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AAFCS M33 TECHNICIAN TRAINING PROGRAM VOLUME IV. TRACK RADAR.(U)

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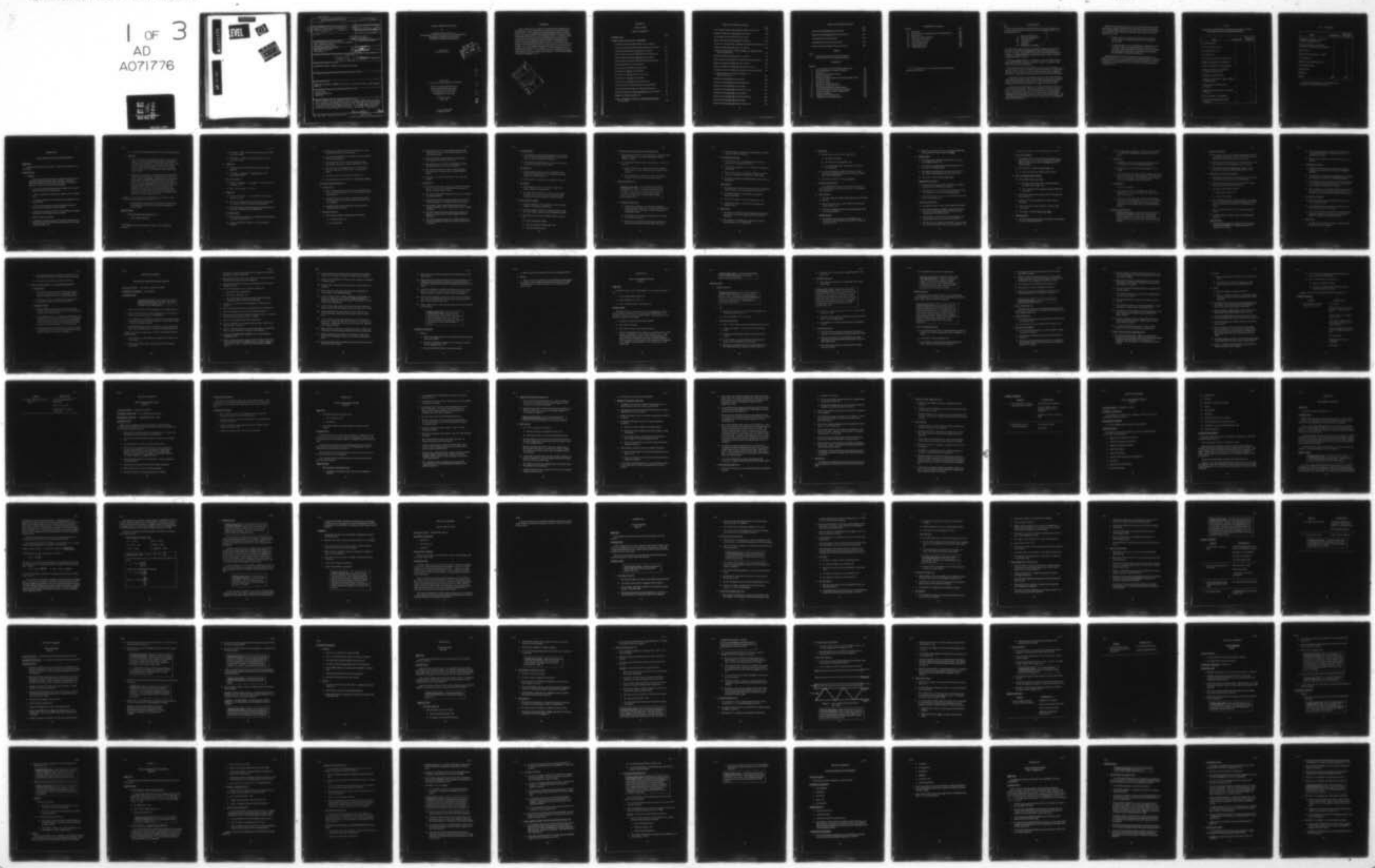

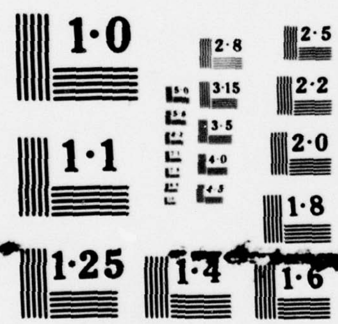

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This is volume IV of six volumes of training material prepared for an experimental course of maintenance instruction on the AAFCS M33 Fire Control System. This volume contains instructional material for the Track Radar subcourse of a program of fire control radar instruction. It includes lesson plans and practical exercises designed to be covered in 180 periods of instruction.

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Technical Supplementary Material

for

HumRRO Technical Report 46:
DEVELOPMENT AND EVALUATION OF AN EXPERIMENTAL PROGRAM OF INSTRUCTION FOR FIRE CONTROL TECHNICIANS (RADAR VI)

Lesson Plans
Practical Exercises

Prepared by
U.S. Army Air Defense Human Research Unit

Under the Technical Supervision of
The George Washington University
Human Resources Research Office
operating under contract with
The Department of the Army

Fort Bliss, Texas
June 1958

FOREWORD

This is volume IV of six volumes of training material prepared for an experimental course of maintenance instruction on the AAFCS M33 Fire Control System. This material was developed during research conducted by the U.S. Army Air Defense Human Research Unit at Fort Bliss, Texas, in cooperation with the U.S. Army Air Defense School. A detailed account of the research, the results and recommendations emerging from the experiment, and the rationale by which this material was prepared and used, is included in HumRRO Technical Report 46, "Development and Evaluation of an Experimental Program of Instruction for Fire Control Technicians." It is recommended that readers familiarize themselves with the contents of this report before attempting to use the training material contained in these volumes. A copy of this report may be obtained by writing to the Director, Human Resources Research Office, The George Washington University, Washington 7, D.C.

VOLUME IV

TRACK RADAR

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TABLES

DIAGRAMS [1/]

DIAGRAMS [1] (continued)

1/ The diagrams refer to drawings that have been specially prepared by the authors.

INTRODUCTION

This volume contains instructional material for the Track Radar subcourse of a program of fire control radar instruction which consists of the following subcourses:

I	Operation Orientation
II	Electronic Fundamentals
III	Acquisition Radar
IV	Track Radar
V	Computer
VI	Maintenance and Supply

It includes lesson plans and practical exercises designed to be covered in 180 periods of instruction: 100 periods of conference and 80 periods of practical exercises. Each instructional period is approximately 50 minutes in length. A detailed breakdown of instructional topics and time allotment is presented in table 1, page 3.

The Track Radar subcourse is designed to provide the student with the information and skills necessary to maintain, repair, and adjust the track radar subsystem of the AAFCS M33.

Instructional material contained herein is that issued to instructors. Material issued to students was identical with two exceptions: (1) copies of practical exercises were not issued, and (2) instructor's notes, suggested explanations, and problems (shown in boxes in the lesson plans) were deleted.

A difference in format exists between material in this volume and those used during the research, in that the experimental lesson plans were printed only on the left-hand pages of the volumes. This arrangement provided student and instructor with convenient and appropriate space for notes.

It will be noted that each page of lesson plans and practical exercises is coded at the top of the page. This code is interpreted as follows: the first letter "I" indicates that these are instructor materials, the second letter indicates the volume (in this case "T" for Track Radar), and the number following the dash indicates the number of the lesson plan in the volume. The code found on practical exercises is similar except for the "P" preceding the number following the dash.

Experience gained during the course of an experiment frequently enables researchers to suggest modifications in design and/or material that should lead to significant improvement of the product. Such modifications have been incorporated into these volumes to the possible benefit of the user and are indicated in two ways:

1. Changes relating to content are described in the introduction to each volume. No such changes have been recommended for volume IV.

2. Changes relating to topic time allotments are indicated in table 1. Numbers indicate recommended hours of instruction for each topic: where recommended time differs from time actually allotted during the experiment, actual time consumed during the experiment is indicated in parentheses.

Although materials in this volume have been carefully prepared, imperfections may still exist. Your cooperation in eliminating them is requested. Notification of errors and suggestions for improvement should be forwarded to the Director of Research, U.S. Army Air Defense Human Research Unit, Fort Bliss, Texas.

Table 1

SUMMARY OF INSTRUCTIONAL* PERIODS ALLOTTED TO TOPICS INCLUDED IN THE TRACK RADAR SUBCOURSE

TOPIC	CONFERENCE	PRACTICAL EXERCISE
Track Radar Block	4	3
Track Transmitter System	8	6
The Decibel and Its Use	4	3
Track Receiver	8	6
Review Track Transmitter and Receiver	4	3
Range Tracking System, Range Servo	4	3
Range Tracking System, Block Diagram	4	3
Main Gate Generator, Timing Wave Generator, Pip Generator	4	3
Pip Selector and Phantastron	4	3
5,000-yard Multivibrator, TRGA, QTRM, TRMK Channels	4	3
Pulse Generator and Range Error Channels	4	3
Range Modulator and Automatic Tracking Controls	4	3
Review of Range Tracking System	3	2
Antenna Positioning System, Block Diagram	4	3

Table 1 (continued)

TOPIC	CONFERENCE	PRACTICAL EXERCISE
Lobing Error Channel, Azimuth and Elevation Angle Detectors	4	3
HP Servo Amplifier, Preamplifier, Azimuth, and Elevation Servo Channels	4	3
Optics Servo	4	3
Antenna Positioning System, General	4	3
Track Indicators	4	3
Monitor Control and Signal Relay	4	3
Track Radar Review	4	3
Examinations	6	9
Critiques	3	3
Total	100	80

*Does not include 20 periods of nonacademic time: Commander's time, physical training, etc.

LESSON PLAN

TRACK RADAR FUNCTIONAL BLOCK DIAGRAM

OBJECTIVE:

To acquaint the student with the purpose, operation, and function of the track radar.

INTRODUCTION:

1. Purpose.

The purpose of the track radar is to furnish the computer with information regarding the slant range, azimuth, and elevation angle of the target. In order for the track radar to accomplish its purpose, it is necessary to provide the following:

a. A system of transmission and reception capable of detecting all types of aircraft out to 100,000 yards;

b. A movable range mark, continuously variable from 0 to 100,000 yards;

c. A dc voltage proportional to the observed slant range D_0 of this movable mark;

d. A servo system designed to keep the movable mark and the reflection from the target in time coincidence;

e. A method of developing an azimuth - and elevation-error signal by which the track antenna can be positioned;

f. Angular target position data;

g. A method of presentation which will furnish the operators with information relative to the position of the target and the setting of the track radar; and

h. A method of positioning the periscope on the target being tracked.

2. Operation.

a. The major function of the acquisition radar is that of locating targets. Since the acquisition antenna rotates continuously, a moving target will appear at a different position on the screen each time the sweep passes over the target. By watching several of these target reflections as they move across the screen, the operator is furnished with an idea of the path the target will take.

b. The process of referring or relaying information regarding the position of the target from the acquisition radar to the track radar is known as designation. Designation is accomplished by positioning the steerable, azimuth line and the acquisition-range circle so that they intersect directly over the target and then activating the ACQUISITION switch. While this switch is being held, the track radar will slew to the range of the acquisition-range mark and to the azimuth of the steerable, azimuth line. As these marks intersect over the position of the target, the track radar will come to rest somewhere in the vicinity of the target's range and azimuth.

Note: It is important that the ACQUISITION switch be held until the track antenna and the range servo both come to rest.

c. At this point the track operators position the track radar more accurately on the target so that the system may begin automatic tracking.

PRESENTATION:

1. Track Transmitting System (fig 11-1). 2/

a. Track Trigger Generator.

2/ Figures are direct references to figures in the AAFCS M33 schematics.

1) The input is a +20v, 2-microsecond sync pulse with 1,000 pulses per second.

2) The output is a +450v, 4-microsecond pulse with 1,000 pulses per second.

b. Modulator.

