CHAPTER 14

OPERATING PRINCIPLES OF A HEMISPHERICAL SCAN RADAR AN/SPS-42 (PART I)

INTRODUCTION

A hemispherical scan radar system presents three-dimensional target information. The ground range (distance) and azimuth (bearing) and elevation (height), of a target are displayed on plan position indicators and the elevation and slant range are displayed on range-height indicators.

A representative hemispherical scan radar system presently in naval use is the Radar Set AN/SPS-42 (fig. 14-1). The circuits of the AN/SPS-42 are used in discussing the operating principles of a hemispherical scan radar.

Recent changes in the AN/SPS-42 led to the development of the AN/SPS-39. The latter equipment underwent a change to become the AN/SPS-39A. The first change from the AN/SPS-42 to the AN/SPS-39 is significant in that it modified the basic elevation scanning process. The change to the AN/SPS-39A was a physical change in the various units in the system but did not change the functional or circuit operation of the radar set.

The treatment of the AN/SPS-42 is contained in two parts. Part I (this chapter) considers the major circuits involved in producing the r-f pulse envelope which is radiated by the radar antenna. Part II (chapter 15) presents a discussion of the major receiving and display circuits. Block diagrams are used to illustrate functional operation.

GENERAL DESCRIPTION

Radar Set AN/SPS-42 provides three-dimensional target position data under all weather conditions, at ranges up 160 miles, in 360° azimuth and up to 75,000 feet in elevation. As is true of all radar systems, the AN/SPS-42 consists basically of a single antenna, a transmitter, and a receiver indicator and synchronizer (fig. 14-2). The presentation of range, azimuth, and elevation information for all targets in the field of scan is accomplished by detecting the video echo pulse in the receiving function and displaying the information on the screen of a cathode-ray tube located in the indicating function.

The azimuth scanning is performed by the antenna. The antenna is motor driven at 4.8, 11, 15, or 30 revolutions per minute (rpm). The elevation scanning is accomplished electronically by changing the frequency of the transmitted radar beam in discrete increments.

A synchronizing function provides master timing triggers necessary to coordinate the operation of all units in the Radar Set AN/SPS-42.

From a stable attitude of the antenna, the radiated beam scans in elevation from approximately 48° to 3/4° above the horizontal plane in 26 steps, each step having a discrete scan frequency. To permit stabilization of the elevation-scan pattern in space irrespective of pitch and roll of the ship, additional frequencies are available to compensate for radar-beam positions above 48° and below the horizontal plane. These additional frequencies are used to cancel out the effects of the pitch and roll motions of the ship so that the indicator displays the correct information.

Radio-frequency energy in the range from 2910 to 3090 mc is generated and supplied by the transmitter circuits to the antenna. Each applied frequency causes the radar beam to be radiated at a different elevation angle. The selection of a frequency to provide the proper elevation angle is performed by the frequency-selection channel in the transmitting function. This channel receives gate pulses from the synchronizing function to control the radiation frequency. An increase in the radiation frequency lowers the radar beam and a decrease in frequency raises the radar beam in the elevation scan.

The frequency-generating system in the transmitting section consists of three banks of oscillators, frequency multipliers, and amplifiers.
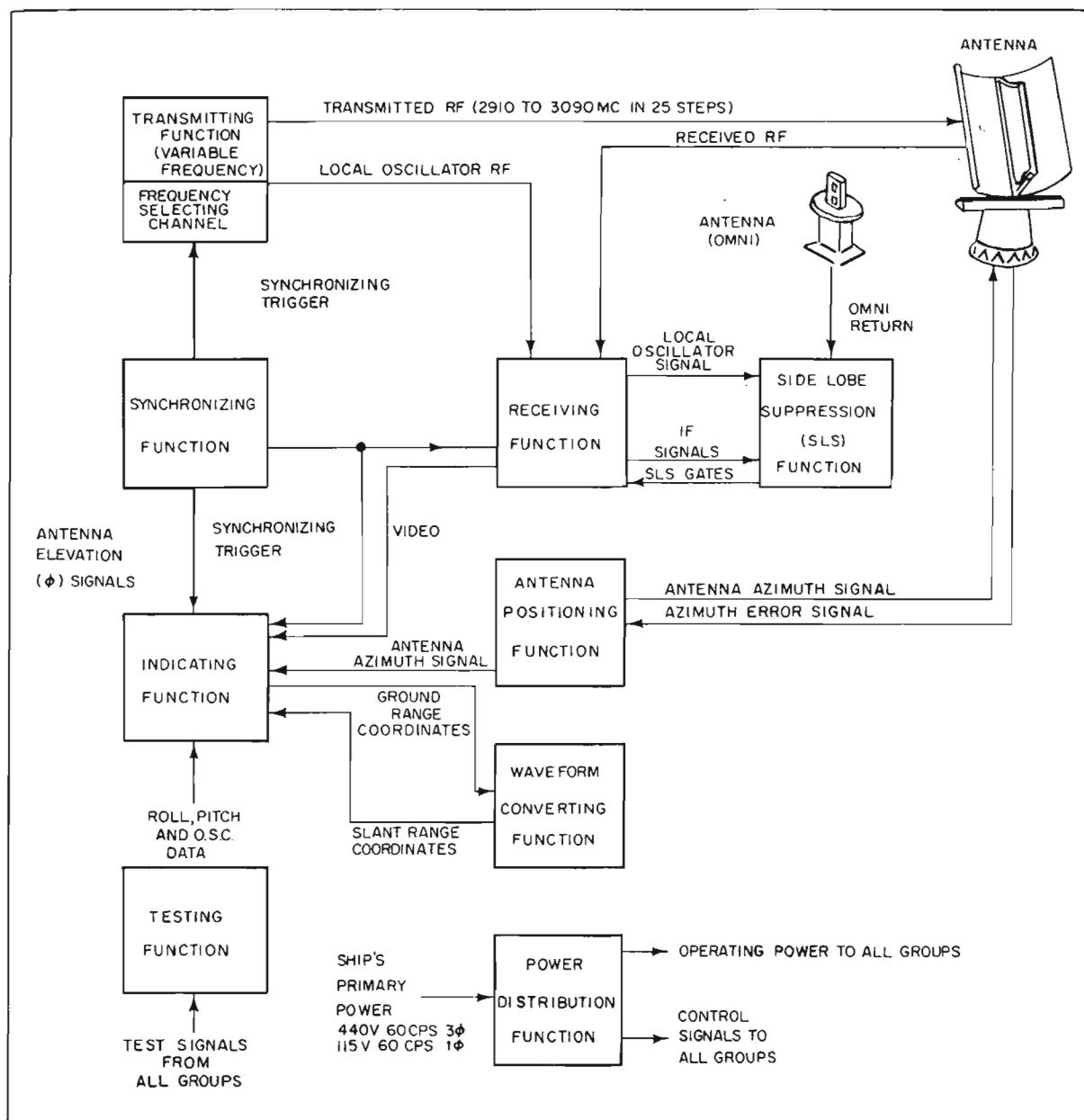
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Figure 14-2.—Simplified block diagram of Radar Set AN/SPS-42.

The oscillators receive binary gates from flip-flop circuits in the synchronizing section. These gates combine the oscillator outputs in accordance with the computer programming to produce the various output frequencies of the radar transmitter.

The target video signal returned to the antenna is applied to the receiving function. After amplification in the receiver, the video signal is supplied to the indicating function which uses two types of indicators (fig. 14-1). One of these is a plan position indicator (PPI) and displays the azimuth and range of the various targets. The other is a range height indicator (RHI), and displays target data in slant range, altitude, and elevation angle. The PPI indicates target position with reference to either true north (true bearing) or to own ship's course (relative bearing).

The radar set is provided with operating power from the ship's primary power source. This power is delivered at 440 volts, 60 cps, 3Ø and at 115 volts, 60 cps, single phase to the power distribution circuits, which, in turn, supply the entire radar system.

The radar system consists of nine system functions (fig. 14-2). Seven of these functions are shown in more detail in figure 14-3. Function, as applied in this discussion, refers to a group of electronic circuit sections, channels, and stages combined to produce a specialized radar operation. The seven functions shown are: antenna positioning, testing, receiving, indicating, power distribution, transmitting, and synchronizing. The other two functions (treated later) which make up the total of nine functions are the side lobe suppression (SLS) and waveform converting functions (fig. 14-2).

Each function (fig. 14-3) performs a specific operation which will be discussed fully later. A brief description of each function is given in the following paragraphs to show the purpose and relationship of the various functions, and should be considered introductory to the specific performance.

The purpose of the synchronizing function is to provide master timing triggers and control signals necessary to coordinate the operation of transmitting, receiving, indicating, and testing functions.

The transmitting function generates a series of precise frequencies between 2910 and 3090 megacycles, which are transmitted as one-megawatt r-f pulses during the transmitting period. The pulse width of the transmitted r-f energy may be either 1 or 4 microseconds in duration as determined by the radar operating mode. During the receiving period, the transmitting function supplies the local oscillator signal to the receiving function.

The transmitting function consists of three channels, namely, the r-f channel, the modulator channel, and the power supply channel (not shown). The microwave circuits, i.e., the r-f input waveguide and mixer circuits, are also contained in the transmitting function.

The r-f channel comprises a frequency selection channel. This circuit contains a frequency counter which controls the frequency of the transmitted radar beam. Reference to this frequency counter (not shown) and its effect on the transmitter output is repeated several times throughout this chapter.

The r-f channel provides the necessary power amplification for a low-level r-f signal generated in an oscillator-amplifier section

similar to that in the transmitting functional section of the Radar Set AN/SPS-29. The action is treated in chapter 12 of this training course. The modulator channel gates high-power r-f amplifiers in the r-f channel during the transmitting period. The power supply channel (not shown) supplies the necessary d-c potentials for the generation of the transmitted pulse.

The receiving function of the AN/SPS-42 consists of three major parts, exclusive of the antenna. These are the i-f amplifier channel, the clutter gate channel, and the moving target indicator (MTI) channel.

The receiving function provides the detection and amplification of target echoes. Echoes received at the antenna are routed through the microwave circuits in the transmitting function to a crystal mixer assembly similar to that in the Radar Set AN/SPS-10D discussed in chapter 10 of this text. The echo pulses are heterodyned with a local oscillator signal in the microwave circuits to produce a 12-mc i-f signal. This signal is amplified and fed to the i-f amplifier channel in the receiving function.

The i-f signal is detected and the resultant video is routed to a clutter gate channel and to a moving target indicator (MTI) channel. Each of these are video channels which operate under specific conditions.

The clutter gate makes possible the detection of moving targets located amidst large targets, such as clouds and sea return, which would otherwise be lost. The MTI unit is designed to compare the video returns from two successive transmitter pulses at the same beam position.

The clutter gate is essentially an electronic switch which normally channels the video signal to the radar indicators. Under certain conditions, however, the clutter gate automatically suppresses the clutter gate normal video channel to the indicators and gates on the moving target indicator video channel. This action provides MTI video to the radar indicators. If all of the requirements for MTI presentation are not met, the clutter gate channel will suppress the output of the MTI video channel, and gate on the clutter gate normal channel.

The moving target indicator presentation shows only those targets that are in motion in the midst of clutter. Signals from stationary targets in clutter are removed from the return by memory circuits.

The purpose of the antenna positioning function is to control the azimuth rotation of the radar antenna. Control of the antenna speed is accomplished either automatically or manually.

When the antenna positioning function is in the automatic mode of operation the antenna will rotate at a specific rate of speed as determined by the setting of antenna control switches on an electrical test panel (not shown), a radar set control (fig. 14-1), or the radar test set group. In the automatic mode the antenna may be operated at one of four speeds that are automatically controlled by a closed loop servo-amplifier system (fig. 14-3). The normal operating speed is 15 rpm. The other three speeds are 11.5 rpm for MTI operation, 4.8 rpm for coincident video operation, and 30 rpm for antenna testing. In the manual mode of operation, antenna speed and positioning are controlled by a hand-operated tachometer generator.

The indicating function displays airborne targets on the screens of cathode-ray tubes so that the position of the various targets may be determined in terms of azimuth, height, and range. The cathode-ray presentation is displayed at the radar set console (fig. 14-1). Two cathode-ray indicators are used. One of the indicators, azimuth-range indicator, displays the target information in the form of ground range versus azimuth bearing. The other indicator, the range-height indicator, displays the target information in the form of slant range versus height.

The range-height indicator (fig. 14-3) receives its video input directly from the receiver while the video to the azimuth-range indicator is routed through the IFF equipment. The azimuth-range indicator presents target information in true or relative bearing.

The indicating function receives synchronizing triggers from the synchronizing function to initiate and terminate the indicator sweeps.

The indicating function contains a data stabilization section which supplies space stabilized information to the target positioning circuits of the two indicators. The space stabilization signals compensate for pitch and roll of the ship before application to the target positioning circuits.

The purpose of the power distribution function is the production, distribution, and control of a-c and d-c power within Radar Set AN/SPS-42. Utility functions such as heaters, blowers, and delay and interlock circuits are also part of the power distribution function.

The power distribution function obtains three-phase, 440-v, 60-cps power, and single-phase 115-v, 60-cps power from the ship's primary power source. Output power is applied to the various functions of the radar system.

The radar set console and the antenna pedestal space heaters are remotely located from the radar room. These units therefore obtain single-phase, 115-v a-c power directly from the ship's primary power source.

The testing function (fig. 14-3) provides a means of checking the operation of Radar Set AN/SPS-42, and aids in the isolation of malfunctions within the radar system. This is accomplished by routing samples of the major signals and voltages from various functions to a test instrumentation console, and checking their operation characteristics. The instrumentation console consists of the radar test set group (fig. 14-1) and associated oscilloscopes.

Contained in the meter monitoring and oscilloscope monitoring section of the testing function is an r-f power monitoring channel, a voltage standing wave ratio measuring channel, an antenna speed monitoring channel, and two monitoring oscilloscopes. The circuit to be tested is selected by the operator. Testing the various functions of Radar Set AN/SPS-42 may be accomplished without interfering with the normal operation of the radar system.

The waveform converting and side lobe suppression functions are not shown in figure 14-3. The relationship of these functions to the various other functions in the radar system is treated in chapter 15 of this text. The side lobe suppression (SLS) function detects and eliminates return echoes originating outside the main lobe beam of the radar antenna. The SLS circuit also prevents enemy jamming signals from disrupting the indicator displays.

A signal from an omnidirectional antenna is utilized to provide a reference signal with which the radar return signal from the main antenna is compared. When the signal from the omnidirectional antenna is greater than that from the radar antenna, an undesirable signal is present and an SLS gate is generated which reduces the radar receiver gain during the time that the objectionable return is being received.

The purpose of the waveform converting function is to convert ground range target information to slant range target information.

SYNCHRONIZING FUNCTION

As forestated, the synchronizing function generates the timing and control signals for Radar Set AN/SPS-42. The timing and control signals program and coordinate the operation of the indicating, receiving, transmitting, and testing functions. The synchronizing function provides the necessary timing and control signals

for four possible modes of operation: Normal, Normal-MTI, Coincident Video (CV), and CV-MTI. The specific operation achieved in each of these modes is discussed later in this chapter.

The synchronizing function (fig. 14-3) is separated into two main channels; the timing channel and the elscan computer-programmer channel. The channels of the synchronizing function provide separation of the two types of signals produced by the synchronizing function; i.e., timing pulses and control gates.

The timing channel provides the timing triggers necessary to coordinate the operation of the radar system. These triggers synchronize the operation of the testing function, initiate the transmission of r-f energy, turn the receiver on and off, and initiate and terminate the indicator sweeps.

The elscan computer-programmer channel provides control gates to the receiving, indicating, and transmitting functions. The control gates are employed to select the transmitter frequency, and, by means of the frequency, to control the elevation angle beam position of the radiated energy. The control gates also position the indicator sweeps so that they coincide with the radiated beam position, and provide special commands to the receiving function during MTI or CV operation. The elscan computer-programmer channel is divided into the beam positioning subchannel and the MTI-CV subchannel.

The synchronizing function is a digital computer with built-in logic circuits. The production of binary gates and timing triggers is controlled by these logic circuits. Relays and switches, which are activated when the operator selects any of the four modes of radar operation, permit the built-in logic to be modified for the particular mode selected.

The basic theory of computer operation is presented in the training course, Basic Electronics, NavPers 10087-A. However, a brief introduction of computer logic is given here. This information will be helpful in understanding the functional operation of the synchronizing function which follows.

