulator. Utilizing a 4- to 8-kilovolt DC potential from the acquisition high voltage power supply, the pulse shaping circuits of the modulator amplify and shape the trigger amplifier output pulse into a 6- to 6.5-kilovolt trigger pulse. The modulator control-indicator provides monitoring of inverse current and controls the thyratron capsule voltage for the pulse shaping circuits.

(3) High voltage pulse transformer. As illustrated in figure 7, the 6- to 6.5-kilovolt modulator output pulse is applied to the high voltage pulse transformer. The function of the pulse transformer is to step up the modulator output pulse to approximately 40 to 50 kilovolts for application to the tunable magnetron cathode. The high voltage pulse transformer also develops an AFC gate pulse for use by the acquisition AFC circuits which are part of the receiver.

(4) Magnetron. The transmitter output tube is a tunable magnetron operating over a frequency range of 3,100 to 3,500 megahertz (S-band). The tunable magnetron converts the stepped-up modulator output trigger pulses into RF pulses that are conveyed through a waveguide to the acquisition antenna system for radiation into space. As illustrated in figure 7, the magnetron is tuned by the magnetron tuning drive. Control voltages for the magnetron tuning drive are provided through switches on the frequency and power meter, the acquisition RF power supply control, and the LOPAR control-indicator. A relative indication of magnetron frequency is supplied from the magnetron tuning drive (fig 7) to a meter on the LOPAR control-indicator located on the battery control console.

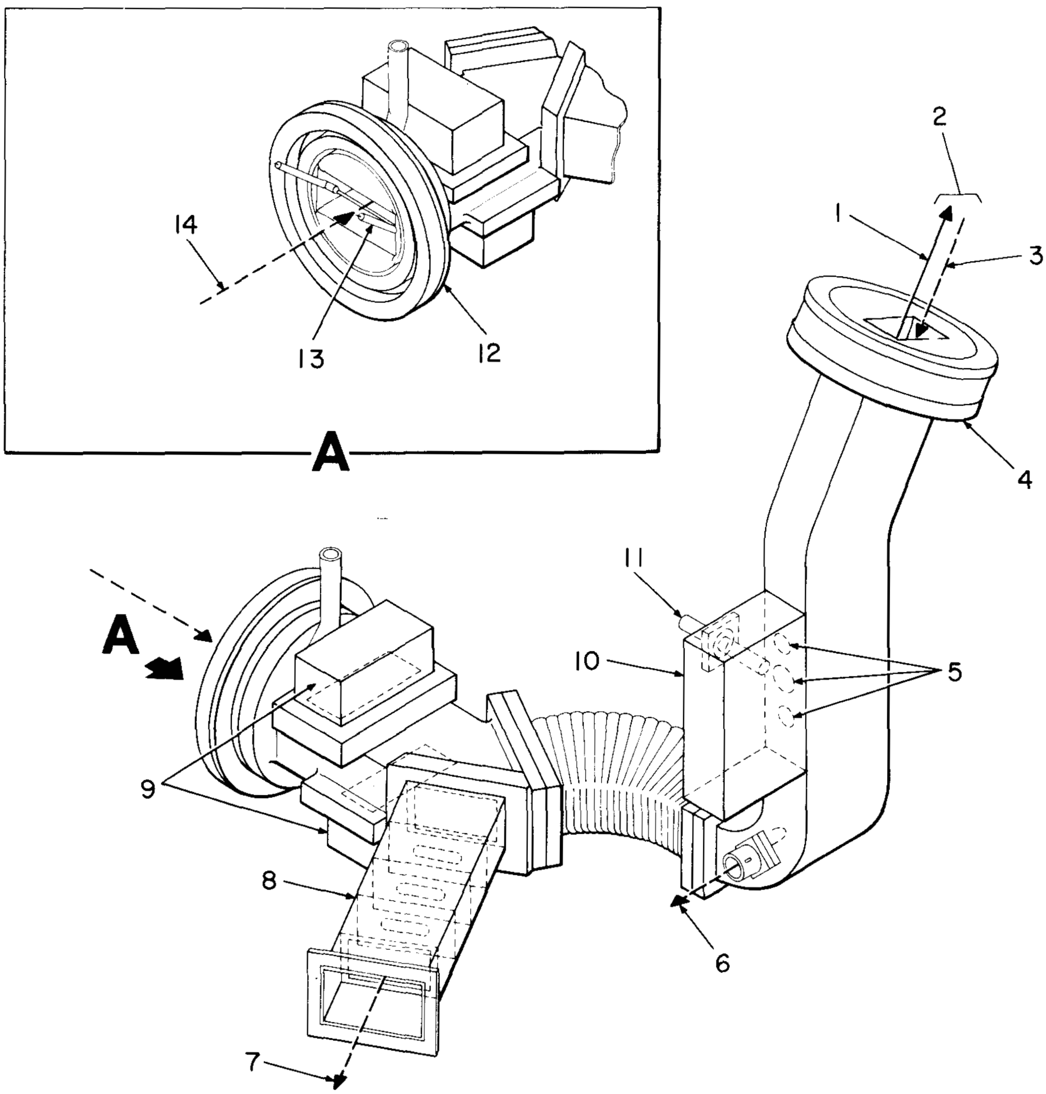


Figure 9. Acquisition duplexer - functional diagram.

Moreover, average magnetron current can be monitored at meters located on the acquisition RF power supply control and on the LOPAR auxiliary control-indicator.

5. ACQUISITION ANTENNA SYSTEM.

a. **General.** The acquisition antenna system (fig 8) consists of a main channel and an auxiliary channel. The main channel provides a means for conveying, shaping, and radiating S-band RF pulse energy into the defense area of the improved Nike Hercules system. It also provides the means for collecting and conveying reflected S-band RF energy to the main receiver channel. The auxiliary channel is a receiving channel only and provides a means for collecting and conveying jamming RF energy to the auxiliary receiver channel. As illustrated in figure 8, the main channel consists of the acquisition antenna, rotary coupler, acquisition duplexer, and frequency and power meter. The auxiliary channel consists of the auxiliary antenna subassembly and rotary coupler. The antenna drive circuits, compressor, and dehumidifier are common to both the main and auxiliary channels.

b. **Waveguide circuits.** The waveguide assembly basically serves two purposes. It couples RF pulses from the magnetron in the transmitter circuits to the antenna, and it conveys the receiver RF echo energy from the antenna to the receiver. The transmitted pulses from the magnetron travel as electromagnetic fields through an acquisition duplexer (fig 8), through a rotary coupler, to the antenna, where they are shaped into a beam and radiated into space. The acquisition duplexer permits the use of a common antenna for both transmitting and receiving. The rotary coupler is used to apply the energy from the stationary waveguide to the rotating antenna system.

(1) Acquisition duplexer. Numbers in parentheses refer to figure 9. (1) transmitter RF pulses, (2) RF signals to and from the acquisition antenna, (3) received RF echoes, (4) waveguide coupling flange to rotary coupler, (5) irises, (6) RF sample to acquisition AFC circuits, (7) received RF echoes to main receiver channel, (8) transmit receive (TR) tube, (9) antitransmit receive (ATR) tube, (10) directional coupler, (11) RF sample to frequency and power meter, (12) waveguide coupling flange to magnetron, (13) arc suppressor probe, and (14) transmitter RF pulses from magnetron. The acquisition duplexer is functionally common to both the transmitter circuits and the receiver circuits. The duplexer, functioning as an electronic switch, disconnects the receiver from the acquisition antenna during transmitting time and the magnetron circuit from the acquisition antenna during receiving time. This duplexing action prevents the transmitter output pulse from entering and damaging the receiver circuits and prevents reflected RF echoes from being absorbed in the transmitter circuits during receiving time; therefore, the waveguide circuits are used on a time-shared basis. Essentially, the duplexer consists of three sections of 10-centimeter waveguide connected between the tunable magnetron and the rotary coupler. The first section, mechanically and electrically coupled to the magnetron, performs the duplexing function. This duplexer section contains an arc suppressor probe (13), a TR tube (8), and two ATR tubes (9). The second section is a flexible piece of waveguide that assures proper mechanical alinement of the waveguide circuits. The third section, coupled to the rotary coupler, contains a directional coupler (10), and an RF sampler probe which furnishes an RF sample to the acquisition AFC circuits (6). These sections are discussed in (a) through (d) below.

(a) The arc suppressor probe is a device located in the end of the duplexer (13). The function of the arc suppressor, part of the magnetron circuitry, is to detect and prevent waveguide arcing from traveling through the waveguide to the magnetron window.

(b) The TR and ATR tubes (8) and (9) are ionized by the RF pulses from the magnetron. When ionized, the TR tube presents a high impedance and the ATR tubes present a low impedance to the transmitter RF pulses. As a result, the transmitter RF pulses, entering at (14), pass on the antenna without entering the receiver circuits. During receive time, however, the received RF echoes (3), do not have sufficient energy to ionize the TR or ATR tubes. Therefore, the deionized ATR tubes present a high impedance at the output of the transmitter circuits, and RF echo energy is blocked from entering these circuits. At the same time, however, the deionized TR tube presents a low impedance at the input to the receiver circuits and received RF echo energy passes freely into the main receiver channel (7).

(c) A waveguide probe, mounted adjacent to the directional coupler, samples a portion of the RF pulses from the transmitting circuits. This RF sample (6) is then made available to the AFC circuits of the acquisition receiver system.

(d) The directional coupler (10) is an enclosed rectangular waveguide cavity permanently attached to the side of the acquisition duplexer. The coupler receives an RF sample through irises (5) in the waveguide wall. The RF sample (11) is then fed to the frequency and power meter for measuring transmitter output frequency and power.

(2) Frequency and power meter. The frequency and power meter (fig 8) is used to monitor the output average power, frequency, and pulse shape of the transmitter circuits. It is a permanently mounted test set located in the acquisition receiver-transmitter. The frequency and power meter obtain its input signals from a single coaxial cable connected to the directional coupler mounted on the duplexer (11).