1) The input consists of the +450v pulse from the trigger generator.

2) The output is a negative, 7.5 negative, 8-kv, 0.25-microsecond pulse.

c. Pulse Transformer.

1) Receives the negative 7.5 to negative 8-kv pulse from the modulator, and

2) Steps it up to negative 25 to 30 kv.

d. Magnetron.

1) Receives the negative 25- to 30-kv pulse from the pulse transformer, and

2) Oscillates for the duration of the 0.25-microsecond pulse at a frequency between 8,500 and 9,600 megacycles.

3) The radio-frequency (rf) power generated during the period of the pulse is between 250 and 400 kilowatts.

e. Track RF System.

1) The 0.25-microsecond burst of rf energy from the magnetron is coupled to the antenna, and

2) A small sample of this energy is sent to the balanced converter.

3) During transmission the function of the TR tube is to keep the transmitted pulse out of the receiver.

4) The rf system terminates in a circular section of waveguide called the scanner horn.

5) The scanner horn is offset 9 mils from the axis of the antenna lens, and rotates at about 1,800 rpm, or 30 cps.

6) After the rf passes through the horn, it is focused by the lens into a pencil beam 20 mils wide at the half-power points.

7) The beam rotates at 30 cps about the antenna axis.

8) Rotating the beam in this manner is called conical scanning.

2. Track Receiving System (fig 11-1).

a. Antenna Lens.

1) With a transmitted pulse of 0.25-microsecond duration and a prt of 1,000 microseconds, 999.75 microseconds remain between pulses.

2) During this time, the lens focuses reflected energy back into the scanner horn, and this energy continues back down the waveguide.

3) During this time, the TR tube allows the energy to pass into the balanced converter.

b. Balanced Converter.

1) The balanced converter is divided into two sections.

a) The signal mixer, and

b) The AFC mixer.

2) The signal mixer receives the reflected signal (8,500–9,600 mc) and mixes it with the output frequency of the local oscillator (LO).

3) The local-oscillator output frequency should <u>always</u> be 60-mc <u>above</u> the transmitted frequency.

4) This mixing results in a 60-mc intermediate-frequency (if) signal which is sent to the if preamplifier.

5) The AFC mixer receives a sample of the <u>transmitted</u> pulse and mixes it with the local-oscillator output frequency.

6) The result is an AFC if signal which is sent to the AFC channel.

c. <u>AFC Channel</u>.

1) Since many of the stages in the track receiver are tuned in 60 mc, it is necessary to control the local oscillator so that the if remains stable at 60 mc.

2) The AFC if signal from the balanced converter is introduced into the AFC channel.

3) If the frequency of this if signal is above 60 mc, the local-oscillator frequency is too high and must be tuned down.

4) Conversely, if the if signal is below 60 mc, the local-oscillator frequency is too low and must be tuned to a higher frequency.

5) The AFC channel determines whether the if signal is too high or too low and sends a control voltage to the local oscillator.

6) The control voltage tunes the local oscillator either up or down in frequency and maintains the signal if and the AFC if at 60 mc.

d. <u>IF Preamplifier</u>.

1) The signal if is sent to the if preamplifier to be amplified prior to sending it through the sliprings to the rest of the receiver system (located inside the van).

2) This immediate amplification is necessary at the antenna to preserve the signal-to-noise ratio.

e. <u>IF Attenuator</u>.

1) The preamplifier output is sent to an attenuator whose purpose is to compensate for loss of gain because of the aging of tubes in the receiver.

2) The attenuator is variable from 0 to 20 db in 5 db steps.

f. <u>IF Amplifier</u>.

1) The attenuated if signal is sent to the if amplifier for further amplification and detection.

2) The output of the if amplifier consists of a video signal composed of the return echo from all targets received during the waiting period between transmitted pulses.

g. <u>Video Amplifier Channel</u>.

1) The video signal from the if amplifier is sent to the video amplifier for additional amplification.

2) The video amplifier consists of a voltage-amplifier stage and a pair of power-amplifier stages arranged in parallel.

3) The outputs from the video-amplifier channel are sent to the:

   a) Delay and nondelay channel,

   b) Trial-fire indicator (TFI) channel, and

   c) Track presentation system.

3. Track Presentation System, Video Channel (fig 11-1).

a. The presentation system is composed of three cathode-ray tubes (CRT) each having its own sweep, unblanking, and video-amplifier channels.

b. A- or K-type presentation may be selected for use in the track indicators.

1) Each track indicator is equipped with a video amplifier which further amplifies the output signal coming from the receiver.

2) This amplified video signal is then sent to the indicator cathode-ray tube for presentation on the screens.

4. Range Tracking System.

> INSTRUCTOR'S NOTE: The components discussed in the following sections are all located in the track range computer. It is important to point out that all parts of the range tracking system are not located within one chassis, even though they are shown within a single block on figure 11-1.

a. Range Mark Generator.

1) As previously mentioned, it is necessary to develop a smoothly variable range mark. In later circuits this mark will be held in time coincidence with the echo from the target being tracked.

2) A dc voltage must be developed proportional to the range setting of the range mark.

3) Since the mark is held at the range of the target, the dc voltage will be proportional to the range of the target.

4) This dc voltage is referred to as the observed slant range D_0 and is sent to the computer.

b. Timing-Wave Generator.

1) A train of sine waves is developed by the timing-wave generator at a frequency of 81.95 kc.

2) The duration of each sine wave is equivalent to 2,000 yards radar range.

3) Fifty-one sine waves are developed, starting at preknock time, and correspond to 102,000 yards radar range.

4) Provisions are made for shifting the phase of this wavetrain through 360°.

c. Pip Generator.

1) The pip generator receives the sine-wave train and develops a positive spike at the leading edge of each sine wave.

2) The peaking amplifier stage produces two outputs of different amplitudes.

3) A 10v chain of spikes is sent to the pip selector, and

4) A 20v chain of spikes is sent to the track-range mark (TRMK) channel.

d. Phantastron.

1) The phantastron develops a negative-going waveform whose least value is +5 volts and whose most positive value is +150 volts.

2) The waveform is 102,000 yards long and has a linearly decreasing slope on its leading edge.

e. Pip Selector.

1) The pip selector receives three signal inputs:

a) The phantastron pulse,

b) The 10v train of timing spikes, and

c) A dc voltage that varies according to the setting of the range servo.

2) The time at which the pip selector develops its output wave will be dependent on the value of its dc input and the phase of the timing spikes.

3) Its output is referred to as the selected pip.

f. 5,000-Yard Multivibrator.

This multivibrator receives the selected pip and yields a 30-μsec (5,000-yd), positive-going, square wave, beginning at *selected pip time*.

g. TRGA Channel.

The track-range gate (TRGA) channel performs the following two functions:

1) Improves the squareness of the 5,000-yard multivibrator output waveform, and

2) Provides an impedance match to the cable taking the TRGA to succeeding channels.

h. QTRMK Channel.

1) The acquisition-track range mark (QTRMK) channel receives the 5,000-yard square wave from the 5,000-yard multivibrator, and

2) Generates a positive spike 15 μsec after the leading edge of the square wave input, called the QTRMK.

i. TRMK Channel.

1) The output of the 5,000-yard multivibrator is also sent to the TRMK channel, and

2) A 20v series of timing spikes from the pip generator is also sent to the TRMK channel.

3) The TRMK channel develops a position-going spike 12.2 μsec after the leading edge of the square wave input.

4) This mark is called the track-range mark.

j. Expansion-Pulse Channel.

1) Receives the track-range mark and generates a negative-going square wave three μsec in duration.

2) The square wave is sent to the sweep channels of all three track indicators and is called the expansion pulse.

3) The expansion pulse is also sent to the TFI for the development of a 500-yard sweep.

k. 100-Yard Notch Channel.

1) The expansion pulse is sent to the 100-yard notch channel.

2) This channel develops a negative, square wave 0.6 μsec wide with a leading edge occurring 1.2 μsec after the leading edge of the expansion pulse.

3) The waveform is sent to the track video amplifier to be mixed with the video at the video-and-notch mixer.

4) The 100-yard notch channel also develops a positive square wave 1.2 μsec in duration called the clear-out pulse, and

5) The clear-out pulse is sent to the lobing-error channel.

l. 35-Yard Gate Channel.

1) This channel receives the expansion pulse and generates a negative square wave 0.2 μsec in duration with a leading edge occurring 1.3 μsec after the leading edge of the expansion pulse.

2) This waveform is called the 35-yard gate, and

3) It is sent to the delay-and-nondelay mixer channel.

m. Delay-and-Nondelay Mixer Channel.

1) This channel receives two inputs.

a) The delay-and-nondelay video signal representing the target and its range, and

b) The 35-yard gate representing the range setting of the track radar.

2) The channel compares the position of the 35-yard gate and the target video.

3) If the two are in time coincidence, no error signal is developed.

4) If the two are not in time coincidence, an error signal is developed.

5) This signal is called the range error signal.

n. Range Modulator.

1) The error signal from the delay-and-nondelay mixer channel is sent to the range modulator.

2) The range modulator develops a 400-cycle signal of either 0° or 180° phase depending on the polarity of the error signal.

o. Range Servo.

1) In MANUAL position, the range servo will be positioned according to the setting of the RANGE handwheel.

2) In AID position, the servo will be positioned by a rate voltage.

3) In AUTO position, the servo will be positioned by the error signal coming from the range modulator. This error signal will be of such a phase as to constantly keep the 35-yard gate in time coincidence with the target echo.

p. ATC Channel.

This channel provides:

1) A *warning for the operator (COAST lamp comes on)* whenever the system ceases to follow the target in automatic tracking, and

2) A means to return the system to aided tracking whenever the target is lost, enabling the system to "coast" at the rate of the target. If the target reappears, the system will relock on it since all conditions for automatic tracking are present.

5. Antenna-Positioning System.

> INSTRUCTOR'S NOTE: At this point it may be well to demonstrate why the amplitude of the reflected video will be modulated at a 30-cycle rate since this point should simplify the discussion of the antenna-positioning system.

a. Lobing-Error Channel.

1) This channel receives from the delay-and-nondelay amplifiers a video signal consisting of a series of 0.2 μsec pulses with amplitudes rising and falling at the rate of 30 cps.

2) The lobing-error channel generates a voltage which rises and falls in proportion to the amplitude of the video pulses.

3) This voltage is called the lobing-error voltage and has components of both the azimuth and the elevation error.

b. Lobing Motor and Reference Generator.

1) The lobing motor is located on top of the track rf section and rotates the scanner horn to form the conical beam.

2) The lobing-reference generator is located within the same housing and is turned by the lobing motor.

3) The output of the generator includes:

a) An east-west voltage, and

b) A north-south voltage.

4) Since the lobing generator is rigidly connected to the lobing motor, it follows that the output of the lobing generator will have a fixed relation to the position of the rf beam at any instant.

5) The N-S reference voltage is sent to the elevation angle detector.

6) The E-W reference voltage is sent to the azimuth angle detector.

c. Angle Detectors.

1) The elevation angle detector compares the N-S reference voltage with the lobing-error voltage and produces an elevation-error signal.

2) The azimuth angle detector compares the E-W reference voltage with the lobing-error voltage and produces an azimuth-error voltage.

3) The two error voltages are sent to their respective servo channels.

d. Azimuth Servo Channel.

1) In MANUAL position the servo positions the antenna in azimuth in accordance with the setting of the AZIMUTH handwheel.

2) In AID position, the antenna is positioned by a rate voltage; this voltage is controlled by the AZIMUTH handwheel.

3) In AUTO position, the azimuth servo receives the azimuth-error signal and repositions the antenna in such a manner as to neutralize the azimuth-error voltage.

4) The azimuth servo can also position the antenna to conform with the azimuth of the steerable, azimuth mark while designating a target from the acquisition to the track radar.

e. Elevation Servo Channel.

1) Control of elevation in AID and MANUAL positions is the same as that for azimuth.