LOGICAL ALGEBRA

Logical algebra is a branch of algebra that expresses formal logic in equation form. The use of logical algebra greatly facilitates the analysis of logic circuits such as those employed in the synchronizing function. Input signals applied to these logic circuits produce logic signal outputs. A logical equation is constructed as follows: The output signal is expressed in terms of the input signals and the operations performed upon these input signals by the logic circuits. Each signal is a variable which is expressed by suitable algebraic notation. These variables are then combined by operational symbols similar to the addition and multiplication signs of ordinary algebra to form a logical equation.

The advantage in writing logic signals (signals produced by logic circuits) in equation form is derived from the fact that the equation can easily be converted into a circuit which is able to produce the output signal expressed by the equation.

As applied to the synchronizing function, logical algebra is restricted to devices which are always in either of two possible states. The two states can be called the on and off states, the transmission and hindering states, and 1 and 0 states, or the true and false states. The logic circuits employed in the synchronizing function consist of AND gates, OR gates, transmission gates, transistor inverters, and flip-flops. The AND, OR, and transmission gates are composed of semiconductor diodes and behave essentially as single throw (ON-OFF) switches.

Flip-flops are multivibrators whose square wave outputs are in either of two possible voltage states. The flip-flop behaves as two single throw switches acting in opposition to each other (i.e., if one switch is turned ON the other is turned OFF). The transistor inverter produces the inverse of the signal applied to it.

Throughout the synchronizing function, logic signals will be described as being in either the 1 state or the 0 state. In the 1 state, the signal voltage ranges from 0 to +4 volts, the value being dependent upon the particular signal involved. In the 0 state, the signal voltage ranges from -15 to -18 volts, again depending on the particular signal. Timing triggers, i.e., clock pulses, are excluded from the logic signal category and are described as being either present or not present.

All logical equations essentially answer the question "When is the output signal in the 1 state?" To determine the answer to this question, write the equation of the circuit, expressing each input signal in algebraic notation; replace each variable by its value, either 1 or 0; and perform the algebraic operations indicated by the equation.

Three logical operations are possible with two-state devices; logical addition (the OR operation), logical multiplication (the AND

operation), and negation. The terms addition and multiplication, as they are used in logical algebra, have no equivalent in ordinary algebra.

The OR operation is symbolized by the plus sign. A typical equation in which the OR operation is performed is $A + B = C$. In words, this is expressed as "If either variable A or B is equal to 1, or if both variables are equal to 1, the output (variable C) is equal to 1." A simple circuit which performs the OR operation consists of two switches in parallel between the input and output terminals of the circuit. If either switch is closed, the circuit is completed and an input signal is passed. If both switches are closed, the input signal is still passed. The rules of OR operation (logical addition) are written as:

$$0 + 0 = 0$$
$$1 + 0 = 1$$
$$0 + 1 = 1$$
$$1 + 1 = 1$$

The AND operation is symbolized in the same way that multiplication is symbolized in ordinary algebra. A typical equation involving the AND operation is $AB = C$. In words, this is expressed as "If, and only if, both variable A and variable B are equal to 1, the output (variable C) is equal to 1." A simple circuit which performs the AND operation consists of two switches in series between the input and output terminals of the circuit. Only when both switches are closed can an input signal be passed. The rules of AND operation (logical multiplication) are written as follows:

$$1 \times 0 = 0$$
$$0 \times 1 = 0$$
$$0 \times 0 = 0$$
$$1 \times 1 = 1$$

Negation is the act of taking the complement of a variable, and is symbolized by placing a bar over the variable which is negated. If variable A is in the 1 state, its negation, $\bar{A}$, is in the 0 state. Conversely, if $A = 0$, $\bar{A} = 1$. The negation of $\bar{A}$ is A which can also be expressed as $\bar{\bar{A}}$. A simple circuit which performs this operation consists of two switches mechanically linked so that if switch A is closed, switch $\bar{A}$ is opened.

LOGIC CIRCUITS

To perform the operations required by logical algebra, physical devices are utilized. A

circuit composed of these devices can be synthesized directly from the logic equation of the output signal which is to be produced. A diode AND gate circuit, or a transmission AND gate circuit (passing a pulse to gate a circuit) satisfies the conditions for the AND operation sign; a diode OR gate or a transmission OR gate replaces the OR operation sign; a flip-flop or a transistor amplifier (inverter) replaces the negation sign. These six circuit elements can be combined in any manner that may be required to reproduce any logic equation incorporating the operations of multiplication, addition, and negation.

AND Gate

An AND gate circuit (fig. 14-4, A) consists of two or more semiconductor diodes connected in such a way that the signal inputs to both diodes are in the 1 state when the output of the AND gate is in the 1 state. The voltage state of the output, C, is determined by the conduction state of input diodes CR1 and CR2. The input voltage at points A and B can be either -18 volts (the 0 state) or +2 volts (the 1 state). If both inputs are in the 1 state, both diodes are forward biased and conducting. Neglecting the forward voltage drop across the diodes, the voltage at point C is also in the 1 state (+2 v). If either input A or input B is in the 0 state, the input diode to which the -18 volts is applied is forward biased. The drop across that diode is still negligible, and the -18 volts at point C back-biases the other input diode. The voltage at point C is therefore in the 0 state (-18 v).

An AND gate can be constructed for any number of input signals. Each input signal must have its own input diode. Regardless of the number of inputs, it is still true that if any one of them is in the 0 state, the voltage at point C is in the 0 state. The truth table (operation table) summarizes the possible combinations of A and B. In each row of the table, the A and B entries produce the C entry. This table is simply a formalized way of writing the rules of logical multiplication.

Transmission AND Gate

The transmission AND gate (fig. 14-4, B) is a modified AND gate used to control the passage of a timing trigger to the input of a flip-flop or blocking oscillator. A and B (enabling gates) are applied to the cathodes of input diodes (fig. 14-4, B). The timing pulse (T_p) is applied to the cathode of diode CR3. Diode CR4 is always

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Figure 14-4.—AND gate logic circuits.

conducting through R1, R2, and the B supply. This diode is essentially a short connecting points C and D.

If either input A or input B is in the 0 state, the voltage at point C is -18 volts to ground. Neglecting the voltage drop across CR4, point D is also at -18 volts to ground. If the -15 volt timing pulse is present at the cathode of CR3, this diode is back-biased by the voltage at point D, and the trigger is not permitted to pass.

If both A and B are in the 1 state, CR1 and CR2 are back-biased 2 volts making the voltage at point C zero with respect to ground. Diode CR4 is still forward biased, placing point D at zero volts to ground, and diode CR3 is forward biased if the -15 volt timing pulse is applied. The timing pulse therefore passes through diode CR3 to the output.

The transmission AND gate can be built for any number of enabling gates. Each enabling gate must have its own input diode. All of the enabling gates must be in the 1 state in order for the timing trigger to be passed. The equation for the transmission AND gate is written as T_p (AB). In words, this is stated as "Timing pulse T_p is passed when and only when both A and B are in the 1 state."

One form of the transmission AND gate (fig. 14-4, C) provides a transmission gate which passes triggers only when the enabling gate is in state 0. When gate A is in state 1, diode CR1 is forward biased, the trigger pulse is shorted to ground through d-c blocking capacitor C1 and diode CR1, and no trigger appears at the output "C" of the transmission gate. When gate A is in state 0, diode CR1 is back biased, the trigger is not shorted to ground, but appears at the "C" of the transmission gate circuit.

OR Gate

An OR circuit (fig. 14-5, A) consists of two or more semiconductor diodes connected in such a way that if any one of the input signals is in the 1 state, the output of the OR gate at "C" is in the 1 state. If input A is +2 volts and input B is -18 volts, ① diode CR1 is forward biased. Because the forward voltage drop across CR1 is negligible, point C is also at +2 volts which back-biases diode CR2, and the -18 volts at point B is dropped across the high-back resistance of CR2. Point C is, therefore, in the 1 state. This condition also exists in ② when A is -18 volts and B is +2 volts. If both A and B are +2 volts, ③, both diodes are forward biased and point C is still in the 1 state. If both

A and B are in the 0 state, ④, C will be in the 0 state because with B- at -20 volts and the drop across R, 2 volts, point C is -18 volts to ground. There is no voltage across the diodes in this condition because both sides of each diode are -18 volts to ground. The truth table summarizes the possible combinations of A and B.

Transmission OR Circuit

The transmission OR circuit (fig. 14-5, B) is a modified OR circuit that is used to control the passage of a timing trigger to the input of a flip-flop or blocking oscillator. The operation of the transmission OR gate is similar to the transmission AND gate. If either the A or the B input is in the 1 state, ① point C is near ground potential and diode CR3 is forward biased when the timing pulse is applied. When the A or B input is in the 1 state, the timing pulse then passes through diode CR3 to the output. The expression for the transmission OR gate is written as $(A + B) T$. In words, this is stated: "Timing pulse T_p is passed when either A or B, or both, are in the 1 state." When both A and B are in the 0 state, ② CR1 and CR2 couple the -18 volts to the anode of CR3, biasing this diode beyond cutoff and no timing pulse appears at point "C."

Flip-Flop

Several flip-flop configurations are used in the synchronizing function; however, their basic operation is the same. The flip-flop (fig. 14-6, A) produces two outputs, each of which is the negation of the other. Basically, the flip-flop is composed of a cathode follower output stage and a bistable multivibrator stage contained in a duo-triode tube (V1A and V1B). Both tube sections of the multivibrator receive input signals, and both sections produce outputs. The plate output signals of the flip-flop are cathode-follower coupled to the output.

The two input signals are generally called the J and K inputs, and the outputs are generally designated Q and $\overline{Q}$. The J and K inputs consist of negative-going triggers whose passage to the grids of the multivibrator stage is usually controlled by a transmission gate. The Q and $\overline{Q}$ output signals are square waves.

Assume that the A section of the multivibrator is initially conducting, the B section is cut off, and the J input trigger is applied to the A section. Since the J input is a negative trigger, it drives the A section into cutoff. The
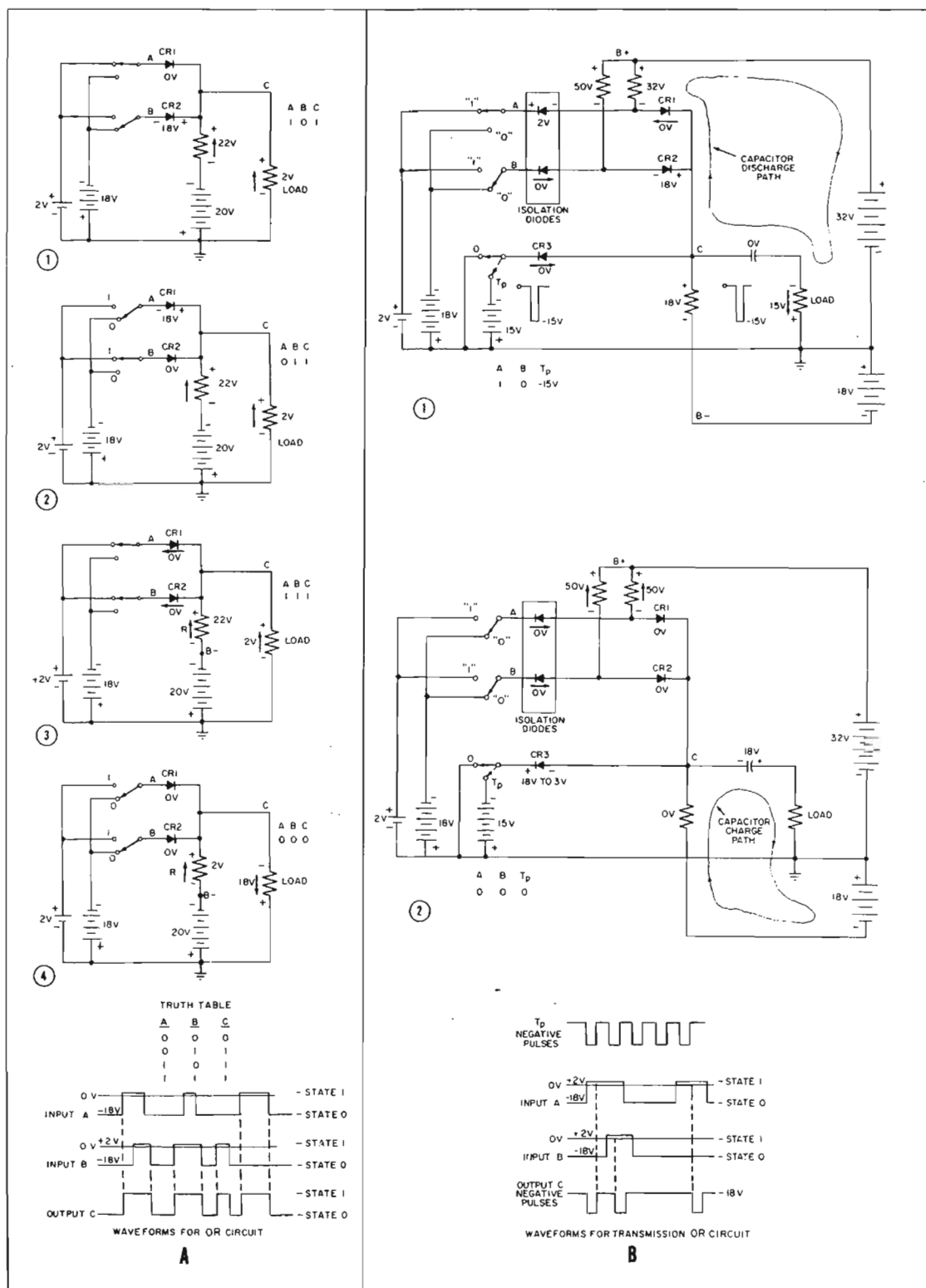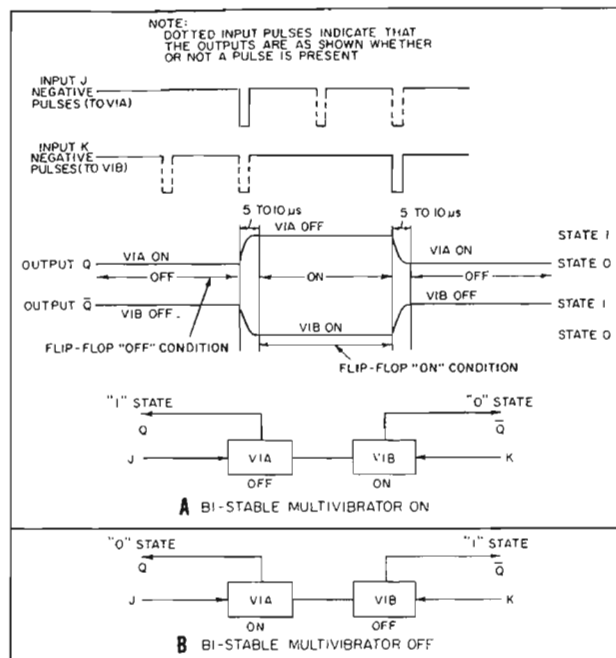
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Figure 14-5.—OR gate logic circuits.

Figure 14-6.—Basic flip-flop circuit.

stabilized in a new state. This is an important consideration in the operation of the synchronizing function since any flip-flop is still in its old state while the short duration input trigger pulse is present. The operation of the flip-flop is summarized in table 14-1.

Table 14-1.—Flip-Flop Operation.

INPUT TRIGGER	FLIP-FLOP STATE PRIOR TO TRIGGER	FLIP-FLOP STATE AFTER TRIGGER
J	ON	ON
J	OFF	ON
K	OFF	OFF
K	ON	OFF
J & K Simultaneously	ON	OFF
J & K Simultaneously	OFF	ON

positive-going Q output is taken from the plate of the A section and is in the 1 state. In this condition, when the A section is cut off and the Q output is equal to 1, the flip-flop is said to be turned ON (fig. 14-6, A).

As the A section goes to cutoff (fig. 14-6, A) a regenerative action causes the B section to conduct, and the $\overline{Q}$ output therefore is negative-going (the 0 state). If another negative trigger is applied to the J side, no change takes place in the state of the flip-flop since the A section is already cut off. However, a negative trigger applied to the K side drives the B section into cutoff (fig. 14-6, B), and the regenerative action causes the A section to conduct. In this condition, when Q = 0 and $\overline{Q}$ = 1, the flip-flop is said to be turned OFF.