(3) Rotary coupler. The rotary coupler (fig 8) serves as the waveguide coupling between the stationary waveguide and the waveguide of the rotating acquisition antenna. The main section of the rotary coupler is composed of a rigid coaxial line using air as a dielectric. Components of the rotary coupler are shown in figure 10; they are: (1) upper waveguide, (2) window, (3) main coaxial center conductor, (4) rotating section, (5) window, (6) waveguide mounting to duplexer, (7) pressurized waveguide, (8) pressurization connection, (9) tapered waveguide, (10) lower section, (11) auxiliary coaxial center conductor, (12) main resonant cavities, (13) knob junction, and (14) auxiliary resonant cavities. As shown in figure 10, a mechanical brake in the outer conductor allows the upper half to rotate while the lower half remains stationary. Impedance continuity around the break is provided by two main resonant cavities (12) functioning as RF chokes. The tapered waveguide is used to provide impedance matching between the waveguide and the coaxial section. The lower section of the coaxial rotary coupler acts as a

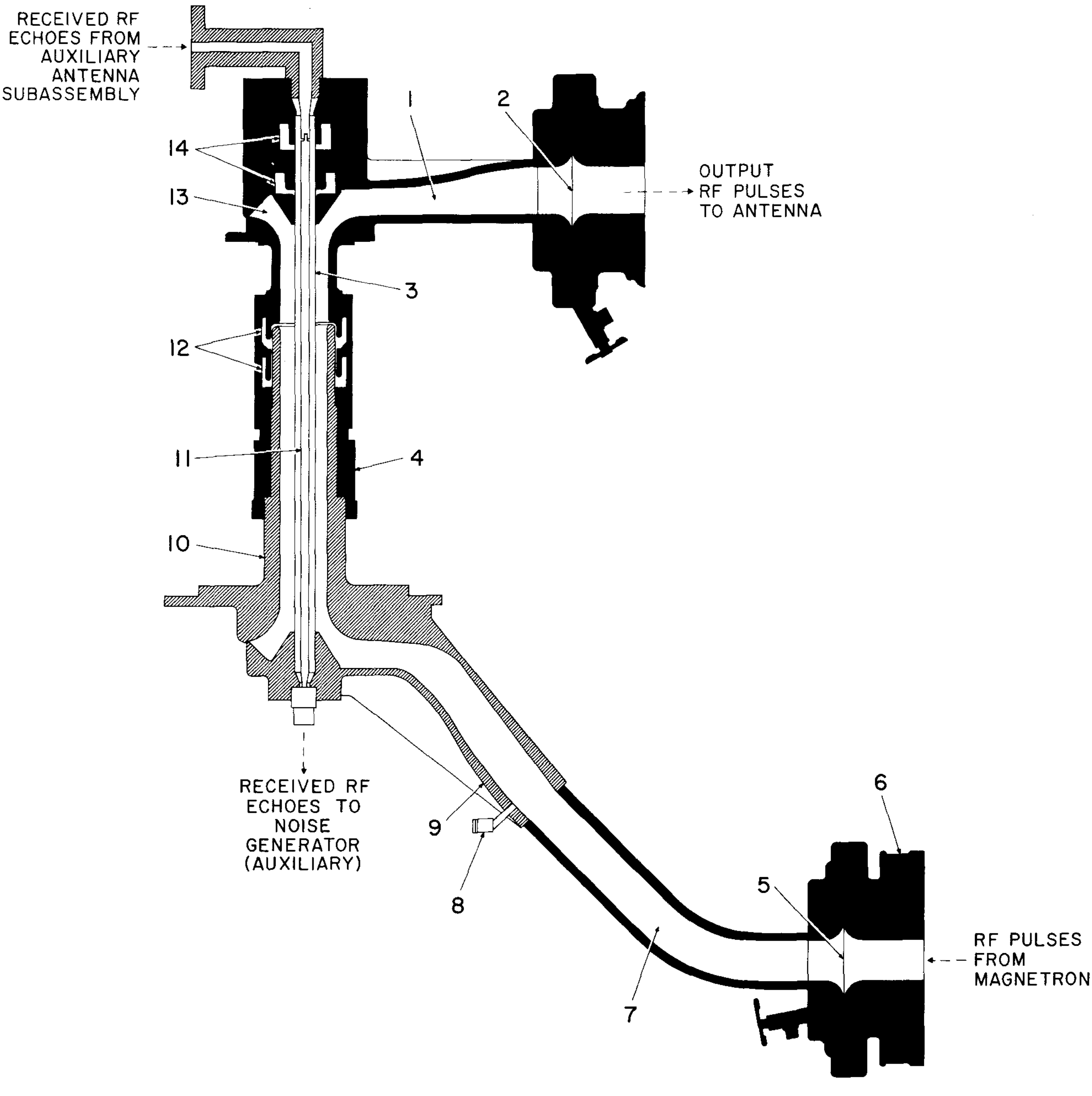


Figure 10. Rotary coupler - functional diagram.

receiving or transmitting antenna. The rigid center conductor carries the RF energy to the top section where a knob junction radiates the RF into the upper waveguide. The knob also acts as a receiving antenna for RF echoes returning through the upper waveguide. The rotary coupler is sealed at each end with glass windows (2) and (5) which offer very little attenuation to RF. The interior is pressurized and dehumidified to prevent arcing and reduce corrosion.

(4) Compressor. A compressor (fig 8) is used to pressurize the rotary coupler. It is driven by a 3-phase, 400-Hertz, 208-volt, AC motor, providing a desired pressure of 10 to 16 pounds per square inch (PSI). Switches connected to a pressure bellows turn the compressor on below 10 PSI and off above 16 PSI. However, if the bellows switch fails to turn the pump motor off at 16 PSI, a safety switch is provided to turn the motor off between 17 and 23 PSI.

(5) Dehumidifier. The demunidifier (fig 8) supplies moisture-free air from the compressor to the

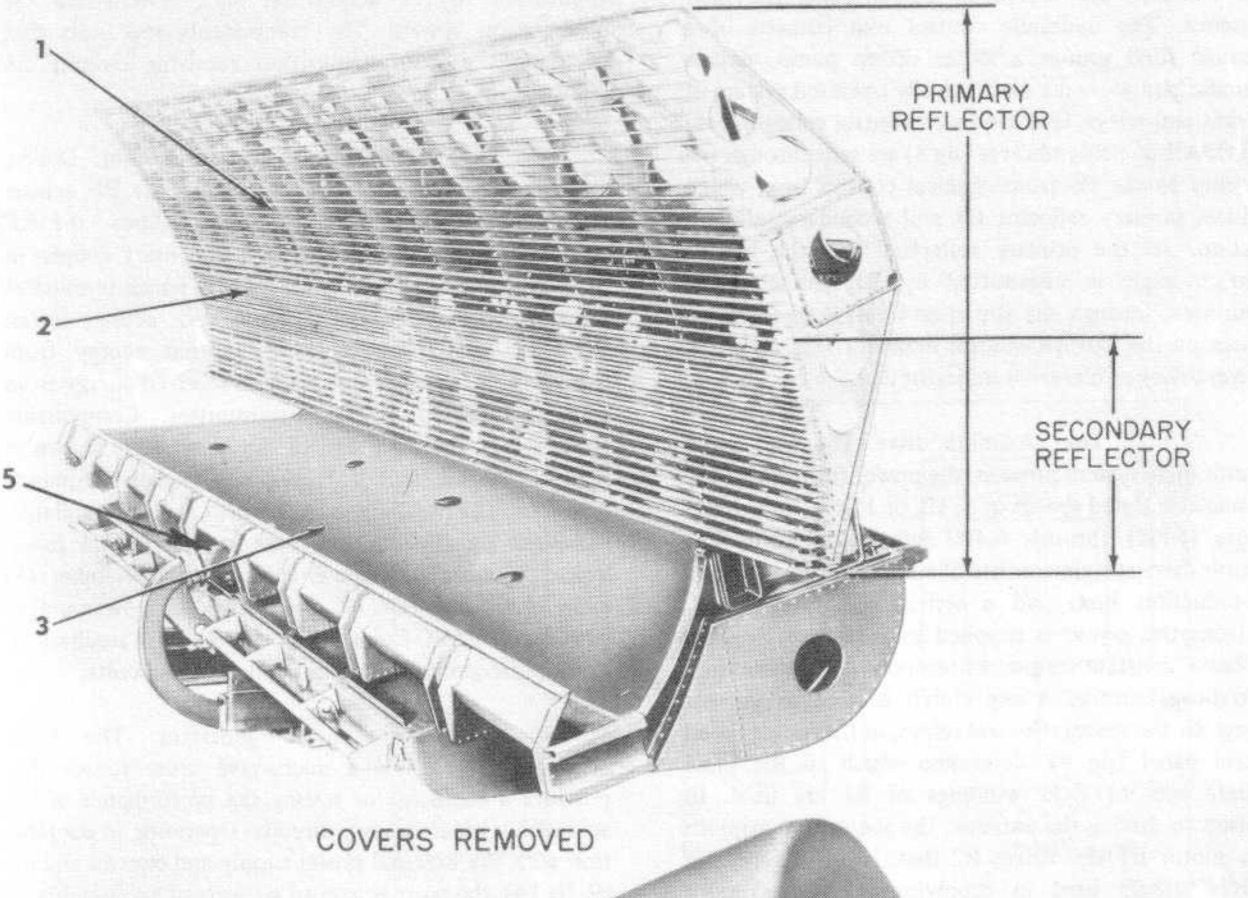


Figure 12. Acquisition antenna - front view.

(a) Elevation drive. There are two types of elevation drive systems for actuating the primary and secondary reflectors. Nike Hercules systems through number 1,070 have a hydraulic elevation drive unit, while systems 1,071 and up have an electric elevation drive unit. The two drive systems work in the same manner, the source of power being the only difference. The hydraulic control unit consists of a hydraulic fluid source, a motor driven pump, various hydraulic pumps, and a mechanically operated system of switches and relays. Elevation scan control voltages from the LOPAR control indicator (fig 8) are sent through the slip rings to the electromechanical control box, which produces primary reflector tilt and secondary reflector injection. As the primary reflector tilts, the beam's elevation angle is transmitted by B1, the elevation transmitter, through the slip rings to B1, and elevation receiver on the LOPAR control indicator. The elevation receiver drives an elevation indicator dial.

(b) Azimuth drive. The acquisition azimuth drive system provides the power for rotating the antenna at selected speeds of 5, 10, or 15 revolutions per minute (RPM) through 6,400 mils in azimuth. The azimuth drive system consists of a motor, a slip-clutch, a gear-reduction box, and a series of control relays. Electromotive power is supplied by a 3-phase, 3-speed, 400-hertz, constant torque, 4-horsepower, AC induction, squirrel-cage motor. A slip clutch is used to prevent damage to the motor. Control relays, in the motor speed control panel (fig 8), determine which of the three separate sets of field windings of B1 are used. In addition to driving the antenna, the acquisition azimuth drive motor B1 also drives B2 that, in turn, generates resolver signals used in supplying antenna azimuth information to the presentation system.

6. ACQUISITION RECEIVER SYSTEM.

a. **General.** The Nike Hercules LOPAR acquisition radar uses a superheterodyne receiver to convert low-level, S-band RF echoes to video signals. The acquisition receiving circuits consist of a main receiver channel and an auxiliary channel, which permits using antijam display (AJD) techniques. The main receiver circuits (fig 13) consist of the acquisition antenna, acquisition duplexer, receiver-tuner, signal frequency converter, acquisition intermediate frequency (IF) preamplifiers, sensitivity time control, IF attenuator, and acquisition IF amplifier.

b. **Block diagram analysis.** The main acquisition receiving circuits receive reflected RF echoes from the acquisition antenna system as low-level pulses within the 3,100- to 3,500-megahertz (S-band) frequency range. Using the heterodyne principle, the receiver mixes the signals from a local oscillator with the received signal to produce an IF of 60 megahertz. These signals are then amplified and converted into video signals for application to the acquisition MTI system and the presentation system. The components and units that comprise the main acquisition receiving circuits are discussed in (1) through (11) below.

