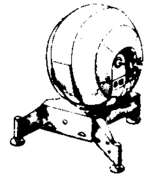


LESSON 5. TARGET RANGING RADAR

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

Lesson Objective . . . . To give you a general knowledge of the purpose, capabilities, and basic function of major units of the target ranging radar system.

Credit Hours . . . . Two

TEXT

1. **PURPOSE.** The target ranging radar (TRR) furnishes target range data to the computer when enemy countermeasures are adverse.

2. **CAPABILITIES.** Since the TRR has no means of determining antenna position errors, its antenna positioning system is slaved to that of the TTR. The TRR contains two transmitter and receiver systems (A and B) that operate in the K_u band of the electromagnetic spectrum. These transmitters radiate a long or short pulse of RF energy into space at a pulse repetition rate determined by the acquisition radar selected and the TTR mode of operation; i.e., long or short pulse mode. The TRR also contains two range receivers (A and B) which operate in conjunction with transmitters (A and B), respectively, to provide target range video in a countermeasures environment. TRR target video is applied to a range and presentation system that is shared by both TTR and TRR. The common range system allows the TTR and TRR to supply slant range (D_T) to the computer. The presentation system, discussed in lesson 4, facilitates target tracking. The TRR contains a panoramic receiver which allows the TRR operator to monitor K_u band transmissions relative to his own transmission.

3. **FUNCTION OF MAJOR UNITS.** Components of the TRR are located in the trailer mounted target range antenna and the trailer mounted tracking station ((7) and (10), fig 9, lesson 1). The TRR system as illustrated in figure 1 is divided into eight systems; i.e., synchronizer, transmitter, antenna, receiver, panoramic receiver, antenna positioning, IF test, and RF test.

a. **Synchronizer system.**

(1) General. The synchronizing system (fig 1) generates pulses that trigger the TRR transmitter and IF test system. The TRR preknock is applied to the video time share amplifier that supplies a modified preknock depending upon which acquisition radar and which mode of TRR is selected. During the short pulse mode, modified preknock occurs at the PRF of the selected acquisition radar; during the long pulse mode, modified preknock occurs at one-half the PRF of the selected acquisition radar. The TRR can be operated at one-half the system PRF since TRR and TTR video are time shared. In addition, the two pulse widths aid in combating enemy countermeasures.

(2) Target range synchronizer. The target range synchronizer is triggered by the modified preknock pulse from the video time share amplifier. TRR preknock is applied to the IF test system and countermeasures indicator while sync pulse is applied to the transmitter system (fig 1). TRR preknock coincides in time with TTR preknock, but TRR sync pulse, which is normally delayed approximately 24 microseconds in