2) In the AUTO position, the antenna is positioned so as to neutralize the elevation-error signal.

3) No provision is made for positioning of the elevation servo during the designation of a target since only range and azimuth are detected by the acquisition radar.

f. Optics Servo.

1) The objective lens of the optic system is mounted on the pedestal just below the antenna.

2) Positioning of the optics in azimuth is no problem as the lens will always point to the same azimuth as the antenna.

3) The optics servo positions the optics in elevation.

6. Track Presentation System, Sweep and Unblanking Channels.

a. Sweep Channel.

1) This channel receives the preknock pulse and develops a 620-μsec, saw-tooth waveform for application to the horizontal deflection plates of the track-indicator CRT.

2) Provisions are made for expanding a 500-yard portion of the indicator sweep to about 3/4 inch of the CRT.

b. Unblanking Channel.

1) With the SWEEP LENGTH selector switch in the OFF position, the unblanking channel allows the track indicators to operate as A-type indicators.

2) In the NORMAL position, the unblanking channel allows the indicators to operate as K-type indicators. K presentation indicates that the azimuth or elevation operator sees two pips for each target, instead of one, and can position the antenna by simply matching the height of the two pips.

3) In the SEL SIG position, the indicators operate as modified K indicators where two 500-yard expanded portions appear and the remainder of the sweep is blanked out.

PRACTICAL EXERCISE

TRACK RADAR FUNCTIONAL BLOCK DIAGRAM

AAFCS M33 SETUP: Track radar completely energized.

EQUIPMENT NECESSARY: Test amplifier.

DEMONSTRATION:

> INSTRUCTOR'S NOTE: Have track radar warmed up and ready for complete operation. Have test amplifier on and ready for use.

1. Monitor the sync pulse on the cable going to J1 on trigger generator.

2. Discuss briefly the purpose of the trigger generator and monitor its output on the cable going to J1 on the modulator.

3. Use a multimeter lead clipped to the end of the test-amplifier probe to monitor the pulse at TP1 on the modulator. Explain why no signal is visible (switch tube not fired).

4. Push TRACK ON button, point out the pulse, and have each student look at the switch tube while it is firing. Push TRACK OFF button.

Caution: Do not let the students go too close to the modulator while the track HV is applied.

5. Point out the track, high-voltage power supply and its connection to the modulator.

6. Discuss the modulator-pulse output and how it gets to the pulse transformer.

7. Go upstairs, and point out the pulse cable emerging from the pedestal and going to the pulse transformer.

8. Open the hotbox cover; point out the connections to and from the pulse transformer and connections to the magnetron.

9. Lift the magnetron blower slightly and demonstrate the action of the tuning-drive motor.

10. Follow the waveguide from the magnetron and point out:

    a. The path the AFC sample takes,

    b. The TR and ATR tubes, and

    c. The local oscillator (caution the students about the 320 volts appearing on the case of the local oscillator).

11. Take the cover off the front of the lobing motor and point out the feedhorn.

12. Note the construction and concave configuration of the antenna lens.

13. Point out the signal-mixer section of the balanced converter.

14. Demonstrate removal of the balanced converter. While it is removed, show the shutter and shutter motor or solenoid.

15. Point out the preamplifier and AFC control chassis.

16. Turn the transmitter on and point out the neon bulb on AFC chassis when the AFC is locked-on.

17. Remove neon bulb and place it in front of the feedhorn. Explain that this is a simple method of checking for radio frequency.

18. Point out the MAGNETRON CURRENT meter and the CRYSTAL CURRENT meters.

19. Remove if input to the AFC channel and note the effect on the neon bulb and on the CRYSTAL CURRENT meters. Replace if input and wait for AFC to lock on. Recheck the two CRYSTAL CURRENT meters.

20. Go back downstairs and point out the if attenuator and if amplifier, using the test amplifier to monitor the output of the if amplifier.

21. Point out video amplifier V19, V20, and V21, using the test amplifier to monitor output.

22. Point out video-and-notch mixer and monitor its output with the test amplifier.

23. Pull out one of the indicators and point out the sweep generator, video amplifier, and unblanking channel.

24. Turn the selector switch to either AZIMUTH or ELEVATION, set indicators to SEL SIG, and turn off the LOBING MOTOR switch. Explain what happened to the split image and mention this as a quick check for the lobing motors.

25. Go to the track range computer and monitor the three output wave-shapes. Remove the track-range mark and note effect on A-scopes.

26. Remove the ACQ track-range mark and track-range gate, and rotate ACQ antenna, noting each time the effect on the electronic cross.

27. Go to terminal 172 in the radar cabinet and use the multimeter to monitor D_O. Explain that while the track radar is in automatic, the voltage that is being read on the meter will represent the observed slant range to the target.

28. Mention briefly that the pulse demodulator generates a range-error voltage that controls the range setting while in automatic operation.

29. Mention that the pulse demodulator also develops a lobing-error signal that has components of both the elevation error and azimuth error.

30. Point out the angle detectors and discuss the formation of the azimuth- and elevation-error signals.

31. Slide out the control drawer and point out the azimuth and elevation preamplifiers.

32. Mention that the azimuth preamplifier drives four high-power servo-amplifiers that in turn drive four motors to position the antenna in azimuth. Explain that the antenna is positioned in elevation by one motor.

33. Point out the handwheel assemblies and their rate pots and clutches. Operate the selector switch from MAN to AID several times and have the students listen for the sound of the clutch engaging.

34. Disconnect the uprighting, prism drive cable and set in an azimuth rate. Have the students look in the periscope and explain that the prism must be rotated by the cable.

35. Refer to figure 19-64. Discuss the operation of the track-transmitter control circuits.

> INSTRUCTOR'S NOTE: Since the student is already familiar with the operation of the ACQ transmitter control circuit, only a brief discussion should be necessary. Point out the location of the various interlocks involved and briefly describe troubleshooting procedure.

SUGGESTED TROUBLES:

1. Primary.

   a. Remove the plunger that closes S1/A on the lower-left-hand door of the radar cabinet.

   b. Pull the track generator slightly out of its Jones plug connector until the green light goes out.

   c. Remove fuse F31/A15 and its associated neon bulb.

d. Remove spade lug on terminal 155 in radar cabinet (fig 19-64).

2. Review.

This part of the class should be actively involved in observing all the symptoms of the troubles inserted and in planning their trouble-shooting approach. Answer any questions on the operation of the control circuit.

LESSON PLAN

TRACK TRANSMISSION SYSTEM
(Part I)

OBJECTIVE:

To give the student a basic understanding of the operation and repair of the:

1. Track trigger generator (fig 12-2),

2. Track modulator (fig 12-2), and

3. Track-transmitter power supply (fig 12-3).

INTRODUCTION:

The track transmitter must produce a pulse strong enough to yield an echo of sufficient amplitude from any target within 100,000 yards. It is designed to develop a peak power of 250 to 400 kw. The characteristics of the track transmitter are as follows:

1. Frequency variable between 8,500 to 9,600 mc.

2. Pulse width of 0.25 μsec.

3. Beam width of 20 mils at the half-power points.

4. Conical scanning with a beam rotation of 9 mils about the axis of the antenna is employed at a speed of approximately 30 cps. A type 5,780 magnetron generates the rf power, and the frequency of operation can be varied between the limits of 8,500 to 9,600 mc. A 10-cm waveguide is used to couple the rf energy from the magnetron to the feedhorn, and the feedhorn, in turn, couples the rf to the antenna lens.

INSTRUCTOR'S NOTE: Cover the detailed block (fig 12-1) before proceeding to the detailed discussion of the transmitter.

PRESENTATION:

1. Trigger Generator.

INSTRUCTOR'S NOTE: Indicate to the student that the 20v, 2-μsec sync pulse is eventually going to become a burst of rf energy traveling through space; the various components used in the transmitter are primarily for the purpose of amplifying the sync pulse to the desired level.

a. T3.

1) The positive 20v, 2-μsec sync pulse is introduced to one of the primary windings of T3.

2) One of the windings of T3 is not used.

b. Blocking Oscillator V1B.

1) V1B is a single-swing, synchronized blocking oscillator, and

2) Is normally cutoff by a -31v bias from the junction of R1 and R2.

3) V1A begins conducting when the 40v sync pulse arrives at its grid.

4) As V1A conducts, a positive voltage is felt at the grid of V1B because of the transformer action of T1.

5) When the grid of V1B goes positive, the tube conducts for a short while and then cuts off because of the action of T1.

6) A positive 460v, 4-μsec pulse is coupled through T1 to the grids of V2.

c. Cathode Follower V2.

1) V2 is biased to cutoff by the -31v appearing at the junction of R6 and R4.

> INSTRUCTOR'S NOTE: Mention the circumstances surrounding the operation of the cathode follower V2. The plate voltage of V2 is +320 volts, yet the signal developed at its cathode has an amplitude of +450 volts. Explain that when the grids of V2 receive the 450v pulse, they start to act as a pair of extra plates. The extra current that flows because of the highly positive grids will develop the 450v pulse at the cathode of the stage.

2) The pulse developed at the cathode of V2 is coupled through C6 and C5 to TP2.

3) The pulse at TP2 is 450v in amplitude and 4 μsec in duration and is called the trigger pulse.

4) The trigger pulse can be monitored with the test amplifier at TP2.

d. General Information.

1) C2 and C7 keep the voltage at the junction of R1 and R2 constant at -31v during periods of grid current flow in V1B.

2) C1B and C3 perform the same function for the voltage appearing at the junction of R4 and R6 whenever V2 or V1A draws grid current.

3) R5 and R8 damp out parasitic oscillations which might occur in T2 and T3.

4) R12 and R10 are also parasitic suppressors.

> INSTRUCTOR'S NOTE: Remind the students that the trigger generator is a separate component, that it is mounted on the modulator, that the trigger pulse is sent to the modulator through a short piece of coaxial cable, and that this cable can easily become loosened or broken.

2. Modulator Section.

The purpose of the modulator section is to develop the 450v, 4-μsec trigger pulse into a negative 28- to 39-kv pulse which will be coupled to the cathode circuit of the magnetron.

> INSTRUCTOR'S NOTE: Have the students draw the primary of the pulse transformer between the dark line leaving P29 on the pulse-forming network, Z1, and ground, and label it T3. Go to figure 12-4, show the actual drawing of the pulse transformer, and explain that the drawing on figure 12-2 is to simplify the following discussion. Mention that the connection between Z1 and the pulse transformer is made through one of the sliprings and can be seen on figure 12-4.

a. Pulse-Forming Network Z1.

1) The pulse-forming network is connected between ground and positive five to nine kv appearing at J2/A3, through L1, V3, and T3.

2) L1 provides resonant charging for Z1.

3) Z1 will begin to charge to the input voltage appearing at J2/A3, which varies between five and nine kv.

4) The charge on Z1 cannot leak off since V3 cannot conduct from plate to cathode.

5) After Z1 reaches its maximum value (1.9 times the input voltage), the switch tube V1/A2 will begin to conduct because of the +450v, 4-μsec trigger pulse applied to its grid.

6) The conduction of the switch tube will discharge Z1.

7) The capacitors in Z1 will discharge in 0.25 μsec.

8) While V1/A2 conducts, the discharge current of Z1 will pass through the primary of the pulse transformer.

INSTRUCTOR'S NOTE: Point out and explain the charge and discharge path of Z1.

b. Pulse Transformer T3.

The discharge current of Z1 flowing through the primary of T3 will couple a neagtive 28- to 39-kv pulse to the cathode circuit of the magnetron (fig 12-4).

c. Switch Tube V1/A2.

1) The waveform appearing at the cathode of the switch tube can be monitored at TP1.

2) This waveform closely resembles the pulse output of Z1.

d. Reverse-Current Diode.

1) Z1 consists of four capacitors in a series-parallel combination with four inductors.

2) T3 and L3/A2 are additional inductances in the discharge path of Z1.

3) When the switch tube discharges Z1, there is a tendency for the combined capacitance and inductance in the discharge path of Z1 to oscillate.