(1) Acquisition antenna system. During receiving intervals, the antenna focuses the RF echoes into the antenna pillbox. From the pillbox, the RF echoes are then conveyed through the rotary coupler in the waveguide circuits to the duplexer, which terminates the antenna system. The duplexer, acting as an electronic switch, prevents transmitted energy from damaging the receiver and prevents received energy from being attenuated by the transmitter. Components contained in the front end of the receiver are shown in figure 14 and are: (1) auxiliary signal frequency converter, (2) auxiliary preselector, (3) local oscillator, (4) main signal frequency converter, (5) main preselector, (6) main magnetic circuits, (7) receiver-tuner, (8) main IF preamplifier, (9) acquisition RF power supply control, (10) AFC frequency converter, (11) auxiliary IF preamplifier, and (12) auxiliary magnetic circuits.

(2) Main noise generator. The noise generator (fig 13) is a microwave noise source that provides a standard for testing the performance of the acquisition radar receiver circuits. Operating in conjunction with the external power supply and control circuits (9, fig 14), the noise generator consists of an assembly of permanent test equipment. The generated noise signals are injected into the receiver circuits and then monitored for metering at the bypass video output of the acquisition IF amplifier (fig 13). Monitoring allows a receiver system performance figure to be calculated by determining the ratio of injected noise to inherent noise. The injected noise should be twice the inherent noise for an acceptable performance figure.

(3) Main magnetic circuit. The main magnetic circuit (fig 13 and (6), fig 14) is the first stage in the acquisition receiving circuits that effects the primary signal flow. It is an RF amplifier that amplifies the microwave frequencies received from the duplexer. Since amplification is provided ahead of the receiver-tuner (fig 13), sensitivity of the receiving circuits is considerably improved. (Amplification is provided by a traveling wave tube enclosed by a magnetic circuit.) The traveling wave tube is a medium-gain, low-noise electron tube consisting of an electron gun (analogous to those of cathode ray tubes), a helix (a long narrow, helically wound coil), and a collector (fig 15). The design of the traveling wave tube produces high signal amplification with low noise level (good signal-to-noise ratio).

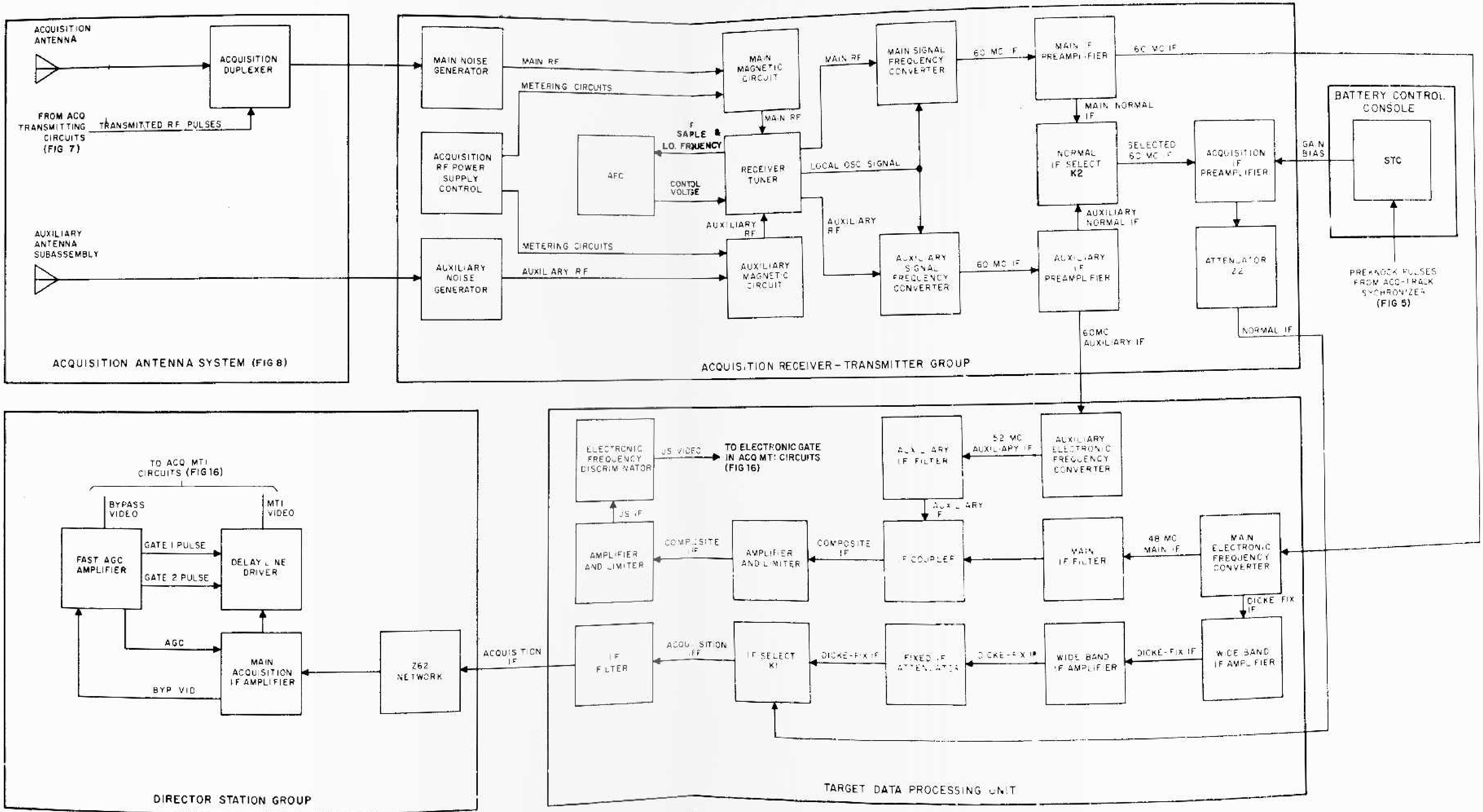


Figure 13. Receiver circuits - block k diagram.

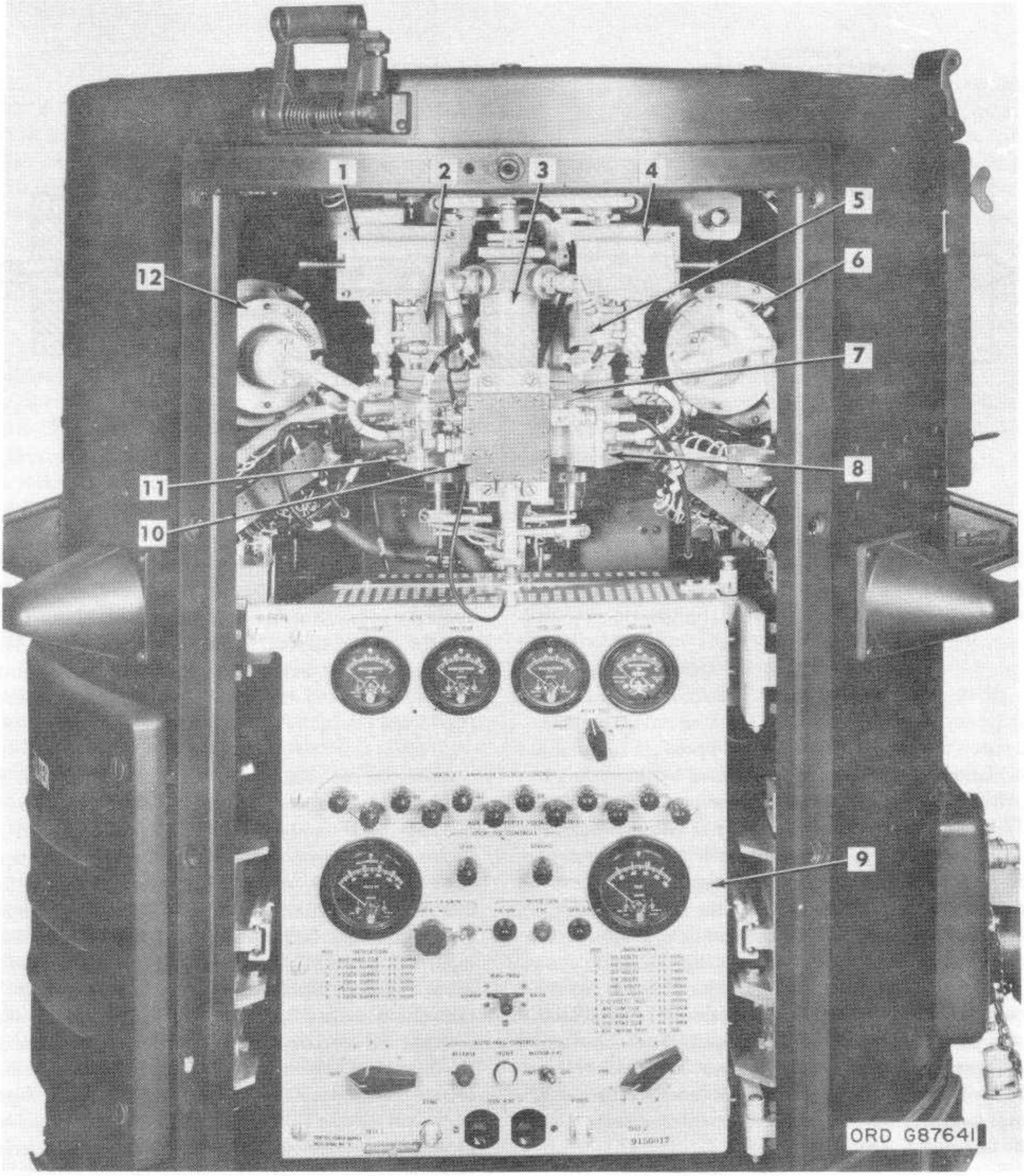


Figure 14. Acquisition receiver-transmitter - internal view.

(4) Receiver-tuner.