If triggers are applied to both the J and K sides simultaneously (flip-flop ON), the K trigger starts the B section toward cutoff and a positive signal is coupled to the grid of the A section. After the short duration trigger pulses have disappeared, the B section still continues toward cutoff due to A section beginning to conduct and coupling a negative signal to the grid of section B. When the flip-flop stabilizes, the B section is cut off and section A is conducting (flip-flop OFF). Approximately 5 to 10 microseconds are required, following the application of an input trigger, before the flip-flop becomes

Transistor Inverter

The transistor inverter (fig. 14-7, A) produces a single output which is the negation of the input signal. The input signal is applied to the base of the PNP transistor. If the input signal, A, is in the 1 state (base emitter reverse biased), the transistor is cut off and the collector potential becomes negative, producing a negative-going output signal, A = 0, at the collector. Conversely, if input A is in the 0 state, the transistor is forward biased and conducts, producing a positive-going output A = 1.

AND-OR Gate

An AND-OR gate (fig. 14-7, B) consists of two or more AND gates the outputs of which are combined by an OR gate to produce a logical AND-OR function. The logical equation of the AND-OR gate is AB + CD = E.

BINARY-NUMBER SYSTEM

There are two systems of number representation in computers: a decimal-number system and a binary-number system. The decimal-number system represents numbers as a sum of powers of ten, where each power of ten is weighted by a digit between zero and 9 inclusive. When a decimal is written, only the weight to be attached to the various powers is noted. The digit immediately to the left of the decimal point

A

TRANSISTOR INVERTER
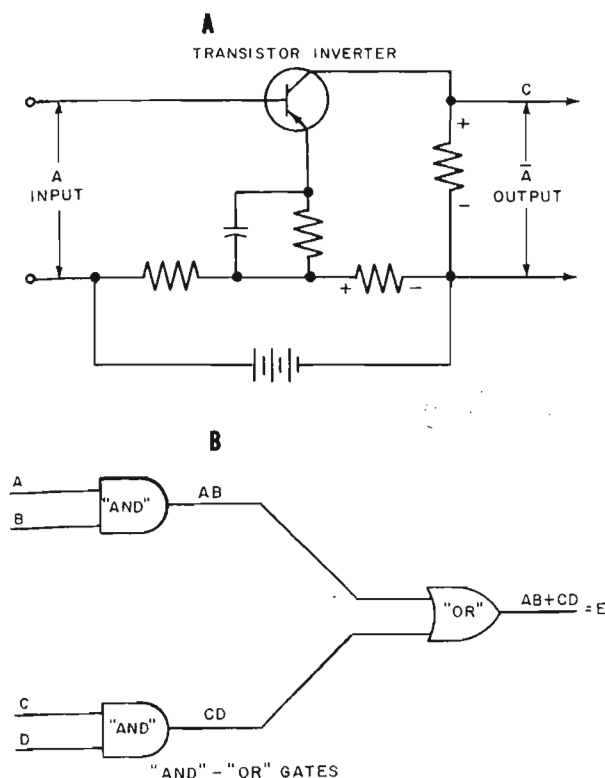
B

"AND" – "OR" GATES

Figure 14-7.—Transistor inverter,   032.250
and AND-OR Gates.

is the weight of ten to the zero power, and the next digit to the left of the first digit is the weight of ten to the one power and so on. For example:

$$27 = 2 \times 10^1 + 7 \times 10^0$$

$$112 = 1 \times 10^2 + 1 \times 10^1 + 2 \times 10^0$$

The binary-number system represents numbers as a sum of powers of two. The weights consist entirely of zero or one, that is, the power is either present or it is not present. For example:

$$27 = 1 \times 2^4 + 1 \times 2^3 + 0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$$

$$= 16 + 8 + 0 + 2 + 1$$

$$= 1\ 1\ 0\ 1\ 1 \text{ in the binary system}$$

$$112 = 1 \times 2^6 + 1 \times 2^5 + 1 \times 2^4 + 0 \times 2^3 + 0 \times 2^2$$

$$+ 0 \times 2^1 + 0 \times 2^0$$

$$= 1\ 1\ 1\ 0\ 0\ 0\ 0$$

It is thus apparent, using the binary system, that any number can be expressed by a series of high and low voltages corresponding respectively to 1 and 0 states or can be stored in a device such as a flip-flop which has two stable states.

FREQUENCY COUNTER

The frequency counter is located in the synchronizing function (fig. 14-3) and consists of seven bistable Eccles-Jordan flip-flop circuits each similar to that shown in figure 14-6. The seven flip-flops operate together to form a binary counter which reproduces any decimal number between 0 and 127 in binary form.

The state of the frequency counters at any given time can be represented by a seven digit binary number. The highest binary count is the binary number 1111111 which is equivalent to 127 in the decimal system. The next lower count corresponds to 1111110 or 126 in the decimal system.

The least significant digit of the binary number is the right-hand digit. A change from 1 to 0 or 0 to 1 in the right-hand digit of the binary number represents a change of 1 in the least significant digit of the decimal number equivalent. This change of 1 acts on the frequency counter to cause a change of 1.5 mc in the transmitter frequency and a change of approximately 3/4° in the beam angle.

The most significant digit of a seven digit the binary number is the left-hand digit. A change from 1 to 0 or 0 to 1 in this digit represents a change of 64 in the decimal number equivalent. This corresponds to a change of 96 mc in the transmitter frequency and approximately 48° in beam angle.

In order for the flip-flop to count in a binary fashion, the state of the least significant flip-flop must control the state of the next-to-least significant flip-flop. In a similar manner the states of the two least significant flip-flops must control the state of the third least significant flip-flop, and so on, until finally the state of the most significant flip-flop is controlled by the states of the other six flip-flops. This control of the state of each flip-flop is acheived by a frequency counter flip-flop transmission gate circuit which controls the passage of program trigger pulse, T_p, to the various grids of the flip-flop circuits.

The frequency counter can perform three types of binary counting operations, the particular counting operation performed being determined by the states of the enabling gates applied to the frequency counter flip-flop transmission

gates. The three possible counting operations are: countdown in steps of one decimal digit (1.5 mc), countdown in steps of four decimal digits (6.0 mc), and reset in steps of 64 decimal digits (96 mc).

The one-digit countdown operation is used only on the lower beam positions where 1.5 megacycle steps are taken as previously discussed. The four-digit countdown operation is used only on the upper beam positions where 6 megacycle steps are taken.

The 64-digit reset is used for two purposes: to change the counter position by 64 counter steps when the radar beam comes within 3/4° of the horizontal plane, and to change the counter position to 63 or 127 in the event of excessive tilt.

THE ELSCAN COMPUTER PROGRAM

The elevation scan (elscan) computer programmer (fig. 14-3) controls and coordinates the operation of Radar Set AN/SPS-42 through a 26-beam (normal) or 29-beam (coincident video) elevation scan cycle. At each beam position, the elscan program provides command signals required by the transmitting, receiving, and indicating functions. Special command signals are supplied for each of the four possible modes of operation (normal, normal-MTI, coincident video CV, and CV-MTI) which define the particular mode selected by the operator. The functional operation of the radar system in each of the operating modes is explained later.

The elscan beam covers approximately 48° in azimuth height. From 48° to 21° during normal operation, the elscan range is limited to about 34.4 nautical miles (fig. 14-8). From 21° to about 3/4° above the horizon, the range is increased to 160 miles. During coincident video operation, the beam range is 60 nautical miles for the entire 48° scan (not shown).

The range is determined by short and long delay lines which are selected automatically during normal operation to produce the 34.4- and 160-mile beam ranges described above. The 160-mile range can be reduced to 60 miles by the operator.

In a complete elscan cycle, the radar beam is positioned in steps through an elevation sweep of approximately 48° (fig. 14-8). Each position of the beam corresponds to a different transmitted frequency. A frequency change of 2 megacycles per second in the transmitted frequency changes the beam elevation angle by approximately one degree. The radar antenna is designed so that an increase in frequency lowers the beam elevation with respect to the horizontal plane and a decrease in frequency raises the beam. The period of one elscan cycle is approximately 27,900 μs; or 35.8 cycles per second.

Binary frequency counter gates from the synchronizing function (fig. 14-3) are applied to r-f exciter stages in the transmitting function to control the transmitted frequency. The frequency counter is capable of controlling the transmitter output frequency in 128 discrete steps of 1.5 megacycles each. Each frequency step corresponds to a change in beam angle of approximately 3/4 degree. During a complete elscan cycle in any of the four modes, 64 of these binary counter steps are used, corresponding to a frequency range of 96 megacycles and a swept angle in elevation from the axis of the top beam to the axis of the bottom beam of approximately 48°, providing vertical angular surveillance volume of approximately 50 degrees.

ELSCAN TERMINOLOGY AND TIMING SIGNALS

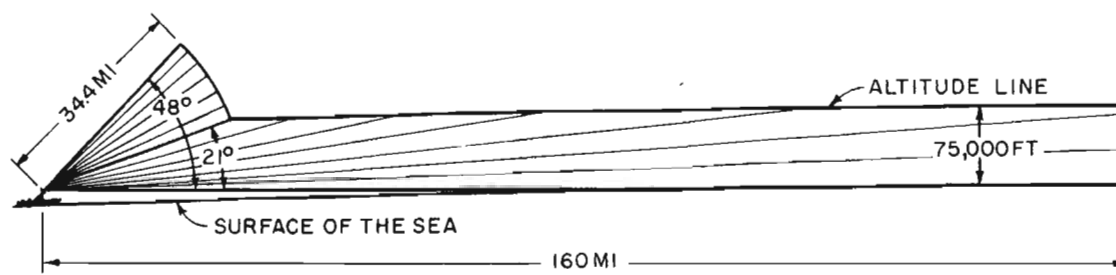An early trigger pulse (T_e) (fig. 14-9) is processed in the elscan computer programmer

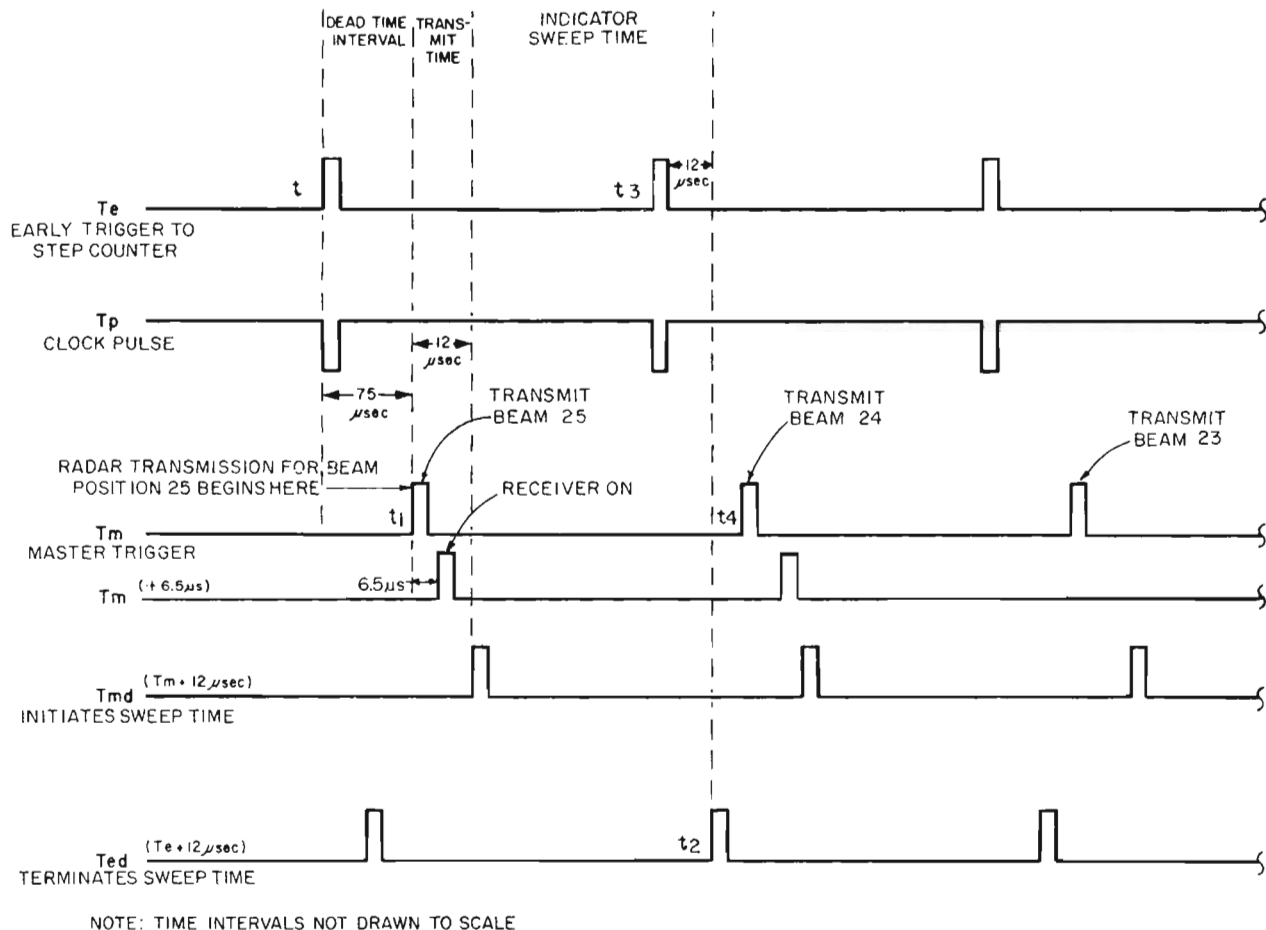Figure 14-8.—Sectional view of radar beam search volume.

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NOTE: TIME INTERVALS NOT DRAWN TO SCALE

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Figure 14-9.—Sequence of basic timing signals.

channel to generate the programmer clock pulse (T_p). T_e and T_p are coincident in time and it is understood throughout this discussion that the clock pulse is generated whenever the early trigger is generated. The clock pulse is used to trigger the frequency counter circuits in the elscan computer programmer and the MTI circuits in the receiving function. The early trigger initiates flyback time or dead time which is defined as the interval during which the indicator sweeps back to the starting position. During this interval the receivers and the transmitters are all turned off.

Seventy-five microseconds after the early trigger time (t), the master trigger (T_m) is generated at t_1, terminating the dead time interval and turning on the transmitter (transmit time). At T_m + 6.5 microseconds, the receiver is turned on. At T_m + 12 microseconds, the indicator sweeps start, beginning the indicator sweep time. When the range/altitude limit of the sweep is reached (the limit of the

surveillance volume), the next early trigger is produced which causes the generation of a T_{ed} (delayed early trigger). This trigger is produced 12 μs after the early trigger to terminate sweep time and start a new dead time interval. At early trigger time, the regenerated early trigger T_p initiates a count by the frequency counters (if the programmer logic so requires) and the r-f exciter output frequency is thereby changed in preparation for the next transmit time.

The Normal Elscan

As stated earlier, the normal elscan cycle (fig. 14-8) consists of 25 discrete elevation steps extending from about 48° above the horizontal plane (beam position 26) down to 3/4° above the horizontal plane and a return step or elscan reset making a total of 26 steps. The radar surveillance volume is limited to a maximum range of 160 nautical miles or an altitude

of 75,000 feet; the one occurring first being the limiting factor. The ranging function is accomplished by ranging circuits in the synchronizing function which automatically terminate the transmission after the 160-mile or 75,000-foot limit is reached.

Initially, the frequency counter system in the synchronizing function is set at 96 megacycles below the position 1 beam frequency (fig. 14-10, A). This frequency is equivalent to a 64 frequency counter step change from the counter position for the (position 1) beam. Radar transmission for beam position 26 begins at master trigger time t_1 (fig. 14-9). When the surveillance altitude reaches 75,000 feet, the ranging circuits produce the next early trigger and indicator sweep time is terminated at t_2.

At the next early trigger time, t_3 (fig. 14-9), the frequency counter (which controls the transmit frequency) is stepped down four counter steps. This action causes the transmitted frequency to be increased by 6 megacycles to beam position 24 (fig. 14-10, A). At master trigger time t_4 (fig. 14-9), the frequency for beam position 24 is transmitted, and the same process is continued until beam position 13 is reached.

While beam position 13 is being transmitted, initiated at t_{13} (fig. 14-10, B) a step size comparator circuit begins to supply the signal $\overline{C3} = 1$. This state 1 condition indicates that the next lower frequency interval between transmitted frequencies is to be 1.5 megacycles (one

counter step) and that the beam is to be lowered 3/4 degree. When the next early trigger occurs (t_{14}), the frequency counter steps down one counter step to beam position 12. From beam position 12 to beam position 1, the frequency counter is stepped down in one-counter step intervals at each early trigger time.

When beam position 1 is reached, a horizon flip-flop circuit is supplying the signal $\overline{C1} = 1$ which indicates that the radar beam is between the horizontal plane and the horizontal plane plus 3/4 degree. At the next early trigger (t_{26}), which is generated by the ranging circuits after the sweep has reached 160 miles, the frequency counter is instructed to reset and steps up 64 counter steps from the bottom beam position to beam position 26. A new elscan then begins which is like the preceding one.