4) The first negative alternation of this oscillation drives the switch tube through its de-ionizing potential, and the switch tube stops conducting.

5) Shortly after V1/A2 quits conducting, the reserve-current diode begins conducting since its plate has become positive with respect to its cathode.

6) The current flowing through V2/A2 passes through R10, R9, and R8 to ground.

7) The voltage developed across R8 is filtered through Z2/A2 and sent to meter M1/A2.

8) Meter M1/A2 then gives an indication of average reverse current.

9) If the magnetron misfires or stops firing altogether, a high impedance is reflected back to the primary of T3.

10) The impedance of Z1 no longer matches the impedance of T3, and the oscillation developed when Z1 discharges is of higher amplitude.

11) The reverse-current diode now conducts harder since its cathode is going more negative, and the reverse current read on M1/A2 is higher.

12) In a normally operating transmitter, reverse current should be at least 10 ma but never more than 20 ma.

e. <u>Track-Transmitter Power Supply (fig 12-3).</u>

1) The track-transmitter power supply is located directly beneath the track modulator section and is used for developing the high dc potentials needed in the operation of the modulator. The unit operates as a conventional, full-wave rectifier.

2) <u>T1/A3.</u>

a) Phase A and neutral are applied across the primary of T1/A3.

b) The output of the secondary is then used to supply filament voltage to the two type 8020 rectifiers.

3) <u>T2/A3.</u>

a) Phase B is applied to terminal 1 of T2/A3.

b) Phase A is applied to terminal 2. The amount of phase A going to terminal 2 can be varied by variac T2/A15 (fig 19-64).

4) The voltage at the primary of the plate transformer can be varied between 120v and 208v by the TRACK MIN MAX control on the radar cabinet power control panel.

5) Filament voltage is applied to the rectifier tubes when the MAIN POWER and RADAR POWER switches are ON.

6) After the TRACK READY lamp is ON, T2/A3 will receive its primary voltage when the TRACK ON button is depressed.

7) The output voltage of the supply at J2/A3 is controlled by variac T2/A15.

8) Relays K2 and K1 are the overcurrent and overvoltage relays, respectively. If the current or voltage exceeds a preset limit, these relays will energize and remove the input voltage from plate transformer T2/A3 in the HV supply.

9) The output voltage and current of the track HV power supply can be monitored at the radar cabinet by meter M4/A15.

10) S1/A3 is a spring-loaded shorting bar that discharges C1 whenever the access door is opened.

11) TY1 and TY2 are spark gaps which provide protection against abnormally high voltages.

12) R1, R2, and R3 perform two functions.

   a) They act as bleeder resistors.

   b) They form a voltage-divider network to provide a voltage suitable for metering.

Caution: Do not work in the modulator with the transmitter on.

COMMON TROUBLES:

Symptom	Probable Cause
1. Meter M4/A15 reads high voltage and no current.	No sync pulse.
	Blocking oscillator or sync-pulse amplifier in trigger generator bad.
	Cathode follower V2 in trigger generator bad.
	Cable between trigger generator and modulator either loose or broken internally.
	Cable from trigger generator goes to TP1 on modulator instead of to J1.
	Switch tube bad.
	Charging diode V3/A2 not conducting.
	L1/A2 open.

	Symptom	Probable Cause
2.	Meter indicates no reverse current.	Reverse-current diode not conducting. R8, R9, or R10 open. Shorted capacitor in filter network Z2.

PRACTICAL EXERCISE

TRACK TRANSMISSION SYSTEM
(Part I)

AAFCS M33 SETUP: Completely deenergized.

EQUIPMENT NECESSARY: Test amplifier and multimeter.

PRELIMINARY TROUBLE: ACQUISITION switch to OFF.

DEMONSTRATION:

Review all the components in the track modulator and their function. Turn the track transmitter on and show the students all the normal indications of a normally operating transmitter.

1. Disconnect the sync-pulse input to the trigger generator and have the students observe the indications on meter M4/A15.

2. Use the test amplifier to monitor the grid waveform at bias monitor TP1.

3. Use the multimeter to measure the bias voltage at TP1.

4. Remove V1 on the trigger generator from its socket and point out the indications on M4/A15. Use test amplifier to monitor grid waveform on TP1 and check the waveform at the trigger-pulse monitor. Demonstrate the "something in, nothing out" method of localizing a trouble to the trigger generator.

5. Disconnect cable going to J1/A2 on modulator. Point out symptoms on meter M4/A15.

6. Measure the dc voltage at pin 4 of E1/A2 with the multimeter.

7. Monitor signal at pin 4 of E1/A2 with test amplifier.

8. Turn the transmitter on and monitor the pulse at TP1/A2.

SUGGESTED PROCEDURE:

Place the TS-147/UP on the ledge at the tactical-control console. Have the group that is not troubleshooting familiarize themselves with the controls on the meter. Go over the check-out procedure for the klystron within the meter.

SUGGESTED TROUBLES:

1. Place a nonconducting V1 in the trigger generator and have the students localize the trouble to the faulty stage.

2. Disconnect trigger-pulse cable entering J1/A2 on the modulator and connect it to TP1/A2.

3. Place a bad V2 in the trigger generator and have students localize trouble to the faulty stage.

4. Disconnect spade lug on pin 4 E1/A2 in the modulator.

LESSON PLAN

TRACK TRANSMISSION SYSTEM
(Part II)

OBJECTIVE:

1. To explain the normal operation of the:

    a. Track magnetron, and

    b. RF channels.

2. To teach the student to recognize abnormal operation in these channels.

INTRODUCTION:

In the previous discussion of the track transmitter, a negative 28- to 30-kv pulse 0.25 μsec in duration was coupled to the magnetron cathode circuit. It will now be necessary to develop a burst of rf energy for the duration of this pulse.

Since the same rf system is used for both transmission and reception, some means must be provided to keep the rf from damaging the crystals forming the first part of the track receiver.

The first part of this discussion will deal with the various circuits used to control the operation of the magnetron.

The second part will deal with the operation of the system after the rf pulse has been developed.

PRESENTATION:

1. Heater-Current Control (fig 19-50).

    a. Transformer T4 supplies heater current for the magnetron filaments.

b. The magnetron heater and cathode are connected internally to prevent arc-over.

c. Transformer T4 is also in series with the two secondary windings of the pulse transformer.

d. Transformer T4 is connected to the low-potential side of the pulse transformer. As a result, T4 does not have to be insulated for the high-potentials that are developed on the magnetron side of the pulse transformer.

e. R3, R2, and S5 are in series with the primary of T4.

f. When the radar power is first turned on, maximum heater current will flow since R3 and R2 are shorted by the contacts of relays K1 and K2.

g. Relay K1 is energized, and its contacts 3 and 2 are made shorting around R2.

h. Relay K2 is deenergized, and contacts 1 and 3 are made shorting around R3.

i. Since maximum heater current will flow at this time, the magnetron filaments will heat up quickly.

j. At the end of five minutes, relay K1 will deenergize, and its contacts 3 and 2 will open; R2 will then be in series with T4, and less heater current will flow.

k. When the track, high-voltage power supply is turned on and the magnetron begins to draw current, relay K2 will become energized, and its contacts 1 and 3 will break. R3 will be in series with R2 and T4.

l. The combination of the remaining heater current and the magnetron plate current will then keep the filaments at the proper temperature.

2. Magnetron Cathode Circuit (fig 12-4).

   a. C5, C6, and C8 in conjunction with L1A, L1B, R21, R20, and R19 all serve to equalize the pulse voltage coupled into both secondaries of the pulse transformer.

   b. Magnetron plate current will flow from ground through R23, the meter M1, relay K2, Z1, L1B, one secondary winding of T3, and through the magnetron.

> INSTRUCTOR'S NOTE: Discuss the parallel path for magnetron current through M4/A15 in the radar cabinet.

3. Meter Circuit.

   a. C9, C10, Z1, and K2 act as filters to:

      1) Smooth out the pulse of magnetron current, and

      2) Allow the meter M1 to read average magnetron current.

   b. Average magnetron current can also be read on M4 (located on the radar cabinet power control panel) when the selector switch is in the CENTER position.

   c. Should an opening in the meter circuit occur, the plate of V3 will increase in potential, and the tube will conduct, allowing the magnetron to continue its operation even though the meter circuit is open.

   d. A spark gap is provided which will short out both secondaries of the pulse transformer in case the voltage on these two windings increases above a prescribed limit.

   e. The voltage across these two windings would rise sharply should the magnetron cease conducting.

   f. Average magnetron current should be at least four ma in order to energize relays K2 and K1.

g. L2 and C7 are not used in the AAFCS M33.

4. Magnetron Tuning Drive (fig 12-4).

a. The operator can select the frequency of operation by use of S1/B29 located in the track receiver control panel.

b. The frequency can also be varied by S1/D9 located on the upper-right hand side of the rf coupler.

c. B2/D17 is the drive motor; its red lead is permanently connected to neutral.

d. Assuming that S1/B29 is operated to increase magnetron frequency:

1) 120v phase A will be applied to the black winding,

2) 120v phase A will be applied to the yellow winding through C4 and C26A,

3) C4 and C26A provide a phase shift for the 120v phase A that is going to the yellow winding of B2, and

4) The motor will now turn in a direction which will increase magnetron frequency.

e. When S1/B29 is operated to decrease magnetron frequency:

1) Neutral will be applied to the phase shift network instead of phase A, and

2) The motor will then turn in a direction which will decrease magnetron frequency.

f. As the motor tunes the magnetron, it will also offset the wiper arm of pot R17A/A17 which is connected between 150v and ground.

g. As the wiper arm of this pot is moved up or down, the voltage picked off is sent to meter Ml/B29 located on the track-receiver control panel. The deflection of the meter will indicate to the operator the portion of the frequency range in which the magnetron is tuned.

h. As motor B2 tunes the magnetron and the pot arm of R17A/D17, it will also vary R17B/ and R17C/D17, which helps to vary the frequency of the local oscillator.

i. When relay K2 is energized by the flow of magnetron current, its contacts 2 and 3 close and apply neutral to one side of T1/D8. The secondary of T1 will then furnish voltage for rectifier V1/D8 (fig 13-2).

j. Relay K4 will energize when contacts 2 and 3 of K2 close. Contacts 1 and 2 of K4 close and apply 150v to the heating element of K3/D10 and the parallel resistors R32, R33, and R34. The current flowing through L12 and L13 at this time will not be sufficient to energize the solenoids. When the heating element in K3/D10 reaches its proper temperature, its contacts 5 and 7 close and furnish a parallel circuit around R34, R33, and R32. At this time, more current will pass through L12 and L13; the solenoid will energize thereby removing the shutter from the waveguide.

k. A directional coupler is provided on the L-shaped piece of waveguide entering the lobing-motor housing. This directional coupler differs from the acquisition directional coupler only in that it is unidirectional instead of bidirectional. This means that it can only be used to measure direct power instead of both direct and reflected power.

l. A rotating waveguide joint is used at the junction of the stationary, L-shaped waveguide housing the directional coupler.

5. <u>Track RF System (fig 13-1).</u>

a. The burst of rf 0.25 μsec in duration generated by the magnetron must be:

1) Coupled to the antenna;

2) The receiver must be protected from this rf energy during the transmitted pulse; and

3) During the waiting period, the receiver must be allowed to respond to any echoes that may be received.

b. The units that perform this function are referred to collectively as the duplexer.

c. The transmitted rf pulse is introduced to the duplexer. Part of this energy goes through an attenuator and is sent to the balanced converter.

d. Most of the rf energy continues down the waveguide and ionizes the gas in the two ATR tubes.

e. The TR tube is held in a state of partial ionization by a -250 keep-alive voltage. When the rf pulse arrives, it completely ionizes the gas in the TR tube.

f. At this time, the two ATR will have no effect on the rf pulse, but the TR will block rf and keep it out of the receiver.

g. Radio frequency continues down the waveguide to the feedhorn and the lens. There it is focused into a narrow beam 20 mils wide at the half-power points.

h. The feedhorn is offset from the axis of the lens by 9 mils and is continually rotated by the lobing motor thereby producing a conical scan.