(a) The receiver-tuner (fig 13 and (7), fig 14) provides a nonamplifying tuned RF stage (preselector) (5, fig 14) for the main channel and one for the auxiliary channel (2, fig 14). The receiver-tuner also consists of a local oscillator cavity (3, fig 14), a tuning motor, and associated equipment. As illustrated in figure 13, the receiver-tuner and a short section of waveguide containing an adjustable cavity, receives amplified RF echoes from the magnetic circuit. The preselector cavity is a resonant cylindrical cavity that attenuates all signals other than the transmitter frequency. As a result, the preselector improves the selectivity of the receiving

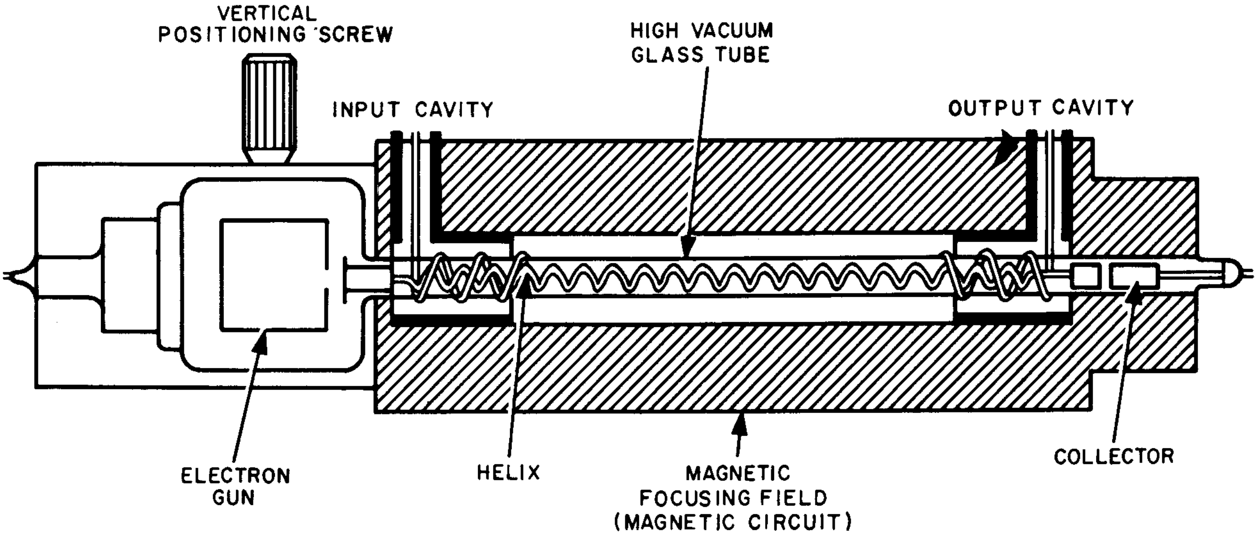


Figure 15. Traveling wave tube - functional diagram.

circuits. From the preselector, the selected signals are coupled through a section of waveguide to the signal frequency converter (fig 13 and (4), fig 14).

(b) The local oscillator (3, fig 14) is a reflex klystron that uses a coaxial cavity as its frequency determining device (tank circuit). The reflex klystron and its tank circuit (cavity) produce continuous oscillations at a frequency determined by the setting of cavity resonance and the repeller voltage applied to the klystron. The tuning of the cavity is accomplished by mechanically varied tuning plungers. The tuning plungers are electrically alined with the tuning of the preselector so that the output frequency of the local oscillator is always 60 megahertz above preselector resonance. If, for some reason, the transmitter frequency shifts by some amount, the AFC circuit (fig 13 and (10) fig 14) will sense the direction (increase or decrease) and amount from the transmitter RF sample. The automatic frequency control will then produce a control voltage that will be utilized in the receiver-tuner to change the local oscillator output frequency to 60 megahertz above the transmitter frequency.

(5) Automatic frequency control (AFC). As illustrated in figure 13, the AFC circuits receive a sample of the transmitted pulse from the acquisition duplexer and a continuous wave (CW) frequency from the local oscillator in the receiver-tuner. The AFC frequency converter combines these signals and applies the difference frequency to the acquisition AFC which, in turn, develops 400-Hz error signals according to the amount and direction of deviation of the difference frequency from 60 megahertz. These error signals are then amplified and applied, as a control voltage, to the tuning drive in the receiver-tuner. The tuning drive mechanically adjusts the size of both the main and auxiliary preselector cavities, the local oscillator cavity, and the amount of local oscillator repeller voltage. These adjustments maintain the intermediate frequency output from the main and auxiliary signal frequency converters (fig 13 and (1) and (4), fig 14) at 60 megahertz.

(6) Main signal frequency converter. The main signal frequency converter combines two frequencies by heterodyning action to produce the IF. As illustrated in figure 13, the main signal frequency converter receives selected RF echoes and the local oscillator output from the receiver-tuner. The RF signals are in the S-band frequency range and the local oscillator input will be 60 megahertz higher than the incoming RF echo. The main signal frequency converter contains the elements necessary for mixing the local oscillator signal with the RF echo signal and extracting the 60-megahertz IF (difference frequency). It is composed of a closed-end section of waveguide attached to the output waveguide of the preselector in the receiver-tuner. A crystal diode, located in the waveguide, detects the lower or difference frequency (IF) and applies it to the main IF preamplifier (fig 13 and (8), fig 14).

(7) Main IF preamplifier. The main IF preamplifier provides two stages of 60-megahertz amplification. It consists of two grounded grid amplifiers that provide low feedback capacitance and reduce oscillations at 60 megahertz. Moreover, this amplifier produces sufficient output to overcome transmission line losses, since the IF will now be sent over long cables to the battery control van, and still provide a high signal-to-noise ratio.

(8) Normal IF select relay K2. As illustrated in figure 13, the normal IF select relay K2 passes or selects either the main channel IF signal or the auxiliary channel IF. The relay is normally deenergized and the main channel IF is selected. For a noise check of the auxiliary channel, relay K2 is energized, electric continuity is established with the auxiliary channel. and the auxiliary IF is selected and passed on to the acquisition IF preamplifier.

(9) Acquisition IF preamplifier. The acquisition IF preamplifier provides five stages of 60-megahertz amplification. As illustrated in figure 13, the gain of the acquisition IF preamplifier is controlled by a bias input from the sensitivity time control (STC). When preknock triggers the STC circuits, a high negative bias voltage is developed. This bias then decreases (goes in a positive direction) until it reaches the level set by the receiver gain. This action decreases the gain of the acquisition IF preamplifier for a short time after the transmitter fires and reduces the effects of RF reflections from nearby objects. The amplified output from the acquisition IF preamplifier is applied to attenuator pad Z2, which provides an impedance match between the acquisition IF preamplifier and the connecting cables that will carry the normal IF from the receiver-transmitter group to the target data processing unit in the battery control van.

(10) Main acquisition IF amplifier. As illustrated in figure 13, the desired IF signal is selected (IF select K1), filtered (IF filter), and then applied to the main acquisition IF amplifier through impedance matching network (Z62). The main acquisition IF amplifier, composed of seven amplification stages and a detector, amplifies the 60-megahertz IF signal and converts it to a video signal. The video energy is then broken down into bypass video and MTI video and applied to the acquisition MTI circuits.

(11) Acquisition RF power supply control. As illustrated in figure 13, the acquisition RF power supply control is located in the acquisition receiver-transmitter group. It furnishes operating voltages for the magnetic circuit, the acquisition duplexer, and the receiver-tuner, and provides metering and control circuits (monitoring) for other components in the acquisition antenna-receiver-transmitter group.

c. **Auxiliary acquisition receiver circuits.** The antijam display (AJD) philosophy is fundamental to all radar techniques in that it provides a target display as free from extraneous noises and disturbances as possible. Moreover, the precise azimuth of the jamming sources can be displayed without distracting from target information. In an AJD system, however, there are two complete receivers (fig 13). One provides an auxiliary channel for AJD and the other, discussed in b above, provides the main or normal channel for the acquisition antenna. The auxiliary acquisition antenna receives energy but does not transmit as does the normal acquisition antenna. Electrically, the two receivers are identical from the antenna input to the IF preamplifiers. Moreover, both receivers are required to operate on the same frequency, and the local oscillator (fig 13) is common to both channels. Since both channels have several identical circuits, only the circuits that differ from those described in b above will be discussed.

(1) Auxiliary IF preamplifier. The auxiliary IF preamplifier provides a 60-megahertz IF signal to the auxiliary electronic frequency converter to be used by jam strobe (JS). (Operation is the same as the main IF preamplifier described in b(7) above.) As illustrated in figure 13, a second 60-megahertz output is applied to normal IF select relay K2 for testing the auxiliary channel.

(2) Auxiliary electronic frequency converter. By heterodyning the 60-megahertz IF with 112 megahertz from a crystal controlled oscillator, the auxiliary electronic frequency converter produces an IF output of 52 megahertz and then applies it through a narrow band IF filter to the IF coupler.

(3) IF coupler. The IF coupler receives two IF signal inputs: the IF input of 48 megahertz obtained by heterodyning the 60-megahertz main IF with 108 megahertz, from a crystal oscillator in the main electronic frequency converter (fig 13), and an IF input of 52 megahertz from the auxiliary channel. The two IF signals are mixed and appear at the output as a composite IF signal.

(4) Amplifier-limiter. As illustrated in figure 13, the output from the IF coupler is applied to an amplifier-limiter stage. Two identical amplifier-limiter units are connected in cascade to provide the desired results of producing only one output, that being the stronger signal. The process of producing an output at the stronger signal is known as stronger signal FM capture. The stronger signal, either the 48- or 52-megahertz IF, is applied to the electronic frequency discriminator. The receiver gain has been set so that the stronger signal will be produced when the antenna main lobe is pointed at the object producing an echo that results in a 48-megahertz IF.

