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MODULATOR, TRANSMITTER, AND RF SYSTEMS OF THE AN/TPS-1G

U.S. ARMY AIR DEFENSE SCHOOL

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Colonel, Arty
Adjutant

CONTENTS

CHAPTER 1

INTRODUCTION

1. PURPOSE AND SCOPE

a. Purpose. The purpose of this text is to provide a source of reference material for the technical maintenance of the AN/TPS-1G.

b. Scope. This text covers the technical operation of the modulator, transmitter, and rf systems.

2. REFERENCES

The AN/TPS-1G Troubleshooting Manual is a basic reference for this text.

CHAPTER 2

MODULATOR

Section I. INTRODUCTION AND BLOCK DIAGRAM, MODULATOR-TRANSMITTER

3. GENERAL

a. In a pulse-type radar, such as the AN/TPS-1G, it is necessary to transmit short, powerful pulses of high-frequency energy, followed by a relatively long period of waiting time. The number of times in each second that the energy is transmitted is known as the pulse recurrence frequency (prf). The purpose of the modulator is to provide the transmitter circuits with high-voltage pulses of the proper shape and prf.

b. Two trigger circuits are available in the radar, depending upon the desired operation. For accurate gated MTI operation, a precision triggering of the transmitter, which is properly timed by the trigger generator circuits in the signal comparator, must occur. This is known as the EXTERNAL trigger whose prf rate is a precision 400 pulses per second. Generation of a variable trigger can be obtained by the INTERNAL trigger circuits in the modulator unit with an output prf ranging from 360 to 400 pulses per second. The INTERNAL trigger can be used only in NORMAL operation, as its repetition time is not stable enough to provide gated MTI. Either the INTERNAL or EXTERNAL trigger sets up the system timing and is used to discharge the pulse-forming network that provides the magnetron with high power for a 2-microsecond pulse duration.

4. MODULATOR TRIGGER CHANNEL

a. Internal trigger generator, V101. The INTERNAL trigger generator V101 is in operation when the trigger is generated within the modulator unit. The generator is a free-running multivibrator with a square-wave output at a variable recurrence frequency of from 360 to 400 pulses per second. The variable recurrence rate of the pulses depends upon the adjustable time constants in the multivibrator. The square-wave output is peaked by RC network, and the positive peak is used as a trigger for the blocking oscillator V102 when the TRIGGER switch is set to INTERNAL.

b. External trigger generator, V1353A and V1352.

(1) When a precision-timed trigger is desired for gated MTI operation, the EXTERNAL trigger generator in the signal comparator is employed. The recurrence frequency of this trigger, which is 400 pulses per second, establishes a 2, 500-microsecond period between transmitter pulses. The origination of the actual timer signal will not be discussed in this text but is covered in the MTI text. A negative synchronizing pulse is supplied at the rate of 400 pps and applied to the external trigger generator, V1353A. The generator is a shock-excited oscillator containing a cathode tank circuit that is cut off by the negative input pulse, and when cut off, the tank circuit

oscillates at a 50-kc frequency. The last half of the first cycle, the positive half-cycle, is used to trigger the amplifier V1352.

(2) The positive input to V1352 is 10 microseconds in duration and is amplified by the stage. The output of V1352 is a negative, 10-microsecond pulse that is cabled from the signal comparator to the modulator unit. With the TRIGGER switch set to the EXTERNAL position, the external trigger is applied to the cathode of the blocking oscillator V102.

c. V102, V105, V106, and Z101. The INTERNAL or EXTERNAL trigger pulse is applied to V102A and amplified. The negative output trigger from V102A is used to trigger V105A. V105A and its associated circuitry comprise a driven blocking oscillator from which two outputs are taken. The first, a positive trigger taken from the cathode of V105A, is sent directly to the IFF unit. The second trigger, of a negative polarity, is taken from the plate of V105A and coupled through V106A to delay line Z101. Z101 inverts and delays the input signal either 12.4 or 37 microseconds. Since its input signal is of negative polarity and occurs at the same time as the trigger supplied to the IFF, its output signal is a positive trigger delayed with respect to the IFF trigger by 12.4 or 37 μsec. The 12.4-μsec delay is used with the Mark X IFF System. The 37-μsec delay is used with SIF (selective identification feature) modification to the Mark X. The positive trigger out of Z101 is then fed to V105B where it is again amplified and inverted and used to trigger blocking oscillator V102B. The function of V105, V106, and Z101 has been to delay the trigger to the AN/TPS-1G transmitter by either 12.4 or 37 microseconds with respect to the trigger to the IFF unit. The positive output trigger, from V102B, is now applied to the grid of the buffer amplifier V103.

d. Buffer amplifier V103. The buffer amplifier is a cathode follower that provides a low-impedance power source for triggering the thyratron keyer tube, as well as providing isolation. The positive input pulse causes the tube to conduct with a positive output pulse that is the input to thyratron keyer tube V156.

e. Thyratron keyer tube V156. The thyratron serves as an electronic switch to provide a path of continuity from the pulse line Z161 to ground. The discharge path for the pulse-forming network is through the primary of the pulse transformer. The resultant voltage pulse formed in the pulse transformer secondary is used both as the trigger and power source for the magnetron. The thyratron is cut off until the positive trigger pulse from the buffer amplifier, V103 is applied to the thyratron grid. When conducting, the thyratron provides a path of continuity to ground of only 0.6 ohm and the pulse-forming network is discharged.

5. HIGH-VOLTAGE POWER SUPPLY AND PULSE-FORMING NETWORK

a. Pulse-forming network Z161. The pulse-forming network Z161 consists of a network of coils and capacitors and is similar to an artificial transmission line. During the resting time of the transmitter, the network is charged up to approximately 10,000 volts by the high-voltage power supply. When the thyratron conducts, the network discharges through the pulse transformer with a negative 5,000 volts impressed across the primary. The electrical properties of the pulse-forming network determine the duration, or width, of the negative output pulse. This pulse width governs the length of time that the magnetron will oscillate.

b. High-voltage power supply T151, V151, and V152. The high-voltage power supply is the source of voltage for charging the pulse-forming network. The input to the supply is 115-volt alternating current and is stepped up to approximately 10, 000-volt alternating current before full-wave rectification by V151 and V152. The rectified output is a positive 5, 000 volts.

c. Charging choke L151. The charging choke L151 enables the pulse-forming network Z161 to charge to approximately twice the source voltage. By applying the principles of dc resonance charging, the pulse network is built up by L151 to approximately 10, 000 volts, even though the power-supply output is only 5, 000 volts.

d. Charging diodes V153 and V154. The pulse-forming network charges up to 10 kv through the charging diodes and the charging choke. The charging diodes provide a one-way path so that the pulse network will retain the 10 kv-charge until the thyratron conducts a discharge path. Without the diodes, the pulse network would still charge to 10 kv but would drop back toward 5, 000 volts when the repetition time becomes longer than the charge time.

e. Shunt diode V155. When the pulse-forming network is discharged, it has a tendency, due to mismatch, to charge up slightly in the opposite polarity to a small negative voltage. The shunt diode V155 is connected so that the negative charge is grounded.

6. TRANSMITTER

a. Pulse transformer T502. The pulse transformer T502 steps up the negative 5, 000-volt output of the pulse network to a negative 27, 000 volts with a 2-microsecond pulse duration. The negative 27, 000-volt pulse is applied to the cathode of the magnetron oscillator. In addition, a positive 100-volt pulse is taken from the secondary winding of the transformer and used to trigger the indicator circuits and indicator equipment.

b. Magnetron V502. The magnetron is the rf oscillator that generates high-frequency, high-power energy from an input voltage pulse. The negative 27, 000-volt input pulse causes the magnetron to oscillate at a frequency variable from 1, 220 to 1, 350 mc. The peak power output is approximately 500 kw. The rf energy is transmitted through the rf system into the antenna.

Section II. DETAILED DISCUSSION OF THE MODULATOR TRIGGER CHANNEL

7. INTERNAL TRIGGER GENERATOR V101

a. When the TRIGGER switch S152 is set to INTERNAL, the EXTERNAL trigger pulses are removed from the modulator trigger circuit and a positive 300 volts is placed on the plates of V101. The timing pulses originate from the operation of the free-running multivibrator V101 and are known as the INTERNAL trigger pulses.

b. The INTERNAL trigger generator consists of a free-running, plate-coupled multivibrator whose output is a square wave with a variable repetition frequency from 360 to

400 pps. The A and B sections are RC coupled amplifiers connected so that the output of the first section is applied to the grid of the second section and the output of the second section is applied back to the grid of the first section. Because only one tube conducts at a time, the output resembles a square wave from either section.

c. Since V101A and V101B constitute a free-running multivibrator, it is necessary to stop its operation at one instant to examine one full cycle of operation. At this instant, assume that V101A is conducting and V101B is cut off. With V101A conducting (fig 1), its plate voltage is low due to the voltage drop across R102 and R103 in parallel and C103 is discharging through R107, R108, R110, and R167 into the power supply. The discharge of C103 places a negative voltage on the grid of V101B and keeps that section cut off during the discharge time of C103. The discharge path contains two variable resistors, R110 and R167, whereby the time constant may be either increased or decreased. During the time that V101B is cut off, its plate voltage is equal to B+, and C102 has charged through the grid of V101A. The grid side of C102 will be at a near ground potential, wheras the plate side is at B+. This condition will remain with V101A conducting and V101B cut off until C103 has discharged sufficiently for the grid of V101B to rise above cutoff.

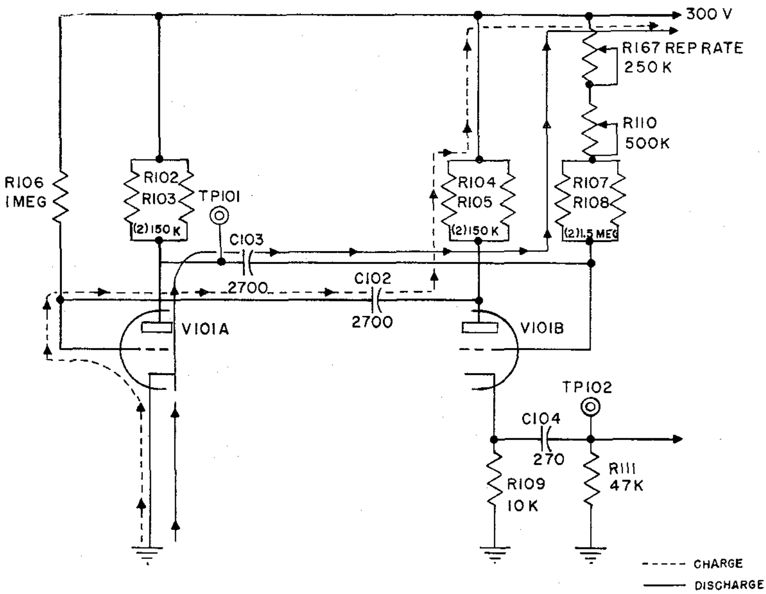


Figure 1. V101A conducting, V101B cut off.

d. V101B begins conducting after the discharge of C103 has allowed the grid to rise up to cutoff (fig 2). With V101B conducting, its plate voltage is decreased by the voltage drop across R104 and R105; C102, which had been charged to a B+ potential, is discharging through R106 and into the power supply. The discharge of C102 places the grid of V101A at a negative level and holds this tube cut off. When V101A is cut off, its plate voltage rises to a B+ potential and causes C103 to again charge to a B+ value. The charge path for C103 is shown in figure 2. The discharge time of C102 through R106 determines the length of time that V101A is cut off and the time that V101B is conducting. The output of the multivibrator is taken across cathode resistor R109 of V101B; therefore, the period of the positive section of the generated gate is determined by C102 and R106 and is fixed in time duration.