Normal-MTI Mode

During MTI operation, the echo pattern resulting from one radar scan is compared with the echo pattern obtained in a second scan which immediately follows the first. Echoes which appear at the same position in both scans are cancelled and do not appear on the radar indicator. Thus, the observed pattern shows only moving targets.

The normal-MTI elscan program is like the normal elscan except for the repetition rate of the bottom four scans of the beam. The
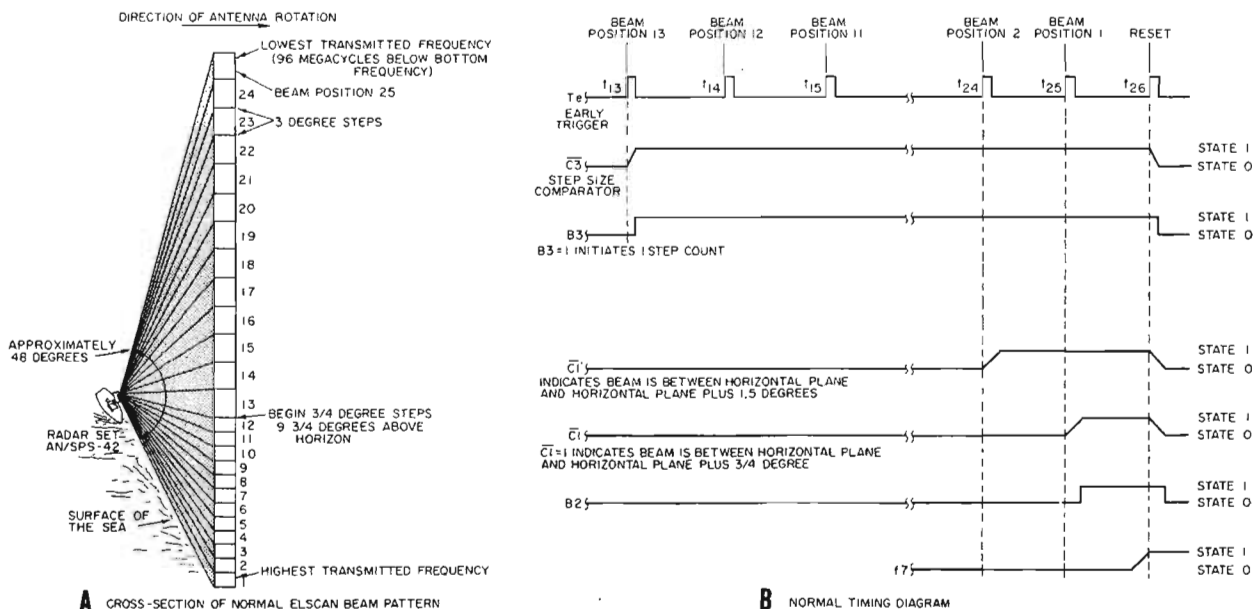

A CROSS-SECTION OF NORMAL ELSCAN BEAM PATTERN

B NORMAL TIMING DIAGRAM

032.253
Figure 14-10.—Elevation scan positions.

transmitted frequency is stepped, as before, at 6 megacycles (3°) per beam position on the top 13 positions and 1.5 megacycles per beam position on the bottom 12 positions. After the 60 miles (short) or 160 miles (long) sweep limit is reached, as selected by the operator, the ranging circuits will terminate the sweep time in all beam positions except after the first scan of the bottom four positions.

The bottom four beam positions consist of an MTI pair, which is formed by providing two transmissions on each beam position. The repetition rate of the early trigger for the bottom four beam positions is controlled alternately by a delay line (not shown) in the MTI unit contained in the receiving function, and by the ranging circuits contained in the synchronizing function. Either a long delay line (for 160-mile range operation) or a short delay line (for 60-mile operation) can be selected by the operator. A frequency count at the transmitter is made at every other (alternate) early trigger time.

The early trigger which terminates the first period of an MTI pair is generated by a trigger from the delay line. The second period is terminated by allowing the ranging circuits to generate the early trigger. A frequency count is accomplished at the second early trigger time.

When beam position 5 is reached at S_5 (fig. 14-11) an MTI comparator (located in the MTI channel of figure 14-3) supplies the signal $\overline{C2}$ = 1, which indicates that MTI operation is to begin on the next beam position. At the next early trigger time, t_{22}, the frequency counter is stepped down one counter step to beam position 4. At this early trigger time, the first period of the MTI pair on beam 4 is started by gating on MTI flip-flop E1 which goes to the state E1 = 1 and E1 = 0 a few microseconds after early trigger time t_{22}. This action permits the generation of gate pulse T_v, which in turn causes the generation of T_{c2}.

Gate pulse T_{c2} is sent to a delay line (not shown) at first period early trigger time on the bottom four beam positions. After 2053 microseconds (long range), T_{c2} is reproduced at the end of the delay line as the MTI trigger (T_{mti}).
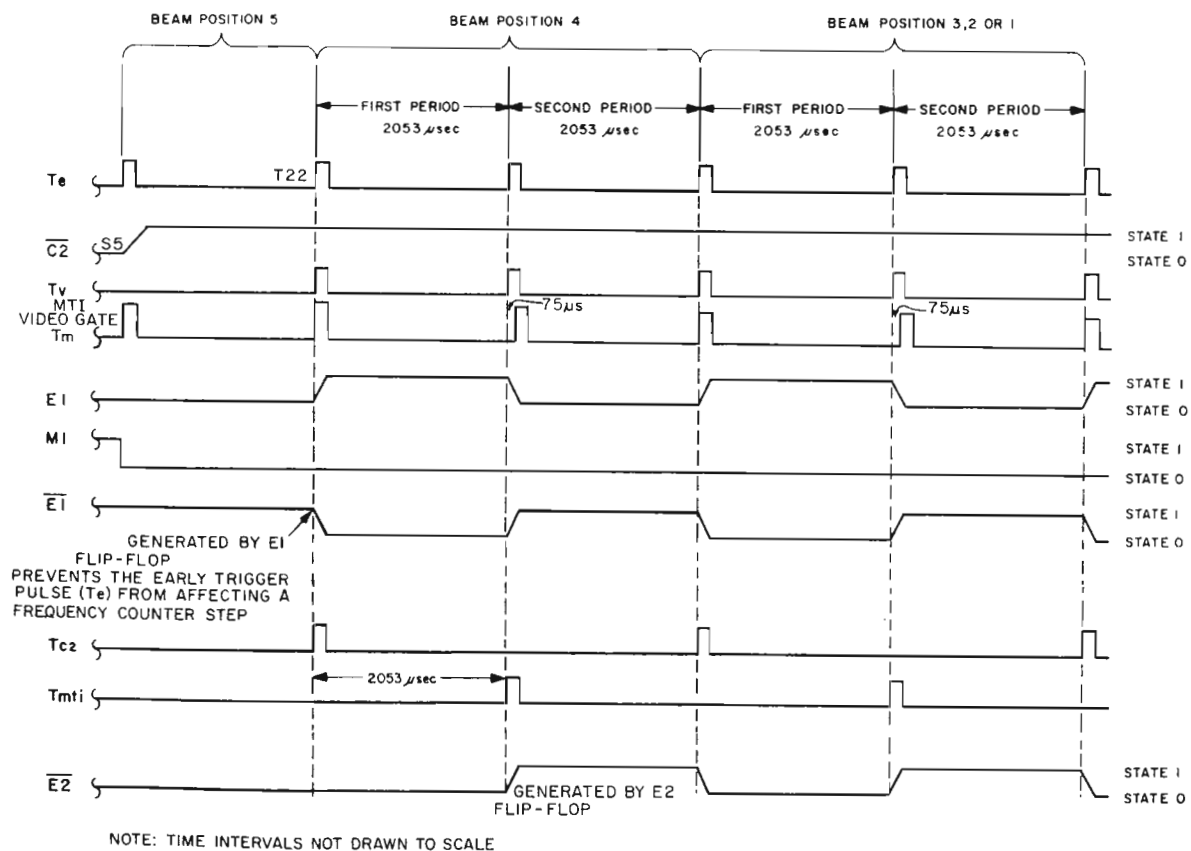

NOTE: TIME INTERVALS NOT DRAWN TO SCALE

Figure 14-11.—Normal MTI timing diagram.

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The generation of the MTI trigger terminates the first period sweep time in beam position 4 and starts the second period of the MTI pair by turning on MTI flip-flop E2 ($\overline{E2} = 0$) and turning off flip-flop E1 (E1 = 0, $\overline{E1}$ = 1) a few microseconds after early trigger time. A frequency count is prevented at the end of the first transmission on beam position 4 by $\overline{E1} = 0$ although an early trigger is generated.

The second early trigger, which starts the second period after 2053 μs, causes the generation of a second T_v pulse. At 75 microseconds after early trigger time, the master trigger (T_m) for the second period on beam position 4 is generated. The delay line pulse, T_{c2}, is not introduced to the delay line in the second period of beam position 4 because E1 (the inhibiting pulse) is still in the 1 state and blocks T_{c2} generation at second early trigger time. Because of this action, the second period is terminated by the ranging circuits which generate the next early trigger after the maximum range is reached. A frequency count is permitted at the second early trigger by $\overline{E1} = 1$, and the counter steps the frequency 1.5 megacycles to beam position 3 where a new MTI pair is generated. This procedure is followed down to beam position 1.

After both periods of the MTI pair on beam position 1 are completed, reset occurs as in the normal elscan program. The MTI video gate, T_v, is sent to the clutter gate channel in the receiving function (fig. 14-3) at the beginning of each period of an MTI pair. This pulse turns on the MTI video channel during the first 50 miles of sweep time for each period so that moving targets amid sea return clutter can be detected.

The signal $\overline{E2} = 1$ is sent to the MTI unit during the second transmission period where it permits MTI cancellation to occur during the second period of an MTI pair.

Coincident Video Mode

When coincidence video (VC) is selected, any random pulse jamming is eliminated. In CV operation, the radar transmits twice on every beam position. The echo return from the first transmission is delayed for one transmission period and is compared in time with the undelayed second echo return. In order to obtain an output from a pulse coincident video system, the radar echo return must be present at the same range on each of the two successive transmissions of a beam position. When CV has been selected, pulse coincident video is substituted for normal video in the clutter gate channel.

The coincident video (CV) mode is selected by the operator. In the CV mode, there are 29 beam positions starting with the 29th beam which is approximately 48° above the horizontal plane. As in the normal mode, 64 counter intervals are required for a complete elscan. The extra three beam positions are obtained by starting the 1.5 megacycle frequency steps at beam position 17 instead of beam position 13. Two transmissions per beam are maintained throughout the CV elscan program and the range is limited to 60 miles.

The repetition rate of the early trigger (fig. 14-12) is controlled alternately by the delay lines in the MTI unit and by the ranging circuits. A frequency count is made at every other early trigger time.

The early trigger which terminates the first period of a transmission pair is generated by a trigger from either the long or short delay line. No frequency count is permitted at this early trigger time. The second period is terminated by permitting ranging to generate the early trigger. A frequency count is made at this early trigger time.

The radar transmission for beam position 29 is initiated by T_e. This pulse passes through gates and causes the production of trigger T_{c1}, which is fed to the short delay line. After 819 microseconds, T_{c1} is produced at the end of the delay line as the MTI trigger (T_{mti}).

The MTI trigger causes the generation of the next early trigger, which terminated the first period, and initiates the second period a few microseconds after early trigger time. The second transmission on beam position 29 begins. A frequency count is prevented at this early trigger time by $\overline{E1} = 0$. Normal ranging occurs during the second period and terminates the second period sweep time by generating the next early trigger. A frequency count takes place at this early trigger time and the frequency counter in the transmitting function steps the beam down to position 28.

This procedure is followed until beam position 17 is reached where the step size comparator for the frequency counter generates a gate ($\overline{C3} = 1$), indicating that the next frequency interval is 1.5 megacycles. At the early trigger time which terminates the second period on beam position 17, the frequency counter which controls the transmitter output frequency is stepped down one counter step to beam position 16.

The early trigger at beam position 16 causes the generation of gate pulse T_v which, in turn,
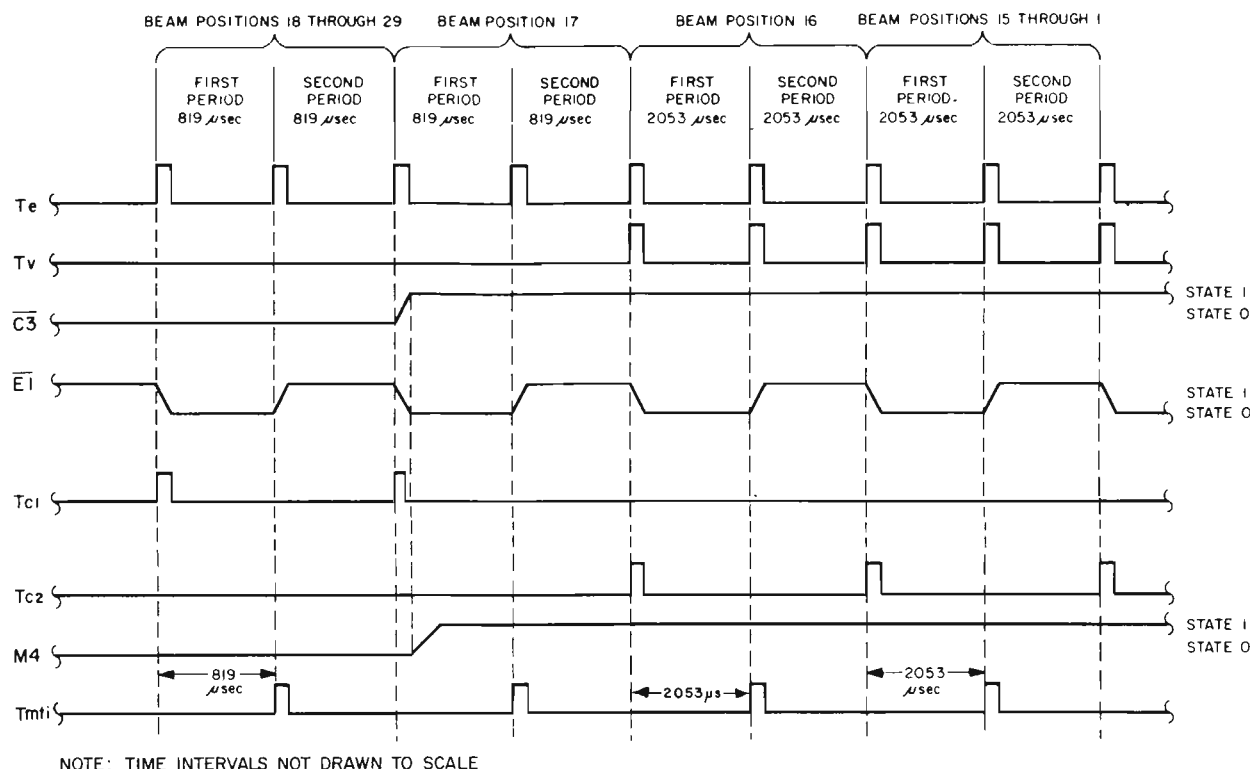
Figure 14-12.—CV and CV-MTI timing diagram. 032.255

produces T_{c2}. The latter pulse is sent to the long delay line and is reproduced at the end of the delay line 2053 μs later. The gate pulse as it leaves the delay line is referred to as the MTI trigger (T_{mti}). This pulse causes the generation of the next early trigger which terminates the first period of the transmission pair and initiates the second period on beam position 16.

The second period is terminated by allowing ranging to occur as was done on the upper 13 beam positions. This procedure is followed down to beam position 1. After both transmissions on beam position 1 are completed, the counter is reset to beam position 29.

CV-MTI Mode

The CV-MTI mode is like the CV mode except that MTI scanning occurs in a portion of each elscan cycle. You will recall that in the normal MTI mode, the MTI scanning was active only on the bottom four beam positions. The MTI scan is not active at all in the normal CV mode. Thus, as might be expected, the CV-MTI mode combines both CV and MTI by permitting CV operation on the top 12 beam positions and MTI operation on the bottom 17 beam positions.