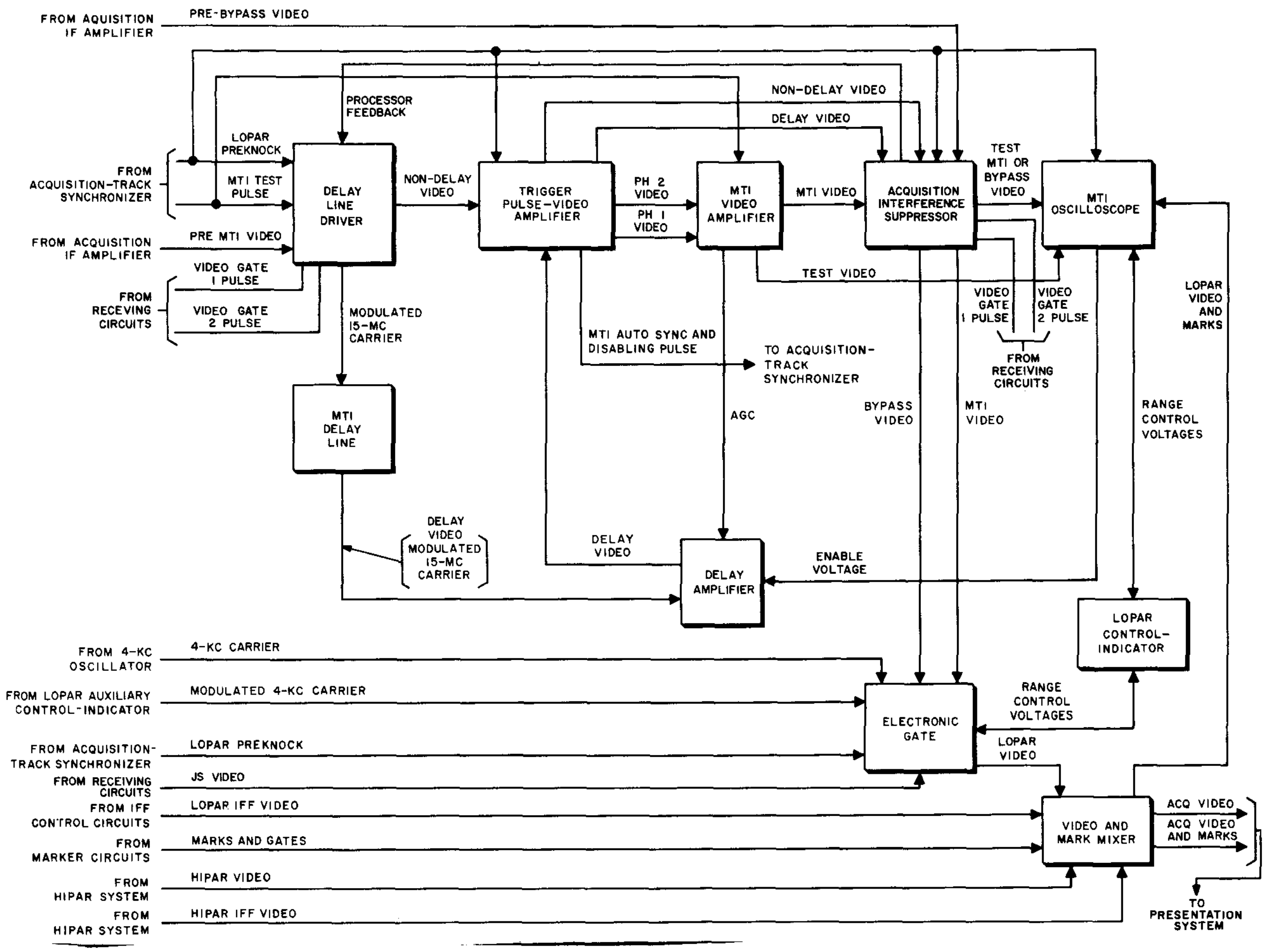


Figure 16. MTI circuits - block diagram.

(5) Electronic frequency discriminator. The electronic frequency discriminator is a dual channel discriminator that will accept either a 48- or 52-megahertz input from the amplifier-limiter. However, the discriminator will only produce a video output (jam strobe video) when the 48-megahertz input is stronger. The JS video is then fed to the electronic gate in the MTI circuits.

(6) Main electronic frequency converter. As illustrated in figure 13, the main electronic frequency converter receives a 60-megahertz IF input from the main IF preamplifier and supplies a 60-megahertz dicke-fix IF input to the wide-band IF amplifier. The dicke-fix channel, consisting of two identical wide-band amplifiers, a fixed attenuator, an IF filter, a main acquisition IF amplifier, and a fast automatic gain control (AGC) amplifier, provides circuitry to reduce the effects of strong jamming signals. The two wide-band amplifiers provide amplification and limiting of the 60-megahertz dicke-fix IF. The output of the wide band IF amplifier is applied to a fixed attenuator, through energized IF select relay K1 (AJD mode) and an IF filter, to the main acquisition IF amplifier (b (10) above). The fixed attenuator at the output of the wide-band IF amplifier reduces the amplitude of the dicke-fix IF, thereby providing the same AGC level for both normal and dicke-fix IF inputs.

(7) Fast AGC amplifier. The fast AGC amplifier (fig 13) receives bypass video from the main acquisition IF amplifier and supplies it with an AGC voltage. The AGC voltage can either be a fixed value or a gated fast AGC voltage. The fast AGC amplifier reduces the effect of wide pulse and CW jamming signals by using fast time constant circuits.

7. ACQUISITION MOVING TARGET INDICATOR (MTI) SYSTEM.

a. **Purpose.** Circuits in the MTI system reduce video interference caused by fixed objects and other radar systems. Since stronger RF echoes are received from fixed objects than from moving targets, the stronger RF echoes (clutter) frequently prevent efficient detection and accurate designation of the moving target. Some common sources of clutter are mountains, hills, woodlands, cloud formations, and precipitation. The MTI circuits are noncoherent and make use of the fact that the amplitude of successive video signals received from a fixed object remain relatively constant, whereas the amplitude of those received from a moving target varies. The pre-MTI video is split into nondelay and delay channels. The delay channel delays the first return pulse one PRT and shifts it 180 degrees in phase. The first delay pulse is compared with the second nondelay pulse. Returns from fixed targets are equal in amplitude and, when compared, cancel. However, successive returns from moving targets are not equal and comparison results in residual video. The processor portion of the MTI circuits uses regenerative feedback to enhance weak return signals for application to the indicators in the acquisition video circuits. The interference suppressor (IS) portion of the MTI circuits may be selected to compare successive pulse intervals in order to reject random or pulsed video signals that are not synchronized with the transmitted pulse rate. This effectively reduces the interference created by radars not operating with the same PRF. The resulting video information--MTI and bypass--is amplified and applied to the appropriate indicators in the acquisition video circuits.

b. Block diagram.

(1) As illustrated in figure 16, the delay line driver in the MTI circuits receives pre-MTI video (fixed and moving targets) from the main acquisition IF amplifier (fig 13) in the acquisition receiving system and three additional inputs: preknock pulse, processor feedback, and test pulse. The four input signals modulate a 15-megahertz sinusoidal carrier, generated within the delay line driver, and produce the compound signal with amplitude variations as shown in C of figure 17. A portion of the compound signal is amplified and detected (15 megahertz removed) to produce the nondelay video supplied as one input to the trigger pulse-video amplifier (fig 16). The remaining or undetected portion of the compound signal voltage is transferred to the MTI delay line where it is delayed 1 PRT by a quartz delay line.

(2) From the MTI delay line, the delayed compound signal (modulated 15-MHz carrier) is applied to the delay amplifier (fig 16). After amplification and detection by this amplifier, the delay video is supplied as one of the inputs to the trigger pulse-video amplifier.

(3) In order to cancel fixed targets, the delay video and the nondelay video, which are 180 degrees out of phase with each other (D and E of figure 17), are algebraically added in the trigger pulse-video amplifier. The algebraic sum of both video signals is applied to a phase splitter and becomes phase 1 and phase 2 video (F and G, figure 17) which is applied to the MTI video amplifier. During this time, the delay preknock pulse from the delay amplifier generates the MTI auto sync and disabling pulse (fig 16) that, in turn, synchronizes the acquisition-track synchronizer in the director station group as discussed in paragraph 3 of this lesson.

(4) The phase 1 and 2 residual video output of the trigger pulse-video amplifier is applied to the MTI video amplifier (fig 16) for amplification and development into three signals. Phase 1 and 2, applied to a full wave rectifier, results in a negative MTI video corresponding to moving targets (H of figure 17). MTI video is applied to the acquisition interference suppressor. When the MTI video consists of more than moving targets due to unbalances in delay and nondelay channels, an AGC voltage is developed and fed back to the delay amplifier to counteract their unbalance and restore good cancellation of fixed targets. Test video is supplied to the MTI oscilloscope for monitoring.

(5) During MTI operation, bypass video (derived from dicke-fix IF when AJD receiver is selected), and MTI video are not altered by the acquisition interference suppressor and are sent directly to the electronic gate. The control inputs to the electronic gate, 4 KHz carrier and modulated 4 KHz, determine the MTI azimuth coverage, whereas preknock and range control determine the range coverage of MTI. During normal MTI operation, the electronic gate alternately passes MTI video, for predetermined range and azimuth coverage, and bypass video.

(6) During IS mode the acquisition interference suppressor functions to remove random interfering video (nonsynchronizing) information from the MTI and bypass video signals. This is accomplished by requiring delay and nondelay video to be in coincidence before producing bypass video for the electronic gate. Random interference is removed from MTI video by supplying an "and" gate with MTI, delay, and nondelay video. The output from this gate is the smallest amplitude, shortest duration of the three inputs. Since delay and nondelay video signals are always larger than MTI, they act as a gate for the MTI video. In this

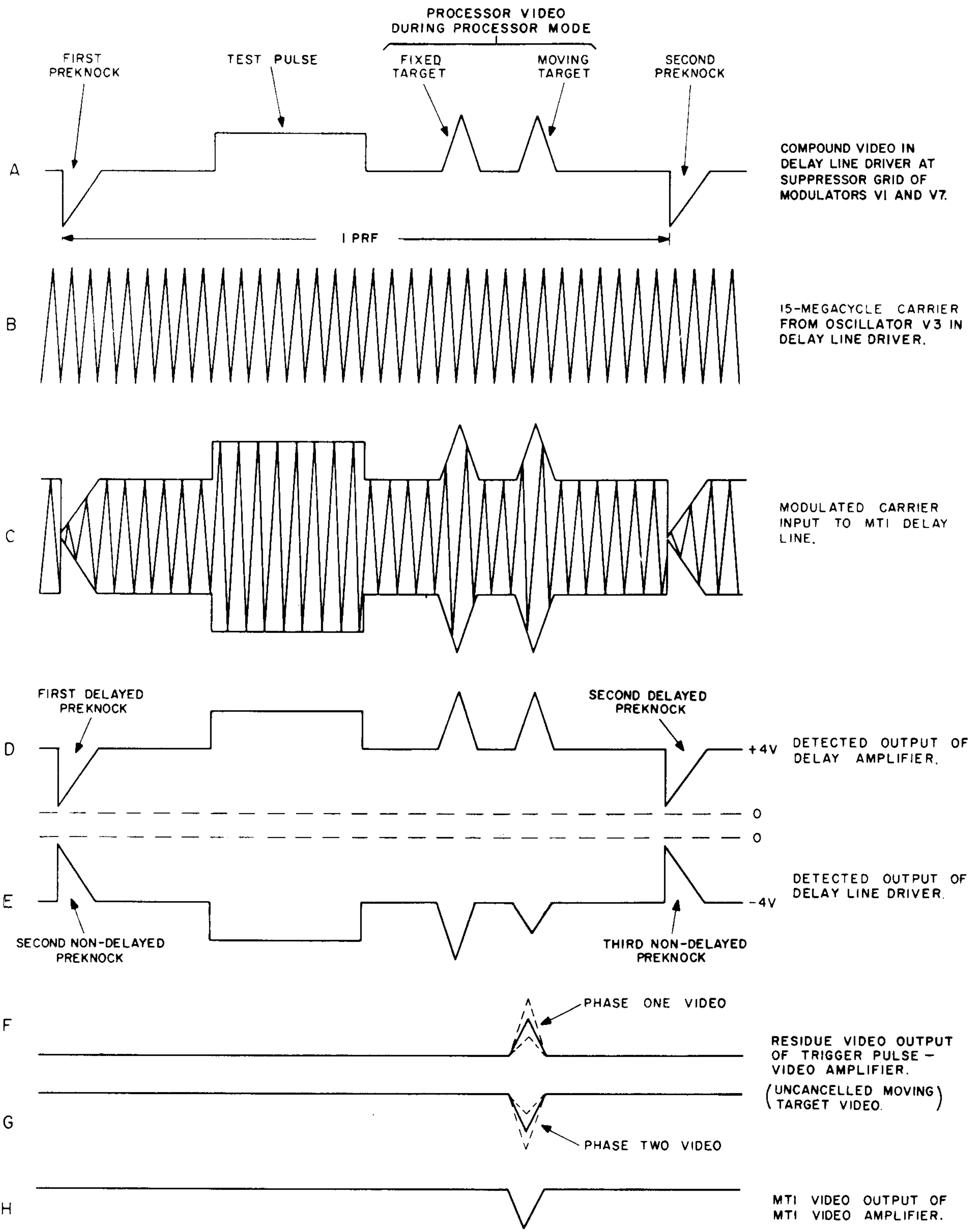


Figure 17. MTI circuits - ideal waveforms.

mode, IS video is applied to the electronic gate as bypass video (fig 16).