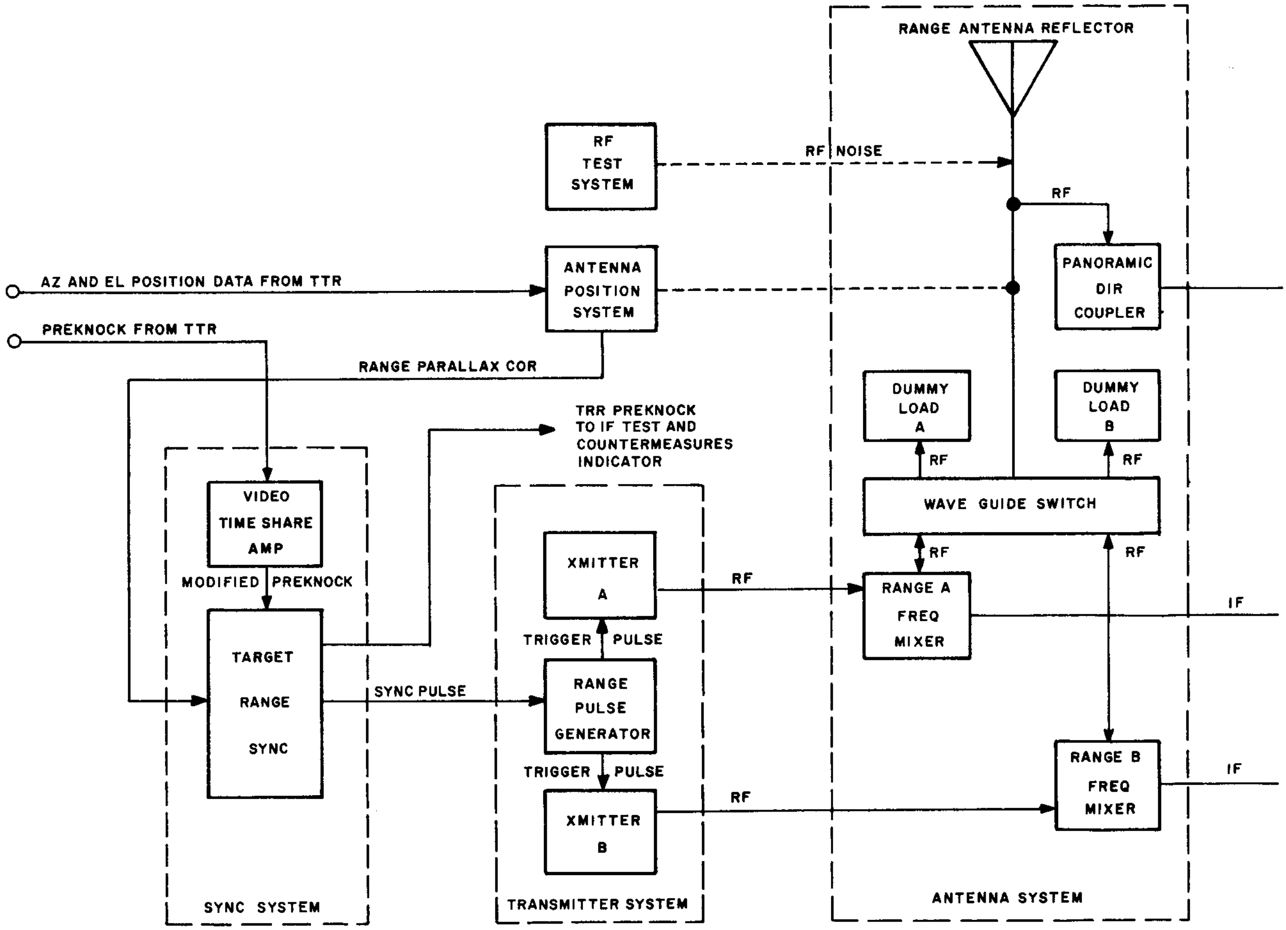


Figure 1. Target ranging radar system - block diagram.

short pulse, can be advanced or delayed an additional 0.5 microseconds by a parallax correction voltage from the antenna positioning system. This advance or delay of TRR sync, in reference to TTR preknock, is necessary because of the difference in position of the TTR and TRR antennas. The computer sees the TTR as the origin of target position information. Since the TTR and TRR cannot be physically in the same place, parallax correction is necessary. This correction is performed by the RANGE PARALLAX CORRECTION COMPUTER and is accomplished by advancing or delaying TRR sync with respect to TTR sync. As illustrated in A of figure 2, no range correction is necessary because, distance to the target is the same from TTR and TRR while the target remains on the line indicated. However, if the target is approaching on a line with TTR and TRR as illustrated in B of figure 2, the TRR sync will have to be advanced to compensate for the TTR being closer to the target. Reverse the latter situation as illustrated in C. With the target approaching 180 degrees from the situation shown in B, the TRR sync must be delayed to compensate for the TRR being closer to the target. The shift in the TRR sync pulse varies the firing time of the TRR magnetron, with respect to the firing time of the TTR magnetron, and insures that RF echoes from the target enter the TTR and TRR angennas at the same time. This insures that the same range information (D_T) is supplied to the computer, regardless of which radar is supplying it. The maximum displacement of TRR sync by this parallax correction is ± 0.5 microseconds. This allows the TTR and TRR antennas to be separated by ± 82 yards. The resultant TRR sync pulse (fig 1) is applied to the range pulse generator in the transmitter system.

b. Transmitter system.

(1) Range pulse generator. The range pulse generator (fig 1) consists of two identical channels which