6. <u>Antenna Lens</u>.

The properties of high-frequency rf make it necessary to use a concave configuration in the lens in order to focus it into a pencil beam.

7. Keep-Alive Power Supply (fig 13-2).

a. When the track magnetron conducts, K2/D8 (fig 12-4) will energize.

b. Contacts 3 and 2 of K2/D8 (fig 13-2) will close and apply ground to the primary of T1/D8.

c. Rectifier V1/D8 and its associated circuitry will furnish the TR tube with -250 keep-alive voltage during the time the transmitter is firing.

8. Crystal Shutter.

a. A copper shutter is inserted into the waveguide during periods when the transmitter is not turned on.

b. When the transmitter is operating, it is necessary to remove this shutter from the waveguide by energizing L12 and L13 (fig 13-2).

c. These solenoids remain energized as long as the transmitter is operating, and they hold the shutter out of the waveguide.

d. When the transmitter is turned off, solenoids L12 and L13 are deenergized.

e. The shutter is spring-loaded so that, when the solenoids de-energize, it will snap back into the waveguide.

f. When the transmitter is off, the TR tube will not receive the keep-alive voltage and will offer no protection for the sensitive receiver crystals. The shutter is inserted into the waveguide for protection of the receiver crystals when the transmitter is off.

g. A time delay is provided, making it impossible to remove the shutter from the waveguide until the keep-alive voltage supply begins applying voltage to the TR tube.

COMMON TROUBLES:

	Symptom	Probable Cause
1.	Very high reverse current; constant arcing in the hotbox.	Glass punctured in magnetron. Filament contacts on the magnetron either loose or corroded. Voltage on modulator raised too high.
2.	Signal-mixer crystals constantly burning out.	No keep-alive voltage. Bad TR tube.

PRACTICAL EXERCISE

TRACK TRANSMISSION SYSTEM
(Part II)

AAFCS M33 SETUP: Energized to standby.

EQUIPMENT NECESSARY:

Test amplifier, TS-147/UP, rope, magnetron, wrench, screw driver, multimeter, and Allen wrenches.

PRELIMINARY TROUBLE:

V1 in track trigger generator replaced with a bad tube.

DEMONSTRATION:

Open the track rf coupler and hotbox and remove magnetron blower motor. Point out the following:

1. Magnetron and magnetron tuning drive,

2. Controls for magnetron tuning drive,

3. Magnetron filament transformer,

4. S5/D7 in the hotbox,

5. V3/D7 in the hotbox,

6. All the cathode connections to the magnetron,

7. Spark gap,

8. Network Z1/D7 in the hotbox,

9. Directional coupler,

10. Lobing motor,

11. TR tube,

12. Keep-alive voltage power supply,

13. Shutter,

14. Meter Ml/D8,

15. ATR tubes,

16. S4/D7 on the door of the rf coupler,

17. Air-operated switch on the blower motor,

18. Frequency meter on the tracking console, and

19. Scan-rate indicator.

SUGGESTED PROCEDURE:

Have the students remove the track magnetron, tuning motor, ATR tubes, and the balanced converter.

Have each student examine the components closely.

While replacing the magnetron, warn the students about checking the frequency setting on new magnetrons before connecting the drive cable. Make sure the blower outlet has slipped over the flanges on the duct going into the hotbox. Mention that this is a common fault in replacing the magnetron blower and will result in shortening the life of the magnetron owing to a lack of ventilation.

Tie the track antenna down and prepare the TS-147/UP for use.

Spend the rest of the lab period showing the students how to measure power and frequency. Have them record their results with grease pencil on the long-range plotting board. Try several voltage and frequency settings and compare the results.

LESSON PLAN

THE DECIBEL AND ITS USE

OBJECTIVE:

To define the decibel and explain its use.

INTRODUCTION:

Before proceeding further with the study of radar, it is necessary that the student learn something of the common methods used to express and compare the operating characteristics of electronic components.

The use of the decibel (db) began back in the early days of radio when electronics meant nothing more than the conversion of electrical power to sound. As a result, some unit of measure to express the loudness response of the human ear was necessary.

In the following years the science of electronics was expanded to include fields such as television, radar, and guided missile development, in which the end result was not the conversion of electrical power to sound. However, the use of the decibel persisted since it had, by then, been well established in the vocabulary of electronics.

In the discussion to follow, the term decibel, as well as the manner in which it is used, will be defined as clearly as possible.

PRESENTATION:

> INSTRUCTOR'S NOTE: It will be necessary to review some of the basic ideas about logarithms. Spend no more time than is absolutely necessary on this subject.

It has been experimentally determined that the human ear is such that the impression it gives of the loudness of a single note is not linearly proportional to the sound energy acting upon it but is approximately proportional to the logarithm of the sound energy. For example: Stan Kenton's orchestra while playing a loud, brassy passage creates a sound energy about one million times as great as does the same passage softly played on an alto sax. However, to the normal human ear, the loud passage does not sound one million times as loud as the soft passage. It sounds only about 60 times as loud. The energy ratio in this case is one million to one, and the loudness ratio is about 60 to one. This fortunate little quirk of our hearing mechanism prevents us from ending up with no eardrums whenever we hear sound waves of great energy.

We have now determined that an increase in sound energy from one to one million will cause an increase in loudness from one to 60.

If we know how much the sound energy is to be increased, we can readily find the corresponding increase in loudness by the formula:

$$\text{Apparent volume increase} = \text{ten times the logarithm of } \frac{\text{larger power}}{\text{smaller power}}.$$

In abbreviated form, this could be written as follows:

$$db = 10 \log \frac{P_2}{P_1}$$

Therefore, if we wish to compute the apparent volume change from the soft alto passage to the same passage played by the complete orchestra including brass, we have

$$db = 10 \log \frac{1,000,000}{1} \quad \text{or} \quad db = 10 \log 1,000,000 .$$

The log of 1,000,000 is 6; therefore, the apparent volume increase would be 10 x 6, or 60.

We can use the same formula in amplifiers to denote the value of amplifier gain. For instance, an amplifier strip will yield an output signal of one watt by using a signal of one microwatt as an input. We have the same ratio here as we had with the orchestra, and we end up with the same figure, except that, this time, we say the amplifier has a gain of 60 db. Any time an amplifier yields one million times as much power as was put in, we can say the gain of that amplifier is 60 db.

Since the decibel can express a degree of gain, it follows that it can also be used to express a degree of loss or attenuation. For instance, one watt of power is developed on the plate of an amplifier stage; yet, on the grid of the following stage, only one microwatt appears. We can say then that there is a 60-db attenuation, or loss, between the plate and grid, or -60 db.

It must be remembered that only logarithms to the base 10 are used in the computation of db.

1. Relationship of Power Ratio to db.

1 to 1 = 0 db	1 to 100 = 20 db
1 to 1.259 = 1 db	1 to 1,000 = 30 db
1 to 10 = 10 db	1 to 1,000,000 = 60 db

INSTRUCTOR'S NOTE: Since $P = I^2R$, or $P = \frac{E^2}{R}$,

if we substitute these values for P in the equation for decibels, we have:

$$db = 10 \log \frac{(I_2)^2 R_2}{(I_1)^2 R_1}$$

which can be simplified to the following:

$$db = 20 \log \frac{I_2 \sqrt{R_2}}{I_1 \sqrt{R_1}}$$

$$\text{Also, } db = 20 \log \frac{\frac{E_2}{\sqrt{R2}}}{\frac{E_1}{\sqrt{R1}}}$$

2. Reference Level.

> INSTRUCTOR'S NOTE: Ask someone in the class how much power we have at the output of an amplifier if the gain of the amplifier is 60 db. If an answer is given, explain why it is wrong. The discussion should now lead naturally to the reference level.

Since the decibel is actually only a ratio, it cannot be used to express a given amount of power. For example, it would be foolish to say that a transmitter has a peak power of one million to one. Since we are trying to denote power with a ratio, the expression is meaningless.

Consider, now, that we have an amplifier with a gain of 60 db, and we insert an input signal with a strength of one milliwatt. A simple calculation will reveal that the output of the amplifier will be 1,000 watts. In other words, if one milliwatt is amplified by 60 db, we end up with a certain amount of power (1,000 watts). If we can always refer to a given amount of power in terms of how many db one milliwatt has to be amplified to equal that power, then we can use the db to actually express a power value.

In the preceding case, we could refer to 1,000 watts of power as 60 db over one milliwatt. By using the conventional abbreviation, we denote 1,000 watts of power as 60 dbm, or one watt of power as 30 dbm.

> INSTRUCTOR'S NOTE: At this time have the students consult one of the watts versus dbm charts and call attention to the fact that as the dbm value is increased by three the power is doubled.

In radar the expression dbm is used to denote average and peak transmitter power. For instance, the acquisition transmitter has a peak power of one million watts or 90 dbm. The track transmitter is capable of 250,000 to 400,000 watts peak power or 84 to 86 dbm. In either case, the dbm figure is arrived at by finding the amount of gain in db's that one milliwatt must undergo to equal the given amount of power.

SUMMARY:

1. The decibel is an expression denoting the ratio between two given amounts of power.

2. When P_2 is the larger, and P_1 the smaller power, db = $10 \log \frac{P_2}{P_1}$.

3. If the proper substitutions in the formula are made, db can be expressed in terms of current and voltage.

4. When we refer to the power output of a transmitter as 60 db, the expression is meaningless.

5. If we refer to the same power as 60 dbm, the expression means 1,000 watts.

6. A-dbm means db below one milliwatt.

7. A dbm means db above one milliwatt.

INSTRUCTOR'S NOTE: The remaining periods for this conference will be devoted to a troubleshooting discussion. Good troubleshooting techniques should be outlined. Following the outline, the discussion will proceed to classroom troubleshooting in which the instructor will list the indications as they would appear on the equipment, and the students will suggest the corrective procedures.

PRACTICAL EXERCISE

USE OF THE TS-147/UP

AAFCS M33 SETUP: TRACK READY light on.

EQUIPMENT NECESSARY:

1. Multimeter,

2. TS-147/UP, and

3. and Rope.

PRELIMINARY TROUBLE:

Remove the 10-ampere fuse, XF32/A15, and its associated light on the radar cabinet (fig 19-64).

DEMONSTRATION:

After the trouble has been cleared by the students, review the symptoms of the trouble: TRACK READY lamp glows brighter as the variac is moved clockwise and the voltage goes down instead of up . . . then, after a while, the HV kicks off. Make sure the students note all the symptoms and then, proceed with the explanation of the trouble. Use both figures 19-64 and 12-3 for the explanation.

Have the students tie down the antenna and prepare the TS-147/UP for use. Have each man use the TS-147/UP for the power and frequency check. Make the first check with the transmitter at about five-kv input and gradually increase the input voltage until the mechanical stop is reached. Have the students note how the power output of the transmitter varies with the voltage input. Record each man's results on the long-range plotting board and constantly call attention to the comparison of the results.

The students should become familiar with the operation of the TS-147/UP to such a degree that reference material (graph excepted) will not be necessary to perform the power and frequency measurement.

IT-P4

It might be a good idea to try different frequency settings on the transmitter in order to find the one frequency at which the transmitter radiates the most power.

LESSON PLAN

TRACK RECEIVER
(Part I)

OBJECTIVE:

To familiarize the student with the operation and repair of the track receiver.

INTRODUCTION:

In preceding discussions, it was learned that the track transmitter emits a burst of rf energy which is later focused into a narrow beam. Any target coming within this beam creates a signal reflection which is picked up by the antenna and sent to the receiver.

The receiver will operate only during the waiting period between transmitted pulses because of the action of the TR tube.

PRESENTATION:

> INSTRUCTOR'S NOTE: Explain the appropriate parts of the track-receiver detailed block diagram (fig 14-1).