(7) During the processor mode of the MTI circuits, MTI video is disabled by removing the range control voltage from the electronic gate and pre-MTI video from the delay channel of the delay line driver. Pre-MTI video is still applied to the nondelay channel of the delay line driver and through the trigger-pulse video amplifier to the acquisition IS. A portion of the first nondelay video pulse is returned from the IS to the delay channel of the delay line driver as processor feedback. This feedback is routed through the MTI delay line, delay amplifier, trigger pulse video amplifier, and into the IS chassis as delay video. In the IS, the first delay pulse is added to the second nondelay pulse, the summation being processor video. Then, 40 percent of the resultant processor video pulse is sent to the delay line driver as processor feedback to be integrated with the third nondelay pulse. The 1 PRT delay applied to processor feedback is similar to MTI action. However, no cancellation takes place. It is best briefly described as regenerative feedback applied to normal video to enhance weak target returns. Processor video is applied to the electronic gate as bypass video.

(8) The electronic gate alternately passes MTI video and bypass video or one of the selected video modes (IS or processor). The resultant video is combined with JS video, by a JS mixer in the electronic gate, when the AJD mode is selected. Remember, K1 (IF select relay (fig 13)) energizes in the AJD mode, so MTI and bypass filter are derived from the dicke-fix IF. When JS only is selected, the JS mixer does not receive MTI or bypass video; therefore, the LOPAR video output from the electronic gate (fig 16) is composed of only JS video which produces a strobe on the presentation system at the azimuth of the jamming source.

(9) The video and mark mixer (fig 16), not an electrical part of the MTI or other acquisition circuits, functions as a distinct signal mixing unit. However, for illustration and orientation purposes, this mixer is functionally subjoined to the MTI circuits. The acquisition video, HIPAR or LOPAR, is combined with azimuth and rangemark signals from the acquisition marker circuit. Combination of these signals produce the acquisition video and marks that are transferred to the presentation system.

(10) The MTI oscilloscope (fig 16), a unit of built-in test equipment, is permanently connected by a multipole switch to the MTI circuits for monitoring purposes. Synchronized by preknock, the oscilloscope is used to monitor the output signals of the MTI video amplifier and the video and mark mixer. In addition, MTI oscilloscope switching controls the application of the DC enabling voltage to the delay amplifier (fig 16).

8. PRESENTATION SYSTEM.

a. **Purpose.** The presentation system displays visual target information upon the screen (face) of CRT indicators. The target information, covering 360 degrees in azimuth, is displayed on PPI and PI scopes, located in the trailer mounted director station, and a B-scope indicator, located in the trailer mounted tracking station; therefore, the same target position information is available to both radar systems. The PPI presents a radial sweep that rotates in synchronism with the acquisition antenna at speeds of 5, 10, or 15 RPM. The PI displays an expanded portion of the target area, selected from an area of the PPI presentation, 533 mils (30 degrees) in azimuth and 25,000 yards in range. This allows a more detailed view of the target area. The B-scope indicator provides a sector display of 1,066 mils (60 degrees) in azimuth and much greater range than the PI. The B-scope presentation is composed of target video and an electronic circle (TTR position symbol) that denotes the range and azimuth settings of the TTR system. Both the PPI and B-scope presentations include target video, range and azimuth information and IFF video. Moreover, the PPI provides identification symbols from the associated FUIF equipment. Either of two presentation systems may be found in the Nike system. One is the antitactical ballistic missile (ATBM) presentation system while the other, discussed in this lesson, is the improved presentation system. The primary difference in the two is the ATBM system contains two long persistency PPI scopes, one short and one long range, while the other has only one medium persistency PPI scope. Information displayed on both presentation systems is the same. During normal operation of the presentation system, before video signals arrive from the receiver circuits, basic displays (fig 18) appear on the three CRT indicators. However, once video signals are received, they become part of the basic presentation. Moreover, to provide additional tactical data (FUIF) and target identification information (IFF), FUIF symbols and IFF responses may be displayed. Marks and symbols appearing on the presentation system (fig 18) are: (1) steerable (steady) azimuth line (visible only when azimuth ring depress switch is operated to remove coincident flashing azimuth line), (2) acquisition track rangemark (range segment of an electronic cross), (3) track azimuth mark (azimuth segment of electronic cross), (4) target video, (5) acquisition range circle, (6) acquisition flashing azimuth line (acquisition azimuth mark), (7) acquisition rangemark, (8) rotating radial sweep, (9) maximum range, (10) sweep (left to right), (11) target video, (12) acquisition range gate, (13) sweep (left to right), (14) TTR position symbol, (15) acquisition range pedestal, (16) target video, (17) acquisition sector unblanking - 1,066 mils, (18) cursor lines, and (19) acquisition azimuth gate unblanking - 533 mils.

b. PPI presentation.

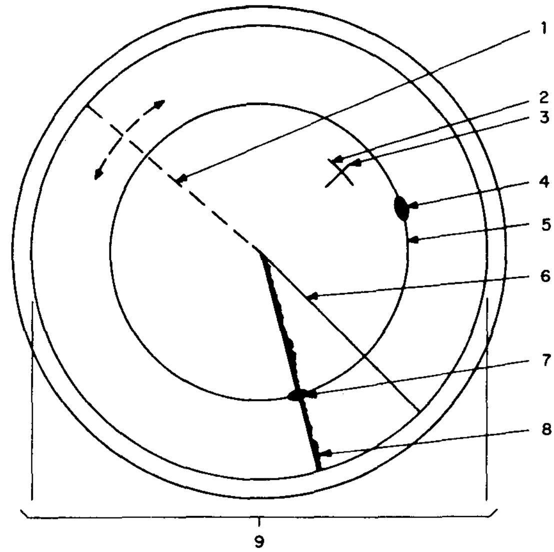
(1) Rotating radial sweep. As illustrated in 8 of figure 18, the rotating radial sweep extends from the center of the PPI CRT to the outer edge. In synchronism with the acquisition antenna rotation, the normal sweep rotates for 360 degrees in a clockwise direction around the face of the CRT. During each revolution, the display brightens as the sweep coincides with the video.

(2) Acquisition range circle. The acquisition range circle (5, fig 18), representing slant range, is continually present as a result of the acquisition rangemark superimposed on the rotating radial sweep. The range circle diameter, appearing on the PPI display, is adjustable over the entire range of the presentation system. As determined by a range control switch, the PPI sweep length may be set to represent three different ranges.

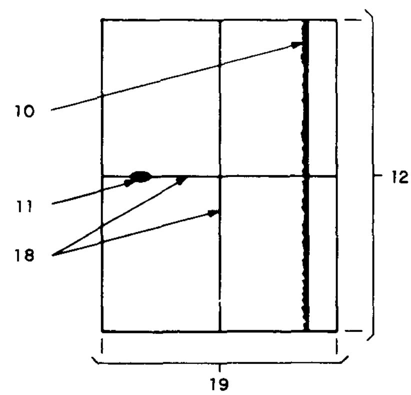
(3) Acquisition flashing azimuth line. The acquisition flashing azimuth line (6, fig 18) appears as a brightened stationary radial line once per 360 degrees rotation of the rotating radial sweep. When this azimuth line is positioned to coincide with the target video, the coarse target azimuth is indicated.

(4) Target video. Target video appears as a brightened spot with each rotation of the rotating radial sweep (4, fig 18). The size of the spot is a relative indication of the target size, and the brightness of the spot depends upon the magnitude of the reflected RF signals from the target. Moreover, the position of the spot on the PPI corresponds to coarse slant range and azimuth of the target. This display appears as if the PPI screen represented a map, in polar coordinates, of the surrounding area.

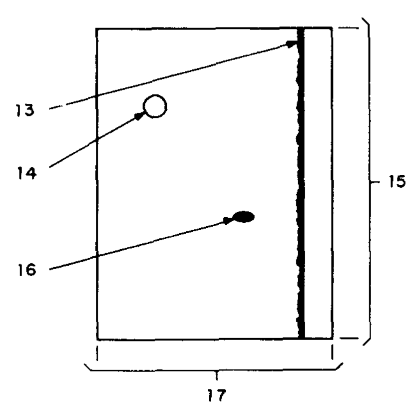
(5) Electronic cross. The electronic cross (2 and 3, fig 18) appears on the face of the PPI as two bisecting short marks which occur once per complete rotation of the radial sweep. This display only occurs when the sweep position is coincident with the azimuth and range setting of the TTR system. This setting is



A. PLAN POSITION INDICATOR (PPI)



B. PRECISION INDICATOR (PI) (BATTERY CONTROL CONSOLE)



C. B SCOPE INDICATOR (TARGET RADAR CONTROL CONSOLE)

Figure 18. Marks display - cathode ray tube indicators.

indicated at the intersection of the two marks. For example, if a target is being tracked by the TTR system, the electronic cross is centered on and moves with the target video.

(6) Steerable azimuth line. The steerable azimuth line (1, fig 18) is coincident with, and replaces, the flashing azimuth line when the azimuth ring depress switch is operated during target designating. With the ring depress switch operated, all presentation is removed except the steerable azimuth line and the acquisition rangemark.

(7) Acquisition rangemark. This mark, which produces the range circle, may be positioned along the steerable azimuth line while the ring depress switch is operated. When steerable azimuth line and acquisition rangemark are positioned to intersect over a target, that target's coarse slant range and azimuth are obtained and may be transferred to the TTR.