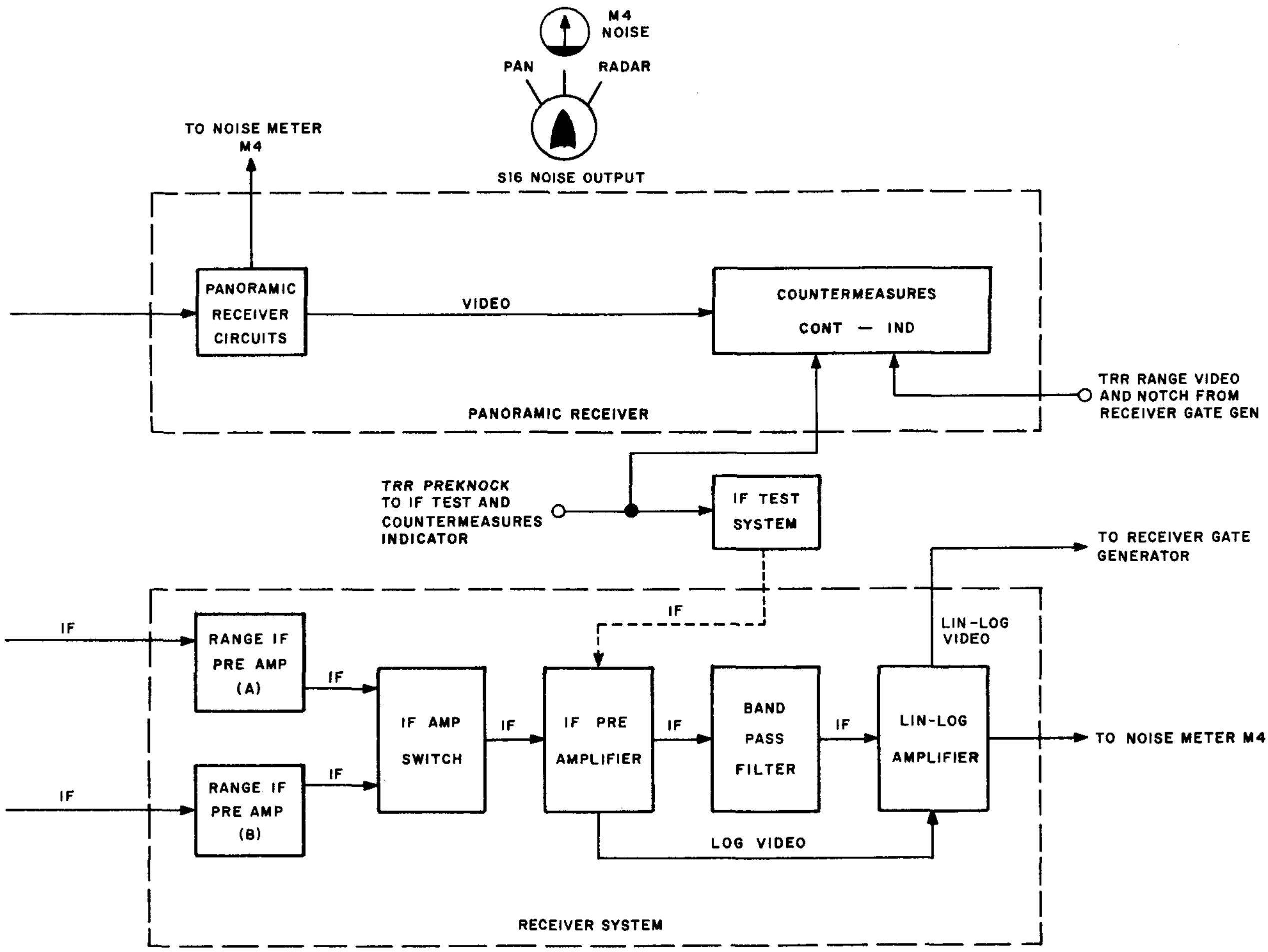


Figure 1. Target ranging radar system - block diagram. (Cont.)

develop trigger pulses that fire transmitters A and B. Each range pulse generator contains a DC resonant charging network, a thyratron switch tube, and an overload protection relay that are used to develop a 4-kv trigger. The 4-kv trigger pulses are applied to transmitters A and B.

(2) Transmitters A and B. Since both transmitters are identical, only one will be discussed. The transmitter contains a high voltage (HV) power supply, a HV pulse transformer, a charging choke, a modulator, a magnetron, an arc suppressor, and associated waveguide. The charging choke allows the pulse forming network in the modulator to charge to twice the voltage applied from the HV power supply. The magnetron is pulsed when the 4-kv trigger from the range pulse generator is applied to the modulator tube. The modulator tube provides a discharge path for the pulse forming network (PFN). As the PFN discharges through the modulator tube and HV pulse transformer, a HV pulse is applied to the magnetron. The magnetron oscillates in the K_u band and this RF energy is applied to the antenna system. The width of the RF pulse is determined by the discharge time of the PFN. When the short pulse mode is selected, fewer sections of the PFN are used and thus a short duration HV pulse is applied to the magnetron. When the long pulse mode is selected, all sections of the PFN are used to develop a long duration pulse. The arc suppressor circuits detect arcing in the magnetrons or mismatch of impedance between the modulator and the magnetron. In these cases the arc suppressor circuits electronically adjust the voltage from the HV power supply to prevent excessive current and damage of the HV power supply.

c. **Antenna system.** The RF energy from the magnetron is applied through the waveguide to range A and B frequency mixers. Each frequency mixer contains

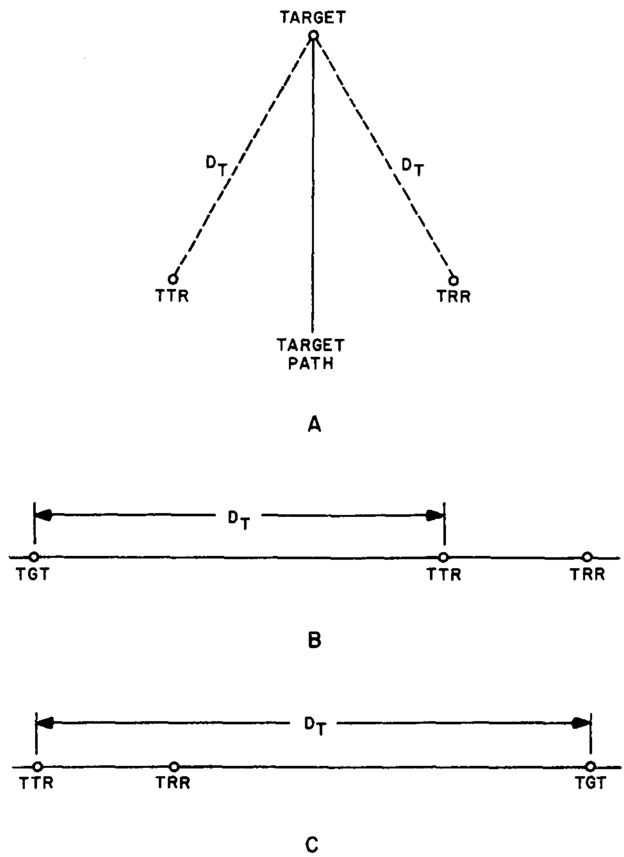


Figure 2. Target ranging radar - parallax correction.

a ferrite duplexer that passes transmitter energy through a waveguide switch to the antenna and passes only received energy to the receiver. The ferrite duplexer (fig 3) consists of: (1) short slot hybrid junction, (2) nonreciprocal phase shifter, (3) folded hybrid tee junction, (4) ferrite slabs, and (5) slot.