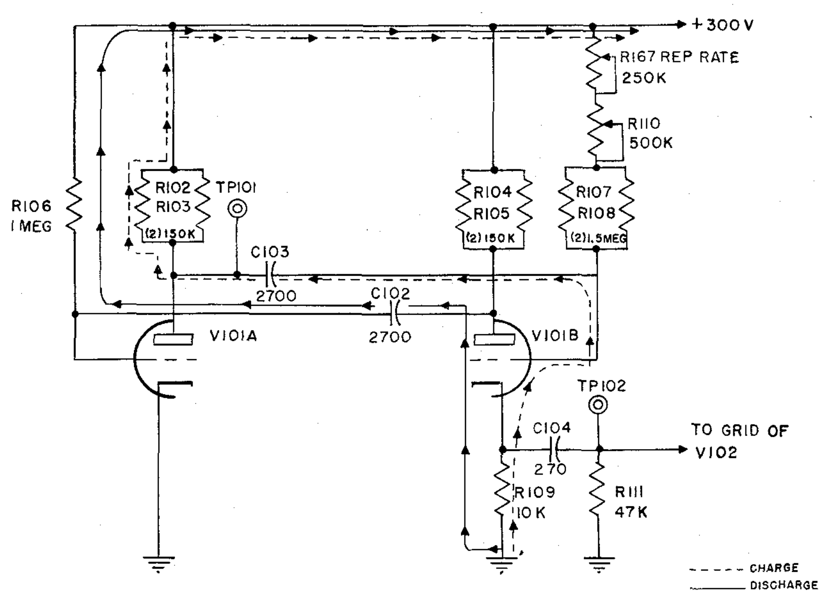


Figure 2. V101B conducting, V101A cut off.

e. The components that determine the cutoff condition of V101B and the conduction of V101A are C103, R107, R108, R110, and R167. This RC circuit determines the negative portion of the output gate from the cathode of V101B. The negative portion of the gate may be varied in time by both R110 and R167. R110 is inside the modulator unit and is adjusted so that the REP RATE CONTROL, R167, on the outside of the unit, can be varied to change the frequency from 360 to 400 cycles per second.

f. The output of the multivibrator at the cathode of V101B is shown at A in figure 3. The output is taken from the cathode of V101B since the waveform at this point has a very steep leading edge. The leading edge of this output square wave begins at the time when V101A is first cut off and its plate voltage rises to B+. The rise to B+ is instantly coupled across C103 to the grid of V101B. This high positive voltage on the grid, with the resultant peak plate current plus the grid drawing current, tends to steepen the front edge of the output. Since it has relatively low impedance, the cathode circuit is less subject to high losses of frequency due to distributed capacity. The duration of the negative half-cycle is approximately 1, 250 microseconds, depending upon the time that V101A conducts and V101B is cut off. The positive half of the output cycle is obtained from the conduction of V101B, and its duration is dependent upon the fixed discharge time of C102 and R106. The output square wave is peaked by C104 and R111 in the grid circuit of V102; the peaked waveform is shown at B of figure 3.

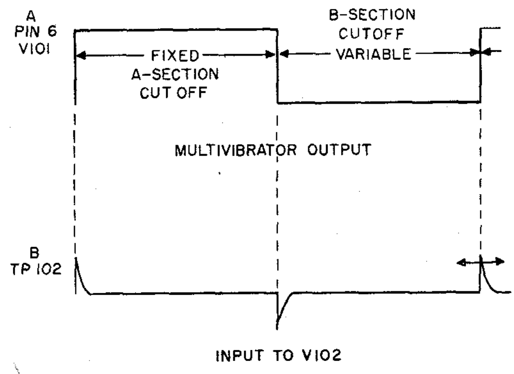


Figure 3. Internal trigger waveforms.

8. EXTERNAL TRIGGER GENERATOR V1353A AND V1352

a. The actual timing of the external trigger cannot be discussed in this text, since an understanding of the signal comparator circuits must first be obtained. However, a correct timing output will be assumed and the discussion of V1353A and V1352 can be continued. These two stages provide the generation of the trigger pulse after being properly gated in time.

b. A negative input to the grid, pin 7, of V1353A is used to initiate the action of the tube. The external trigger generator, V1353A, is a shock-excited oscillator with a tank circuit, L1352 and C1363, in its cathode. The tank is resonant to 50 kc; therefore, each positive or negative half-cycle will be 10 microseconds in duration. Before the negative pulse is applied, the tube is in maximum conduction due to a positive signal derived from the carrier gate length; during this time there will be no output from the tank circuit of the ringing oscillator. When the negative pulse is applied to the grid, the tube is cut off and the tank circuit starts oscillations, going first in a negative half-cycle. The frequency of these oscillations is 50 kc, giving a total period of 20 microseconds for one complete cycle. Due to damping action, the oscillations last only a few cycles and the output is coupled through an RC network R1358 and C1362 to the grid of V1352.

c. Trigger amplifier V1352 is operating near cutoff, due to the large cathode resistance R1357, which is bypassed by C1358. The first negative alternation drives the tube into cutoff, and there will be no output until the first positive alternation is seen at the grid of V1352. The positive alternation causes conduction of the tube and a decrease in plate voltage with a negative output signal. Succeeding positive alternations, all of smaller and smaller amplitude, will not be able to bring the tube into conduction again because of the bias built up across C1358 by the first positive swing. The external trigger pulse is a negative, 10-microsecond signal cabled from the signal comparator into the modulator. When the TRIGGER switch S152 is set to EXTERNAL, the negative trigger is applied to the cathode, pin 3, of the blocking oscillator V102. The recurrence frequency of the external pulses is precision-timed at 400 pulses per second.

9. BLOCKING OSCILLATOR AND IFF PRETRIGGER V102, V105, V106 and Z101

a. V102 and its associated components comprise a driven blocking oscillator, which means that the circuit is not free running but must be triggered to produce an output. Each time that a positive trigger is applied to a driven blocking oscillator one cycle of operation is produced in the plate circuit.

b. V105, V106, Z101 and their associated circuitry constitute the IFF pretrigger network connected between V102A and V102B. The function of the IFF pretrigger network is to provide a trigger to the IFF unit, and to delay the trigger to the radar transmitter with respect to this IFF trigger.

c. V102A, the driver section for the driven blocking oscillator, is biased to cutoff by means of a voltage divider consisting of R112, R113, and R114. The positive voltage across R112 is applied to the cathode as a fixed bias of approximately 12 volts. When the TRIGGER switch, S152, is set to INTERNAL, the positive peaks of the differentiated wave across R111 form the input to the grid of V102A. The negative peaks have no effect since the tube is at cutoff. If S152 is set to EXTERNAL, the negative triggers from the trigger amplifier V1352 are the input to the cathode of V102A.

d. When V102A is triggered, plate current flows through the primary of T105 from terminals 2 to 3. This flow of current through the primary of T105 induces a voltage in its secondary of such polarity that the grid of V105A is driven positive, which causes V105A to conduct, starting one cycle of blocking oscillator action. When V105A conducts, the current through terminals 2 to 3 of the transformer T105 is further increased, resulting in an increase of the positive potential being induced on the grid of V105A. This is a cumulative process, and almost instantaneously it drives V105A to a point where the grid will no longer increase plate current. The grid voltage rises in a positive direction, causing the plate current to increase but only to the point where the plate current increase is no longer linear with a grid-voltage increase; this is near the point of tube saturation. Above zero grid voltage, the plate current will not increase with an increase in grid voltage, and the voltage on the secondary, terminals 1 to 6, will reverse its polarity. This reversal of polarity places a negative potential on the grid of V105A, which cuts it off and ends the blocking oscillator operation. The blocking oscillator is prevented from free running due to bias developed by voltage divider resistors R127 and R128. There are two outputs from the blocking oscillator One is a positive pulse taken from the cathode and is used to trigger the IFF. The second output, taken from the plate, is a negative trigger that is coupled through diode V106A, a positive limiter, and sent to delay line Z101. Z101 delays the trigger by 12.4 or 37 μsec and inverts it to a positive trigger, which is applied to the grid of V105B. The delay provided by Z101 is set by USEC DELAY switch S101 to allow the AN/TPS-1G to operate with the Mark X IFF system or the SIF system. S101 is located on the front of the modulator in later sets; however, in older models S101 is an internal switch. V105 is an RC coupled amplifier, biased at cutoff by voltage divider R133 and R134. When the positive trigger from Z101 is felt on the grid of V105B, it conducts causing blocking oscillator V102B to operate through one cycle. V106B acts as a clamper in the respect that it clamps the signal output of Z101 to the same reference level for each cycle of operation.* It is termed a line discharge diode, and its funcion is to insure that the delay line is completely discharged after each cycle of operation.

e. Blocking oscillator V102B operates identically to the blocking oscillator operation of V105A. When RC coupled amplifier V105B conducts, current flows through the primary of T102 from terminals 5 to 3 lowering the plate voltage of V102B and causing it to conduct through one cycle of blocking oscillator operation. V102B is biased below cutoff by means of a voltage divider consisting of R118, R115, and R116. The fixed cathode bias is approximately 17 volts, which is sufficient to keep the B section cutoff until a trigger is applied. In order that the backswing of the signal through terminals 1 to 6, which results at the end of each cycle, will not trigger the blocking oscillator again, the cathode current has charged C105B to a high positive value. When V102B initially is cut off, C105B discharges and provides an additive positive bias to the cathode of V102B. C101B and R117 are in the plate circuit of V102B to form a decoupling circuit. C101B forms an ac ground at terminal 3 during the trigger time, thus increasing the voltage felt across T102, terminals 3 to 5. This increase in voltage also increases the output trigger amplitude.

10. BUFFER AMPLIFIER V103

a. The buffer amplifier V103 is a cathode follower that serves to isolate the blocking oscillator from the thyratron keyer tube. V103 acts to eliminate any kickback from the thyratron when it conducts, which would seriously affect the operation of the blocking oscillator. This positive kickback results from the thyratron control grid being near the thyratron plate; therefore, when the tube is ionized, a positive portion of the high plate voltage is felt on the grid.

b. The buffer amplifier V103 furnishes the trigger pulse to V156. R119 serves as a grid return resistor; R120 is a grid current-limiting resistor that tends to flatten the top of the positive input signals.

c. R122 forms the cathode load resistance for V103, and the output is developed across it. The impedance of the buffer is isolated from the low dc impedance of the primary of T103 by C107, therefore reducing the shunt-loading effect. The positive pulses from V102B cause the tube to conduct heavily and develop a large positive signal across R122. The output pulse, which has a sharp leading edge, is coupled through C107 and into the primary of T103 and can be monitored at TP104.

d. T103 matches the output impedance of V103 to the coaxial cable that carries the signal to the thyratron, V156. With no phase inversion across the transformer, the output trigger pulse is a positive 230-volt, 8-microsecond pulse that is the input to V156; it can be observed by a scope at J153 on the front of the modulator unit.

11. THYRATRON KEYER TUBE

a. Thyratron V156 functions as an electronic switch. It is fired by the positive pulse from the cathode of V103 and effectively grounds the pulse line at the charging diode (V153 and V154) side. At this time the charge on the pulse line discharges through the pulse transformer primary to ground and from ground through V156, which is now conducting to the other side of the pulse forming network.

b. The output recurrence frequency of the trigger channel remains the same as was generated by either the EXTERNAL or INTERNAL trigger generator. If the EXTERNAL trigger generator is used, the pulse repetition rate is 400 pulses per second; with the INTERNAL trigger, the number of pulses may be varied from 360 to 400 per second.

Section III. HIGH-VOLTAGE POWER SUPPLY AND PULSE-FORMING NETWORK

12. INTRODUCTION

NOTE: Do not attempt to measure or monitor any voltages in the high-voltage power supply and pulse network, except those at test points.

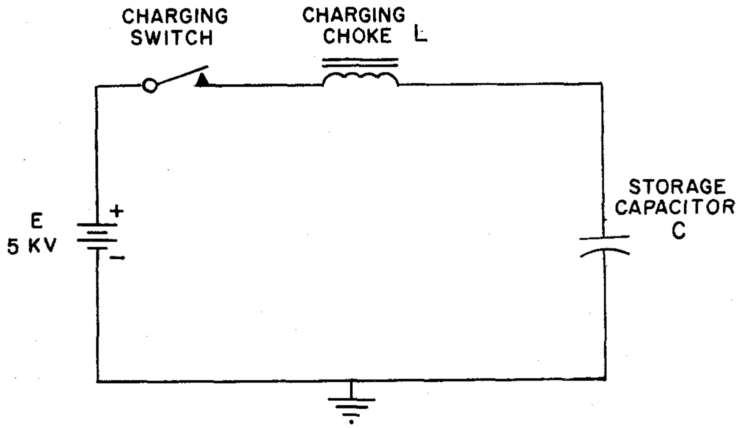
The discussion in the text thus far has pertained to the generation of a trigger that is t(ionize the thyratron tube. However, during the 2, 500 microseconds between the trigger pulses, the operation of the pulse-forming network is being charged to a high voltage durin the 2, 500 microseconds between the trigger pulses. This section covers the operation of the pulse-forming network circuits, which must use the trigger signals that are generated to discharge the network. Since dc resonance charging is employed in the charging of the pulse-forming network, the theory of charging is covered before the circuit analysis is outlined.

13. DC RESONANCE CHARGING AND PULSE-FORMING NETWORK

The modulator of the AN/TPS-1G employs a pulse-forming network that is charged up slowly to a high value of voltage. The network is discharged rapidly through a pulse transformer by the thyratron keyer tube to develop an output pulse. The shape and duration of the pulse are determined by the electrical characteristics of the pulse-forming network anc of the pulse transformer. The dc resonance charging principle places certain requirement on the modulator circuitry, and a thorough knowledge of this principle is necessary for proper understanding of the modulator.

14. DC RESONANCE CHARGING PRINCIPLE

a. Figure 4(1) shows the basic dc resonance charging circuit; 5, 000 volts direct current is applied through the charging switch and charging choke L to a storage capacitor C. At th instant the charging switch is closed, the voltage across the storage capacitor is zero, and the capacitor begins to charge through the charging choke L. The flow of charging current causes a magnetic field to build up about the charging choke. When the voltage across the storage capacitor equals the value of the applied battery voltage, the charging current through L begins to decrease, and the magnetic field about L begins to collapse. The collapsing magnetic field induces a voltage in the circuit that tends to keep current flowing in the same direction, further charging the capacitor. The energy contained in the collapsing magnetic field causes the voltage across the capacitor to rise to approximately twice the value of the applied battery voltage. Because of losses in the circuit, the voltage across the capacitor never quite reaches a value of 10, 000 volts. In effect, L and C form a series-resonant circuit that is shock-excited by the applied battery voltage. When the voltage across the storage capacitor C has risen to a value of approximately 10, 000 volts and the magnetic field about the charging choke L has completely collapsed, the capacitor begins to discharge, and current begins to flow in the opposite direction. Because L and C form a series-resonant circuit, the voltage across the capacitor varies sinusoidally about the 5, 000-volt level (fig 4(2)). The oscillations set up are damped out by the resistive losses of the circuit. The frequency of the oscillations is determined by the value of L and C.