SPACE-STABILIZATION GEOMETRY

The radar antenna is mounted on a platform parallel with the ship's deck plane. As the ship pitches and rolls, the attitude of the antenna varies accordingly. Unless compensated for, these motions appear on the radar indicator and could possibly be interpreted falsely as target motions. For instance, when the ship's bow pitches 10° down, a target directly ahead at 20° from the horizontal plane will be displayed as though it were at an elevation of 30° from the horizon. In order to make proper corrections for such errors, the ship's motions are electronically subtracted from the signal data prior to display on the indicators. This electronic method is quicker, simpler, and more accurate than providing an electronmechanical servo system to stabilize the radar antenna platform.

The space-stabilization geometry refers to the accurate relationships of the various angles giving rise to the signal data displayed on the

Figure 14-13.—Radar beam stabilization geometry.

indicators. These relationships include the position of the radar beam with respect to the ship's deck, the attitude of the ship's deck with respect to the horizontal plane, and the angle of the ship's course with respect to the meridian. They are expressed as equations involving the position coordinates of the radar beam, the deck attitude, and the ship's bearing. Referring to figure 14-13, A, X represents a line through the bow of the ship and corresponds to the ship's direction of motion (heading). The line Y is drawn at right angles to line X and represents the ship's starboard direction. Both X and Y are in a horizontal plane. The line Z is drawn perpendicular to both the X and Y lines and represents the space vertical in the figure. The space position of the radar beam can be specified by a vector (a quantity having a direction and magnitude) whose components are X, Y, and Z.

When the ship is motionless, i.e., when it is not moving forward, pitching, or rolling, target range and bearing information can be displayed on the radar indicator in coordinates designated by X, Y, and Z. The target position on the indicator is formed by vectorially combining the information forwarded to the X-axis of the cathode-ray tube with that of the Y-axis. For example, if the PPI scope receives a target signal of +15 volts at its X-axis and +10 volts at its Y-axis, the resultant position of the target will appear at T on the screen as shown in figure 14-14, A. The vectorial summation is presented in figure 14-14, B.

The data stabilization section performs vectorial operations on target signals specified by X, Y, and Z coordinates when the ship is motionless. As shown in figure 14-13, B, reference voltage V_R represents a unit length on the radar beam projected at an elevation angle of ϵ (epsilon) with respect to the horizontal plane OMQB. The angle ϵ is called the space elevation angle, which represents the angle between the radar beam and the horizontal plane. The vertical component Z of the unit beam length V_R will
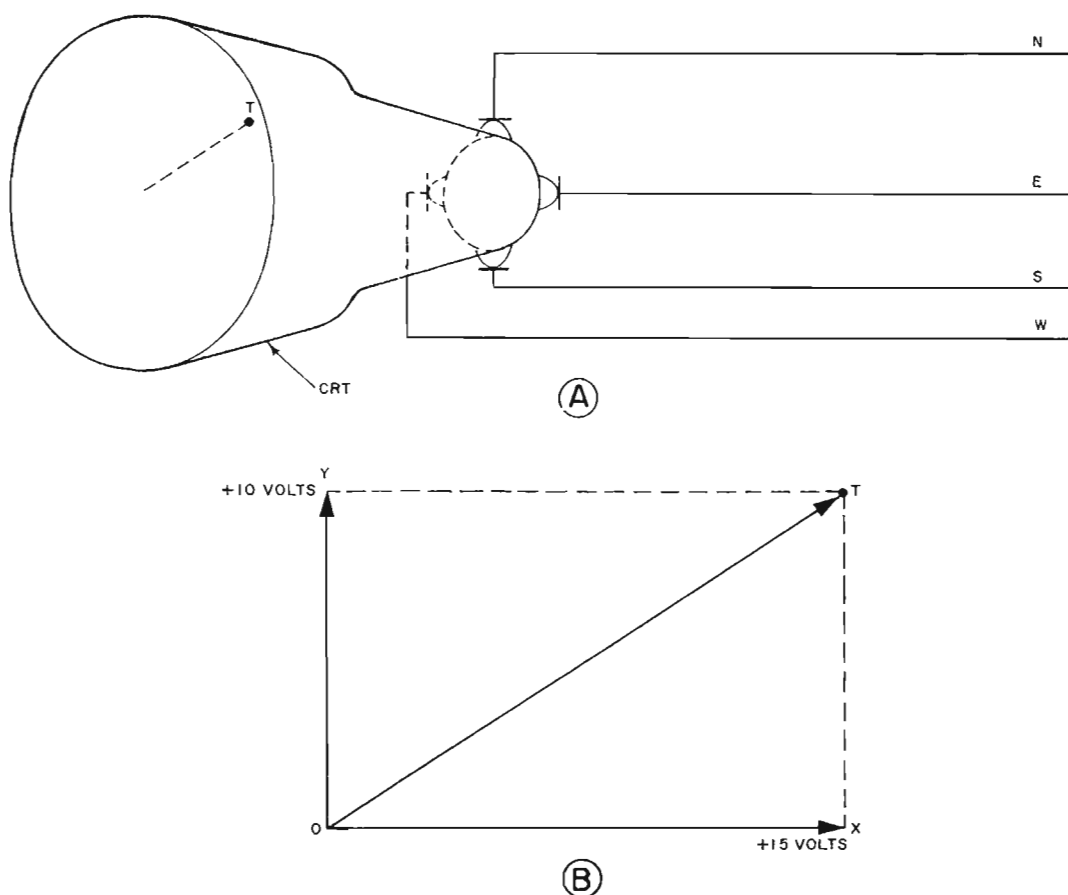

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Figure 14-14.—Target position information.

then be $V_R \sin \epsilon$, the vertical distance between the target and the horizontal plane.

Relative Bearing Components

The projection of the radar beam vector V_R on the horizontal plane is shown as OQ (fig. 14-13), which is equal to $V_R \cos \epsilon$. The projection of OQ or $V_R \cos \epsilon$, through angle α (alpha), the space azimuth angle in the horizontal plane, on the X-axis yields the X component equal to OQ $\cos \alpha$, or $V_R \cos \epsilon \cos \alpha$, which represents an azimuthal vector quantity in the direction of the ship's motion. Similarly, the projection of OQ on the Y axis gives the component OQ $\sin \alpha$, or $V_R \cos \epsilon \sin \alpha$. Thus, X, Y, and Z components represent direction cosines and are projected at right angles to each other. These components specify the radar beam direction with respect to the heading of the ship and hence are called the relative bearing components.

With a motionless ship, the component X = $V_R \cos \epsilon \cos \alpha$ represents the ship's course direction, Y = $V_R \cos \epsilon \sin \alpha$ represents the starboard direction of the ship, and Z = $V_R \sin \epsilon$ represents the direction perpendicular to the ship's deck or parallel to the ship's mast. The angles α and ϵ are measured by the antenna position and the synchronizing function, respectively. However, when the ship is in motion, these angles are no longer measured directly. Consequently, the data-stabilization function is used to compensate for the signal errors. These signal errors are the direction cosines of the quantities representing the angles provided by the ship's motion and antenna attitude.

True Bearing Components

The direction of the radar beam can also be specified with respect to the meridian line (U-axis), latitude line (V-axis), and the space vertical (Z-axis). This relation is illustrated in figure 14-15, in which the ship's heading is represented by X and its starboard direction by Y. The own ship's course angle γ (gamma) is measured clockwise, on the horizontal plane, between the meridian N (true north) and the ship's heading X.

To determine the radar-beam direction with respect to the earth coordinates or the true north N, the X and Y axes are rotated electronically counterclockwise through angle γ by the data-stabilization function so that the X and Y axes coincide with U and V axes, respectively. Thus the U component is equal to $V_R \cos \epsilon \cos (\alpha + \gamma)$ or $V_R \cos \epsilon \sin [90-(\alpha + \gamma)]$. The

components $V_R \sin \epsilon$ and $V_R \cos \epsilon$ remain the same as for the relative coordinates. Since these three components U, V, and Z specify the direction of the radar beam with respect to true north, they are called the true coordinates. The desired coordinates can be selected by means of the true-relative switch in the data-stabilization section.

Pitch and Roll Compensation

Pitch and roll compensation is applied by shifting the bottom beam frequency as the angle between the axis of the radar antenna and the horizon plane varies with pitch and roll. Due to the small angular change in the aspect of the ship during a single elscan cycle (27,958 μs), the correction takes the form of a 1.5 megacycle (one counter step of $3/4°$) frequency shift for approximately one elscan cycle out of every 20 to 50 cycles.

The correction rate depends upon the pitch and roll rate. By shifting the bottom beam frequency up or down, the entire elscan pattern is shifted up or down since all other beam position frequencies are referenced to the bottom beam position (reset initiated from this beam position). The necessity for a compensation is sensed essentially by the horizon comparator and its associated horizon flip-flop. Pitch and roll information is compared in the horizon comparator with a fixed voltage which is analogous to the horizon plus $3/4$ degree.

Because reset does not occur until the signal $\overline{C1} = 1$ from the horizon flip-flop is produced, the frequency counter continues to step the radar beam down only so long as this signal is not present. Thus, if pitch and roll occurs, it will occasionally require, in the case of a normal elscan, 25 or 27 beam steps depending upon the direction of motion of the ship, to reach horizon plus $3/4$ degree. If the ship is pitching up, for instance, an extra beam position is occasionally required before the horizon comparator detects that the beam is within $3/4°$ of the horizon. If the ship is pitching down, on the other hand, only 25 beam positions are occasionally required before $\overline{C1} = 1$. The horizon comparator therefore shifts the horizon frequency by forcing the frequency counter to count down until horizon plus $3/4°$ is reached.

Due to the slow rate of change in the ship's aspect relative to the elscan rate, the correction will never involve more than one beam step of $3/4°$ in a single elscan cycle, and the correction therefore is made in $3/4$-degree increments.
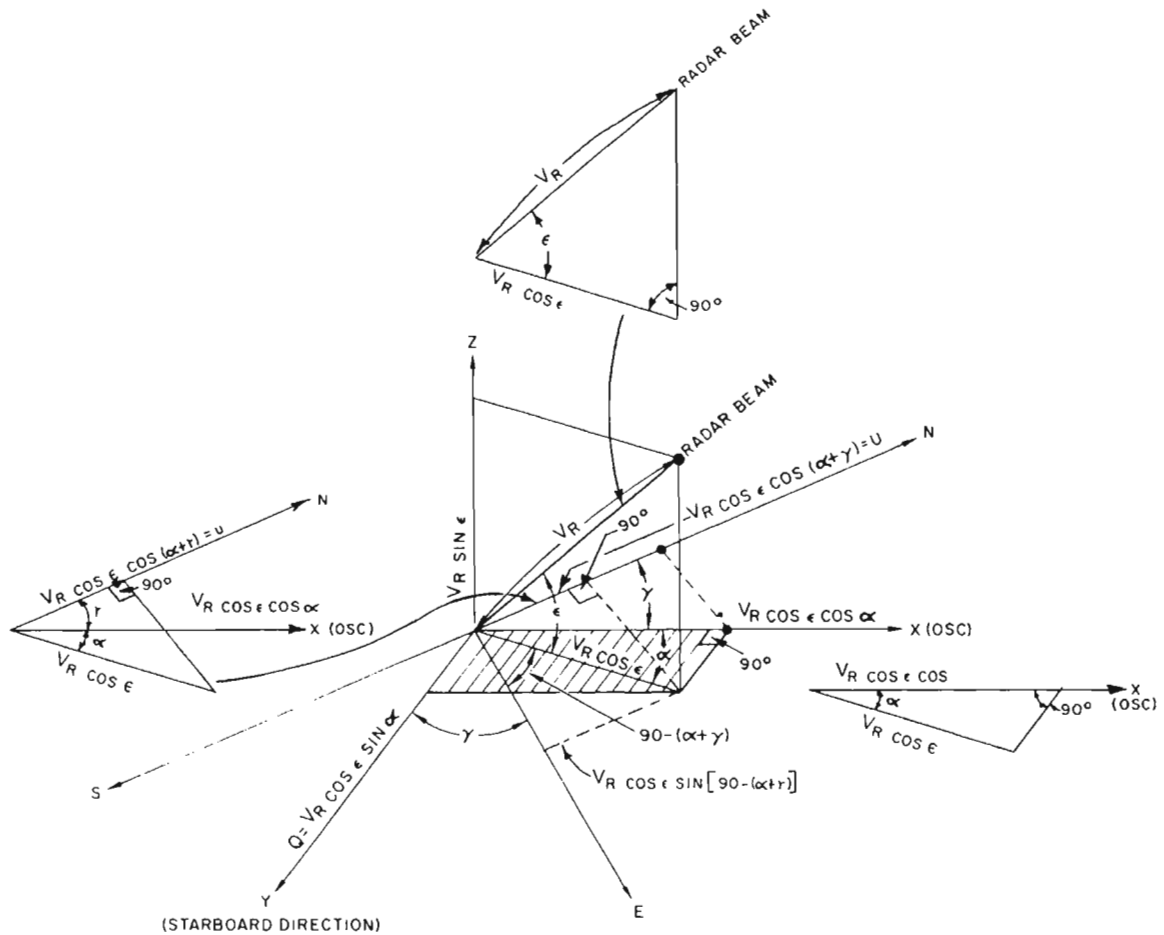
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Figure 14-15.—Ship's heading and attitude geometry.

In the event of excessive pitch or roll (greater than ±20°), a full elscan program cannot be covered since some of the frequencies required for such an elscan program are above or below those selectable by the frequency counters. When the excessive tilt gate senses this condition, it generates the signals Q = 1 and $\overline{Q}$ = 0 which reset the frequency counter to 63 counter steps above position zero (3100.5 megacycles) if the horizon cannot be reached, or to position 127 (2910 megacycles) if a beam elevation of 48° cannot be obtained. This action ensures that the full elscan program will be followed. Radar echoes will not be accurately displayed when the roll or pitch of the ship is in excess of limits of the elscan program.

TRANSMITTING FUNCTION

The transmitting function of the AN/SPS-42 consists of an oscillator-amplifier type system.

(Another oscillator-amplifier system in the AN/SPS-29 radar system was discussed in chapters 12 and 13 of this training course.) The oscillator amplifier (fig. 14-16) generates a low level r-f energy pulse which is amplified and used for detecting and locating surface and airborne targets. The system transmits the r-f energy from the radar antenna at a nominal peak power of 1 megawatt and at frequencies between 2910 and 3090 megacycles. The transmitted energy is a pencil beam which scans a search volume of 360° in azimuth and 48° in elevation. This function comprises a radiofrequency (r-f) channel, a modulator channel, and a power supply channel.

The transmitted energy is generated in the r-f channel. This channel consists of an oscillator amplifier, an r-f driver amplifier, and a microwave section. The oscillator amplifier generates continuous-wave energy which is
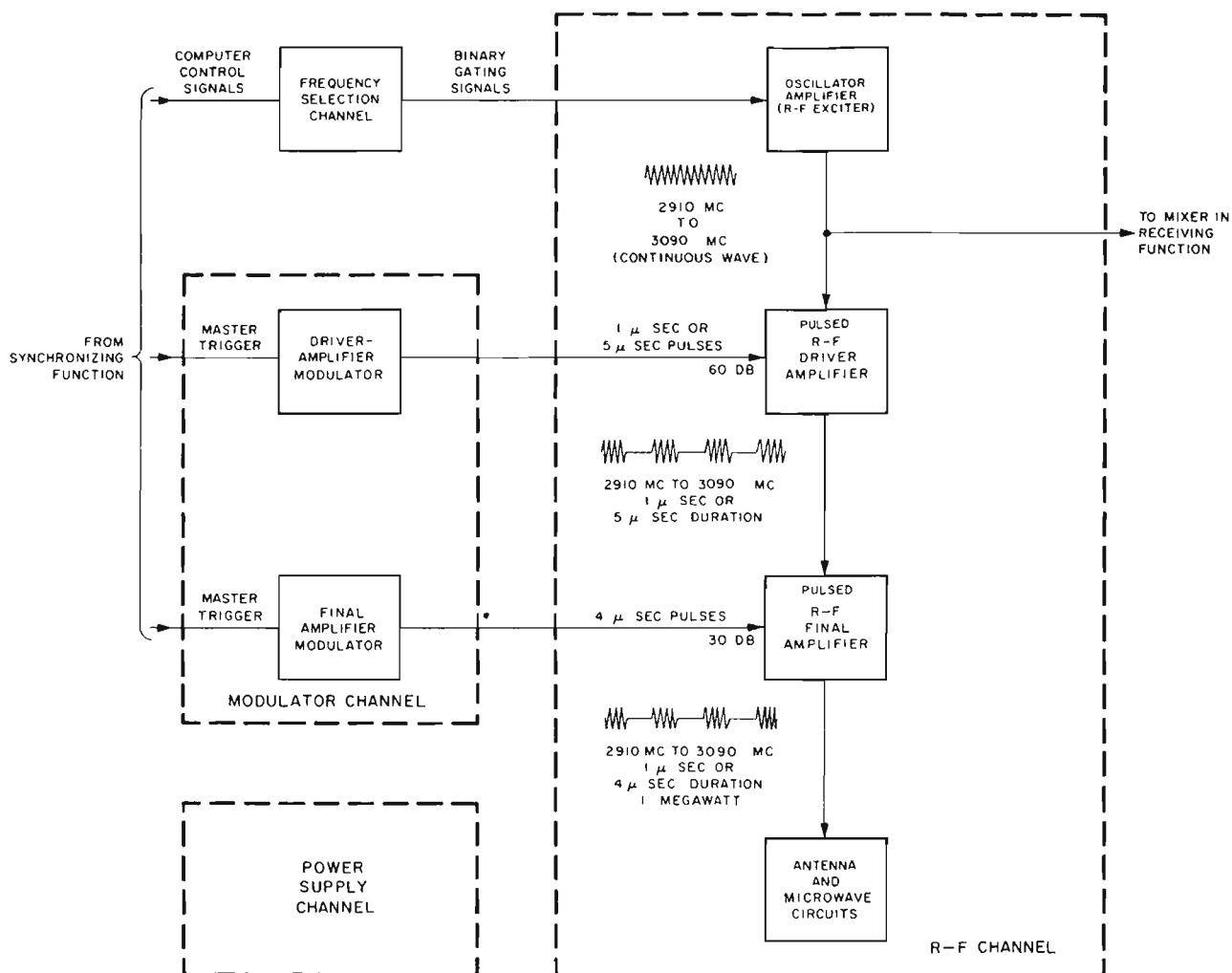
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Figure 14-16.—Transmitting function, block diagram.

modulated in the driver and final amplifiers by gates received from the modulator channel. The oscillator amplifier output is amplified by a factor of 1 billion to produce a peak power output from the final amplifier of 1 megawatt.