(1) Folded hybrid tee junction. The folded hybrid tee junction (3, fig 3) has four waveguide connectors: E, H, M 1, and M 2 arms. RF energy from the transmitter, applied to the H arm, is divided equally between the M 1 and M 2 arms with no phase shift. Transmitted energy from M 1 and M 2 is shifted 180 degrees at the entrance to the E arm and cancellation occurs. RF signals from the antenna, applied to M 1 and M 2 arms 180 degrees out of phase, are combined in the E arm but cancel in the H arm. (Refer to the T junction discussed in paragraph 5h of lesson 4.)

(2) Nonreciprocal phase shifter. The nonreciprocal phase shifter (2, fig 3) is two adjacent sections of waveguide with a ferrite slab (4, fig 3) attached to the inside surface of the outside wall of each section. These ferrite slabs develop a 90 degree phase shift of RF energy passing through the waveguide section in one direction. Since this phase shift is nonreciprocal, the phase of the RF energy passing in the opposite direction is not shifted. The two sections are positioned so that RF energy from the transmitter is shifted 90 degrees by the A section, and received RF energy from the antenna is shifted 90 degrees by the B section.

(3) Short slot hybrid junction. The short slot hybrid junction (1, fig 3) consists of two adjacent waveguide sections with one common wall. The common wall is slotted to form a path for RF energy from one waveguide section to the other. Any RF energy passing through the slot (5, fig 3) is shifted 90 degrees in phase, but travels only in the same direction as the original energy. The two portions of the transmitted energy enter sections A and B with the portion of section A already shifted 90 degrees by the nonreciprocal phase shifter. The portion from section B that passes through the slot to section A is shifted 90 degrees in phase. Since the two portions are now in phase, they combine in the A section. RF signals from the antenna enter section A and are divided equally between sections A and B by the slot. The portion of the signal from section B is shifted 90 degrees in phase.

(4) Transmitted signal flow. The transmitted RF energy from the magnetron enters the H arm of the folded hybrid tee junction and is divided equally between the M 1 and M 2 arms with no change in phase. The portion of RF energy from the M 1 arm passes through one nonreciprocal phase shifter with no change in phase, while the portion from the M 2 arm is shifted 90 degrees in phase by the other nonreciprocal phase shifter. The portion of RF energy, shifted 90 degrees in phase, enters section A of the short slot hybrid junction, while the other portion enters section B. The portion in section B passes through the slot to the A section and is shifted 90 degrees in phase. Since the two portions are now in phase, they add and are applied from the range frequency mixer to a waveguide switch.

(5) Waveguide switch. The waveguide switch (fig 1) directs the energy from one magnetron into the range antenna reflector, while the energy from the other magnetron is directed into the dummy load. The waveguide switch may also be used to direct the output of both magnetrons into their associated dummy loads. The waveguide switch (fig 4) consists of a slotted shutter (13, fig 4) and two rotary solenoids (2 and 12, fig 4) mounted one on each side of the shutter. The dimensions of the shutter slots (5, fig 4) are the same as the inside dimensions of the waveguides connected to the switch. Four sections of waveguide are connected to