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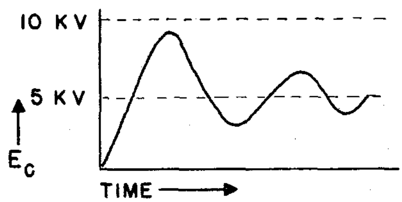


(2)

Figure 4. Basic dc resonance-charging circuit.

b. Figure 5 shows the addition of a pulse transformer, magnetron, and discharge switch to the basic circuit. The primary of the pulse transformer is connected in the charging circuit, and the resonant frequency of the circuit is now determined by the electrical characteristics of L, C, and the pulse transformer. In practice, the impedance of the pulse transformer to the flow of charging current is made quite small compared to the impedance of the charging choke. When the charging switch is closed, the voltage across capacitor C begins to rise toward a maximum value of approximately 10, 000 volts. When the voltage reaches its maximum value, closing the discharge switch discharges the capacitor rapidly to zero and produces a high voltage across the pulse transformer primary. The high impedance of charging choke L to this rapid change of voltage effectively isolates the battery from the discharge circuit. If the discharge switch is opened at the time the voltage across the capacitor reaches zero, the capacitor again charges approximately 10, 000 volts. When the discharge switch is closed, the flow of discharge current through the primary of the pulse transformer increases rapidly, and a sharply rising voltage is induced in the secondary winding of the transformer. When the secondary voltage is applied to the magnetron, the magnetron fires. With a properly designed pulse transformer and magnetron, the impedance of the primary appears as a pure resistance, and the voltage across the primary appears as is shown in figure 5.

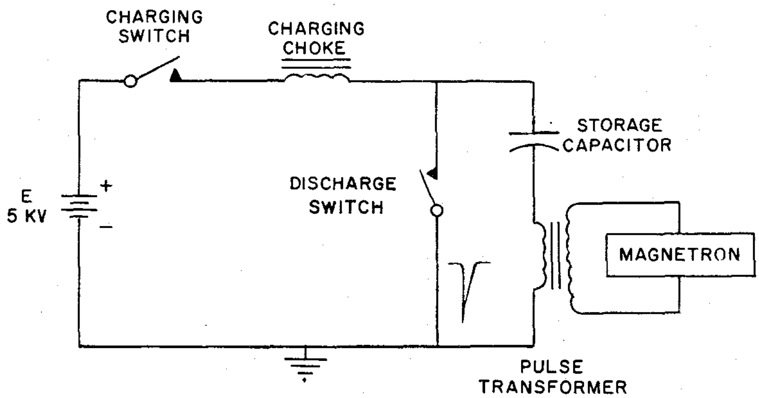


Figure 5. Basic modulator circuit.

c. To obtain the rectangular voltage pulse necessary for proper magnetron operation, the storage capacitor C is replaced by a pulse-forming network (fig 6). Since the pulse-forming network is made up of inductance and capacitance, the resonant frequency of the dc resonance charging circuit is determined by the charging choke, pulse transformer, and the elements of the pulse-forming network. When the charging switch is closed, the capacitors of the pulse-forming network begin to charge in the same manner as previously described. When the capacitors of the pulse-forming network are charged to their maximum voltage of approximately 10, 000 volts and the discharge switch is closed, the pulse-forming network begins to discharge through the primary of the pulse transformer. When the discharge switch is closed, the current flow through the primary of the pulse transformer rises very rapidly to a maximum value. If the impedance of the pulse transformer is equal to the characteristic impedance of the pulse-forming network, the voltage drop across the primary of the pulse transformer is approximately 5, 000 volts. Since the pulse transformer is effectively connected directly across the pulse-forming network during discharge, the terminal voltage of the pulse-forming network also is 5, 000 volts. When the discharge switch is closed, the voltage waveform across the pulse-forming network will show a sudden drop from 10, 000 volts to 5, 000 volts. The voltage across the pulse-forming network remains at 5, 000 volts for 2 microseconds, the time required for the pulse-forming network to discharge, then drops to zero. At the end of the discharge time, the current flow through the primary of the pulse transformer drops to zero. The pulse of voltage across the primary of the pulse transformer is approximately 5,000 volts in amplitude and 2 microseconds in duration. The discharge switch must be closed only when the voltage across the pulse-forming network is at a maximum, in order to obtain maximum voltage in the pulse applied to the magnetron. Since the time required for the pulse-forming network to charge to maximum voltage depends on the resonant frequency of the charging circuits, the recurrence frequency of the closing of the switch is limited to one specific frequency. The charging diode added to the circuit, as shown in figure 7, allows the frequency of the closing of the discharge switch to be variable by maintaining the maximum voltage across the pulse-forming network. Since the diode allows current to flow in only one direction, the pulse line charges through the diode but is not allowed to discharge, and the voltage across it remains at the maximum value. The frequency of the closing of the discharge switch can now be made variable over wide limits, so long as it is timed to close only after the pulse-forming network has been charged to maximum voltage. To make the circuit more efficient, a hydrogen-thyratron tube is used as a discharging switch. If the impedance of the pulse transformer and magnetron circuit is mismatched to the characteristic impedance of the pulse-forming network, a negative charge will appear on the capacitors of the pulse-forming network after the thyratron fires. This reverse voltage is in opposition to the charging voltage, and on the next charging cycle the flow of current through the charging choke will

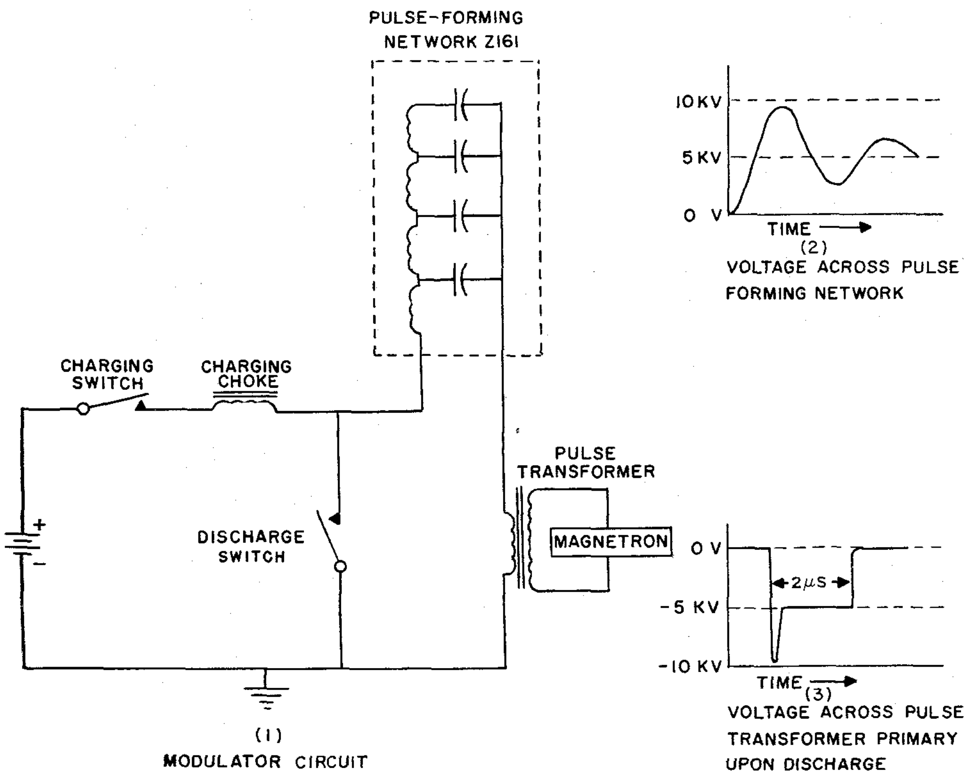


Figure 6. Basic modulator circuit with pulse-forming network.

be increased. The additional current flow causes more energy to be stored in the magneti field of the charging choke. When the voltage across the pulse-forming network reaches 5,000 volts and the magnetic field about the charging choke begins to collapse, the extra energy stored in the field will cause the pulse-forming network to be charged to a value greater than 10,000 volts. After several cycles of operation, the voltage across the pulse line may reach a value that is high enough to fire the thyratron even though no trigger is applied to the thyratron grid. The excessive voltage may also break down the insulation i the pulse-forming network. To prevent the formation of the negative charge on the pulse-forming network, a bypass or shunt diode is connected between the pulse-forming network and ground.

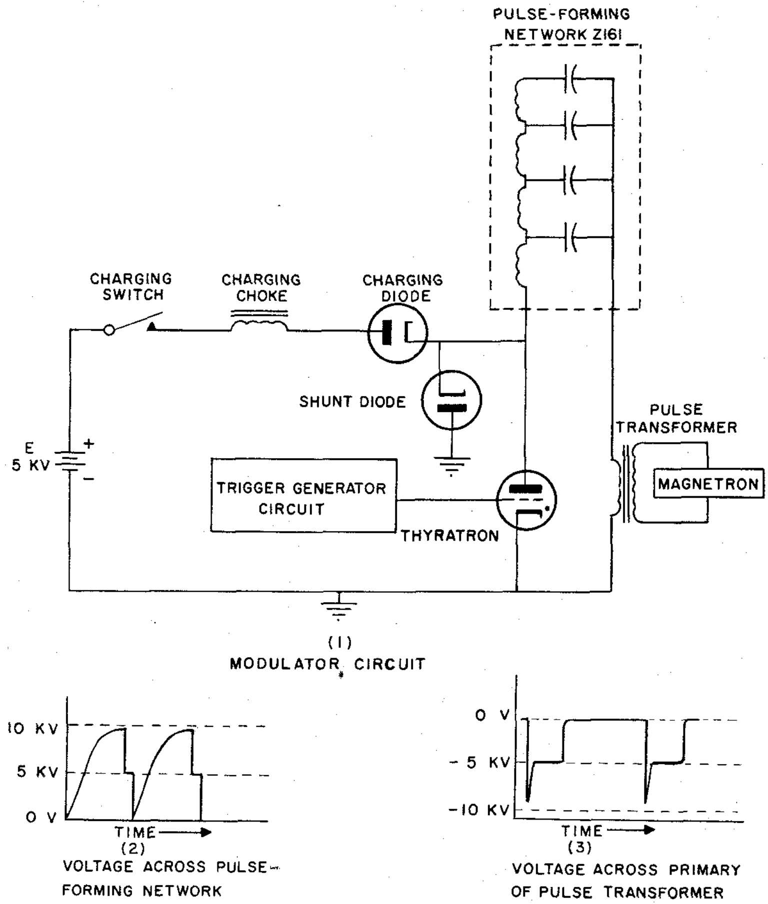


Figure 7. Complete modulator circuit.

d. Figure 7 shows a circuit with all the necessary elements for charging and discharging the pulse network with maximum efficiency. In this circuit, when power is applied, the pulse-forming network charges through the charging choke and the charging diode to a value of approximately 10,000 volts. The charging diode prevents the pulse-forming network from discharging and holds it at the maximum voltage until a trigger fires the thyratron. The pulse-forming network is discharged through the pulse transformer to ground, and from ground up through the thyratron; it is completely discharged and is prevented from charging in the opposite direction by the bypass diode. A thyratron is used as the discharge switch because of its ability to carry a large current (approximately 100 amperes) and because of its low internal impedance (about 0.6 ohm when conducting). With the principles of dc resonance charging understood, the high-voltage power supply and pulse network of the AN/TPS-1G can be explained readily. The value of voltages and components that have been used are applicable to the radar.

15. HIGH-VOLTAGE POWER SUPPLY

a. The high-voltage power supply consists of T151, V151, V152, and filter capacitor C153, which constitutes a full-wave rectifier circuit. The supply steps up and rectifies the ac line voltage to give the high dc potential necessary for charging pulse-forming network Z161.

b. When the RADIATE relay K152 is energized, 115 volts alternating current is applied to the primary of T151 through S156, the magnetron aging variac switch. With S156 in the OUT position, power is applied directly to the primary winding of T151. When S156 is in the IN position, T155, the magnetron aging variac, is connected across the 115-volt line and power is applied to the primary windings of T151 through T155. Full instructions for aging the magnetron will be given in chapter 3 under section IV. Transformer T151 steps up the voltage to approximately 10,500 volts alternating current across its secondary terminals 5 to 7. The primary of T151 is tapped to provide a means of adjusting the modulator pulse output over a range of 5 percent.

c. At the instant that the voltage is positive at terminal 5, the voltage at terminal 7 is negative. The positive voltage at terminal 5 is felt on the plate of V152, which causes it to conduct on the positive half cycle. When the phase of the alternating current is changed, V151 will conduct, giving full-wave rectification. C153 filters out the ac ripple frequency so that the final output is approximately a positive 5,000-volt steady, direct current. Because the input frequency is 400 cps, after full-wave rectification, the output ripple frequency is 800 cps; therefore, a small capacitance is sufficient for filtering.

d. Bleeder resistor R151 discharges C153 when the input voltage is removed from T151. Safety switch S151 is operated by the modulator interlock switch S153B when the unit is pulled from its case so that C153 will be discharged instantaneously.