The r-f energy is supplied to the antenna through a microwave section and is radiated into space at elevation angles dependent on the step frequencies of the radiation. The frequency of the radiated r-f energy is controlled by the elscan computer-programmer in the synchronizing function.

The radar set is capable of scanning in elevation by programming 128 discrete step frequencies. Each of these frequencies alters the wavefront of the radiated energy, thereby changing the elevation position of the radar beam in steps. The radar beam is raised or lowered by respectively decreasing or increasing the frequency of the radiated energy from the antenna. Because the antenna scans in two coordinates of azimuth (bearing and height), the resultant scanned field is a three-dimensional search volume in space around the ship.

MODULATOR CHANNEL

Modulating pulses for the r-f driver amplifier (fig. 14-16) and the r-f final amplifier in the r-f channel are generated in time coincidence by two separate modulators contained in the modulator channel. The action is similar to the modulation process used in Radar Set AN/SPS-29, which is discussed in chapters 12 and 13 of this text.

Both of the modulators are triggered simultaneously by each master trigger pulse (T_m)

which is supplied from the synchronizing function. Due to a difference in time duration of the two modulating pulses, a variable delay line (not shown) at the input of the driver amplifier modulator permits delay of the output trigger from this circuit, thereby permitting an optimum coincidence of outputs from the two modulator sections.

The r-f driver amplifier contains two traveling wave tubes (TWT) which are described later. When triggered, the driver-amplifier modulator delivers a high voltage negative pulse to each traveling wave tube in the r-f driver amplifier. Delay lines in the modulator permit selection of pulse widths of either 1 microsecond or 5 microseconds. The minimum time duration of the transmitted r-f energy, therefore, is determined by the driver-amplifier modulator.

The final-amplifier modulator also generates a high voltage negative pulse for each trigger input. This pulse is applied to the klystron final amplifier in the r-f channel. The pulse is generated by discharging a 4-microsecond pulse-forming network through the primary of a pulse transformer. The secondary of the transformer furnishes -90 kilovolts to the cathode of the klystron during the pulse transmit time. The maximum time duration of the transmitted r-f energy is thus established at 4 microseconds by the final amplifier modulator.

R-F CHANNEL

The r-f channel produces pulses of S-band r-f energy between 2910 and 3090 megacycles once during each operating cycle of the radar system in response to binary control signals from the frequency-selection channel. These S-band pulses are radiated from the frequency-scanning antenna into space at programmed angles of elevation, and may have a time duration of either 1 microsecond or 4 microseconds as selected by the operator.

The oscillator-amplifier also produces the heterodyning signal required for the reception of target echoes. During the receive period of each operating cycle, a voltage is generated by the r-f channel which causes the oscillator-amplifier output frequency to be increased or decreased by 12 megacycles. This signal is supplied as the local oscillator signal to the receiving function.

The r-f channel may be considered as a master oscillator-power amplifier type transmitter containing four major functional groups: a continuous-wave oscillator amplifier (r-f exciter), a pulsed r-f driver amplifier, a pulsed

r-f final amplifier, and microwave circuits together with the antenna. An output signal from the oscillator amplifier appears continuously at the input of the pulsed r-f driver amplifier. The exact frequency of this signal (between 2910 and 3090 mc) is determined by gating signals from the synchronizing function. The r-f driver amplifier and r-f final amplifier produce an output only when they are supplied with high voltage pulses from their respective modulators.

Under conditions of no pitch and roll of the ship, the first transmission in the elscan cycle (which is the highest transmitted elevation scan) takes place on 2955 megacycles. This frequency corresponds to a counter state of 97, which is 30 counter states down from the top state of 127. If pitch and roll do exist, the beam position number (and its corresponding elevation angle) move up and down to compensate for the movements of the ship.

For example, if the combined pitch and roll of the ship are such that the plane of the deck makes an angle of 20° below the horizon, the first beam position (normally beam position 97) will move up 30 counter states to become counter state 127. Because this position now represents the first transmitted beam position, all of the other beam positions will move up an equal number of counter states. Thus, the final (bottom) counter state will be 127 - 64 = 63, and the elscan beam angle is maintained between 48° maximum and 3/4° minimum above the horizon.

Oscillator Amplifier

The oscillator amplifier (fig. 14-17) consists of the following sections: two matrices (A and B), three banks of oscillator units (A, B, and C), two mixers, a doubler-limiter, and a frequency multiplier. The two matrices supply the switching voltages necessary to gate on one selected A, B, and C crystal-controlled oscillator unit in the respective oscillator bank.

The output frequencies of the three selected oscillator units are mixed and filtered to produce a resultant r-f signal which has a frequency equal to A - B - C. Through the doubler-limiter and frequency-multiplier units, the A - B - C signal is amplitude limited and frequency multiplied to produce an output which has a constant amplitude and a frequency of 64 × (A - B - C).

Each of the oscillator banks A and C contain eight oscillator units, and B contains two oscillator units. Thus, 8 × 2 × 8 different combinations, or 128 resultant frequencies, are possible in the range of 2910 to 3090 megacycles.

The two diode matrices (A and B) are identical. Each consists of nine d-c amplifiers and eight AND gates. One d-c amplifier of each matrix is used for switching oscillator units B1 and B2. The remaining eight d-c amplifiers of each matrix are individually controlled by an associated AND gate, and are used for gating oscillator units A1 through A8, and C1 through C8.

Fourteen binary gating signals that originate in the synchronizing function are used by the matrices in selecting the three oscillator units A, B, and C. Each of the gating signals has two states: a high binary state represented by 2 volts, and a low binary state represented by -15 volts.

R-f Driver Amplifier

The r-f driver amplifier (fig. 14-17) provides an intermediate level of power amplification for the r-f energy generated in the oscillator amplifier. The power divider at the input consists of two quarter-wave coaxial matching transformers (not shown) that have a common r-f input connection. Each of these transformers is connected to a 50-ohm coaxial cable which terminates in a 50-ohm load. However, the power output ratio is 2:1. Two-thirds of the input power is supplied to the r-f mixer in the receiving function as the local oscillator signal, and the other one-third is routed to the input of the first traveling wave tube (TWT No. 1).

The r-f driver amplifier contains two traveling wave tubes (TWTs) which provide amplification of the oscillator amplifier output to a nominal one-kilowatt level. The output of the second TWT, after passing through an attenuator and two directional couplers, is used to drive the final klystron amplifier.

R-f Final Amplifier

The r-f final amplifier provides amplification of the pulsed r-f output from the r-f driver amplifier to a nominal one-megawatt peak-power level. The major component of the r-f final amplifier is the klystron which supplies its amplified r-f output through the microwave circuits to the radar antenna where it is radiated into space.

The klystron, in order to produce an r-f output pulse, requires an r-f driving pulse and a negative modulating pulse. The r-f driver pulse is applied to the klystron signal input cavity from the r-f driver amplifier, while the negative modulating pulse is applied to the klystron cathode from the final amplifier modulator.

The klystron in the final amplifier is of broadband design for operation in the S-band region. The klystron is provided with an electron gun at one end and a collector at the other end. Between the electron gun and the collector are six cascaded cavities, which are stagger-tuned for operation over the range of frequencies between 2910 and 3090 mc. Electrons flowing from the cathode to the collector form a beam which passes through each cavity. The cathode is pulsed with a potential of -90 kv. An electromagnetic focusing coil for each cavity confines the electron beam to the center of the cavity.

R-f input pulses from the r-f driver amplifier are fed into the input cavity by means of a probe. This energy interacts with the electron beam passing through the input cavity, alternately accelerating and retarding the electrons to produce a modulated electron beam. This electron beam further interacts with the succeeding cavities so that increasingly more beam energy is transferred into the cavities as the beam progresses toward the collector. In this manner the r-f energy is amplified as it traverses the cavities, and becomes maximum in the last cavity. Energy from the last cavity is coupled into the transmission system through a dielectric window from the klystron which opens into the antenna microwave circuits.

The electron tube liquid cooler supplies a flow of coolant to the electromagnet, body, and collector of the klystron to maintain a safe operating temperature. The coolant fluid is circulated through the system by means of a motor-driven pump. A pressure relief valve connected across the pump prevents rupture of the interconnecting hoses in case the coolant flow is blocked while the pump is operating.

Thermal and flow switches are incorporated in each of the coolant distribution branches for klystron protection. In the event that the fluid flow through a branch falls below a set limit, the flow switch in that branch cuts off the high voltage to the klystron. If the coolant temperature in a branch exceeds a set limit, the thermoswitch in that branch cuts off the klystron high voltage.

TRAVELING WAVE TUBE

The traveling wave tube (fig. 14-17) is a device which provides signal amplification by the interaction between an electromagnetic wave

and a beam of electrons within a TWT helix. This interaction results in a transfer of energy from the electron beam to the electromagnetic components of the input signals, which are propagated down the helix to the output cavity of the tube. Thus, a small r-f input results in a large r-f output over a wide frequency band. The action is described below. Magnetic focusing is used to confine the electron beam to the center of the helix as closely as possible.
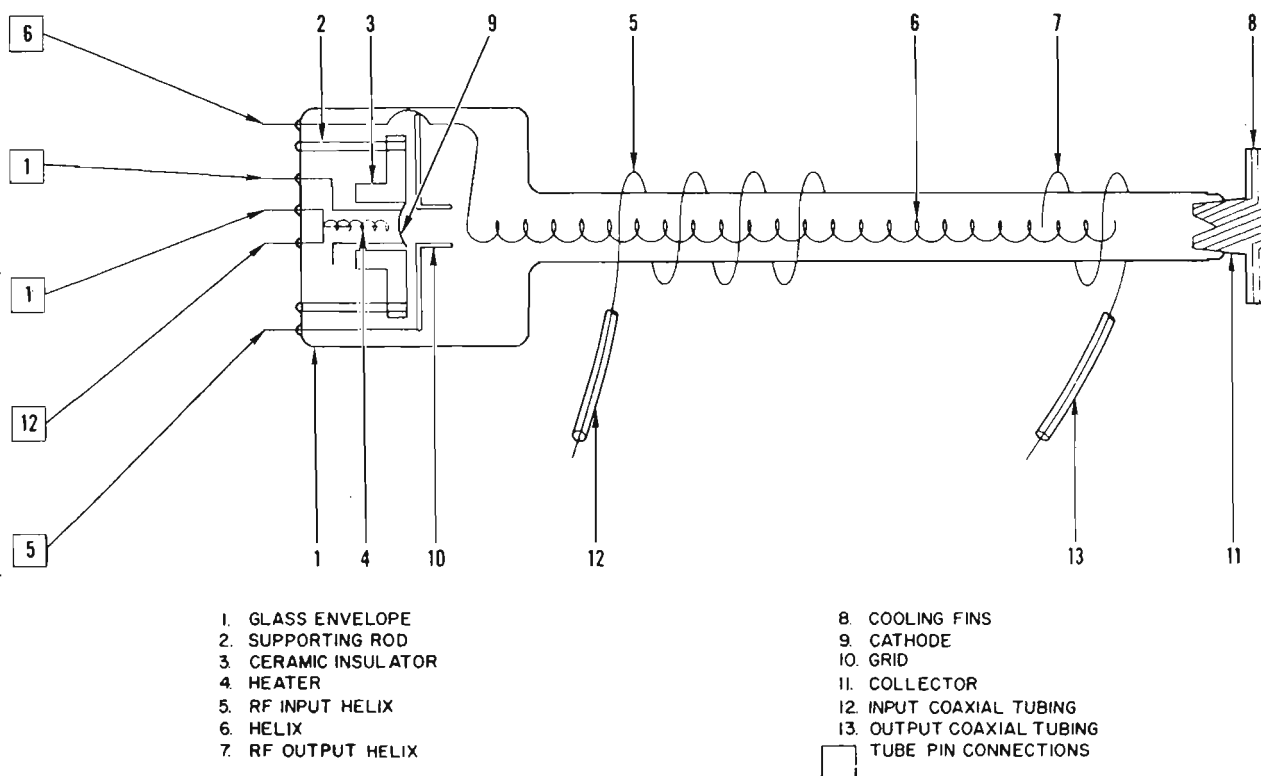
A simplified diagram of a traveling wave tube is shown in figure 14-18. The r-f energy to be amplified is delivered to the input helix 5 of the TWT by means of coaxial tubing 12. The energy is then coupled from input helix 5 to TWT helix 6, where it is propagated within the tube toward output helix 7.

In the presence of a negative modulating pulse at the cathode 9, the TWT conducts and becomes an amplifier. The electrons emitted by the cathode are accelerated and focused to form a narrow beam which travels axially through the center of TWT helix 6 toward collector 11. The focusing action creates a periodic magnetic field around the TWT to prevent dispersion of the electron beam.

The electron beam within helix 6 interacts with the r-f energy propagating relatively slowly along the helix. As the beam progresses through helix 6, electron bunching, which occurs as a result of the interaction, results in a transfer of energy from the electron beam to helix 6. Because of a small velocity difference between the electrons which comprise the beam and the r-f energy traveling down the helix, the two arrive near the end of the helix out-of-phase. At this point, the r-f energy in the output helix 7 increases as it absorbs energy from the electron bunches. The electron beam continues through the TWT to the collector 11, where the remaining energy of the beam is dissipated as heat by cooling fins 8. A blower (not shown) is supplied to remove heat.

The r-f energy from the driver amplifier is almost completely attenuated by an r-f attenuator (fig. 14-17) when the two TWTs are not conducting.

Output from the first TWT is routed through a directional coupler to the second TWT, which is like the first. The cathode modulating pulse required to key-on the traveling wave tubes is generated in the modulator channel and applied

1. GLASS ENVELOPE	8. COOLING FINS
2. SUPPORTING ROD	9. CATHODE
3. CERAMIC INSULATOR	10. GRID
4. HEATER	11. COLLECTOR
5. RF INPUT HELIX	12. INPUT COAXIAL TUBING
6. HELIX	13. OUTPUT COAXIAL TUBING
7. RF OUTPUT HELIX	⬚ TUBE PIN CONNECTIONS

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Figure 14-18.—Traveling wave tube, structural drawing.

simultaneously to both TWT cathodes. These two stages therefore produce simultaneous r-f pulsed outputs.

The output from the second TWT is applied through directional couplers and an attenuator to the r-f final amplifier klystron. The directional couplers provide small amounts of r-f energy from various points in the r-f driver amplifier to the testing function.

Microwave Circuits and Antenna

S-band energy in the frequency range from 2910 to 3090 mc is supplied to the radar antenna by means of the waveguide microwave circuits (fig. 14-17). The energy is concentrated into a narrow beam at the antenna and radiated into space at an elevation angle dependent on the instantaneous S-band frequency. The azimuth angle of the transmitted energy is determined by the angular position of the antenna with respect to ship's bow (relative bearing) or true north (true bearing).