1. ATR Tubes V4 and V5.

   a. The reflected signal is focused into the feedhorn by the antenna.

   b. The signal travels down the waveguide to the Y-junction.

   c. The amplitude of the reflected signal is not sufficient to ionize the gas in the ATR tubes.

   d. The ATR tubes present maximum impedance, at this time, to the branch of the Y-junction which leads to the magnetron.

e. The action of the ATR tubes prevents the echo from being dissipated within the magnetron.

f. The TR tube presents minimum impedance to the echo.

g. The echo then passes through the TR tube and the waveguide shutter and arrives at the balanced converter.

2. Balanced Converter (fig 14-2).

a. The converter is a mixing device in which the frequency of the received signal is mixed with the frequency of the local oscillator.

b. The local-oscillator frequency is maintained at 60 mc above the received frequency.

> INSTRUCTOR'S NOTE: Point out that the present discussion deals with the signal-mixer section of the balanced converter and that the AFC sections will be covered later.

c. Two crystals CR1 and CR2 are used in the signal mixer to detect the frequency difference between the echo and the local-oscillator frequency.

d. The current passing through the two crystals can be measured by M2.

e. By manipulation of S6, M2 can be made to read the current through CR1 or CR2.

f. Current through each crystal should be approximately one ma.

g. The 60-mc if signal, resulting from the action of the two crystals, is sent to the preamplifier.

3. Track IF Preamplifier (fig 14-4).

a. The output of the signal mixer consists of an extremely weak, 60-mc signal. This signal will eventually be displayed on the

A-scopes and will control the auto tracking circuits. For this reason it must be greatly amplified.

b. Since any noise picked up at this time will be amplified at the same ratio as the signal, some method must be employed to limit the amount of noise pickup.

c. Noise is reduced by amplifying the weak if signal as soon as it leaves the balanced converter.

d. The preamplifier is located about four inches to the left of the signal mixer.

e. The short length of coaxial cable that connects the signal mixer to the preamplifier reduces the amount of noise pickup.

f. The preamplifier will amplify the 60-mc if signal to such a level that noise picked up in the sliprings and cable to the if amplifier will not materially reduce the signal-to-noise ratio.

g. <u>V1 and V2.</u>

1) The 60-mc if signal arrives at *J13/D10 (fig 14-4)*.

2) C1 couples the signal to the cathode of V1.

3) The grids of both V1 and V2 are grounded to reduce grid noise.

4) T1 couples the output of V1 to the cathode of V2.

5) C8 couples the output of V2 to the grid of V3.

h. <u>V3, V4, and V5</u>.

1) The final three stages of the if preamplifier consists of high-gain pentodes.

2) Coupling between the final three stages is accomplished by means of the double-tuned transformers T2 and T3.

3) R7, R8, R12, and R13 load T2 and T3 to broaden the bandpass.

4) Z2 tunes the grid circuit of V3 to approximately 60 mc.

5) The bandpass of the preamplifier is 10 mc.

i. Delay Line DL1.

1) By energizing K1, DL1 is inserted in the grid circuit of V3.

2) DL1 uses the if signal from the transmitted pulse to generate a series of range calibrate marks 12.2 μsec apart (2,000 yd).

3) The calibrate marks are visible on the A-scopes, as a series of gradually diminishing vertical spikes.

> INSTRUCTOR'S NOTE: Explain the method of controlling the gain of the last stages in the preamplifier with MGC AGC switch S2/B29 in the MGC position only.

4) The output of the preamplifier is sent to the if attenuator located in the radar cabinet.

4. Attenuator A40 (fig 14-5).

a. When the tubes in the if preamplifier and if amplifier are new, the gain of these two units will be higher than necessary.

b. An attenuator is used to maintain the gain of the two units at a uniform level over the lifetime of the tubes.

c. The attenuator is variable from 0 to 20 db in 5 db steps.

5. IF Amplifier.

a. The if amplifier is mounted on the pulse demodulator chassis located in the radar cabinet.

b. The first five stages are conventional if amplifiers.

c. The last stage is a detector.

d. Double-tuned if transformers are used for coupling between stages with the exception of T1 whose primary can be tuned by C2 to match the impedance of the input cable.

e. The resistor across the transformer windings widens the band-pass of the if amplifier to 10 mc.

f. The output of V5 is coupled to the cathode of V6 through T6.

g. Only one half of V6 is used.

h. The detector will pass only the negative half of the signal applied to its cathode.

i. L7 and C13 filter the if component of the output of the detector.

j. The envelope of the if signal will be developed across R21 and is called track video.

6. Video Amplifier V19, V20, and V21.

a. The video output of V6 must be amplified to a sufficiently high level in order to control the automatic track circuits and for application to the track indicators.

b. Voltage amplifier V19 is a high-video amplifier with R144 providing cathode bias.

c. Any signal more negative than negative four volts will bias the tube to cut off.

d. The output of V19 is coupled to the grids of the two parallel power amplifiers through C45.

e. The grids of the power amplifiers are returned to a bias of -23 volts at the junction of R147 and R148.

f. V20 and V21 amplify the output sufficiently to drive the automatic track circuits and the video-and-notch mixer.

g. The output of V20 and V21 is coupled to delay line Z1 through C48 and C49.

h. The video sent through Z1 is delayed by 0.22 μsec and is labeled delayed video.

i. Part of the video does not go through the delay line and is labeled nondelay video.

j. The delayed video is applied to the grids of the video-and-notch mixer.

7. Video-and-Notch Mixer.

a. The purpose of this stage is to mix the track video with the 100-yard notch.

b. Both halves of twin-triode V7 are used to provide larger current-carrying capacity.

c. Since the output of the stage is taken from the cathode and since track video is applied to the two grids, V7 will act as a cathode follower for the video.

d. Mixing is accomplished in this stage by using R43 as a common cathode resistance for both V8B and V7.

e. Energizing relay K1 with the FILAMENTS switch in the trial-fire indicator, or with NOTCH ELIMINATE switch S3/B1, will remove the 100-yard notch altogether.

f. The output of V7 is sent to the video amplifiers in the three tracking indicators for further amplification before application to the A-scopes.

> INSTRUCTOR'S NOTE: Explain that for normal vertical deflection on the A-scopes, a video signal from 50 to 70 volts is necessary, and that the average signal picked up by the antenna is somewhere in the neighborhood of 5 to 8 microvolts. This means that the reflected signal must be amplified between 10 and 15 million times. It is for this reason that so many stages of amplification are used. As much time as possible should be devoted to classroom troubleshooting discussion.

COMMON TROUBLES:

	Symptom	Probable Cause
1.	No track video or receiver noise.	S2/B29 in the MGC position and gain control R21/B29 at minimum. Bad stage in the preamplifier. Bad stage in if amplifier. V19 video amplifier bad.
2.	Receiver noise present but no track video.	Bad crystal CR1 or CR2. Shutter not opening. Bad tube in V1 or V2 in the preamplifier.
3.	Very large amplitude on the 100-yard notch and no track video.	V7, video-and-notch mixer, bad.
4.	No 100-yard notch.	FILAMENTS switch on trial-fire indicator ON.

	Symptom	Probable Cause
5.	No range calibrate marks.	K1/D11 in preamplifier not energizing (check switch S12/B31 in tracking console).
		Bad preamplifier chassis.
6.	Very weak track video.	Crystal CR1 or CR2 weak.

INSTRUCTOR'S NOTE: Caution the students about the frequent mistake of connecting one end of the cable going to the if amplifier to the range-calibrate jack instead of the attenuator.

PRACTICAL EXERCISE

TRACK RECEIVER
(Part I)

AAFCS M33 SETUP: Track transmitter warmed up and ready to energize.

EQUIPMENT NECESSARY: Test amplifier and eight feet coaxial jumper cable.

DEMONSTRATION:

1. Open the rf coupler, point out the TR tube and its connection to the keep-alive voltage power supply, and answer any questions regarding the path of the return, or echo, through the balanced converter and if preamplifier.

2. Return to the radar cabinet and go to terminal 3 on P1/A39 on the if preamplifier. Show the students how the track video signal can be monitored at this point. Also, remind the students that this is the first place in the track receiver at which track video can be seen.

3. Attempt to monitor the if input to the track if amplifier. Explain why there is such poor presentation.

4. Explain what the if amplifier does to the 60-mc if signal, and that, since the output of the last stage has been rectified or detected, it will now be a video signal.

5. Monitor the input signal to the grid of V19.

6. Monitor the plate signal of V19.

7. Monitor the signal on pin 1 of Z1, the 0.22-μsec delay.

8. Remove either V20 or V21. Monitor the signal at pin 1 of Z1. Explain that if one power amplifier goes bad, the other will still pass video.

9. Monitor the signal at the grids of V7, the video-and-notch mixer.

10. Monitor the output of the video-and-notch mixer, both with V7 in its socket and with V7 removed.

11. Remove V6 in the track if amplifier and monitor the video signal at pin 3 of P1/A39.

> INSTRUCTOR'S NOTE: Explain that with this condition it would be impossible to determine whether the trouble lies in the preamplifier, the if amplifier, or the cabling in between. Mention that at this point, it would be desirable to monitor the output of the preamplifier to determine if the trouble is in that stage.
>
> Explain that the output of the track preamplifier is now being sent to the acquisition if amplifier, and that, if the preamplifier is yielding an output, it will be amplified in the ACQ receiver.

12. Turn the track transmitter on and point the antenna at some distant, fixed target.

> INSTRUCTOR'S NOTE: Explain that a target in the distance will cause a reflection which will now be presented on the ACQ indicators instead of the track indicators. Turn the RANGE CALIBRATE switch ON and observe the range calibrate marks as presented on the PPI.

13. Explain that since the PPI indicates the presence of track video, it can be assumed that the track preamplifier is working.

    Example: If we have determined that no video is present at pin 3 of P1/A39, and if we have also determined that the track if amplifier is receiving an input, the trouble has to be in the track if amplifier.

14. Disconnect the cable carrying track intermediate frequency from its jack on the antenna pedestal.

15. Proceed to check the output of the if preamplifier as mentioned in the preceding example.

> INSTRUCTOR'S NOTE: This time it will be found that the track if amplifier is not receiving its proper input. Explain to the students that this could be because of the if preamplifier or to the cable between the if preamplifier and if amplifier. To eliminate the preamplifier as a source of trouble, proceed as follows.

16. Connect a coaxial jumper from the output jack of the preamplifier J1/D11 through the window of the radar van, to the input jack of the if amplifier J2/A39.

> INSTRUCTOR'S NOTE: Explain that this jumper bypasses all the permanent cabling and the slip-rings.

17. With the jumper in place, monitor the signal at pin 3 of P1/A39 on the if amplifier.

Example: With the jumper in place, it was noticed that video was present at P1/A39. With all the cables normally connected, it was found that video was not present at P1/A39.

Conclusion: The preamplifier is working, and the trouble is evidently in the cabling between the if preamplifier and the if amplifier.

> INSTRUCTOR'S NOTE: Explain to the students where the if cable was disconnected and how this same procedure can be used to locate troubles anywhere in the line between the if preamplifier and the if amplifier.

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SUGGESTED TROUBLES:

1. Primary.

   a. Replace video amplifier V19 with a bad tube.

   b. Place a nonconducting tube in detector V6 of the if amplifier.

   c. Disconnect the if cable leaving the rf coupler J9/D7.

   d. Loosen the cable entering J4/A40 on the track if attenuator.

   e. Place S2/B29 in MGC and run gain control R21/B29 to minimum gain.

   f. Loosen the if input cable on the track if amplifier.

   g. Disconnect terminal 88 in the radar cabinet.

2. Review.

   a. Loosen the video-and-sync cable from its connection to the back of the van.

   b. Lower capsule voltage on the hydrogen thyratron.

   c. Remove the jumper carrying the sync pulse from the center tub to the lower tub.

LESSON PLAN

TRACK RECEIVER
(Part II)

OBJECTIVE:

To present the operation and repair of the AFC mixer, AFC channel, and local oscillator.