16. CHARGING THE PULSE-FORMING NETWORK Z161

a. The pulse-forming network, Z161, is a 4-section LC network that is charged to approximately 10,000 volts between the transmitter pulses. It is rapidly discharged through the primary of the pulse transformer T502 thus firing the magnetron.

b. When the dc voltage from the high-voltage power supply is applied to the network, the network begins to charge from ground, through the primary of T502, Z161, L152, V153 or V154, and L151 into the power supply. The combination of Z161, L151, and the other circuit components in the charging path comprise a dc resonance-charging circuit, which is resonant to 200 cycles per second. The resonance charging provides a charge on the network of 10,000 volts, in the same manner as explained in paragraph 14. While Z161 is being charged up to the power supply voltage of 5,000 volts, current flows through the charging choke L151. This builds up a magnetic field around L151 that begins to collapse as soon as the charge on Z161 rises to the source voltage of 5,000 volts. The collapse of the magnetic field causes current to continue to flow through the circuit in the same direction and to charge Z161 to about 10 kv.

c. As soon as Z161 is charged to 10 kv, there is a tendency for it to discharge back down to the supply voltage, 5,000 volts, but it cannot because of the charging or holding diodes V153 and V154. The diodes conduct in only one direction, and once the network is charged to 10 kv, it cannot be discharged except through the conduction of the thyratron tube or a slow discharge through very large RC time constant circuits. As the prf of the radar is 400 pulses per second or less, the pulse network must be charged fully in 2,500 microseconds. In a series resonant circuit, it takes exactly half a cycle for the storage element to charge from zero to a maximum voltage; therefore, it takes Z161 a half cycle to charge to 10 kv. As the circuit is resonant to 200 cps, it will take 2,500 microseconds for the pulse network to charge fully. The only requirement in respect to charge time is that the network be fully charged before it is discharged.

17. DISCHARGING THE PULSE-FORMING NETWORK

a. The trigger output of the buffer amplifier V103 is applied to the grid of the thyratron keyer tube V156. The thyratron is normally cut off until triggered by the positive trigger pulse. The thyratron is in a nonconducting state due to an aluminum shield between the cathode and plate. The shield, acting also as the grid, prevents ionization until it goes positive.

b. When the positive pulse ionizes the thyratron tube, a low-impedance discharge path is provided from Z161 through the primary of T502 to ground and from ground through V156, L152, and back to the network. A total time of 2 microseconds is required for the capacitors of the network to discharge through their series choke coils and into the primary of the pulse transformer T502. Therefore, the discharge time is determined by the electrical construction of the pulse network Z161. L152 is used to slope the leading and trailing edges of the pulse across the pulse transformer during discharge, which will ease the magnetron into high-powered oscillations.

c. During discharge the impedance of T502 is approximately equal to the impedance of Z161; therefore, for the 10-kv charge on the network, only 5 kv is dropped across the pulse transformer with the other 5 kv being dropped across the internal impedance of Z161. The 5-kv trigger that appears at the primary of T502 acts not only as a time reference pulse but also contains the power that is necessary to drive the magnetron into oscillations at the desired power level. The primary power must equal the power in the secondary of T502; therefore, the primary power is high during the 2-microsecond discharge. The output of the pulse network (fig 7) is a 2-microsecond, negative 5-kv pulse taken across the primary of T502.

18. SHUNT DIODE V155

During the discharge of Z161, if the impedance of T502 and Z161 is slightly mismatched, a negative charge will appear across Z161 in respect to ground. This negative charge, as explained in detail in paragraph 14, tends to increase the charging current through L151, causing its generated cemf to exceed 10 kv. The shunt or bypass diode V155 removes the negative charge and provides a zero reference point at the beginning of each charge cycle. The shunt diode current flows through R156, R154, and R155 to ground. The reverse current charges C156 and C157, and in its absence, the discharge of the capacitors makes an average current flow through K151B that equals and balances the current flow in K151A under normal conditions. Any abnormal condition gives either an increased or decreased current condition, causing one of the relay section to become unbalanced and energized.

19. OVERLOAD RELAY K151A/B

The inverse voltage that is built up on Z161 after it discharges is shorted to ground through V155. This action produces voltage pulses across R154 and R155, which are filtered by C156 and C157 to give a constant current through K151B. At the same time, a portion of the current drawn from the high-voltage power supply flows through K151A. R168 is adjustable to balance these two currents. During proper operation of the modulator and transmitter circuits, the magnetic fields that are built around these coils cancel and there is no energizing effect on the relay. However, most irregularities that could be experienced in the modulator and transmitter circuits result in a change in the ratio of the two currents. For example, should an arc-over occur in the pulse line, the charging current would increase. At the same time the shunt diode current would decrease, and K151A would be energized, opening relay K152. In the same manner, K151A/B provides protection for the following conditions:

Gassy magnetron.
Shorting of magnetron.
Failure of magnetron to oscillate.
Mode skipping of magnetron.
Excessive arcing of magnetron.
Continuous conduction of thyratron keyer.
Shunt diode burnout.
Open coil in relay K151A/B.

Variation in line voltage does not cause K151A/B to operate because the balance in the coil currents is not disturbed.

20. TEST POINT

a. TP151. A voltage divider, consisting of R157 and parallel resistors R158 and R159, is connected from the positive end of Z161 to ground. This divider provides an attenuated replica of the voltage on Z161, which may be monitored by an oscilloscope at TP151. The monitored waveform (fig 8) illustrates the charging and discharging of Z161. If an oscilloscope is not available, the voltage from TP151 to TP152 (ground) may be measured with a voltmeter. A positive reading of approximately 75 volts indicates that Z161 is being charged to its proper voltage.

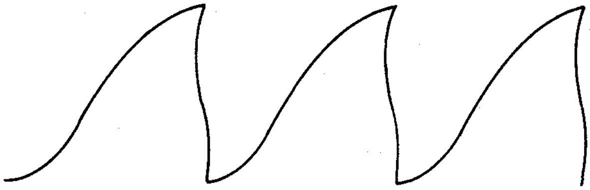


Figure 8. Output of TP151.

b. J156. Test jack J156, located on the front of the modulator, is used to monitor the negative 2-microsecond pulses that appear across the primary of T502. J156 is in parallel with the primary of T502 and is connected to it by a voltage divider consisting of R169 and R162 through R166. The voltage divider provides an attenuation network so that the negative output signal at J156 is approximately 80 volts in amplitude and 2 microseconds in duration, and can be observed by an oscilloscope.

21. MISCELLANEOUS AND CONTROL CIRCUITS

a. Control circuits. The RADIATE RELAY K152 is energized by 27 volts direct current when the RADIATE ON switch S616 is pressed to ON. The relay is kept energized by the action of the HOLDING RELAY K405 which bypasses the RADIATE ON switch when K405 is energized. At the time that K152 is energized, 115 volts alternating current is applied to the primary of T151 in the modulator high-voltage power supply; this starts charging the pulse-forming network. Relay K152 after being energized can be deenergized under the following conditions:

(1) RADIATE OFF switch S615 is pressed.

(2) The OVERLOAD RELAY K151A or K151B, energizes.

(3) Interlocks S153B and S504B are opened.

(4) Thermal switch S501 is opened.

(5) Indirect malfunctions throughout the modulator or power supply units.

b. OPERATING HOURS meter M402. When the RADIATE ON switch S616 is closed, 27 volts is applied to the OPERATING HOURS meter M402. The meter indicates the total time that the modulator and transmitter circuits are fully energized.

c. Interlocks S153A and S153B. The ganged safety interlock switches S153A and S153B automatically open when the modulator chassis is withdrawn from its case. S153A controls the operation of warning lights I151, I152, and I153, which indicate the removal of high voltage by going out. S153B opens the 27-volt dc circuit to RADIATE RELAY K152, thereby removing the 115-volt alternating current from the primary of T151. The interlock may be manually closed by a cheater switch on the right side of the unit when it is withdrawn from its case.

d. Filament supply. The filaments for the trigger circuit are taken off the secondary windings of T101. For V101 and V102, the filament voltage is 6.3-volt alternating current. For the buffer amplifier V103, the 6.3-volt alternating current is riding on a positive 91.5-volt dc level to eliminate arcing between the cathode and filament during trigger time.

e. Blower B151 and heaters HR151 and HR152.

(1) The cooling blower B151 is thermally controlled by S154, which closes at 25° C and opens at 10° C. When the switch is closed, the blower motor operates to cool the components within the modulator.

(2) Heaters HR151 and HR152 are included for operation in cold climates. They are energized by thermostat switch S155 when the temperature falls below 0° C. For the heaters to operate, the heater connection jacks must be connected so that W102 connects to 02 and W103 connects to 03 on E406 (see left inside of power supply chassis).

Section IV. TROUBLESHOOTING

22. OVERALL TROUBLES

The troubles that cause malfunction can generally be divided into the following categories:

a. Troubles that eliminate the INTERNAL trigger.

b. Troubles that eliminate the EXTERNAL trigger.

c. Elimination of both triggers.

d. Removal of the high-voltage power supply.

23. MODULATOR TRIGGER CHANNEL

a. Internal trigger. The generation of the INTERNAL trigger can be checked by having the RADIATE ON and switching the TRIGGER switch S152 to INTERNAL. If the set ceases to radiate when switched from EXTERNAL to INTERNAL, the faulty stage must be the INTERNAL TRIGGER GENERATOR V101. This method cannot be used if the set is inoperative with the TRIGGER switch set to EXTERNAL.

b. External trigger. The complete external trigger circuit is not covered in this text, and troubleshooting it cannot be discussed in detail until the signal comparator circuits are studied. To check for the presence of the EXTERNAL trigger, the same method is used as for the INTERNAL trigger. If the transmitter operates with an INTERNAL trigger but will not operate when the TRIGGER switch S152 is set to EXTERNAL, then the circuits that must be considered faulty are in the signal comparator or in cabling from that unit to the modulator.

c. Elimination of both triggers. If the set fails to radiate when switched to either EXTERNAL or INTERNAL trigger, an oscilloscope check should be made at J153 to determine if triggers are being generated. If no triggers appear at the test jack, the probable trouble is in V102, V105, V106, or V103. Should pulses appear at the jack, a visual inspection of the thyratron keyer tube V156 should be made to determine its state of conduction. If the keyer is conducting, a pinkish glow can be seen within the tube.

d. Removal of the high-voltage power supply. The charging of the pulse network can be checked by a voltage reading at TP151, which should indicate about 75 volts direct current. In the absence of a voltage reading at the test point, any one of the following components may be inoperative.

(1) K152 deenergized.

(2) K151 energized.

(3) S153B or S504B open.

(4) An open in T151.

(5) Blow fuze F410, which removes the high-voltage filament. Many other components can cause the pulse network and high voltage to operate improperly; however, these listed give a guide for troubleshooting procedure.

e. Interlock troubles. The safety interlocks in the following units cause either a loss of the trigger pulse or a loss of power-supply voltage.

(1) Power-supply, receiver-transmitter, and indicator interlocks S402, S504A, and S603 remove the plate voltage from the tubes in the trigger circuit, when any one of the interlocks is opened.

(2) Modulator and transmitter interlocks S153B and S504B will remove the 27 volts direct current from the RADIATE RELAY K152 when either is opened. By deenergizing K152, the 115 volts alternating current is removed from the primary of T151.

Section V. SUMMARY AND QUESTIONS

24. SUMMARY

a. The modulator produces, amplifies, and shapes a voltage pulse with sufficient power to drive the transmitter circuits. The INTERNAL trigger is produced in the modulator at a variable rate from 360 to 400 pps. It is used for NORMAL operation of the radar and for test purposes. The EXTERNAL trigger is generated in the signal comparator at a precision rate of 400 pps, which is used in gated MTI operation. These timing triggers determine the pulse recurrence frequency of the radar.

b. The timing triggers are employed to discharge the pulse-forming network, which provides the power trigger to the transmitter. During the 2, 500 microseconds between successive timing triggers, the pulse network is charged to 10 kv by direct-current resonance charging. The timing trigger causes the thyratron keyer tube to conduct and the pulse network is discharged at a very fast rate through the primary of the pulse transformer in the transmitter unit. The discharge results in a negative 2-microsecond, 5-kv pulse applied across the primary of T502; it occurs at a 360- to 400-pps rate for INTERNAL or a 400-pps rate for EXTERNAL operation.