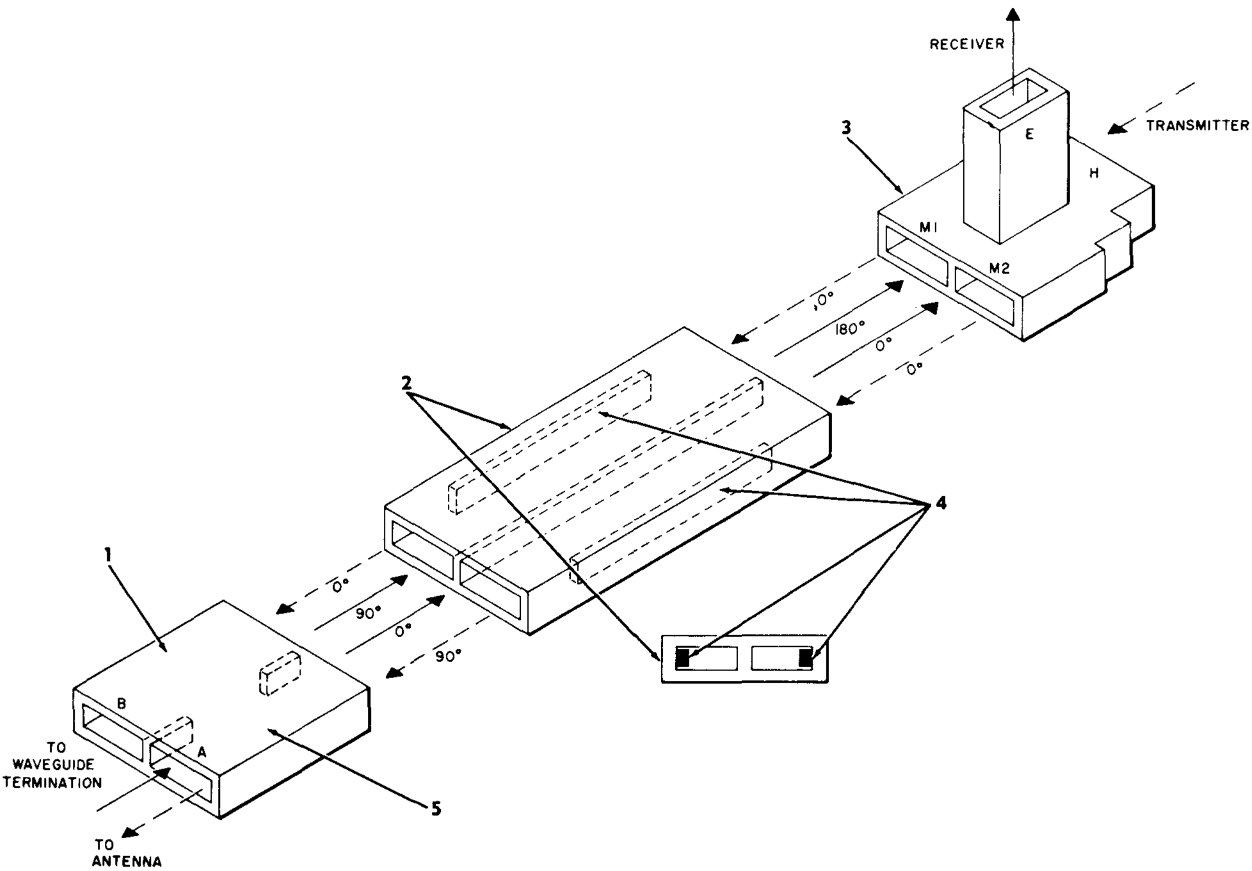


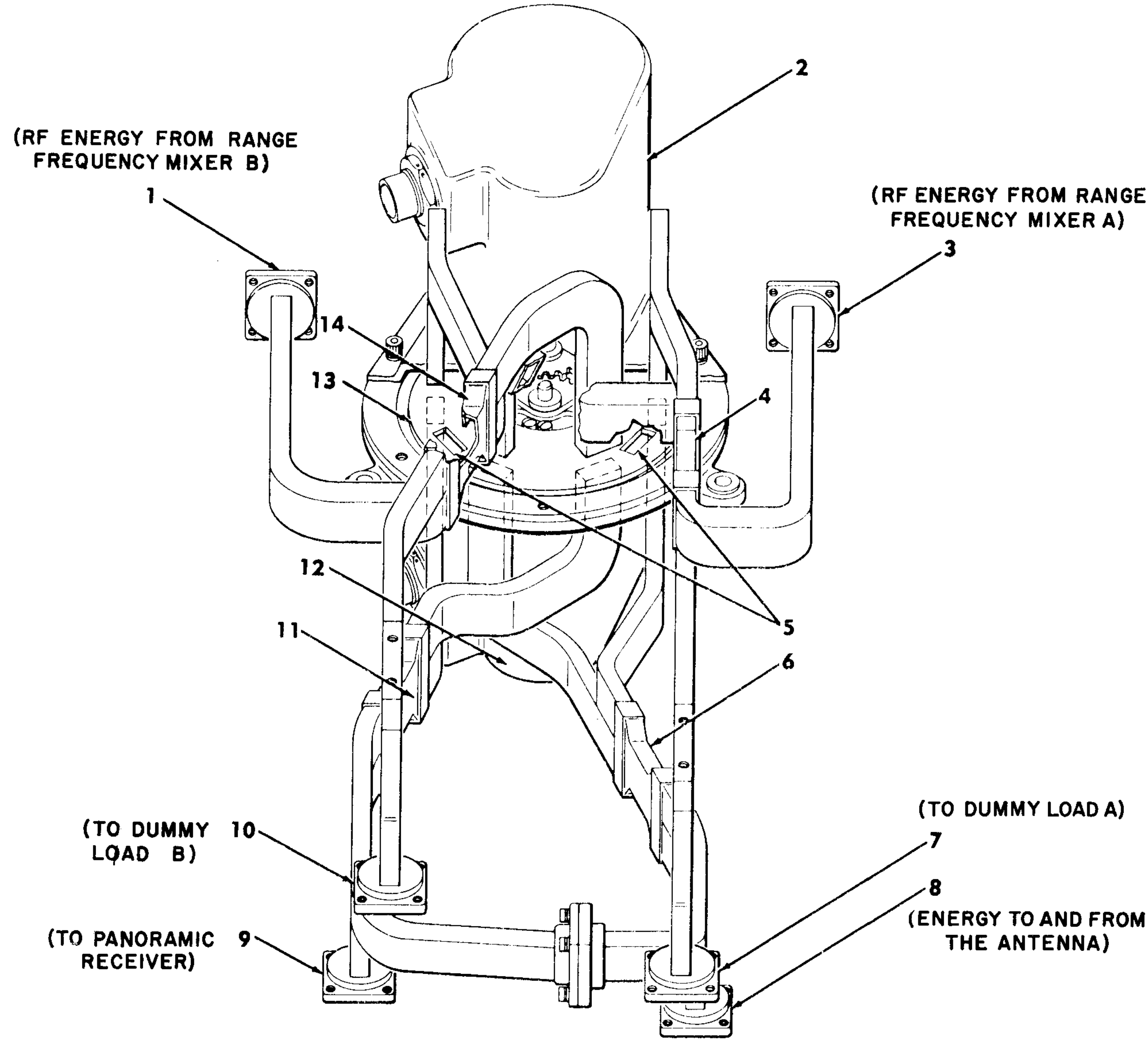
Figure 3. Ferrite duplexer - simplified mechanical diagram.