The duplexer portion of the microwave circuits permits the use of the same antenna for transmission and reception of the radar signal. The duplexer consists of two hybrid couplers, an antitransmit-receive (ATR) section, an attenuator, and a transmit-receive (TR) section. The duplexer acts as a high speed electronic switch whose operation is controlled by pulses of S-band energy from the r-f channel.

During transmission, the duplexer routes the r-f output of the transmitter to the antenna and blocks the input to the receiver. During reception, the duplexer routes the target-reflected energy from the antenna to the receiver and isolates the receiver from the transmitter.

The hybrid couplers of the duplexer provide the switching and isolating functions during transmission and reception. R-f energy from the transmitter is divided into two equal-power components by hybrid coupler 1, and routed through the ATR section of the duplexer. After passing through the ATR section, the two components are combined by hybrid coupler 2 and routed to the antenna.

The action is as follows. The hybrid couplers (fig. 14-19) are four terminal structures, and consist essentially of two parallel sections of waveguide. These waveguide sections are joined at their narrow dimension by an opening referred to as the interaction space. R-f energy from the klystron final amplifier is injected into No. 1 terminal of hybrid coupler 1, and divides equally between the two opposite terminals (i.e., terminals 2 and 4), with little or no energy supplied to the adjacent terminal 3.

Because of the greater distance that the r-f energy travels diagonally through the interaction space to terminal 4, the phase of the energy at terminal 4 of coupler 1 is 90° lagging with respect to the energy at terminal 2. Negligible energy is coupled to terminal 3, the adjacent arm of the coupler.

The ATR tubes are resonant-cavity, gas-filled tubes with a window in one side. The ATR tubes are electrically placed in series with the waveguide by substituting each window for a portion of the broad side of the waveguide wall.

Two ATR tubes are used in each of the two paths through the ATR section. One tube has a design frequency range of 2900 to 3000 mc, while the second has a design frequency range of 3000 to 3090 mc. Thus, the total range of
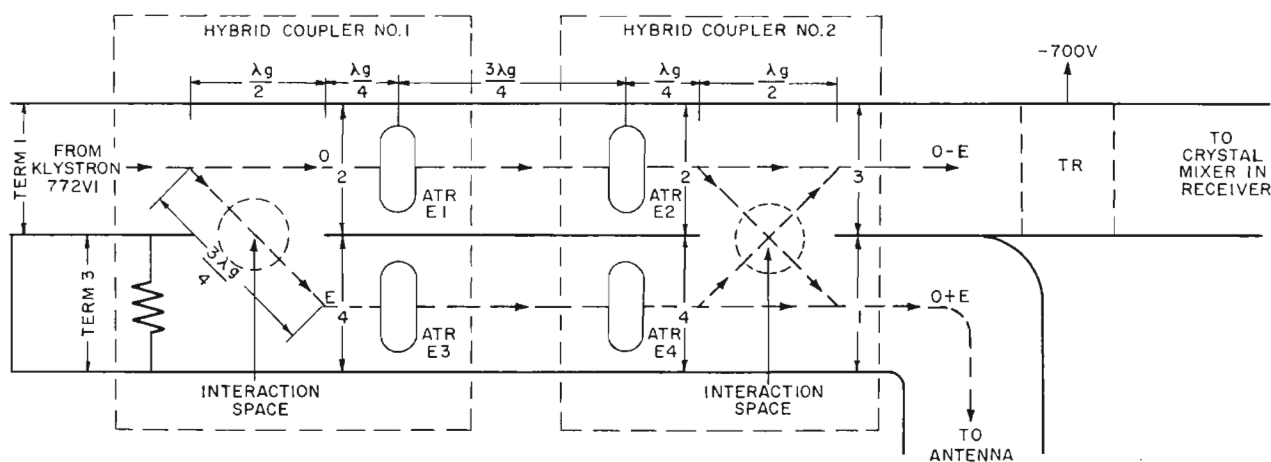

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Figure 14-19.—Microwave circuits, simplified diagram.

frequencies over which the ATR tubes can operate effectively is 2900 to 3090 mc.

R-f energy from hybrid coupler 1 causes ionization of the gas in the ATR tubes, E1 and E3, during the transmit period. Ionization of the gas then causes short circuits to be reflected across the windows of each ATR tube. The waveguide walls therefore appear to the signal to be continuous, and the r-f energy is allowed to pass through coupler 1 without reflection or attenuation.

After passing through the second ATR section (E2 and E4 are ionized), the r-f energy is applied to input terminals 2 and 4 of hybrid coupler 2. As mentioned before, the phase of the energy applied at terminal 4 is 90° lagging with respect to the energy applied at terminal 2.

From arms 2 and 4 of hybrid coupler 2, the r-f energy reaches a second interaction space. Because of the greater distance it travels through the interaction space, energy from arm 4 arrives at arm 3 (of hybrid coupler 2) displaced by 90° from arm 4 and therefore 180° from arm 2. Therefore, the two r-f components are almost entirely canceled, and only a small amount of this energy will be coupled from arm 3 to the receiver input during transmission.

However, the r-f energy which follows the path 1 to 4 in hybrid coupler 1, and 4 to 1 in coupler 2 arrives at the antenna input in phase with the energy traveling path 1 to 2 in coupler 1 and 2 to 1 in coupler 2. This action causes the r-f energies to add at terminal 1 of hybrid coupler 2 in route to the antenna. Thus, the duplexer introduces very little loss in the transmitter output.

The TR tube is a resonant-cavity, gas-filled tube which is used to protect the receiver crystal mixer during transmission. Like the ATR tubes, the TR tube is an electronic switch which is capable of opening and closing the circuit at the radar pulse-repetition rate. The TR tube is placed in shunt with the waveguide section which supplies r-f energy to the receiver crystal mixer.

Because of the inability of the waveguide to maintain exact matching over the range of operating frequencies, a small amount of the transmitted r-f energy is coupled to the TR tube from terminal 3 of hybrid coupler 2. This energy causes the TR tube to ionize and establish a short circuit across the waveguide. Thus, transmitted energy that leaks through hybrid coupler 2 is blocked from the receiver input.

A keep-alive voltage of 700 volts maintains a source of ions to assist in ionizing the TR

tube at the instant the radar pulse begins. This voltage permits rapid ionization during transmission, but is sufficiently low to prevent ionization of the tube during reception. Thus, received echo signals pass into the receiver.

During reception, the ATR tubes are deionized, and their windows appear as discontinuities in the waveguide walls. Received energy from targets is therefore blocked and cannot pass into the transmitter.
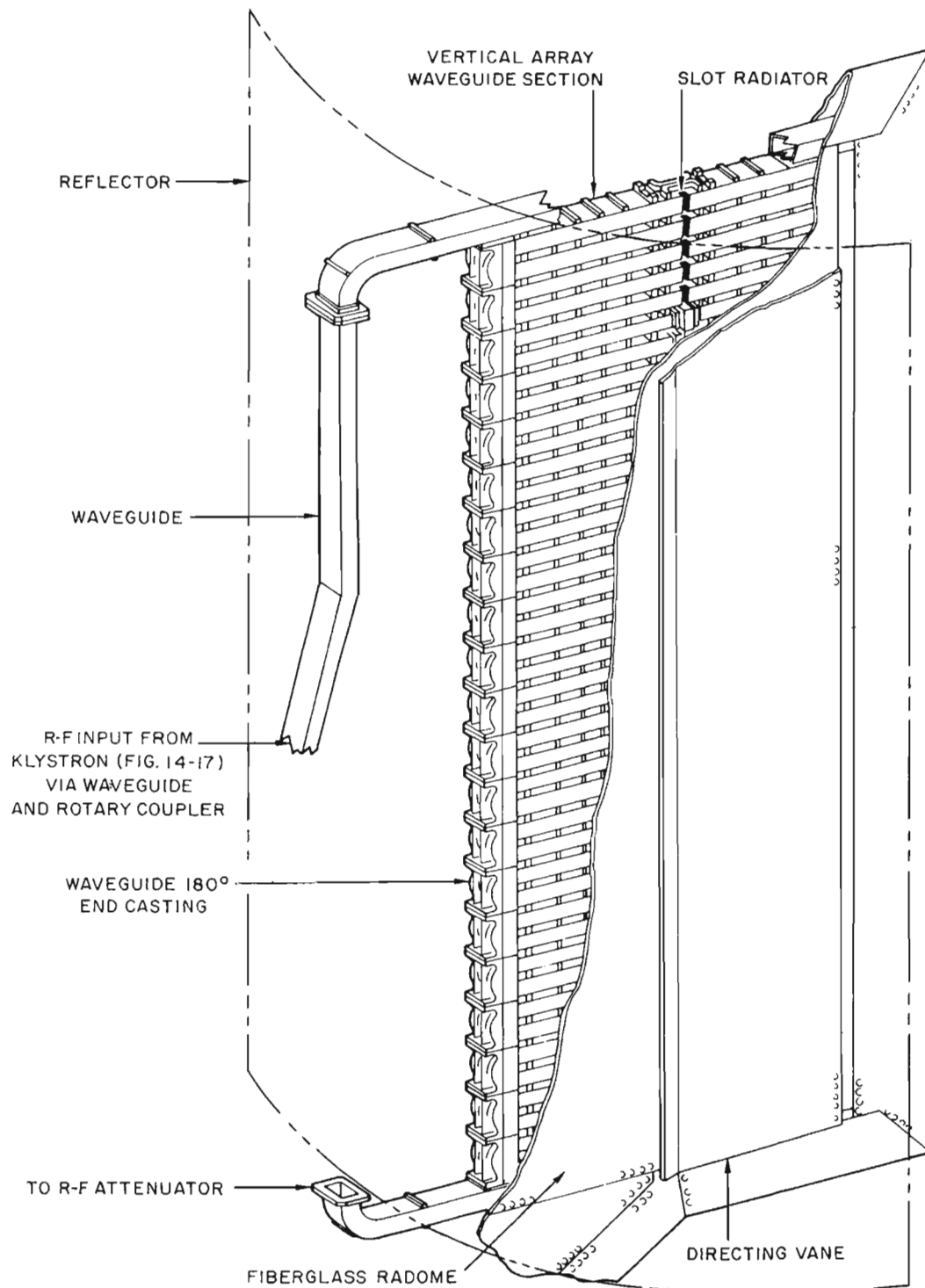
ANTENNA

The antenna is mounted on a pedestal (14-1), which permits rotating of the antenna and scanning of the beam through 360° of azimuth. The transmitting and receiving elements of the antenna consist of a vertical linear array of radiators and a parabolic reflector.

Energy from the klystron r-f final amplifier (fig. 14-17) is fed through the microwave circuits to the antenna (fig. 14-20). The r-f energy is radiated by an array of slots, directed to a parabolic-cylinder-section reflector (fig. 14-1) by means of directing vanes, and reflected into space by the parabolic reflector. The reflector and array are inclined from the vertical by an angle such that a line through the broadside axis of the assembly forms an angle of + 25° with respect to the deck.

The frequency scanning technique is employed to permit variable positioning of the radiated beam in the vertical plane. With this technique, the elevation angle of the radiated beam is altered by changing the frequency of the energy supplied to the antenna. A series of at least twenty-five different frequencies thus results in scanning of the beam through 48° of elevation.

Because scanning in the vertical plane is accomplished electronically, it is not necessary to move the antenna in the vertical plane. Thus, mechanical stabilization of the antenna platform is not required. Both the position of the transmitted beam in space and the indicator-presentations are stabilized electronically.

In order to use the vertical electronic scanning principle effectively, and to obtain a high degree of resolution in azimuth, the radiated energy is directed within narrow angular limits. The antenna vertical array of radiating elements limit the vertical beamwidth, and the parabolic cylinder section reflector limits the horizontal beamwidth. The resultant pencil-shaped beam is narrow in both planes. The radiated beam is 3.0° wide in the vertical plane and 2.4° wide in the horizontal plane.

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Figure 14-20.—Radar antenna sinuous feed assembly.

The vertical array of radiators is formed by folding the waveguide transmission line back and forth on itself. This forms what is known as a "sinuous feed." R-f energy is supplied to the upper end of the sinuous feed from the klystron r-f amplifier via the waveguide transmission line and rotary coupler. The feed consists of 44 straight waveguide elements joined at their ends by 180° end castings.

Vertical slot radiators are cut in the narrow dimension on each side of a straight waveguide element, and are covered by a Fiberglas radome to permit the waveguide to be pressurized. Two metallic directing vanes, which extend the length of the array, are positioned so that the r-f energy radiated from the slots is directed to the parabolic reflector. The sinuous feed is terminated at its lower end in a load which absorbs the r-f energy not radiated from the antenna, thus preventing reflections of the energy within the feed.

The conductance of a slot at the frequency being transmitted is a measure of the power that it radiates. It is related to the angle of inclination of the plane of the slot from a perpendicular to the waveguide axis increasing as the angle increases. In order that equal power be radiated from the first and last slots of the array, the conductance of the last slot must be considerably greater than that of the first slot. Therefore, the slot inclination is increased progressively along the array from the minimum conductance near the input.

The reason for the slot configuration can be explained as follows: If all of the slots were inclined at the same angle, thus having the same value of slot conductance, the greater part of the r-f energy would be radiated from the first few slots near the input of the array. Thus very little energy would be available for radiation near the end of the array.

The vertical angle of inclination of the slots in relation to the narrow side of the waveguide keeps the antenna elevation side lobes at -20 db or less, relative to the main lobe. The slots exist on both sides of the waveguide. The pairs of slots on opposite narrow sides of the rectangular waveguide are crossed so that the beams from the two halves of the reflector will be in phase in the horizontal plane.

The method of forming the radiated pattern is illustrated in figure 14-21. Although 44 pairs of slot radiators are used in the sinuous feed, only three slots are represented. In the explanation, it may prove helpful to consider each

slot radiator as the equivalent of a small dipole antenna.

When the distance between energy maxima is equal to the slot spacing λ (fig. 14-22), the energy pattern moving down the sinuous feed reaches its maximum value at the same time for each slot. Thus, each slot radiates a wavefront at the same time. The radiated wavefronts reinforce or form the beam maximum in a direction broadside to the array of slots. However, when the distance between energy maxima differs from the spacing between slots, wavefronts are radiated by the slots at different times. Figure 14-22 illustrates a case in which the distance between energy maxima λ is greater than the slot spacing, and the beam elevation is thus altered. The amount this distance is greater than the spacing is a function of the frequency of the energizing wave. For example, as the r-f energy moves down the waveguide the crest of the wave reaches slot 1 first, slot 2 later, and slot 3 last.

The three wavefronts are reinforced to form the beam maximum at an angle α above the broadside position (N) of the array.

In a like fashion, when the distance between energy peaks is less than the slot spacing, the radiated wavefronts are reinforced to form the beam maximum at an angle below the broadside position (N) (not shown).

The distance between peaks in the energy pattern may be increased or decreased in accordance with the frequency of the energy fed to the slots. When the frequency is decreased the wavelength increases, and hence the distance between the peaks increases with a corresponding increase in beam elevation. When the frequency is increased the wavelength decreases, and hence the peak-to-peak distance of the wavefront decreases. This action lowers the beam elevation. The overall effect is that an increase of frequency causes the beam to scan away from the fed end, while a decrease of frequency causes the beam to scan toward the fed end.

From the foregoing discussion it should be understood that by changing the transmitter frequency in steps, the position of the radiated beam can be made to step in angular increments relative to the broadside position. The broadside position of the beam occurs at a frequency of 3000 megacycles.