25. QUESTIONS

a. What is the prf limit of the radar when using the INTERNAL trigger? EXTERNAL trigger?

b. TRIGGER switch S152 is ganged to give two functions. What occurs from a circuit analysis viewpoint when the switch is set from EXTERNAL to INTERNAL?

c. What are the controls for varying the INTERNAL trigger rate?

d. What is the purpose of C104 and R111?

e. Why is the discharge of C105B important?

f. What is the purpose of the driven blocking oscillator V102?

g. The buffer amplifier V103, provides an isolation between what stages?

h. What accounts for a 2-microsecond pulse width at the output of Z161, even though the timing trigger that ionizes the thyratron is approximately 8 microseconds in pulse width?

i. What is the output of the full-wave rectifier circuit T151, V152, and V151?

j. Why is L151 needed in dc resonance charging?

k. How is the 10-kv charge held on Z161 until the thyratrons are triggered?

l. When the RADIATE RELAY K152 is energized, what is its function?

m. What does the OPERATING HOURS meter M402 indicate?

n. If the shunt diode, V155, should become inoperative, what would happen to the modulator circuits?

o. What is the correct synchroscope and voltmeter indications at TP151?

CHAPTER 3

TRANSMITTER

Section I. INTRODUCTION

26. GENERAL

The purpose of the transmitter is to convert a high-voltage pulse into a high-powered rf output that is propagated into space by the antenna. This rf pulse, having a proper frequency and power, enables the detection of targets at the extreme ranges of 160 nautical miles.

27. REVIEW

The pulse recurrence frequency is determined by the timing triggers from the signal comparator or modulator trigger circuits. The external trigger rate is 400 pps, and the internal trigger is variable from 360 to 400 pps. The timing trigger is applied to the thyratron keyer tube causing it to conduct. Upon its conduction, the pulse-forming network is discharged through the pulse transformer T502. The voltage pulse across the primary of the transformer is a negative 5, 000 volts that remains for a duration of two microseconds. This pulse provides the power as well as the timing for the magnetron.

Section II. TRANSMITTER BLOCK DIAGRAM

28. PULSE TRANSFORMER T502

The pulse transformer T502 is the means of coupling the output pulse from the pulse-forming network to the cathode of the magnetron. The turn ratio of T502 gives a 5:4 step-up of the voltage pulse from the primary to the secondary windings. The transformer does not generate power but merely transfers it from the pulse-forming network with a minimum loss. The secondary output is a negative 27, 000-volt, 2-microsecond pulse, which is the input to the cathode of the magnetron.

29. MAGNETRON V502

The 5J26-type magnetron V502 oscillates to provide a high-power, high-frequency pulse. By applying the negative 27, 000 volts to its cathode, the voltage causes it to oscillate at a manually tuned frequency from 1, 220 mc to 1, 350 mc with a peak power of 500 kw. The rf energy from the magnetron is coupled through the rf system and into the antenna.

30. FILAMENT SUPPLY T504, CR501, C508, AND L502

The filament supply T504, CR501, C508 and L502 furnishes the voltage for heating the cathode of the magnetron. The supply rectifies the ac voltage into a dc potential that is applied to the filament of the magnetron.

31. PULSE TRANSFORMER T502

a. When the pulse-forming network Z161 discharges, a negative 5,000-volt pulse of 2-microsecond duration is applied to the primary of pulse transformer T502. The function of this transformer is to match the impedance of the input pulse cable from the modulator to that of the magnetron without introducing a substantial change in the waveform. To effect a change or transformation of impedance, a step-up turn ratio between the transformer primary and secondary of about 5:4 is required. This ratio of turns increases the secondary voltage by 5:4 times the primary voltage, or to a negative 27,000-volt pulse that is applied to the cathode of the magnetron. The step-up makes possible the use of the comparatively low 5,000-volt input, which reduces the problem of high voltage flashovers and insulation breakdown. The transformer has a welded steel case that contains oil in which the windings are immersed to act as insulation as well as a cooling agent.

b. The pulse transformer T502 has four windings: a primary that connects to the pulse cable; a secondary that provides a positive 100-volt, 2-microsecond trigger for the indicator and two identical secondaries known as bifilar windings. The two bifilar windings, each of which induces exactly the same voltage, are wound so the inductive reactance of one cancels the other. These two bifilar windings are connected, one in each line, between the magnetron filament and the filament power supply. Since each winding has an induced voltage identical to the other, the potential that one winding adds to the magnetron filament voltage is subtracted by the other winding; thus the net magnetron filament voltage is equal to the filament power supply. If a single high-voltage secondary were used on the pulse transformer, the filament power supply would introduce great additional capacitance, which would destroy the pulse. It would also require high-voltage insulation between the entire filament supply and ground. By using the two bifilar secondaries and connecting the filament power to the low-voltage ends and the magnetron filament to the high-voltage ends, these problems are eliminated. The outer case or shell of the magnetron is connected to the plate, or anode, of the magnetron; since the plate is grounded the case is also at ground potential, this eliminates the rather large capacitance between the plate and outer case of the magnetron. The grounded case is also a safety factor. The low-voltage and high-voltage ends of the pulse transformer secondaries are shorted for video frequencies by the capacitors C504 and C505 thus shorting out any possible secondary voltage difference.

32. DESPIKING NETWORK C509 AND R509

At the moment the high-voltage pulse is applied to the magnetron cathode, the magnetron is not oscillating, and it acts as an open circuit. The primary impedance of a transformer to a large extent depends on the impedance reflected by the secondary; when the secondary circuit is open, the primary impedance appears very large. For this reason, the primary impedance of the pulse transformer appears very large at the moment the modulator pulse is applied. Since the largest voltage in any closed circuit is developed across the largest impedance, a large voltage develops across the transformer primary during the instant the pulse is first applied since the magnetron is not oscillating and reflects no load. If this condition were allowed to exist, the magnetron would immediately arc over. C509 and R509, which are in series across the transformer primary, provide a means of dissipating the energy in this sudden high-voltage surge. During the brief pulse rise time, C509 appears as a short circuit and leaves the 20-ohm resistor R509 as a path of continuity to ground. After the pulse rise time, C509 no longer appears as a short circuit since it is no longer charging.

33. MAGNETRON CONSTRUCTION

Magnetrons are basically self-excited oscillators that convert dc input power into rf output power. A constant and uniform magnetic field is maintained perpendicular to the plane of the resonant cavities, as shown in a magnetron cutaway view (fig 9). This magnetic field is provided by a large permanent magnet that is external to the magnetron yet part of its operation. The magnetron anode is made up of eight resonant cavities that are arranged in a circular formation about an open space in the center; this space is known as the interaction space. The inner surface of the circular formation of cavities is a series of alternate segments and slots. The ends of the cavities open into a chamber called end spaces through which pass the lines of magnetic flux perpendicular to the plane of the cavities. The coupling between resonators is increased by conducting-bars or straps between alternate anode segments. The cathode is oxide-coated to increase the emission of electrons and is supported mechanically by an insulating material. Each cavity is similar to a simple oscillating circuit consisting of lumped LC values; the magnetron frequency is a function of the single cavity dimensions. The power output is a function of the total number of cavities, since straps connecting them effectively place the cavities in an electrical parallel circuit.

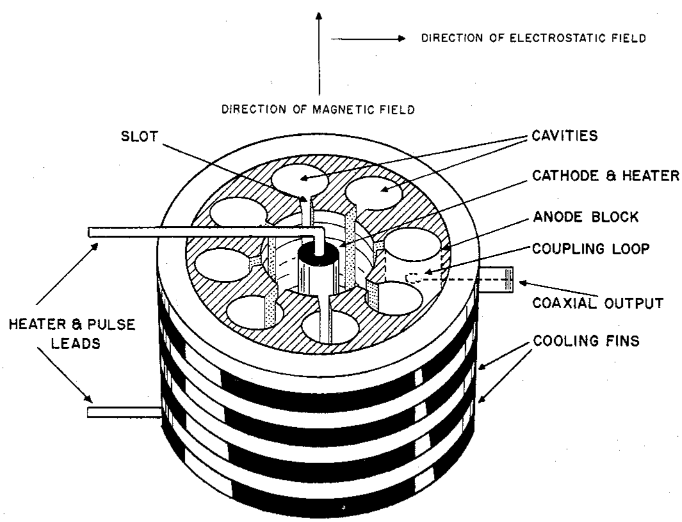


Figure 9. Cutaway view of a typical magnetron.

34. MAGNETRON OPERATION

a. In operation, the input dc voltage is applied as a negative potential to the cathode, with the positive side of the input voltage and the anode block grounded. This results in an electrostatic field between the magnetron cathode and anode block; thus there is a strong accelerating force attracting the electrons from the cathode to the anode. The magnetic field of the permanent magnet is at a right angle to the plane of the electrostatic field, and two forces result that are at right angles to each other. These two fields act upon the electron as it is emitted from the cathode; the result is that each electron takes a spiral path in its transit from the cathode to anode. These circling electrons excite each cavity of the circular anode block as they pass by the cavity opening, causing oscillations in each cavity. These oscillations give a frequency of 1, 220 mc to 1, 350 mc, and the variable frequency range is possible by tuning the cavity size or volume.

b. A spark-gap circuit E505 is connected to the cathode of the magnetron. If the magnetron fails to fire, the high voltage is removed from the cathode by an arc-over across the spark gap. This arcing protects the pulse transformer from damage due to the extremely high voltages across it.

35. METERING CIRCUITS

a. The average magnetron plate current is indicated by the MAGNETRON CURRENT meter M502, which is located on the left front side of the receiver-transmitter unit. When the magnetron fires, the high voltage induced in the bifilar secondaries of the pulse transformer is grounded through C506 and C507B, which are then charging. When charged, the grounded side of the two capacitors is negative; during the time interval between pulses, the capacitors discharge through R517 and meter M502 to ground. Capacitors C510 and C542 in parallel with the meter, act as filters to smooth out the sharp pulse and allow the meter to indicate average magnetron current. With the magnetron and the transmitter system functioning properly, the meter should read from 40 to 44 milliamperes.

b. TEST METER M501, when TEST SELECTOR switch S506 is switched to the MAG FIL position, shows the proper magnetron filament by a red line indication during the time the transmitter is radiating.

36. FILAMENT POWER SUPPLY

a. The magnetron filament is operated by direct current for reasons of greater frequency stability. The dc filament voltage is provided by a full-wave bridge rectifier comprised of T504, a dry-disk rectifier (CR501), and a filter circuit made up of L502 and C508. After long use, the dry-disk rectifier develops an increased voltage drop that reduces the filament voltage. To compensate for the increased voltage drop, the primary of the transformer is tapped in several places, which enables the secondary voltage to be adjusted to give the proper dc output voltage.

b. During the time that the magnetron plate current is flowing, a great amount of heat is generated by the I^2R loss within the magnetron and this heat is added to the filament supply heat. If the filament supply is not reduced upon radiation, the additional heat would result in overheating the cathode and reducing the life of the cathode oxide-coating. To prevent this damage, R516 is placed in the primary of the filament transformer when radiating. During warmup and standby periods, the magnetron cathode current is not flowing and a greater filament voltage is required; therefore, R516 is removed from the primary circuit. Relay K405, located in the power supply, places R516 into the primary circuit during the complete transmission time, thus decreasing the filament voltage. With the TEST SELECTOR switch S506 set to the MAG FIL position, the TEST METER M501 should indicate a red line reading when the transmitter is turned on. When the transmitter is turned off, the reading will be 150 percent of red line due to R516 being removed from the primary circuit.

37. CONTROL AND INTERLOCK CIRCUITS

a. Safety switch S501. A thermal safety switch S501, mounted directly above and behind the magnetron, is connected into the radiate control circuits. If the magnetron heats excessively, the switch will open (at temperatures above 85° C), which opens the circuit to the RADIATE RELAY K152, thus removing the high voltage from the magnetron. After the magnetron has cooled, the switch must be manually reset by pressing the white button connected to the switch. A frequent cause of S501 opening was found to be clogged air filters or blower motor B501 not operating normally. Either condition results in a temperature rise of the transmitter.

b. Interlocks S504A/B. S504A/B are safety interlocks that automatically open when the transmitter chassis is pulled from its inner case. S504B opens the 27-volt dc circuit to RADIATE RELAY K152, which in turn removes the high voltage from the transmitter circuits. S504A opens the 115-volt ac circuit to the primary of the power-supply plate transformer T402, thereby removing the generation of trigger pulses in the modulator. S504A also controls warning lights I501 and I502 in the transmitter unit.

c. Other control circuits. The control circuits that are discussed in the modulator (ch 2) apply to the discussion of the transmitter. It must be remembered that the modulator unit must be operating correctly in order for the magnetron to function properly. The action of the following control circuits are discussed in detail in chapter 2.

(1) K151A/B.

(2) OPERATING HOURS meter M402.

(3) K405.

(4) K152.

(5) S153A/B.

(6) RADIATE ON switch S616 and RADIATE OFF switch S615.

38. CARE OF THE MAGNET

The field strength of the magnet is 1, 400 gauss, and it is highly important for it to retain that strength. The magnets are made of a special alloy called Alnico and are usually strong; however, any hard blow on the magnet will result in its loss of field strength. One sharp blow can sometimes cause a loss of 50 gauss. The length of operating time has little effect upon the field strength if the magnet is handled properly. A loss in gauss will cause the frequency of the magnetron to decrease and possibly cause arcing from the plate to cathode.