(8) MTI video. When the MTI circuits are operated, MTI video replaces normal acquisition video over a controllable display area. The MTI circuits reduce the intensity of strong RF echoes from fixed targets (clutter) and permit moving targets to be visible on the indicators in areas where clutter is present.

(9) Expanded PPI. Any portion of the PPI presentation may be expanded by operating a switch and a control. The center (zero range) of the PPI radial sweep is displaced to the edge of the CRT face. A front panel control is used to vary this displaced azimuth point over 6,400 mils. The expansion circuit allows any sector of 1,244 mils (approximately 70 degrees) to be expanded over the full area of the CRT with a sweep double its normal length.

(10) IFF video. IFF video as described in paragraph 9a appears on the PPI.

(11) FUIF video. FUIF video as described in paragraph 9c appears on the PPI.

c. **Precision indicator.**

(1) Precision indicator sweep. The PI sweep (10, fig 18) displays a modified B-type presentation which is a vertical line moving from left to right in synchronism with the acquisition antenna rotation. The display (B, fig 18) is centered about the intersection of the acquisition range circle and the flashing azimuth line.

(2) Target video. The target video is displayed as a brightened spot when the target and the sweep coincide. Since the PI visually displays an expanded view of a selected portion of the PPI presentation, the target video is more accurately distinguished and located in azimuth and range.

(3) MTI video. When the portion of range and azimuth selected for PI display falls within the MTI video sector of the PPI display, MTI video is presented on the PI. MTI circuits also reduce interference between fixed and moving targets by decreasing the intensity of clutter displayed on the PI.

(4) IFF video. IFF video, as described in paragraph 9a, appears on the PI.

d. **B-scope indicator.**

(1) B-scope indicator sweep. The B-scope indicator sweep (C, fig 18) is divided into two time intervals described in (a) and (b) below.

(a) Scan interval. The scan interval is the normal range sweep time. It displays a vertical line (13, fig 18) which moves from left to right across the face of the B-scope indicator in sync with the acquisition antenna rotation. The sweep displays a normal acquisition video sector of 1,066 mils (approximately 60 degrees) in azimuth. This sector is centered on the acquisition flashing azimuth line, which is displayed during the time of initial acquire at the center of the B-scope indicator.

(b) Symbol interval. During the symbol interval, the sweep displays the TTR position circle which represents the range and azimuth of the target tracking radar system. Unless a target is being tracked, however, the circle will not necessarily coincide with target video.

(2) TTR position symbol. The TTR position symbol is an electronic circle representing the range and azimuth of the TTR system. It may appear anywhere on the B-scope indicator display or, until the ACQUIRE switch is operated during target tracking, not appear at all. During acquire, it will encircle the target video and accurately display range and azimuth of the designated target.

(3) Target video. Normal acquisition video, without marks, is presented on the B-scope indicator CRT. Target video appears as a brightened area when the sweep coincides with it. Moreover, the size of

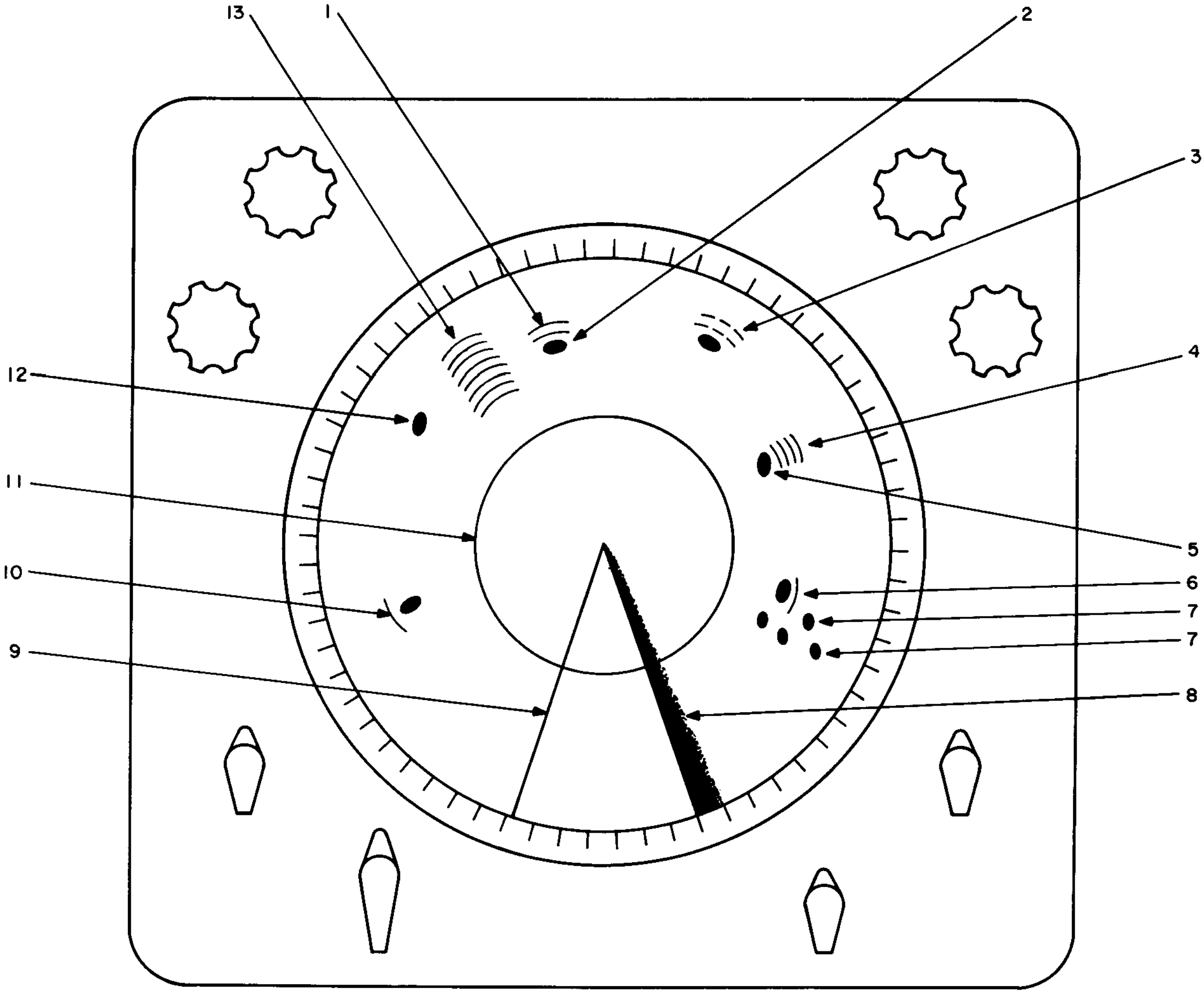


Figure 19. PPI presentation - IFF and SIF/IFF symbol.

the target can be estimated by observing the size and brightness of the target video display.

(4) MTI video. MTI video presentation for the B-scope indicator is similar to that described in b(8) above.

(5) IFF video. IFF video as described in paragraph 9a also appears on the B scope indicator.

9. ASSOCIATED TARGET IDENTIFICATION AND DESIGNATION EQUIPMENT.

a. SIF/IFF equipment integration.

(1) The identification friend or foe (IFF) equipment (interrogator set AN/TPX-20) supplements the improved Nike Hercules system to furnish one of the available means of identifying targets as friendly or hostile. With the selective identification feature (SIF) added to the basic IFF equipment, the combination is designated the Mark X SIF/IFF equipment (AN/TPQ-27). The units of the Mark X SIF/IFF equipment are operated as auxiliary equipment in conjunction with the LOPAR and HIPAR systems. Provisions for the remote operation of the SIF/IFF equipment are furnished by the SIF/IFF and LOPAR remote control circuits. The SIF/IFF system can be used to challenge any target detected by the LOPAR or HIPAR systems. The challenging action is initiated by remote controls located on IFF control-indicator at the battery control console in the trailer mounted director station. If the challenged target is equipped with a suitable transponder, operating at the designated frequency and mode, it transmits an IFF signal as a reply. This reply appears on the presentation system (fig 19) as one or more arcs at a position slightly greater in range than the target video. The IFF video presentation will vary with the type IFF equipment and codes used. The IFF replies, shown in figure 19, are: (1) IFF video

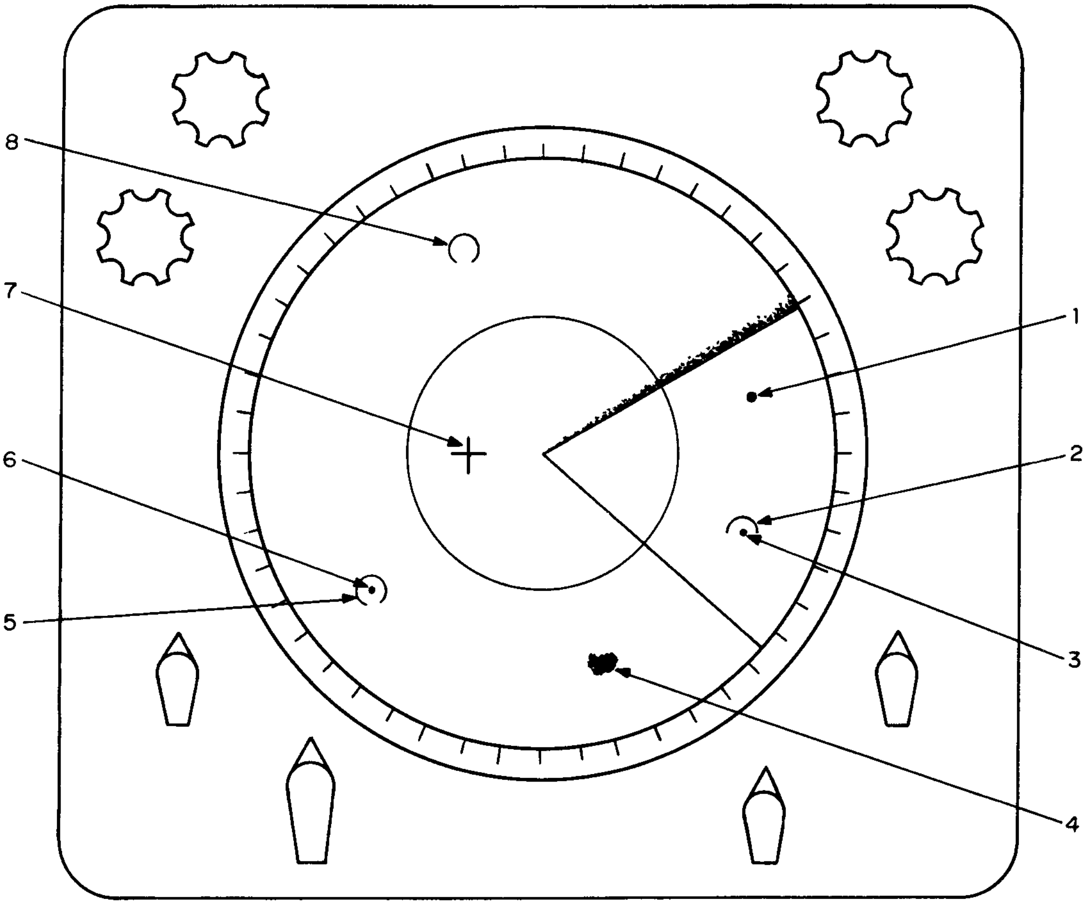


Figure 20. PPI presentation - FUIF symbols.