INTRODUCTION:

Conversion of the received signal is accomplished in the signal mixer by mixing the received signal with the local-oscillator output which is always 60 mc higher than the received signal. The difference between the two signal frequencies is detected by a pair of crystals and sent to the preamplifier.

Since all the if stages in the receiver are tuned to 60 mc, it is extremely important that the if frequency be maintained at 60 mc regardless of any frequency drift or shift of the magnetron.

The AFC channel controls the local-oscillator frequency by automatically tuning the local oscillator to 60 mc above the transmitter frequency.

> INSTRUCTOR'S NOTE: Explain the appropriate parts of the track-receiver detailed block diagram (fig 14-1).

PRESENTATION:

1. AFC Mixer (fig 14-2).

   a. The AFC mixer receives two inputs:

      1) The local-oscillator output, and

      2) A sample of the transmitted frequency.

b. The difference between the two signal frequencies is detected and sent to the AFC channel.

c. The frequency difference is called the AFC if.

d. The current flowing through either CR3 or CR4 can be monitored at meter M3.

INSTRUCTOR'S NOTE: Explain that only one of the crystals in the AFC mixer is used for the actual mixing. The other crystal is used for balancing the "magic T."

2. IF Amplifiers V1 and V2 (fig 14-3).

   a. The AFC if arrives at F1/D12.

   b. C1 and T1 couple the signal to the grid of V1.

   c. Both V1 and V2 are conventional if amplifiers, tuned to 60 mc, with a bandpass of 10 mc.

   d. The two if amplifiers will raise the level of the AFC if appearing at J1/D12 to a level high enough to operate the discriminator.

   e. Any frequencies outside the 10-mc bandpass of the if amplifiers will not be passed to the discriminator.

3. Discriminator.

   a. The discriminator generates a pulse whose polarity is governed by whether its input frequency is above or below 60 mc.

   b. The output of the discriminator is coupled to the grid of V4A.

   c. If the input to the discriminator is higher than 60 mc, the voltage on the grid of V4A will be negative.

d. If the input to the discriminator is <u>lower</u> than 60 mc, the voltage on the grid of V4A will be <u>positive</u>.

4. <u>Flip-Flop Multivibrator V6.</u>

a. V6 is a bistable multivibrator furnishing either a +20v or -30v output at J2/D12.

b. With V6A conducting and V6B cutoff, the output at J2/D12 will be +20v.

c. With V6A cutoff and V6B conducting, the output at J2/D12 will be -30v.

<u>Example:</u> Assume that the AFC if is <u>less</u> than 60 mc.

1. This means that the local oscillator is too low in frequency and must be tuned higher.

2. The input to the discriminator will be less than 60 mc. Therefore, its output to the grid of V4A goes positive.

3. Since the grid of V4A goes positive, the tube will conduct harder, and the plate voltage of V4A will decrease.

4. This drop in voltage is coupled through C17 to the grid of V6A and will result in cutting off V6A.

5. When V6A cuts off, the other half of the tube will conduct.

6. The output at J2/D12 will be -30v.

7. The -30v output will cause the local oscillator to tune <u>up</u> in frequency.

<u>INSTRUCTOR'S NOTE:</u> Make sure the class understands the circuit action and outputs for intermediate frequencies either higher or lower than 60 mc. After the class has become familiar with the operation, ask someone what the AFC channel output will be for an if of 66 mc. Since this

INSTRUCTOR'S NOTE (continued)

if is out of the bandpass, the discussion will naturally lead to the pulse selectors V5A and V5B, and the 10-second oscillator.

d. It is entirely possible that the AFC if may lie outside the bandpass of the two if amplifiers V1 and V2.

1) In this case, there would be no if signal input to the discriminator. As a result the AFC channel will not be able to control the frequency of the local oscillator.

2) This condition makes it necessary to provide some means for causing the local oscillator to search up and down in frequency until the if comes within the bandpass of V1 and V2.

3) As soon as the if comes within the bandpass, normal AFC operation resumes.

4) The local oscillator is caused to search in frequency by *changing the mode of the flip-flop* multivibrator every ten seconds.

5) When this is done, the AFC channel output at J2/D12 will be -30v for ten seconds and +20v for ten seconds. This control voltage will cause the local oscillator to search through its frequency range.

5. Ten-Second Oscillator V7.

a. V7 is connected as a free-running phantastron with a period variable from 7 to 12 seconds by adjustment of R39.

b. The output is taken from the screen grid and is a negative-going, rectangular waveform.

c. The output of V7 is coupled to the cathodes of V5B and V5A.

6. Pulse Selectors V5A and V5B.

a. The pulse selectors serve to couple the negative output of V7 to the grid only on the conducting side of V6.

b. When the negative pulse is applied to the grids of V6, the multivibrator will reverse its mode of operation.

7. Bias Control (diag 1).

a. An if of 60 mc can be developed with the local oscillator tuned 60 mc below the transmitter frequency.

b. In this condition, the AFC channel operation is reversed.

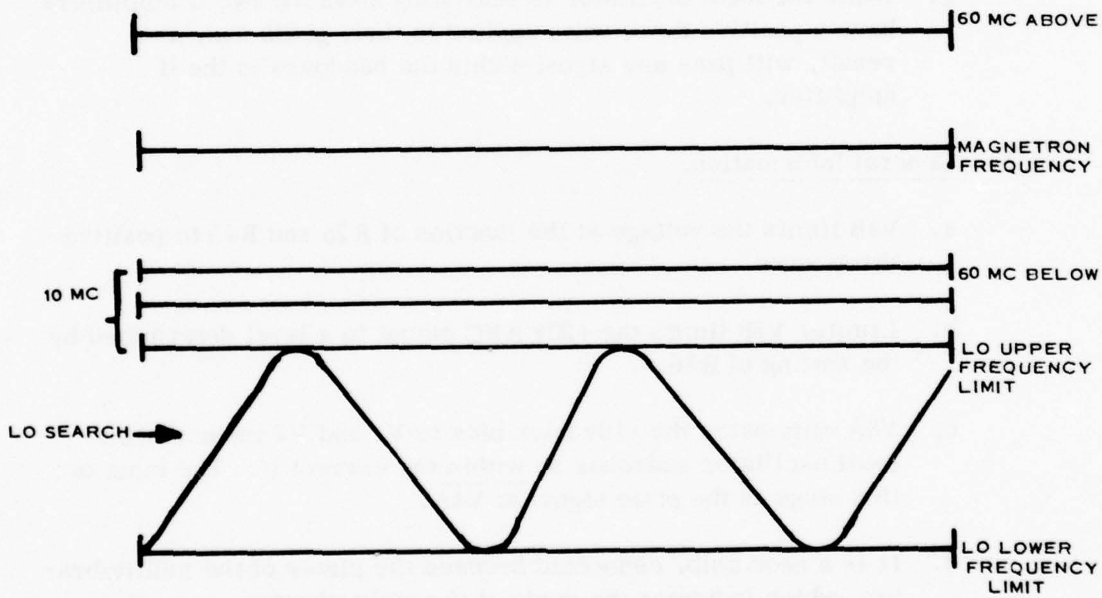

Diagram 1. Local oscillator (LO) search without bias control.

> INSTRUCTOR'S NOTE: Explain why the local oscillator will never establish the correct intermediate frequency if the preceding condition is present, then suggest the technique of preventing the AFC from locking on during the local oscillator's upward search.

c. During the local oscillator's upward search, the output of the AFC channel is -30v.

d. At this time the voltage at the junction of R26 and R46 will be -10 volts.

e. This voltage will be applied to the grids of V1 and V2 and result in cutting them off.

f. The two if amplifiers will pass no signal to the discriminator during the upward search of the local oscillator. This enables the local oscillator to search through the lower if and lock on the upper if.

g. While the local oscillator is searching down the two if amplifiers have a positive three volts applied to their grids and, as a result, will pass any signal within the bandpass to the if amplifier.

8. General Information.

a. V4B limits the voltage at the junction of R26 and R46 to positive three volts.

b. Limiter V8B limits the +20v AFC output to a level determined by the setting of R36.

c. V8A eliminates the -10v back bias to V1 and V2 whenever the local oscillator searches up within the correct if. The input to this stage is the plate signal at V4A.

d. I1 is a neon bulb, connected between the plates of the multivibrator, which indicates the mode of the multivibrator, rate of change of the mode, or whether the LO is locked on frequency.

1) When the local oscillator searches up, one electrode glows brightly.

2) When the LO searches down, the other electrode glows dimly.

3) When the LO is locked on the proper frequency, both electrodes flicker rapidly.

9. Local Oscillator.

a. The local oscillator is a thermally tuned reflex klystron whose frequency is controlled by the output of the AFC unit.

b. A klystron and a tuning triode are encased within one envelope to form the 2K45.

c. To control the frequency of the LO, either a positive or negative voltage is applied to the tuning triode.

> INSTRUCTOR'S NOTE: Give a brief explanation of the tuning action of a positive and negative voltage applied to the tuning triode.

d. E2 adjusts the amount of power from the LO sent to the mixing crystals.

e. R13/D8 and R15/D8 are adjusted to cause the local oscillator to "track" the magnetron frequency over the entire frequency range.

f. R17B/D17 is driven by the magnetron tuning motor and varies the repeller-plate voltage of the LO.

COMMON TROUBLES:

Symptom	Probable Cause
1. Local oscillator searches but never locks on frequency.	Amplifier V1 or V2 bad.
	Either crystal in AFC mixer bad.
	No local-oscillator output.
	High and low adjustments incorrectly set.

Symptom	Probable Cause
2. Local oscillator does not search (one electrode of I1 remains lit).	Ten-second oscillator bad. Flip-flop multivibrator bad.

PRACTICAL EXERCISE

TRACK RECEIVER
(Part II)

AAFCS M33 SETUP:

1. Track transmitter warmed up and ready to energize.

2. RF coupler open and interlock cheated.

EQUIPMENT NECESSARY: Multimeter.

DEMONSTRATION:

1. Energize the transmitter and make sure the track AFC is locked-on.

2. Show the normal operation of the track AFC. Point out the continuously blinking neon bulb on the AFC chassis and the steady reading on all four crystals.

3. Remove the if input to the AFC channel. While the AFC is searching, point out the readings on the four crystals and the steady glow of the neon bulb.

4. Monitor the voltage at J2/D12 and explain that this is the voltage that actually tunes the local oscillator.

5. Remove the local-oscillator cover and point out the local oscillator and its connections.

> INSTRUCTOR'S NOTE: 320v is present on the case of the local oscillator. Explain that, although this voltage is not lethal, it could cause a muscular reaction that might knock a person off the van.

6. Demonstrate the effect of OSC ADJUST E2 on the readings of the four crystals.

7. Vary the magnetron tuning and demonstrate how the AFC follows these frequency variations.

8. Return to the tracking console.

> INSTRUCTOR'S NOTE: Make sure the students can determine by looking at the A-scopes whether or not the track AFC is locked-on. This is very important and will save countless trips to the rf coupler. After they have learned to recognize normal AFC operation by inspection of the A-scopes, remove the if input to the AFC channel and demonstrate how the A-scope presentation indicates whether or not the local oscillator is searching.

9. Return to the rf coupler and let each student adjust the AFC.

> INSTRUCTOR'S NOTE: Go through the adjustment yourself, explaining each step as you go along.

10. Use the multimeter to monitor the AFC control voltage at J2/D12 on the AFC channel.

SUGGESTED TROUBLES.

1. Primary.

   a. Disconnect spade lug on terminal 301 in the tracking console (fig 19-20).

   > INSTRUCTOR'S NOTE: Have the students begin by looking at the A-scopes for the symptoms and require that they tell you exactly what the symptoms are. In this case, they will be AFC not locked-on and local oscillator not searching.

b. Replace one of the if amplifiers in the AFC channel with a nonconducting tube.