the switch on each side of the shutter. These sections are directly opposite one another and form four possible paths for RF energy. For each energized position of the switch, two paths are completed by slots in the shutter. In the neutral (no loss) position of the switch, RF energy from the two transmitters is directed into their respective dummy loads.

(a) Neutral position (no loss). Energy from range frequency mixers A and B enters the switch at 3 and 1, figure 4, respectively. The shutter is positioned to block all four waveguide connections. Thus, the energy from transmitter A is divided, reflected, and recombined by the directional coupler (DC1). This energy leaves the switch at 7, figure 4, and is dissipated in dummy load A (fig 1). Energy from transmitter B, blocked by the closed shutter, is divided, reflected and recombined by DC3. It leaves the switch at 10, figure 4, and is dissipated in dummy load B. Any received energy entering the switch at 8, figure 4, which is connected to the antenna, is divided, reflected, and recombined at DC2. From DC2, the energy is applied to DC4 where the division, reflection, and recombination is repeated. The energy leaves the switch through 9, figure 4, and is applied to the panoramic receiver (fig 1) with no loss.

(b) Magnetron A position. When transmitter-receiver A is selected, magnetron A select solenoid (L1 (2, fig 4)) is energized and the slotted shutter rotates to complete the path connecting short-slot directional couplers DC1 and DC2. The RF energy from transmitter A enters the switch at 3, figure 4, and is divided by DC1. The two halves of energy pass through the shutter slots to DC2, which recombines them. All transmitter energy leaves the switch at 8, figure 4, and is applied to the antenna. The RF energy from transmitter B, applied to 1, figure 4, cannot travel through the waveguide switch but is divided, reflected, and recombined by short directional coupler DC3 (14, fig 4). It is then applied through 10, figure 4, to dummy load B (fig 1).

(c) Magnetron B position. When transmitter-receiver B is selected, magnetron B select shutter is energized, and the slotted shutter rotates to



1. Waveguide flange WF2
2. Magnetron A select shutter solenoid L1
3. Waveguide flange WF1
4. Short-slot directional coupler DC1
5. Shutter slots
6. Short-slots directional coupler DC2
7. Waveguide flange WF3
8. Waveguide flange WF5
9. Waveguide flange WF6
10. Waveguide flange WF4
11. Short-slot directional coupler DC4
12. Magnetron B select shutter solenoid L2
13. Slotted shutter
14. Short-slot directional coupler DC3

Figure 4. Waveguide switch - simplified mechanical diagram.

complete the path connecting directional couplers (14 and 11, fig 4). The RF energy from transmitter B is divided by 14, figure 4. The two halves of energy pass through the shutter slots to 11, figure 3, where it is recombined. This energy leaves the switch at 8, figure 4, and is applied to the antenna. The RF energy from transmitter A enters the switch at 3, figure 4, and is divided, reflected, and recombined by 4, figure 4; from DC1 it is applied through 7, figure 4, to dummy load A (fig 1).

(d) Received signal path. A portion of the received signal passes through the panoramic directional coupler (fig 1) where it is attenuated and applied to the panoramic receiver. Received RF energy entering the waveguide switch at 8, figure 4, follows the transmitter selected path in reverse through the switch. When received energy leaves the switch, it is applied to the ferrite duplexer (fig 3) which routes it into the selected range frequency mixer. The received energy from the switch is applied to section A of the short slot hybrid junction (fig 3) where it divides equally. The phase of energy leaving the B section is shifted 90 degrees with respect to the energy leaving the A section. The energy leaving section A passes through a section of the nonreciprocal phase shifter and enters the M 2 arm of the folded hybrid tee junction. The energy leaving section B passes through the other section of the nonreciprocal phase shifter, which shifts it 90 degrees in phase, and enters the M 1 arm of the folded hybrid tee junction. Thus, the energy entering the M 1 arm is 180 degrees out of phase with the energy entering the M 2 arm. The two halves of the received energy are combined in the E arm but cancel in the H arm of the folded hybrid tee junction. Energy from the E arm is coupled into the range frequency mixer.