(mode 2), (2) target video, (3) IFF video (mode 2 - chop), (4) IFF video (emergency mode), (5) identified target video, (6) IFF video (mode 3), (7) target video of unidentified group, (8) rotating radial sweep, (9) flashing azimuth line, (10) IFF video (mode 1) or SIF/IFF video (modes 1, 2, and 3), (11) range circle, (12) unidentified target video, and (13) test video (mode 2, code 77).

(2) Circuits and connections in the LOPAR system are provided to coordinate the operation of the SIF/IFF equipment. These provisions are a primary AC power, IFF trigger pulse (preknock) to synchronize the IFF challenging signals with the transmitted RF pulses of the LOPAR system, and a presentation system to display the IFF coded reply. In addition, the LOPAR system provides mounting space for the IFF equipment and associated IFF antenna and mounting for the SIF equipment within the director station trailer. The units of the SIF/IFF equipment are separately furnished except for the remote controls and indicators.

b. **FUIF equipment.**

(1) The fire unit integration facility equipment causes symbol video to be produced on the presentation system. FUIF equipment, located at each improved Nike Hercules site, is used with missile master AN/FSG-1, located at the AADCP, to provide an integrated air defense for a particular defense area. This integrated system relays accurate and nearly instantaneous designation data and/or information on high speed aircraft between the Army Air Defense Command Post and related improved Nike Hercules air defense guided missile system. Many improved Hercules systems and their associated FUIF equipment can be used in a single defense area. To avoid unintelligible combinations of information, a method of time sharing is provided by the master timer, an integral part of missile master. This timer provides a sequential interrogate signal to each

FUIF in order, interrogating and listening for a report back, a procedure known as reference. The report back is regenerated, stored, and retransmitted to FUIF equipment in another battery within the defense area. When improved Hercules system I, for example, is tracking a target in a sector also defended by improved Hercules system II (overlapped), system II can obtain and observe regenerated target data from system I.

(2) FUIF video. When target identification data is received from the Army Air Defense Command Post through FUIF equipment, the data appears on the PPI as small symbols. These symbols, appearing during the blanked intervals of the normal sweep, are produced by the PPI marker generator and the PPI video amplifier. Positioning of these symbols is accomplished by the electronic gates in the PPI sweep circuits. The four available video symbols are described in (a) through (d) and illustrated in figure 20.

(a) The FUIF symbol (2, fig 20) appears as a half circle or 180 degrees arc with its open end facing downward. This symbol partially encloses the video display of the target identified as friendly.

(b) The battery ground position symbol (8, fig 20) appears as an empty 330 degree arc with its open end facing downward. Display of this symbol at the center of the PPI indicates the position of the system. Any other battery ground position system appearing on the PPI indicates the relative range and azimuth of another integrated improved Nike Hercules system.

(c) The foe symbol (5, fig 20) is generated by displacing the battery ground position symbol from the center of the PPI to enclose the video display of the target identified as hostile. Moreover, display of the foe symbol indicates that the target is to be engaged.

(d) The battery engagement symbol (4, fig 20) appears as a defocused spot over the target video selected for engagement. The defocused spot symbol moves with the target video return as it traces across the indicator and indicates another Hercules system is engaging this target.

APPENDIX

The frequency band designators P, L, S, C, X, K, Q and V are no longer authorized and are being phased out of U. S. Army publications. Where letter band designators are required those shown in Chart 1 have been officially adopted for U. S. Army usage. The letter band designators are in the left column and the bandpass in the center column. Each band, A thru M, is divided into ten (10) channels i.e., A 1, A 2, ... A 10; B 1, B 2, ... B 10 etc. The width of each of these channels is given in the right column.

Band	Frequency MHz	Channel Width MHz
A	0 - 250	25
B	250 - 500	25
C	500 - 1000	50
D	1000 - 2000	100
E	2000 - 3000	100
F	3000 - 4000	100
G	4000 - 6000	200
H	6000 - 8000	200
I	8000 - 10000	200
J	10000 - 20000	1000
K	20000 - 40000	2000
L	40000 - 60000	2000
M	60000 - 100000	4000

EXERCISES FOR LESSON 2

1. To what unit of the LOPAR transmitter is the transmitter sync pulse applied?

   A. Acquisition modulator
   B. Acquisition trigger amplifier
   C. Magnetron
   D. Delay line driver

2. Why is there a 23.5-microsecond delay between the preknock and sync pulses?

   A. Compensate for delay in the transmitter
   B. Compensate for delay in the receiver
   C. Stabilize the system prior to transmission
   D. Stabilize the acquisition track synchronizer

3. Which initiates operation of the LOPAR receiver system?

   A. LOPAR preknock
   B. Target return pulse
   C. MTI test pulse
   D. LOPAR sync

4. What information is obtained by the LOPAR system when the flashing azimuth and range circle intersect over the target?

   A. Target tracking radar position
   B. Target ground range and azimuth
   C. Target elevation and slant range
   D. Target slant range and azimuth

5. What circuit in the LOPAR receiving system reduces the effects of RF echoes from nearby objects?

   A. Preselector
   B. Sensitivity-time control
   C. Automatic frequency control
   D. Receiver gain

6. Within what frequency band is the LOPAR designed to receive?

   A. L
   B. S
   C. X
   D. K_u

7. What scope displays the FUIF symbols?

   A. "B"
   B. PI
   C. PPI
   D. MTI

8. In what unit of the MTI circuits does cancellation of clutter take place?

   A. Delay amplifier
   B. MTI delay line
   C. MTI video amplifier
   D. Trigger pulse video amplifier

9. Which is used to accomplish 3-speed azimuth drive to the LOPAR antenna?

   A. 3 slip clutches
   B. 3 constant speed motors
   C. 3 gear ratios
   D. 3 sets of field windings

10. When precessor video is selected, how is MTI video disabled?

    A. Removing the range control voltage from the electronic gate
    B. Terminating MTI video into the interference suppressor
    C. Removing pre-MTI video from the delay line driver
    D. Applying precessor feedback to the non-delay channel of the delay line driver

11. How far above the horizon is the longitudinal axis of the LOPAR radiated beam when the secondary reflector is completely injected and the primary reflector is tilted 4 degrees?

    A. 6 degrees
    B. 8 degrees
    C. 10 degrees
    D. 12 degrees

12. When is JS (jam strobe) video from the electronic frequency discriminator produced?

A. When 48 MHz is stronger than 52 MHz
B. When 52 MHz is stronger than 48 MHz
C. When the receiver is in the normal mode of operation
D. When the side lobes of the main antenna are receiving a stronger signal than the main lobe

13. Which is NOT part of the built-in test equipment for the LOPAR system?

A. Noise generator
B. MTI oscilloscope
C. AFC circuits
D. Frequency and power meter

14. Which is the minimum acceptable performance figure for the LOPAR receiver?

A. Injected noise equals twice the inherent noise
B. Injected noise equals one-half the inherent noise
C. Injected noise equals one-third the inherent noise
D. Injected noise equals one-fourth the inherent noise

15. What size waveguide is used in the acquisition RF system of the LOPAR radar?

A. 3 CM
B. 5 CM
C. 10 CM
D. 20 CM

16. If the HIPAR radar is selected instead of LOPAR, what is synchronized by HIPAR preknock?

A. PPI sweep and receiver circuits
B. Marker circuits and acquisition track synchronizer
C. Target track radar and PPI sweep circuits
D. Marker and receiver circuits

17. What are the functions of the LOPAR system?

A. Locate, designate, and interrogate
B. Locate, interrogate, and discriminate
C. Locate, designate, and track
D. Locate, interrogate, and track

18. What provides a means for adjusting acquisition modulator thyratron capsule voltage and measuring inverse current?

A. Acquisition RF power supply control
B. LOPAR control-indicator
C. Modulator control-indicator
D. Frequency and power meter

19. Which component allows the LOPAR antenna system to transmit and receive?

A. TR tube
B. Duplexer
C. Directional coupler
D. Rotary coupler

20. What azimuth and range coverage is provided by the precision indicator display?

A. 360 degrees azimuth, 250,000-yard range
B. 60 degrees azimuth, 220,000-yard range
C. 30 degrees azimuth, 25,000-yard range
D. 30 degrees azimuth, 4,000-yard range

21. What is the function of the magnetron in the LOPAR acquisition radar?

A. Converts high voltage DC pulses to RF energy
B. Discharges pulse-shaping circuits
C. Triggers the modulator tube
D. Converts RF energy to high voltage DC pulses

22. What type circuit removes nonsynchronous video from MTI video while the MTI circuits are in the IS mode?

A. Coincidence gate
B. Full wave rectifier
C. "OR" gate
D. "AND" gate

23. Why is K2, normal IF select relay in the receiver, energized?

A. To view auxiliary video
B. To view AJD video
C. To do a noise check on the main receiver
D. To do a noise check on the auxiliary receiver

24. On what principle does LOPAR MTI operate?

   A. Phase comparison
   B. Amplitude comparison
   C. Frequency shift
   D. Reducing intensity of moving targets

25. Which BEST describes the movement of the LOPAR antenna?

   A. Moves in azimuth and elevation as the target moves
   B. Scans in azimuth and elevation
   C. Constant speed azimuth drive and elevation scan
   D. Rotates 360 degrees in azimuth and scans 20 degrees in elevation

26. What controls the output frequency of the LOPAR local oscillator in normal operation?

   A. Manual control
   B. Operator's desired level control
   C. AFC tuning drive
   D. Preselector tuning

27. How is the target tracking radar range and azimuth displayed?

   A. Electronic cross on PPI and B scope
   B. Circle on B scope and electronic cross on the PPI scope
   C. Electronic cross on the B scope and circle on the PPI scope
   D. Intersection of the flashing azimuth and range circle

28. When is FUIF video displayed on the LOPAR presentation system?

   A. During blanked intervals of the sweep
   B. During the normal scan interval
   C. In coincidence with target video
   D. Slightly greater range than the target video

29. How many stages of amplification are contained in the main acquisition IF amplifier?

   A. 2
   B. 3
   C. 5
   D. 7

30. What equipment is used at the Nike battery to provide an integrated air defense for a particular area?

   A. IFF
   B. FUIF
   C. SIF
   D. AADCP