39. MAGNETRON SPECTRUM

A perfect square wave may be thought of as being made up of a fundamental sine wave plus an infinite number of inphase odd harmonics that are progressively smaller as the harmonic frequency increases. For example, a 100-cycle per second square wave would contain frequencies of 100, 300, 500, 700, and on to infinity. Since a perfect square wave is impossible to obtain, only a limited number of harmonics are involved. The fundamental sine wave component of a rectangular pulse is related to the width of the pulse as shown in figure 10.

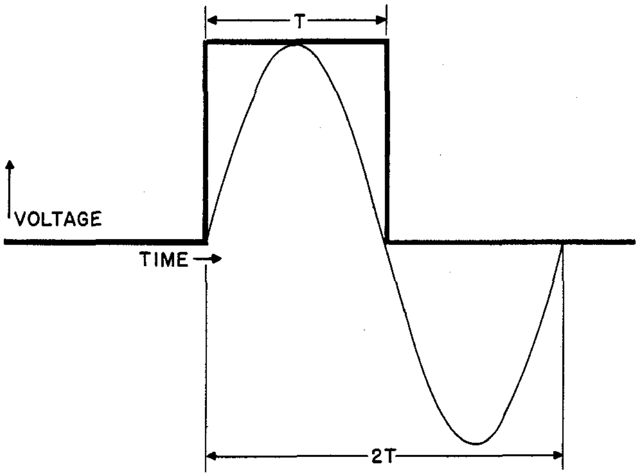


Figure 10. Relationship of the fundamental sine wave to a rectangular pulse.

In figure 10, the width of the pulse is T, and the period of the sine wave is 2T; thus the fundamental frequency, or the pulse frequency as it is usually called, is $\frac{1}{2T}$. Any harmonic of this frequency may be determined by multiplying the expression $\frac{1}{2T}$ by the number of the harmonic. For example, the third harmonic would be $\frac{3}{2T}$. For a 2-microsecond pulse, the fundamental pulse frequency will be $\frac{1}{4 \times 10^{-6}}$ = 250 kc, and the odd harmonics would be 750 kc, 1, 250 kc, 1, 750 kc, etc. These harmonic frequencies modulate the carrier frequency by adding to and subtracting from the carrier, giving rise to side lobes, as shown in figure 11.

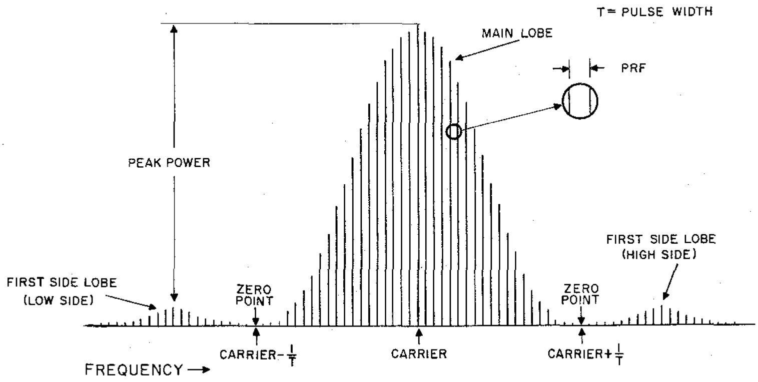


Figure 11. Ideal transmitter spectrum.

40. SPECTRUM TYPES

a. By plotting echo-box meter readings against frequency dial readings, a graph may be constructed indicating the frequency and amplitude of the fundamental and harmonic frequencies for a transmitter. This graph, which is the transmitter spectrum, will disclose maladjustments and troubles that might otherwise be difficult to locate. A transmitter in satisfactory condition should give a spectrum similar to curve (1) of figure 12. Good spectrums are those in which the two halves are symmetrical and in which there are deep, well-defined, minimum points immediately adjacent to the main peak. A curve without a deep minimum, as figure 12(2), indicates that the transmitter output is frequency-modulated during the pulse. This may be caused by too much slope on the sides of the high-voltage modulator pulse, or a pulse that does not have a flat top. It can also be caused by an unstable magnetron. When the spectrum is extremely irregular, as figure 12(3), it is an indication of severe frequency modulation. When the spectrum has two large peaks, which are spaced far apart, it indicates that the transmitter is operating on two frequencies; as a rule this condition is caused by a faulty rf line connection, a bad antenna rotating joint, obstructions in the rf line, or a damaged rf line.

b. The amplitude of the main lobe on either side of the carrier recedes until it reaches zero at the points corresponding to the second harmonic of the fundamental pulse frequency. The side lobes on the high-frequency side of the main lobe represent the result of adding harmonics to the fundamental, while those on the low side of the fundamental result from subtraction. Thus the pattern formed by an ideal spectrum is symmetrical about a vertical line through the center of the main lobe. In the ideal spectrum (fig 11), the first side lobe represents 4.5 percent of the carrier amplitude and the second side lobe is 1.6 percent of the carrier amplitude. The main lobe of the magnetron spectrum has a width of 1 mc. For proper receiver operation, the receiver bandwidth must be wide enough to cover the entire main lobe of the spectrum.

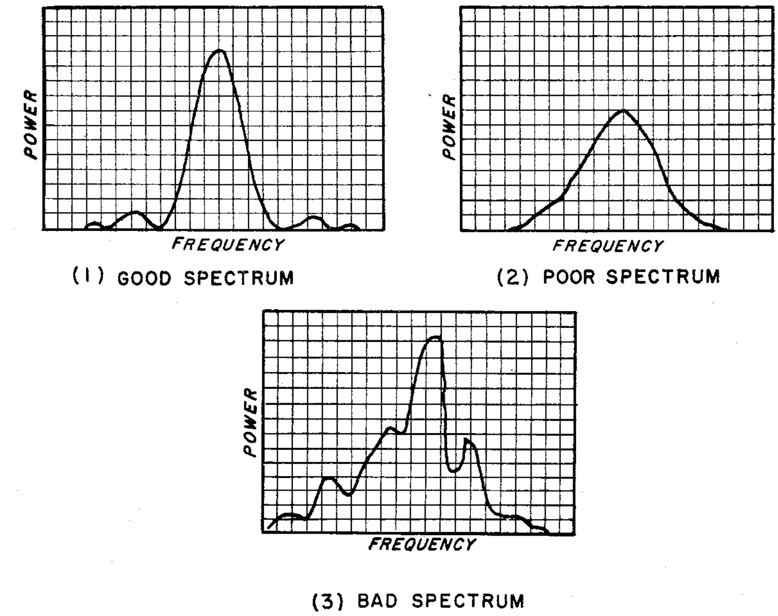


Figure 12. Typical transmitter spectrums.

c. The transmitter spectum may be readily plotted with the aid of the echo box, TS-172B/UP. Essentially, an echo box is a hand-tuned cavity resinator of high Q, excited by means of a loop that is connected by a cable to the R-F TEST POINT J501, of the transmitter. A second loop removes a small amount of power from the cavity and applies it to a power meter. A transient oscillation is induced in the cavity by the radar pulse, and as this transit dies out, a signal from the cavity is fed back into the radar receiver. The tim required for this signal to become imperceptible on the radar screen is known as ringtime

41. MAGNETRON AGING

a. When the magnetron is new or has been out of service for approximately a month or more, it must be aged according to the procedure given below. A magnetron that needs aging produces unstabel magnetron current and is likely to produce arcing in the rf system This is frequently apt to energize the overload relay K151.

b. To age a magnetron, proceed as follows:

(1) Set the MAGNETRON AGING VARIAC switch (modulator unit) to the IN position.

(2) Set the MAGNETRON AGING VARIAC control to 0 (fully counterclockwise).

(3) Log the magnetron tuning dial reading or, preferably, log the transmitter frequenc as measured by the echo box.

(4) Tune the magnetron to the high-frequency end of its spectrum.

(5) Set the RADIATE ON switch S616 to ON and adjust the variac so that the magnetron plate current reads approximately 20 milliamperes as monitored by the MAGNETRON CURRENT meter M502.

(6) Let the transmitter operate under this condition until stable magnetron current and operation are obtained. The time required to reach stable operation cannot be conclusively stated; however, it may require eight hours or more to obtain proper operation. Stable magnetron operation is indicated by stable magnetron plate current and no arcing in the rf circuits.

(7) After stable operation has been obtained at a plate current of 20 ma, slowly increase the plate current by means of the variac. At points of instability, stop the variac and permit the magnetron current to stabilize.

(8) When stable operation has been obtained at a plate current of 40 to 44 ma, slowly tune the magnetron to the low-frequency end of its spectrum. Again, stop the magnetron tuning whenever unstable operation is encountered and permit the magnetron to stabilize.

(9) Tune the magnetron to the original frequency.

(10) The MAGNETRON AGING VARIAC control should now be in the maximum clockwise position. Set the MAGNETRON AGING VARIAC switch to the OUT position. The system is now ready for normal operation.

CAUTION: The MAGNETRON AGING VARIAC switch, S156, should be set to the IN position only when the variac is used for magnetron aging. At all other times the switch should be set to the OUT position to prolong the life of the variac and prevent inadvertent operation of the equipment at a reduced power setting.

42. SYSTEM PERFORMANCE CHART

Radar maintenance may be divided into three main types:

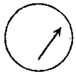
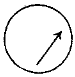
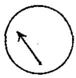
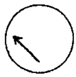
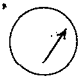
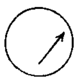
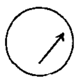
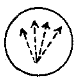
a. Localizing and correcting the specific cause of certain troubles,

b. Recognizing gradual deterioration trends, which lead to the anticipation of failure, and

c. Establishing system performance.

These three functions may be carried out with the aid of an echo box and the information in figure 13.

OVER-ALL RADAR SYSTEM PERFORMANCE

EFFECT	APPEARANCE ON RADAR INDICATOR	APPEARANCE ON ECHO-BOX METER	PROBABLE CAUSE
RINGTIME AND ECHO BOX OUTPUT SATISFACTORY.			RADAR PERFORMANCE SATISFACTORY.
RINGTIME LOW, OUTPUT READING SATISFACTORY.			RECEIVER TROUBLE: DETUNED MIXER OR LOCAL OSC. BAD CRYSTAL, ADJUSTMENT OF PROBES IN MIXER CAVITY. DETUNED T R TUBE CAVITY.
RINGTIME LOW, ECHO BOX METER READING LOW.			LOW POWER OUTPUT. CHECK SPECTRUM.
RINGTIME LOW, ECHO BOX METER READING VERY LOW.			TROUBLE PROBABLY IN TRANSMITTER AND RECEIVER AND OR FAULTY TRANSMISSION LINE.
RINGTIME ERRATIC. ECHO BOX METER READING STEADY.			ECHO BOX DETUNED. BAD PULSING, DOUBLE MODING TRANSMITTER, OR LOCAL OSCILLATOR POWER SUPPLY TROUBLE. CHECK SPECTRUM.
RINGTIME ERRATIC, ECHO BOX METER READING ERRATIC.			FAULTY TRANSMISSION LINE OR CONNECTION. CONDITION WORSE WHEN LINE IS RAPPED.
END OF RINGTIME SLOPES GRADUALLY, POSSIBILY RINGTIME EXCESSIVE. GRASS APPEARS COURSE. TEST SET METER READING STEADY AND SATISFACTORY.			OSCILLATING I F AND/OR NARROW RECEIVER BANDWIDTH.
PRONOUNCED DIP IN RINGTIME AT END OF PULSE.			FAULTY T R TUBE OR DUE TO RECEIVER GATING ACTION.
RINGTIME SLIGHTLY LOW, POOR OR BAD SPECTRUM.		*  POOR SPECTRUM	TRANSMITTER TROUBLE.
BLANK SPACES OR ROUGH PATTERN ON PPI RINGTIME. ECHO BOX METER READING VARIES AS ANTENNA IS ROTATED.			FREQUENCY PULLING OF TRANSMITTER DUE TO BAD ROTATING JOINT OR REFLECTING OBJECT NEAR RADAR ANTENNA.

*PLOTTED ON GRAPH PAPER

Figure 13. System performance chart.

43. SUMMARY

a. The pulse transformer T502 matches the impedance of the pulse-forming network to the magnetron and gives a voltage step-up of about 5:4. The secondary voltage is a negative 27, 000 volts and is applied to the cathode of the magnetron through the bifilar windings, which eliminates the need for high-voltage insulation between the filament supply and ground.

b. The magnetron is essentially a diode with a magnetic field between the cathode and plate that is perpendicular to the electric field. The tuned circuits included in the tube are in the form of cylindrical cavities that are tunable in frequency from 1, 220 mc to 1, 350 mc. The peak power output is 500 kw.

44. QUESTIONS

a. What are the outputs from the pulse transformer T502?

b. What are the multiple purposes of the pulse transformer?

c. High-voltage insulation is not required between the filament supply and ground. How is this possible?

d. Briefly explain the purpose of C509 and R509.

e. What forms the tunable resonant circuits in the magnetron oscillator?

f. Why is there a need for a magnet in the magnetron operation?

g. Name five malfunctions of the magnetron that will cause K151A/B to energize and turn the set off the air.

h. How is the magnetron filament voltage reduced when the RADIATE ON switch S616 is closed?

i. If the magnetron filament voltage reads above red line when radiating, what is the needed adjustment?

j. What are the symptoms that indicate the need for magnetron aging?