(6) Range frequency mixer. In addition to the ferrite duplexer discussed in paragraph 3c, each range frequency mixer (fig 1) contains mixer, automatic frequency control (AFC), and local oscillator circuits that are used to heterodyne the received RF into an IF signal.

d. Receiver system.

(1) Range IF preamplifiers. The range IF preamplifiers (fig 1) establish a high signal-to-noise ratio and amplify the IF signal from the frequency mixer stage to compensate for subsequent coupling losses. Both range IF preamplifiers are identical.

(2) IF amplifier switch. The IF amplifier switch (fig 1) contains circuits that change receiver bandwidth when switching from long to short pulse operation. A wide bandwidth is available during short pulse operation and a narrow bandwidth is available during long pulse operation. Also, since the frequency output of both range IF preamplifiers is 60 MHz, the same IF preamplifier is used for the outputs of both mixer channels. The IF amplifier switch contains relay K1 for the switching necessary to select the output from the appropriate range preamplifier (A or B).

(3) IF preamplifier. The IF preamplifier receives the selected range IF signal (A or B) from the IF amplifier switch and provides a linearly amplified IF output at the plate of the final stage for the weak signals. A log video output from this preamplifier is provided at the cathode of the final stage if a signal at the grid of the final stage has enough amplitude to cause this stage to draw grid current. Diode action is produced when this grid draws current and the signal is detected into a log video signal in the cathode and is applied to the lin-log amplifier. This action separates the strong and weak echos for separate processing which results in low amplification for the strong signals and high amplification for the weak signals.

(4) Bandpass filter. To realize full range capabilities of long pulse operation, the bandpass filter provides a narrow bandpass during long pulse operation and a wider bandpass during short pulse operation. This aids in filtering noise and adjacent interfering frequencies.

(5) Lin-log amplifier. This amplifier receives a linearly amplified IF signal from the bandpass filter and logarithmic video signal from the IF preamplifier cathode. Each stage in the lin-log amplifier functions like the final stage of the IF preamplifier. This type amplification prevents the strong signal returns from obscuring the weak returns which could occur if a conventional AGC action were used and results in the two outputs being nearly closed together in amplitude regardless of the return signal strength. At the output of the lin-log amplifier, the amplified IF is detected into a video signal to form lin-log video. This video is applied to the receiver gate generator in the TTR range system (fig 10, lesson 4). From the receiver gate generator this video is added at its proper place on the presentation system time base.

e. IF test system. The IF test system (fig 1) provides a 60-MHz IF test signal for performing accurate tests, calibrations, and adjustments on the TRR system. A variable amplitude IF pulse with a long duration for long pulse testing and a short duration for short pulse testing is developed by this unit. To simulate range, the IF signal may be delayed with respect to the target preknock pulse. The detailed function of this unit is covered in paragraph 11 of lesson 4.

f. RF test system.

(1) Since the TRR system supplies only range information and uses a single feedhorn to transmit and receive RF signals; angle adjustments and checks are not required. The ranging antenna horn, semiconductor device holder, and RF detector assembly of the radar test set group provide a means of evaluating the width and symmetry of the RF beam and of boresighting and orienting the TRR antenna. These components were also discussed in lesson 4.

(2) The sensitivity of the receiver system and the panoramic receiver is measured by use of a noise lamp in the TRR antenna. The noise lamp contains a single argon-filled gas discharge tube that ionizes to produce RF noise signals when an AC voltage is applied between plate and cathode. Part of the RF noise signal (fig 1) that covers a wide frequency band is applied to the panoramic directional coupler and into the panoramic receiver circuits. The RF noise is heterodyned with the panoramic receiver local oscillator signal to produce a 60-MHz IF noise signal. This 60-MHz noise signal is amplified by IF amplifiers in the panoramic receiver and supplied to S16 (fig 1) by a pan video detector, which is also in the panoramic receiver. The remainder of the RF noise signal is applied through the waveguide switch (fig 1) to the selected frequency mixer stage where it is mixed with the local oscillator to produce a 60-MHz IF noise signal. The resultant 60-MHz IF noise signal follows the normal IF signal path through the receiver where it is detected in the lin-log amplifier and applied to S16, the noise output switch.

(3) When performing a sensitivity check on the panoramic receiver, S16 is set to pan and pan gain switch is set to noise test. The noise lamp is energized and the pan gain control is adjusted to produce full scale deflection on M4. When the noise lamp is deenergized, M4 should indicate 60 or less.

(4) When performing a receiver system sensitivity check, S16 (fig 1) is set to radar and the radar gain switch is set to manual. The noise lamp is energized and the radar gain control is adjusted to produce full scale deflection on M4. When the noise lamp is deenergized, M4 should indicate 55 or less.

g. Panoramic receiver.