The microwave circuits and antenna, as they are related to the receiving function, are treated in chapter 15 of this text along with all of the remaining functions of the AN/SPS-42.
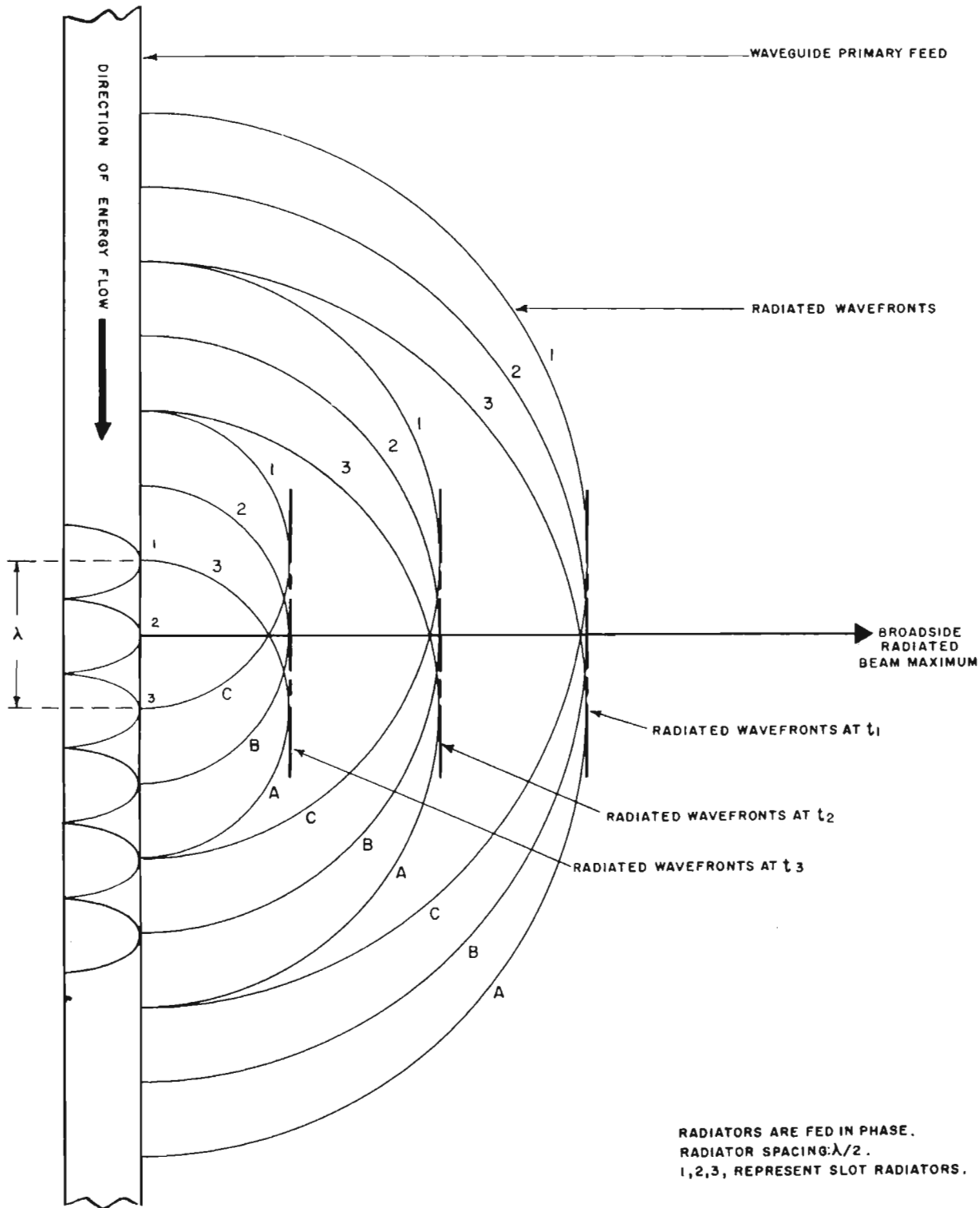
Figure 14-21.—Formation of broadside beam, simplified diagram, side elevation.
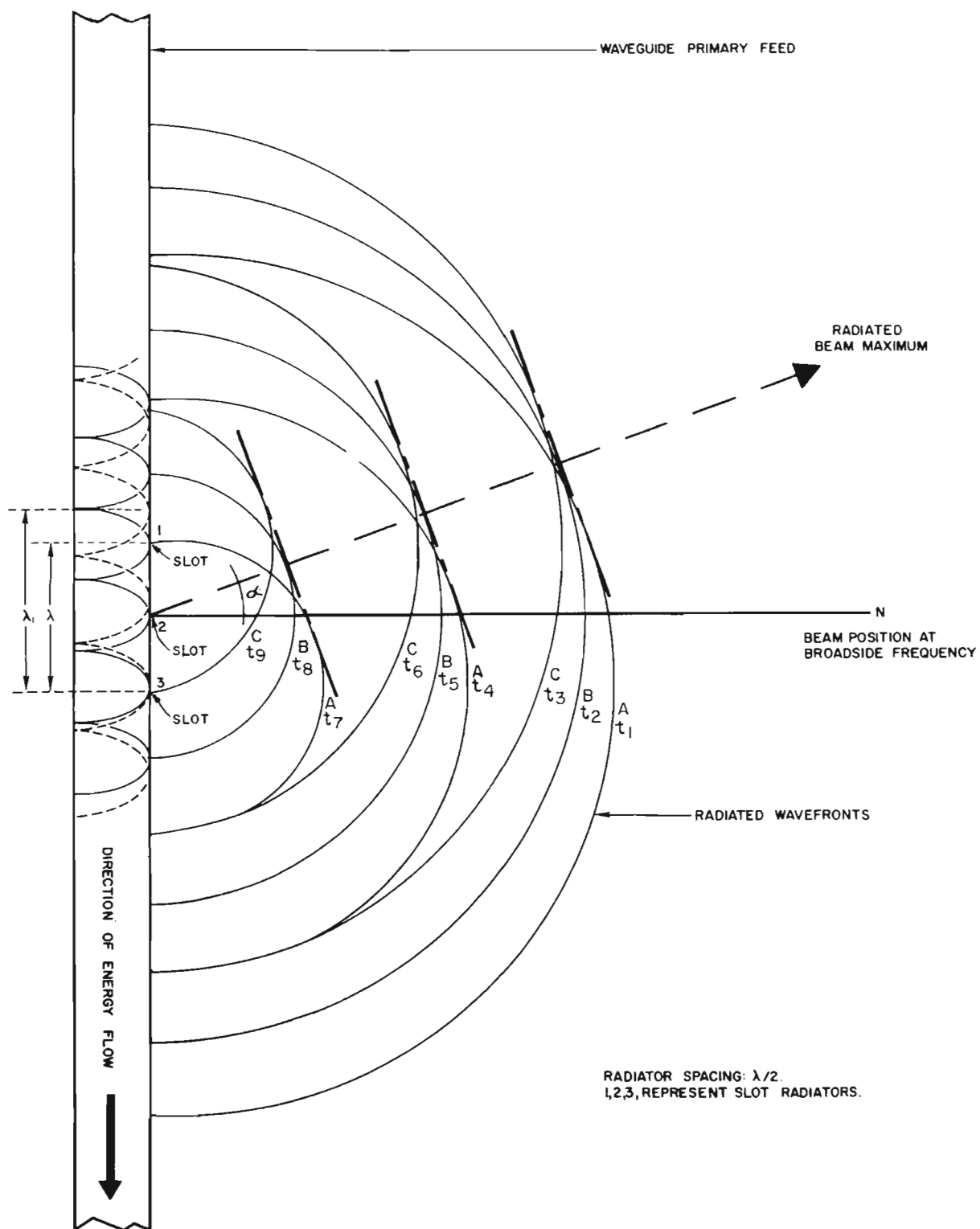
Figure 14-22.—Formation of the elevation beam.

AMPLIFIER-OSCILLATOR GROUP

CONVERTER-DUPLEXER GROUP

MODULATOR GROUP

ANTENNA

CONTAINS SLOT RADIATORS

DIRECTING VANE

ANTENNA GROUP

ELECTRON TUBE LIQUID COOLER

AMPLIFIER GROUP

PARABOLIC REFLECTOR

S7
ANT SAF SW

WAVE GUIDE SECTIONS

RADAR RECOGNITION SET
SHIPS HEADING MK #2
115 VAC± 10 PER CENT
60±3 CPS SHIP'S SOURCE

SI

RADAR SET GROUP

POWER SUPPLY GROUP

MOTOR-GENERATOR

115 VAC ± 10 PER CENT
60 ± 3 CPS
SHIP'S SOURCE

440 VAC ±10 PER CENT
60 ± 3 CPS
SHIP'S SOURCE

TO RADAR DISTRIBUTION SYSTEM

RADAR TEST SET GROUP

POWER SUPPLY GROUP

032.244

Figure 14-1.—Radar Set An/SPS-42, relationship of units.

WAVE FORM CONVERTER GROUP

RADAR SET CONTROL

AMPLIFIER-OSCILLATOR GROUP

CONVERTER-
DUPLEXER GROUP

ELECTRON
TUBE
LIQUID
COOLER

SLANT RANGE SIGNAL
FOR USE AS NEEDED

RADAR SET CONTROL

RANGE-HEIGHT
INDICATOR

RADAR SET GROUP

BRG. SYNCHRO I
BRG. SYNCHRO 2
RANGE SYNCHRO
ELEV. SYNCHRO

AZIMUTH-RANGE
INDICATOR

POWER
SUPPLY GROUP

115 VAC ± 10 PER CENT
60 ± 3 CPS
SHIP'S SOURCE

RADAR SET CONSOLE

TO RADAR
DISTRIBUTION SYSTEM

TO
DECODER

TO RADAR DISTRIBUTION SYSTEM
TO VL-I MOD. KIT (W.C.S.)
TO VL-I MODIFIED (W.C.S.)
TO VL-I MODIFIED (C.I.C.)
TO DG SYNCHRO AMPL.
TO SHIP'S STABLE DATA SET
TO SHIP'S GYRO
TO RADAR RECOG. SET

RADAR TEST SET GROUP

Figure 14-3.—Overall system, block diagram.

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RECEIVING
TEST SIGNALS

RECEIVING FUNCTION

INDICATING
FUNCTION

OSCILLOSCOPE
MONITORING
SECTION

CLUTTER
GATE
CHANNEL

IF
AMPLIFIER
CHANNEL

MTI
CHANNEL

IFF
EQUIPMENT

MIXED
VIDEO

PPI SECTION
AZIMUTH-RANGE
INDICATOR

MIXED VIDEO

MIXED
VIDEO

RHI SECTION
RANGE-HEIGHT
INDICATOR

SPACE STABILIZED MONITORING SIGNALS

SYNCHRONIZING MONITORING SIGNALS

DATA
STABILIZATION
SECTION

TARGET RETURN (ECHO)

RF SIGNAL

LOCAL OSCILLATOR SIGNAL

MTI
CONTROL
TRIGGER

SYNCHRO
DATA

RF CHANNEL
CONTAINS
FREQUENCY
SELECTION
CHANNEL

MICROWAVE
CIRCUITS

TARGET
RETURN
(ECHO)

TIMING
CHANNELS

SPACE STABILIZATION SIGNALS

SHIP'S STABLE
ELEMENTS &
GYRO COMPASS

SYNCHRONIZING SIGNALS

MODULATOR
CHANNEL

ELSCAN
COMPUTER
PROGRAMMER
CHANNEL

SYNCHRONIZING
SIGNALS

TRANSMITTING FUNCTION

FREQUENCY
COUNTING
GATE

SYNCHRONIZING FUNCTION

Figure 14-17.—R-f channel, block diagram.

032.260

OSCILLATOR AMPLIFIER

"A" OSCILLATOR BANK WITH 8 OSC UNITS

(A1 THROUGH A8)

MATRIX A 9 d-c AMPLIFIERS & 8 AND GATES

"B" OSCILLATOR BANK WITH 2 OSC UNITS

(B1 AND B2)

FIRST MIXER

CRYSTAL MIXER AND AMPLIFIER

F=A-B
50.46870 mc to 53.28120 mc

SECOND MIXER

CRYSTAL MIXER AND AMPLIFIER

F=A-B-C
45.46870 mc to 48.44526 mc

DOUBLER LIMITER

F=2 (A-B-C)
90.93740 mc to 96.89052 mc

FRE
MULT

FIRST T
FIFTH D

14 BINARY GATES

MATRIX B 9 d-c AMPLIFIERS & 8 AND GATES

"C" OSCILLATOR BANK WITH 8 OSC UNITS

(C1 THROUGH C8)

FREQUENCY COUNTER IN SYNCHRONIZING FUNCTION

FROM MODULATOR CHANNEL (-7.5 KV MODULATING PULSES 1 OR 5 μ SEC DURATION)

FROM MODULATOR CHANNEL (-90 KV MODULATING PULSE 4 μ SEC DURATION)

R-F DRIVER-AMPLIFIER

R-F FINAL AMPLIFIER

f=64 (A-B-C)
2910 mc to 3100.5 mc

FROM FIFTH DOUBLER IN OSCILLATOR-AMPLIFIER (ABOVE)

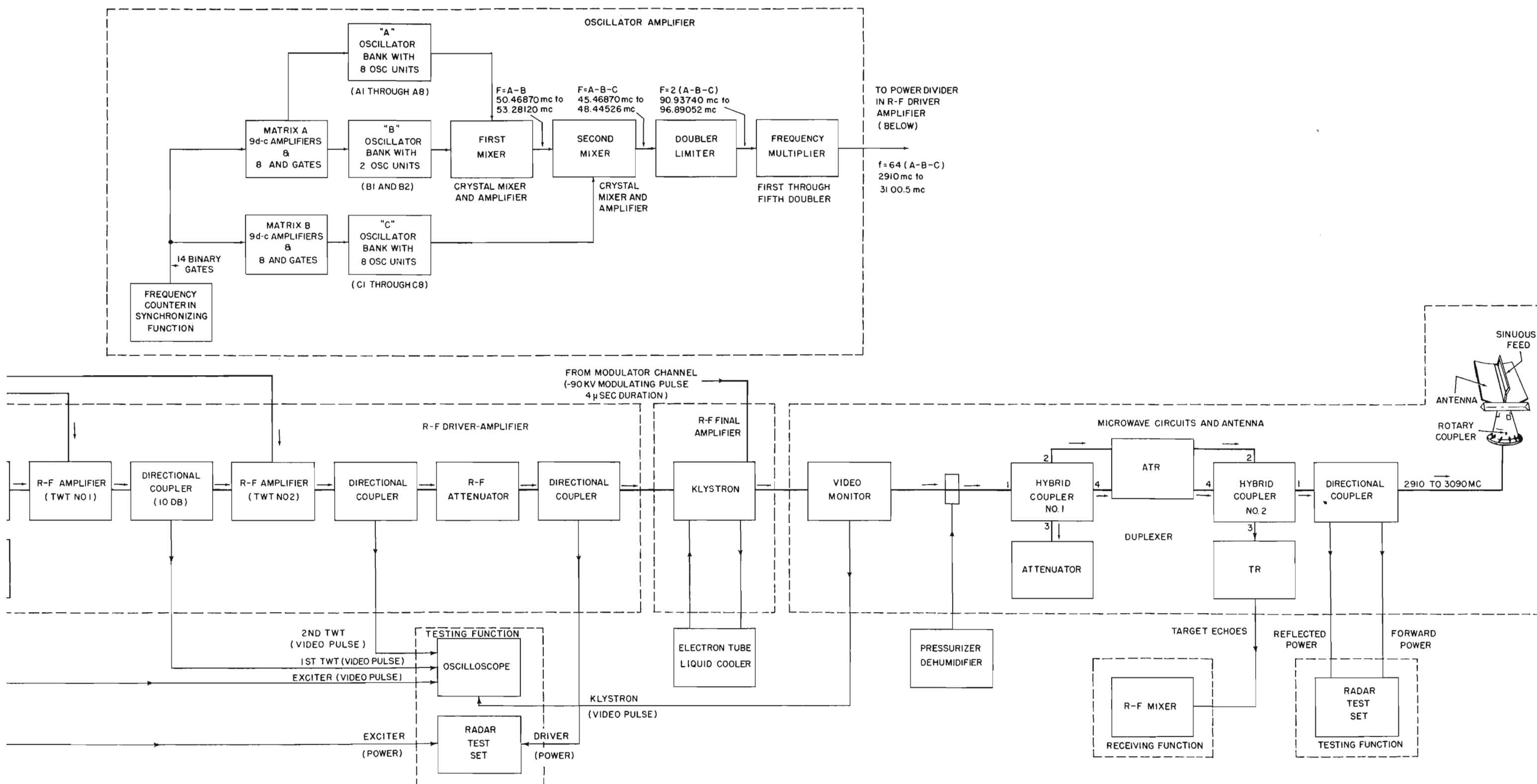POWER DIVIDER

R-F AMPLIFIER (TWT NO 1)

DIRECTIONAL COUPLER (10 DB)

R-F AMPLIFIER (TWT NO2)

DIRECTIONAL COUPLER

R-F ATTENUATOR

DIRECTIONAL COUPLER

KLYSTRON

R-F MIXER

2910 to 3100.5mc

DIRECTIONAL COUPLER

RECEIVING FUNCTION

ELECTRON TUBE LIQUID COOLER

2ND TWT (VIDEO PULSE)

TESTING FUNCTION

1 ST TWT (VIDEO PULSE)

FROM FIFTH DOUBLER

OSCILLOSCOPE

EXCITER (VIDEO PULSE)

KLYSTRON (VIDEO PULSE)

EXCITER (POWER)

RADAR TEST SET

DRIVER (POWER)