CHAPTER 4

RF SYSTEM

Section I. INTRODUCTION AND COAXIAL LINES

45. PURPOSE

The choice of a transmission line from the magnetron to the antenna is determined by the frequency that is employed. For a general breakdown, coaxial lines are used for frequencies from about 250 to 1,000 mc, and waveguides are employed with frequencies above 1,000 mc. The transition between the coaxial lines and waveguides is rather broad in frequency, with either being successful in the 1,000-mc range of frequencies. Since the frequency range of the AN/TPS-1G is from 1, 220 mc to 1, 350 mc, either coaxial lines or waveguides would satisfy the transmission requirements with a minimum of loss to the rf energy. The most practical transmission for the AN/TPS-1G is by coaxial lines due to the radar and IFF signals being transferred through the same line and rotary joint. A waveguid could not carry the two different signals. The only point in the line where a waveguide is incorporated is at the antenna feedhorn. At this point, the impedance of the antenna and free space is matched. The theory of coaxial lines and the AN/TPS-1G rf system are covered in this chapter.

46. CONSTRUCTION OF COAXIAL LINES

a. The concentric or coaxial line has advantages that make it very practical for efficient operation at extremely high frequencies. It consists of a wire inside of and coaxial with a tubular outer conductor (fig 14). In some cases, the inner conductor also is tubular. The inner wire or conductor is insulated from the outer conductor by insulating spacers or bead at regular intervals. The spacers are made of Pyrex, polystyrene, or some other material possessing good insulating qualities and low loss at high frequencies. Coaxial cables are also made with the inner conductor consisting of flexible wire insulated from the outer conductor by a solid continuous insulating material. Flexibility may be gained if the outer conductor is made of metal braid, but the losses in this type are higher than in rigid lines.

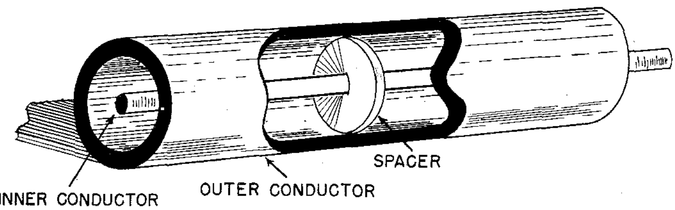


Figure 14. Construction of a coaxial line.

b. The chief purpose of the coaxial line is to keep down radiation losses. The need for a coaxial line arises because in the 2-wire parallel line, the electric and magnetic fields extend out into space for great distances and tend to cause radiation losses and noise pickup from other lines. In a coaxial line, however, no electric or magnetic fields extend outside of the outer conductor, and all fields exist in the space between the two conductors. Thus, the coaxial line is almost a perfectly shielded line.

47. IMPEDANCE OF COAXIAL LINES

a. When a coaxial line is short compared to the length of the radio waves that it carries, the opposition to a voltage applied to its input terminals is chiefly at the load, with a small voltage used in overcoming the resistance of the line. When the line is long as compared to the length of a wave and if the load is not of a certain value, the voltages necessary to drive the current or power over the line may vary greatly from the amount that can be accounted for by the impedance of the load in series with the resistance of the line. The line has other properties besides resistance that create this effect of increased or decreased input impedance. These properties are inductance in series with the line, capacitance across the line, and resistance-leakage paths across the line.

b. If the dimensions of a coaxial line are known, the characteristic impedance can be determined by the following equation:

$$Z_o = 138 \log_{10} \frac{D}{d},$$

where D is the inside diameter of the outer conductor and d is the diameter of the inner conductor. Example: if the inner conductor is a 1/4-inch rod, and the outer conductor is a 0.875-inch tube (inside diameter), find Z_o.

$$Z_o = 138 \log_{10} \frac{D}{d}$$

$$Z_o = 138 \log_{10} \frac{0.875}{0.25}$$

$$= 138 \log_{10} 3.5$$

$$= 138 \times 0.5428$$

$$= 75 \text{ ohms.}$$

This equation can be conveniently plotted as impedance versus dimensions, as shown in figure 15. This graph shows the above example drawn in dotted lines. Notice that 75 ohms is the proper value for the characteristic impedance.

48. TERMINATION OF RF LINES

a. Standing waves. There is a large variety of terminations for rf lines. Each type of termination has a characteristic effect on the standing waves on the line. From the nature of the standing waves, the type of termination that produced the waves can be determined.

b. Impedance termination. One of the outstanding characteristics of lines terminated in a resistive load, which equals its characteristic impedance, is that it will have no standing waves. The voltage and current waves will always be in phase because all of the energy transmitted down the line is dissipated by the load. Therefore, there can be no reflections and no resulting shift in phase between current and voltage waves.

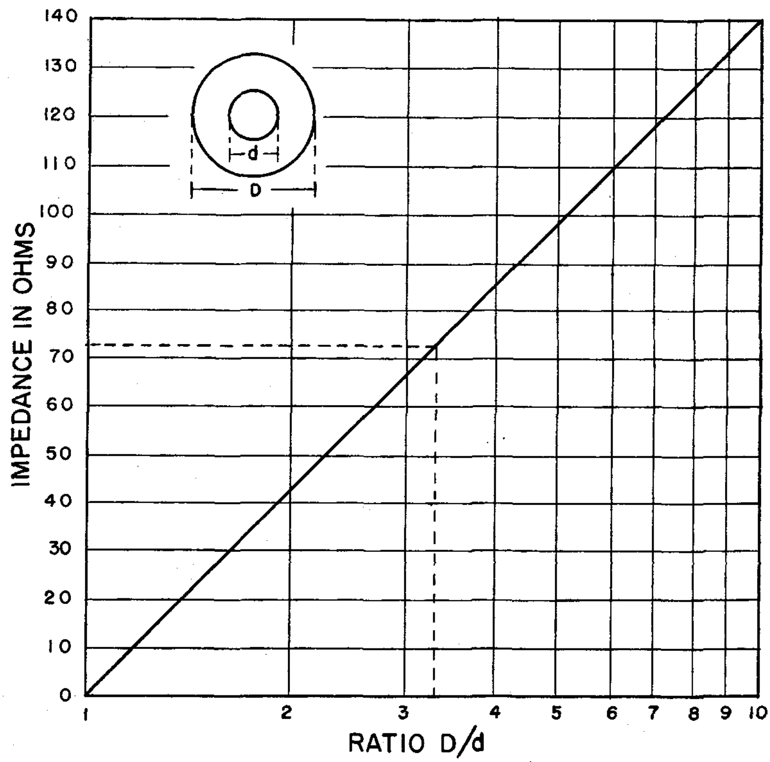


Figure 15. Coaxial line impedance.

c. Open-end line. An open-end line is a transmission line of finite length, and it has no load connected to its output. The output impedance may be considered to be infinitely high, hence no current will flow through it and no energy will be expended into the load. There will always be a maximum amount of reflection along the line to the input terminals except that small amount that is expended as losses in the line. The maximum voltage points and the minimum current point will always be fixed at the end of the line regardless of the frequency of operation (fig 16). The minimum voltage points will always appear at odd multiples of quarter wavelengths back from the end, while minimum current points will always appear at even quarter wavelengths back.

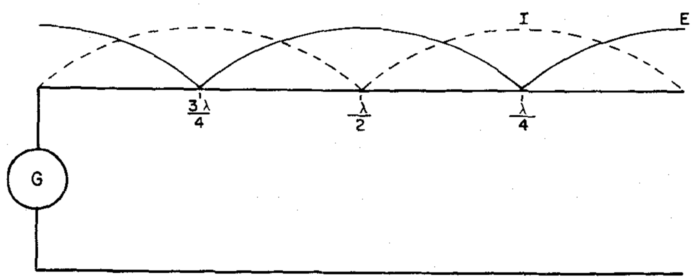


Figure 16. Open-end line.

d. Shorted line. As indicated from its name, the shorted line is a transmission line with a load that is directly shorted. This line again gives a maximum of reflections since there can be no energy expended into a load that has zero impedance. Like the open line, the shorted line is used extensively as an impedance device, such as matching stubs, high-frequency insulators, and resonant tank circuits. As with the open line, nearly all the energy along a shorted line will be reflected back toward the input terminals. However, the phase relationship between the voltage and current waveforms is exactly reversed, as shown in figure 17. This may readily be understood when it is considered that the shorted end of the line would have a fixed minimum value of impedance, which would present a maximum current point and a minimum voltage point at all times. Therefore, all voltage maximum points will appear at odd quarter wavelengths back from the shorted end, while the maximum current points will appear at all even quarter wavelengths. The electrical operation of the shorted line is identical with that of the open line except that the voltage, current, and impedance points are at all times exactly opposite in phase.

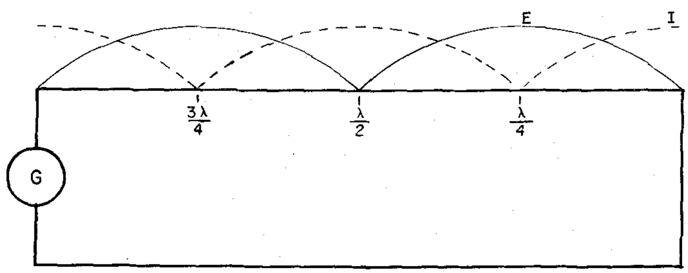


Figure 17. Shorted line.

e. Resonant lines. A resonant line can be defined as a line that possesses standing waves of current and voltage. The line is of finite length and is not terminated in its characteristic impedance. A resonant line is considered at a particular frequency, which means that it is acting as either a high- or a low-resistive impedance. To act in this manner, the line is either open or short-circuited at the output end and is cut to some multiple of a quarter wavelength. If the line is not a multiple of a quarter wavelength, the

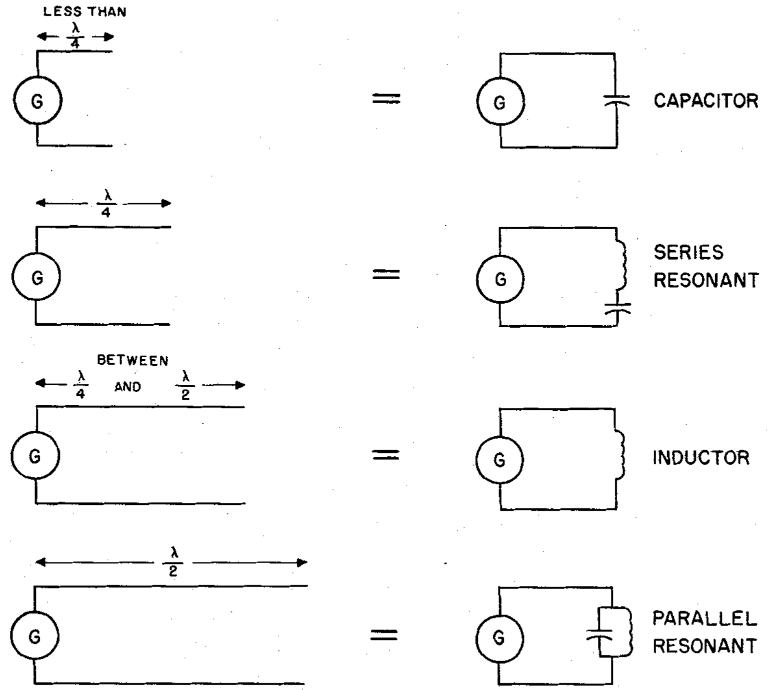


Figure 18. Equivalent circuit diagrams for open end resonant lines

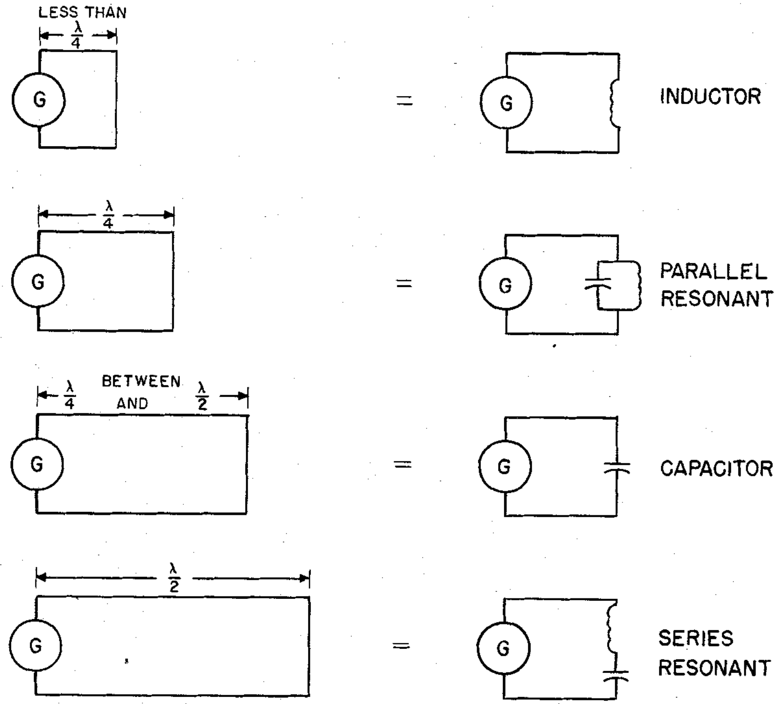


Figure 19. Equivalent circuit diagrams for closed end resonant lines

line acts as a capacitor or an inductor. A resonant line may assume many characteristics of a resonant circuit that is composed of lumped inductance or capacitance. The more important circuit effects that resonant lines have in common with the more familiar circuits are given in figures 18 and 19.

f. Metallic insulators and filters. When a quarter-wave line is shorted at the output end and is excited to resonance at the other end by the correct frequency, there will be standing waves of current and voltage on the line. At the short circuit, the voltage will be zero while the current is maximum. At the input end, the current is nearly zero and the voltage is maximum; therefore, the E/I ratio (and thus the impedance) is very large. An exceedingly high impedance across the terminals looks like an insulator to another line. At a certain frequency a line can be cut to a quarter wavelength, shorted at the output end, and used as an insulator at its two input terminals. Figure 20 illustrates a type of quarter-wave insulator and support for the inner conductor that is used on the AN/TPS-1G. The quarter-wave shorted stub from A to B acts as a high impedance at the radar frequency.