(1) RF energy in the operating frequency range of the TRR is coupled into the panoramic receiver (fig 1). This receiver uses a backward wave oscillator (local oscillator) to permit rapid voltage-tuning over a wide frequency range. Any received RF is heterodyned in a panoramic frequency mixer with the local oscillator frequency to produce an IF signal. The frequency of the pan local oscillator is varied by a sawtooth voltage that is synchronized with the countermeasure control indicator sweep. By synchronizing these sweep voltages, a frequency-verses-time presentation is obtained on the countermeasures indicator. Video from the pan receiver circuits is applied to the countermeasures control indicator.

(2) The countermeasures control indicator, in the trailer mounted tracking station, contains a dual-gun countermeasures display tube (CRT) and associated circuits for displaying panoramic and TRR video, TRR metering circuits to monitor operation of the transmitter, high voltage indicator lights for the transmitter, and transmitter controls. Video from the panoramic receiver and TRR range video from the receiver gate generator are applied to a dual channel video amplifier in the countermeasures control-indicator. One channel amplifies panoramic video for presentation on the upper trace while the other channel amplifies TRR range video for presentation on the lower trace of the countermeasures control-indicator display tube.

h. Antenna positioning system. As indicated in figure 1, the TTR antenna azimuth and elevation data are applied to the TRR antenna positioning system. This azimuth and elevation position information is applied to the TRR antenna azimuth and elevation servosystems which position the TRR RF beam parallel to the TTR beam if target range is greater than 20,000 yards. This insures that the TTR and TRR beams illuminate the same area. However, when the target is inside a 20,000-yard range, the TRR antenna positioning system employs analog computer techniques to calculate parallax corrections. The azimuth and elevation parallax correction modifies TTR antenna azimuth and elevation position data and insures that the target area remains illuminated by the TRR beam. The range parallax correction, due to difference in TTR and TRR antenna location, is calculated by the antenna positioning system and advances or delays TRR transmitter firing as described in a(2) above. This advance or delay of sync pulse insures that the same range information (D_T) is supplied to the computer by both TTR and TRR.

EXERCISES FOR LESSON 5

. In which frequency band does the TRR operate?

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

. In which TRR mode of operation is the TRR preknock one-half of the PRF of the selected acquisition radar?

A. No loss
B. Short pulse
C. Long pulse
D. Transmitter A

. What is the maximum distance, in yards, between the TTR and TRR antennas for which parallax correction system will compensate?

A. 5
B. 41
C. 82
D. 164

. All sections of the transmitter pulse forming network are used in which mode?

A. No loss
B. Short pulse
C. Long pulse
D. None of the above

. What circuits are contained in the range frequency mixer of the TRR?

A. Mixer only
B. Waveguide switch and mixer
C. Mixer, local oscillator, AFC, and ferrite duplexer
D. Mixer, local oscillator, and AFC

. Where are the weak and strong echos separated for linear and logarithmic amplification in the TRR receiver?

A. IF preamplifier
B. Range IF preamplifier
C. IF amplifier switch
D. Lin-log amplifier

7. In which portion of the TRR ferrite duplexer is energy canceled?

A. Received energy in the E arm
B. Transmitted energy in the H arm
C. Transmitted energy in the nonreciprocal phase shifter
D. Received energy in the H arm

8. What are the proper conditions for establishing the noise reference while performing a sensitivity check on the TRR receiver system?

A. Gain to AGC, noise lamp energized, S16 to Radar, and M4 to full scale
B. S16 to Radar, noise lamp energized, gain to manual and adjusted for full scale deflection of M4
C. S16 to Pan, noise lamp energized, gain to manual and adjusted to indicate 60 or less on M4
D. S16 to Radar, noise lamp deenergized, gain to manual and adjusted to indicate 55 or less on M4.

9. Which is displayed on the lower trace of the countermeasures control-indicator display tube?

A. TRR elevation error video
B. TRR range video
C. TRR azimuth error video
D. Frequency versus time

10. Where are the target ranging radar transmitter controls located?

A. TRR antenna
B. Acquisition track synchronizer
C. ECCM console
D. Countermeasures control indicator

11. During which mode is A and B transmitter outputs applied to dummy loads?

A. No loss
B. Short pulse
C. Long pulse
D. Automatic tracking

12. At what target ranges are the TTR and TRR RF beams parallel?

A. Less than 20,000 yards
B. All target ranges
C. Greater than 20,000 yards
D. Never parallel

13. The TRR sync pulse is delayed with respect to TTR sync pulse for the emplacement shown in figure 1 when the target azimuth lies between

A. north and south, measured counter-clockwise.
B. north and east only.
C. north and west.
D. north and south, measured clockwise.

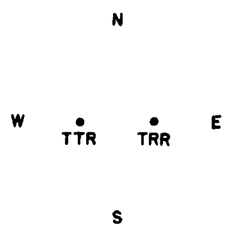


Figure 1.

14. Which is the acceptable noise reading on M4 when performing a panoramic receiver sensitivity check with the noise lamp deenergized?

A. 60 or more
B. 60 or less
C. 55 or less
D. 55 or more

15. All energy propagated into space by the TRR leaves the waveguide switch by traveling through which waveguide coupling flange?

A. WF 6
B. WF 5
C. WF 4
D. WF 3