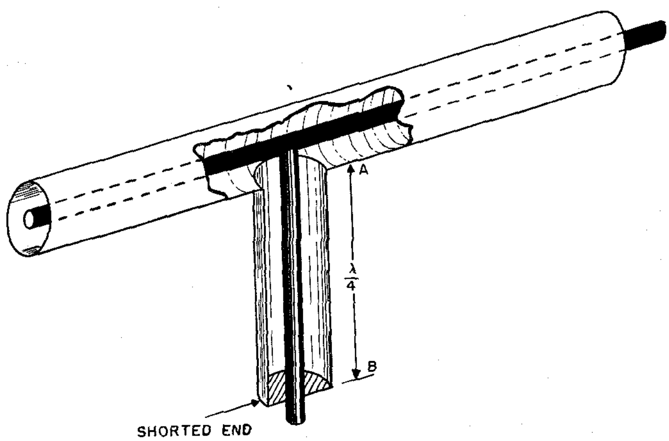


Figure 20. Quarter-wave support used on the AN/TPS-1G.

Section II. AN/TPS-1G RF SYSTEM AND PREVENTIVE MAINTENANCE

49. COMPONENTS

a. The duplexer system in the receiver-transmitter unit consists basically of a length of rigid coaxial line RF501. The output connector of the magnetron is attached to one end of the line, and the other end is terminated at the unit rf output connector J502. Starting from the magnetron end, the energy is coupled past the CAVITIES ASSEMBLY (TR' s), DIRECTIONAL COUPLER, and the COHO MIXER pickoff loop.

b. The directional coupler provides an rf pickup that supplies a small amount of the transmitted energy via P/J504 and a coaxial cable to the RF TEST JACK J501. The attenuation of the coupler is approximately 27 db, but the actual attenuation for each particular coupler in every radar is marked on the coupler. Thus, J501 can be used for checking the transmitter frequency and power. The echo box is connected to J501 for frequency measurement and obtaining the ringtime signal. The sample of the rf energy resonates in the echo box, and the oscillations are coupled back through the directional coupler and into the receiver.

c. The COHO MIXER assembly RF502 is coupled to the line by a small hole or iris at the point of attachment opposite to the directional coupler. The size of the hole, which adjusts the degree of coupling, is predetermined so that the 60-mc output level of the COHO MIXER is approximately 0.5 volts.

d. From RF501 the energy travels through rigid coaxial line RF855 to a flexible coaxial line RF854. RF854 provides a connection between the transmitter and the antenna base and enters the antenna base at RF751. The signals then pass from RF751 through the rotary joint RF752 to the antenna at RF856 and into the waveguide nozzle subradiator through RF754.

50. DUPLEXER AND KEEP-ALIVE POWER SUPPLY

a. The duplexer system consists of dual TR cavities, located in RF503. The duplexer provides an electrical isolation between the magnetron and the receiver circuits. When the transmitter fires, the high rf voltage pulse must not enter the receiver, because it would disable the first mixing stages of the receiver. Returned echo energy must not be allowed to enter the transmitter circuits since this energy is then lost to the receiver.

b. The first TR cavity V503A picks up either the transmitted rf or the echo signals, but the high-voltage transmitted rf energy causes the tube to conduct, which effectively shorts the cavity. Because of the high voltage of the rf energy, it is not necessary to have a keep-alive voltage on the first cavity. When V503A conducts, a short is reflected at the pickoff cavity RF501 and effectively keeps the transmitter signals from entering into V503B and the receiver. However, V503A does not reflect a perfect short, and a portion of the rf will enter V504A. The rf that enters V504A is greatly attenuated and it is necessary to have a keep-alive voltage applied to an electrode inside the tube to insure its conduction upon a small amount of rf voltage. When the transmitter signal travels through RF501 and enters RF503 V503A and V504A conduct and reflect a closed line at this point for the transmitter. Between pulse periods of the transmitter, the TR's V503A and V504A are not conducting and received echo signals are then passed to the receiver mixer circuit.

c. The position of RF503 is made adjustable to provide blocking of returned echo energy from the transmitter circuits. When the distance between the magnetron and the TR cavities is adjusted properly, the transmitter will appear as a very poor path to returned echo signals, and they will enter the receiver with little loss.

d. The keep-alive voltage power supply is composed of V501 and its associated circuit. V501 is a half-wave rectifier with a negative output of approximately 800 volts which is RC filtered by C501, C502, and R501 through R504. Since the rectifier is of the half-wave type, C501 and C502 charge for each half cycle and discharge for a half cycle. In order to limit the peak value of charging current, R505 is placed in series with the charging source and capacitors. R522 and R523 limit the current flow in V504A; therefore, the TR-tube life is increased.

51. OPERATION

a. The method used to transfer rf energy to and from the antenna and the antenna arrangement itself is similar to that used in many microwave radar systems. The antenna uses a waveguide nozzle subradiator that feeds the energy into a narrow beam. Received signals are focused by the reflector onto the subradiator. For simplicity, operation of the antenna system is here described in terms of transmitted energy. Transmitted rf power, conducted to the antenna input connector by a coaxial cable, is transferred to the waveguide nozzle by a rigid, coaxial line system. This system consists mainly of a rotary coaxial joint RF752 mounted concentric to the rotation axis of the antenna.

b. The rotary joint consists of two concentric coaxial lines, the inner conductor of the outside line being the outer conductor of the inside line. The inside line is the transmission line for the IFF signals with the outside line for the radar signals. The circuits of all three conductors are carried through the rotary joint by sliding contacts. The sliding contacts for the outer conductor of the radar line are located just above RF751, at the bottom of the antenna base unit. The sliding contacts for the two inner conductors are located at the top of the antenna spindle in the junction of the spindle and RF856. Connection into the coaxial joint is made through a coaxial T-section. Two input circuits are provided, one for the radar and the other for IFF. The circuits become physically common at the junction of the T, and the quarter-wave stub is used for insulation and support of the inner conductors.

c. Filtered warm air from the antenna servoamplifier unit is supplied to the rotary joint by B701. The warm air, which prevents moisture from collecting on the sliding contacts, enters the air duct in RF751, flows through the rotary joint, and escapes through the air outlet in RF856 at the top of the antenna base unit.

d. At the antenna end of the rotary joint, the two circuits are separated by a method similar to that used at the input. Both output circuits are brought out to separate coaxial connectors. A length of rigid coaxial line, RF754, conducts the radar energy into a fitting on a short length of waveguide that conducts the energy to the radiator horn. The two connectors of this coaxial line are at right angles to the line, and stub supports are used for insulating and positioning the center conductor. Energy is coupled into the waveguide by a short radiator and the waveguide, in turn, feeds the horn. The match between the coaxial line and the waveguide is determined by the size and shape of the short radiator. The waveguide is matched to the horn by an iris, which consists of a short metallic projection, in the center of the broad side of the waveguide at the point where the horn is attached to the waveguide. The horn is proportioned to radiate as narrow a beam as possible at the focal point of the antenna reflector. The reflector then concentrates the energy into a narrow beam, 4° wide, with an electric field that is horizontally polarized.

52. IFF ANTENNA-FEED SYSTEM

a. The IFF antenna-feed system consists of a coaxial line that includes an input coaxial fitting, a rigid coaxial cable, and a 39.75-inch length of RG-9A/U cable. The rigid coaxial cable is incorporated into the search radar feed system of the antenna base unit AB-221/TPS-1G and includes the rotary joint. The flexible cable makes connection between the rigid cable and the IFF antenna. The feed system is capable of handling a maximum peak power of 5 kw.

b. Transmitted signals from the IFF equipment enter the antenna base unit at J756, and RF751 carries the signal to the rotary joint RF752 and then to RF856. RF856 and the IFF antenna are connected by flexible cabel W850 that connects between P/J851 of RF856 and P/J850 of E808, which is attached to the IFF antenna assembly. Assemblies RF751 and RF752 are all rigid coaxial sections with the inner conductor of the IFF line supported inside the inner conductor of the radar coaxial line. In this manner the inner radar conductor becomes the outer conductor of the IFF coaxial line. From E808 at the IFF antenna, connection is made to the IFF radiator through a rigid coaxial line that supports the antenna radiator and has a stub-supported inner conductor.

c. The IFF radiator consists of a half-wave dipole, which is backed up by five rods arranged to form a reflector. The reflector directs the transmitted signal into the radar antenna reflector, which concentrates the signal into a narrow beam. The antenna is so positioned in the nozzle of the radar horn that loss and pattern distortion of the radar and IFF signal are negligible.

53. ROTARY JOINT ADJUSTMENT

a. The arrangement of the rotary joint makes it necessary to center the inner conductor of the rf line at the upper section of the rotary joint. The upper section of the rotary joint consists of the sliding contacts for the two inner conductors. The inner conductor must be centered to prevent arcing at the sliding contacts and to keep the proper spacing between the inner and outer conductors. The inner conductor may become bent if it is not centered properly. Adjustments are provided at the bottom of the antenna base unit for centering the inner conductor. One adjustment, on the front of the antenna base, provides adjustment in the forward-back direction. The other adjustment, on the right side of the unit, allows adjustment in the right-left direction. The centering of the inner conductor should be checked every time the set is emplaced and also at one-week intervals.

b. The centering is done in the following manner:

(1) Remove RF856 from the antenna spindle. RF754 must also be removed.

(2) Move the adjustments until the inner conductor is centered.

(3) Replace RF856 and RF754.

c. If the sliding surfaces of the inner conductor are slightly pitted, they can be burnished with crocus cloth. If they are badly pitted, the complete assembly RF756 must be replaced. Before assembling any rf lines, be sure that the connections are clean and dry and that the rubber gaskets are firmly in place. When joining 2 sections, insure that the 2 pieces fit snugly into each other before the collar is tightened. Use the strap wrench and enough force to tighten the line securely. Take extra precautions in attaching the rf sections at the antenna base. This must be done in the following manner:

(1) Securely attach RF851 to RF751.

(2) Fasten the line support bracket on RF851 to the antenna base, leaving the securing bolts slightly loose.

(3) Loosen the securing bolt at the bracket on the end of RF751.

(4) Remove the cap cover from the top of the antenna spindle, which will expose the inner coaxial conductor. Moving of RF751 and RF851 at the bracket supports will move the inner conductors, as viewed from the top of the spindle.

(5) While observing the inner conductors for exact centering in the spindle, gradually tighten the securing bolts until the lines are rigidly secure with the inner conductors still centered. Exact centering is essential, or the tension on the different sections of the serrated split connector will be unequal when mated with the graphalloy center conductor of RF856. Unequal tension will cause excessive wear to the graphalloy connection, resulting in erosion and arcing; if it is not corrected both RF751 and RF856 will require replacement in a very short time.

(6) Attach and secure RF854 with the line support bracket. Recheck the inner conductor of RF751 at the spindle top for centering.

(7) Attach RF856 at the spindle top. Care must be taken when mating the graphalloy inner conductor with the serrated split conductor to prohibit damage to any of the sections.

Section III. SUMMARY AND QUESTIONS

54. SUMMARY

a. Coaxial lines are used for transmission lines at frequencies around 1,000 mc to give shielding for both magnetic and electrostatic fields and avoid radiation losses. The characteristic impedance of coaxial cables is determined by the physical dimensions of the inner and outer conductors. If a line is terminated with an impedance equal to its characteristic impedance, there will be no standing waves on the line. Quarter-wave shorted stubs are used to support the center conductor.

b. The AN/TPS-1G rf system is basically a length of rigid coaxial line that feeds a short section of waveguide. The transmitted energy passes through a rotary joint and then into the antenna radiating horn. The IFF transmission line is located inside the main radar coaxial line, and the antenna is a half-wave dipole that is located inside the nozzle of the radar horn.

55. QUESTIONS

a. Why are coaxial lines used for the transfer of rf energy instead of two open wire lines?

b. What factors determine the characteristic impedance of coaxial lines?

c. Why is it possible to use shorted quarter-wave stubs as center conductor supports?

d. Explain briefly the rotary joint used in the AN/TPS-1G.

e. Where are the adjustments for the centering of the inner conductor located?

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