> INSTRUCTOR'S NOTE: Again require that the students name the symptoms, after a visual inspection of the A-scopes and before they go up to the roof to begin troubleshooting. Stress constantly the importance of collecting all available data before troubleshooting.

c. Replace the 10-second oscillator with a nonconducting tube.

> INSTRUCTOR'S NOTE: If the AFC remains locked-on, turn the transmitter off for a few seconds and then turn it back on. Explain that the symptoms can determine which part of the AFC channel the technician will troubleshoot.

Example:

1. AFC does not search.

   a. The trouble is either in the local oscillator itself or in V6, V5, or V7 on the AFC channel.

   b. V1, V2, V3, and V4 on the AFC channel are probably operating normally.

2. AFC searches but never locks on.

   a. This symptom means that the flip-flop multivibrator, both pulse selectors, and the 10-second oscillator are working normally.

   b. The trouble is, then, in one of the if amplifiers, the discriminator, or video amplifier V4A.

2. Review.

Insert various troubles in the if amplifier, video-amplifier channel, video-and-notch mixer, and associated cabling for this group. Care must be taken not to interfere with the group on the AFC channel.

LESSON PLAN

TRACK TRANSMITTER AND RECEIVER
(Review)

OBJECTIVE:

To review the various methods of troubleshooting the track transmitter and receiver.

PRESENTATION:

1. Track Transmitter, Meter M4/A15 (fig 12-4).

A high-voltage reading and no current reading on the track HV supply indicate that the thyratron switch tube is not conducting. The switch tube's not firing is probably because of a missing trigger pulse. The lack of a trigger pulse at the grid of the switch tube is usually caused by:

a. No trigger pulse to T3,

b. Bad V1 in the trigger generator, or

c. Bad cathode follower V2.

> INSTRUCTOR'S NOTE: Be sure the class understands what the symptoms would be on meter M4/A15 should the above conditions occur.

2. Track Transmitter, Trigger Generator (fig 12-2).

If a check with the test amplifier has determined that the trigger generator has a sync input and is not delivering a pulse at TP2, the trouble has been localized to the trigger generator. In most cases, it is desirable to localize the trouble to the faulty stage before removal of the trigger generator. To isolate the faulty stage, the following procedure is recommended:

a. Remove V2 from its socket.

b. Monitor the waveform appearing at pin 2 of the socket.

c. If the waveform appears, replace the tube and monitor the input to V2 at pin 2 or pin 7.

d. If the positive 460v, rectangular waveform is present, it can be assumed that V1 is operating normally and V2 is faulty.

e. If the waveform is not present, V1 is probably defective.

3. Modulator Channel (fig 12-2).

In most cases of modulator failure, switch tube V1/A2 is at fault. Before removal, however, check to see that:

a. Bias on pin 4 of E1/A2 is -28v,

b. Trigger pulse is present at pin 4 of E1/A2, and

c. There is continuity from pin 3 of E1/A2 to ground.

4. Reverse Current (fig 12-2).

If meter M1/A2 does not show reverse current, it is highly probable that reverse-current diode V2/A2 is at fault. Before replacement, however, the following checks should be made.

a. Put the multimeter on one of the high-resistance scales.

b. Place the probes on ground and pin 5 of E1/A2.

c. If the multimeter shows a deflection, it can be assumed that Z2/A2 is intact and the meter is working properly.

Caution: All checks in the modulator must be made with track high voltage off.

5. Magnetron Channel (fig 12-4).

If a continuous arc in the magnetron is heard as soon as the transmitter is turned on, proceed as follows.

a. Check the filament voltage of the magnetron (with high voltage off).

b. Look at the pulse transformer for signs of leaking oil or bulging sides.

c. Look at the components in the cathode circuit of the magnetron; check for charred wiring and burned insulation.

d. Have someone at the radar cabinet turn the transmitter on and watch meter M1/D8.

e. Watch to see if the shutter operates.

f. If meter M1/D8 does not give a deflection, one more check is suggested before magnetron removal: Remove the neon bulb from the AFC channel and hold it in front of the feedhorn to check for rf; if it does not light, replace the magnetron.

6. Track RF System (fig 13-2).

The most frequent trouble occurring in this channel is a defective TR tube. A faulty TR tube can be suspected if the two signal-mixer crystals continually burn out. With the exception of the TR and ATR tubes, very few troubles are encountered in the track rf system.

7. Track-Receiver IF Preamplifiers and IF Amplifier (figs 14-4 and 14-5).

a. The complete loss of all track video, as well as receiver noise, from the A-scopes will frequently occur.

b. Check to see if the AFC is locked-on.

c. With this indication, it is usually a good idea to check pin 3 of P1/A39 with the test amplifier for the presence of video or noise.

d. If video or noise appears at this point, the preamplifier and if amplifier can be eliminated as sources of trouble.

e. If track video is not present at pin 3 of P1/A39, the trouble is either in the preamplifier, the if amplifier, the attenuator, or the cabling connecting these units.

f. Checking track if preamplifier.

1) It is desirable at this point to check the output of the preamplifier to eliminate this channel as a source of trouble.

> INSTRUCTOR'S NOTE: Explain that the output of the preamplifier is a 60-mc if signal and that if an attempt is made to monitor this signal with the test amplifier, a very distorted presentation on the A-scopes occurs. Explain that some means other than the test amplifier is necessary for testing the output of the preamplifier.

2) Connect a piece of coaxial cable between J1/D11 on the track preamplifier and J1/A27 on the ACQ if attenuator.

3) This jumper cable will then run the output of the track if preamplifier directly to the ACQ if amplifier, bypassing the track if amplifier, if attenuator, and all fixed if cabling.

4) It is now only necessary to watch the PPI for signs of track video which will appear as dark concentric circles on the face of the indicator.

5) If desired, the range calibrate marks can be used as indication of track video since each mark will trace a dark concentric circle about the center of the indicator at 2,000-yard intervals.

6) If track video and range marks are visible on the PPI, it can safely be assumed the track if preamplifier is operating normally.

g. Checking if amplifier.

1) If the track if signal is present on the cable that is going to the ACQ if attenuator, this fact can be used to eliminate the track if amplifier as a source of trouble.

2) Disconnect the jumper cable from the ACQ if attenuator and reconnect it to the input jack P1/D11 on the track if amplifier attenuator.

3) The jumper is now bypassing all permanent track if cabling and the sliprings, and the if amplifier is receiving a proper input.

4) If a waveform check at pin 3 of P1/A39 on the track if amplifier reveals track video, this indicates that the if amplifier is operating normally and the trouble is in the permanent cabling.

5) If a waveform check at P1/A39 reveals no track video, the trouble is in the if amplifier itself.

h. If the trouble is localized to either the if preamplifier or the if amplifier, a tube socket adapter is necessary to pin-point the trouble to the faulty stage.

8. Video-Amplifier Channel and Video-and-Notch Mixer (fig 14-6).

a. If a preliminary check of pin 3 P1/A39 reveals the presence of track video and all three track indicators show no vertical deflection, the trouble is probably due to a faulty stage in the video amplifier. With the test amplifier, check the operation of V19, V20, and V21.

b. If the video-and-notch mixer V7 is at fault, the most probable symptoms on the track indicators will be:

1) No track video on all three A-scopes, and

2) A 100-yard notch that is 3/4 of an inch deep instead of the usual 1/8 of an inch deep.

9.. Track AFC Channel (fig 14-3).

> INSTRUCTOR'S NOTE: By looking at the video presentation on the A-scopes, the technician can determine at a glance whether the track AFC is locked on frequency or not. With a little practice he can also determine whether the local oscillator is searching in frequency. It is suggested that the instructor make sure the class knows how to tell from the A-scope presentation whether the AFC is locked-on and whether the local oscillator is searching.

Failure of the AFC to lock on frequency is the most common trouble in the AFC channel.

a. The system will usually search and attempt to lock on but then continue to search.

b. When troubleshooting this condition, the symptoms present can be used to eliminate possible sources of trouble.

Example: Track AFC searches but does not lock on.

1. Since the system searches, we can eliminate as possible sources of the trouble, the following:

   a. The 10-second oscillator,

   b. The pulse selector, and

   c. The flip-flop multivibrator.

2. The trouble will then have to be either the if amplifiers, the discriminator, or V4.

3. In most cases, proper adjustment of the HIGH ADJ and LOW ADJ will correct the problem of the AFC failure to lock on.

INSTRUCTOR'S NOTE: Troubleshooting discussion should be followed with a block diagram review of the transmitter and receiver. Each troubleshooting procedure should be tied in with the appropriate block diagram.

PRACTICAL EXERCISE

TRACK TRANSMITTER AND RECEIVER

AAFCS M33 SETUP:

Track radar completely energized, antenna tied down.

EQUIPMENT NECESSARY:

1. Test amplifier,
2. Multimeter,
3. TS-147/UP
4. Rope, and
5. One bad IN23.

DEMONSTRATION:

1. Track transmitter on.
2. Antenna tied down.
3. TS-147/UP connected and ready for use.
4. Demonstrate the measurement of frequency, power (both P_{avg} and P_{pk}), bandpass, and receiver sensitivity. Record your results on the long-range plotting board and demonstrate the computation of the radar performance figure.

SUGGESTED PROCEDURES:

1. Have each student go through the four measurements and record his results on the long-range plotting board, as follows:

a. Frequency,

b. Average power,

c. Peak power,

d. Bandpass,

e. Sensitivity, and

f. Performance figure.

2. After each student has used the TS-147/UP, compare the results of their measurements and reset the transmitter at another frequency and input voltage.

3. Insert a pair of bad crystals in the signal mixer and demonstrate the effects on receiver sensitivity.

LESSON PLAN

RANGE TRACKING SYSTEM
(Part I: Range Servo)

OBJECTIVE:

To explain the operation of the range servo in MANUAL, AID, and ACQUISITION.

INTRODUCTION:

One of the three conditions which must be met before automatic tracking is possible is that the 100-yard notch be positioned underneath the desired target appearing on the A-scopes. Since the range at which the 100-yard notch is generated is dependent on the setting of the track-range computer, it is necessary to provide some quick means of changing this setting to correspond to the range of the desired target. This operation can be accomplished in one of five ways.

1. By depressing range SLEW switch S11/B31 and slewing to the approximate range of the target.

2. By depressing ACQUISITION switch S9/B31 and causing the track range to slew to the setting of the ACQ range computer which was initially set to the approximate range of the target.

3. By manipulating the RANGE handwheel until the 100-yard notch appears under the desired target.

4. By manipulating the RANGE handwheel in AID, a rate of range change roughly corresponding to the rate of range change of the target is set into the range servo.

5. In AUTO the range of the target causes the range servo to follow any of its range variations.

PRESENTATION:

> INSTRUCTOR'S NOTE: Explain the block diagram of the range-tracking system (fig 15-3).

1. Manual Range Control (fig 15-12).

With the RANGE SELECTOR switch S4AC/B31 in the MAN position, the range servo is positioned by rotating the RANGE handwheel. Control of the servo's position is accomplished as follows:

a. The RANGE handwheel is rotated by the operator.

b. The RANGE handwheel is mechanically connected to the motor tachometer B1/B47.

c. As the motor tachometer rotates with the RANGE handwheel, the tachometer generates a small 400-cycle error signal which is sent to the R_H amplifier.

d. The R_H amplifier amplifies the small error signal from the tachometer and applies it to the control winding of motor tach B1/A48 through contacts 2 and 3 of S18/B31, contacts 11 and 6 of K12/B31, and terminal 2 of the motor tachometer. The motor tachometer B1/A48 will then move the setting of the range servo to conform with the RANGE handwheel setting.

e. A feedback voltage is taken from pin 7 of the motor tachometer. This voltage will be proportional to the speed at which B1/A48 is tuning and will be in phase with the error-signal input to the R_H amplifier.

f. The feedback voltage goes through phase-reversing transformer T1 and is applied through R4 back to the input of the R_H amplifier.

g. A result of introducing this feedback voltage to the input of the R_H amplifier will be that the motor tachometer B1/A48 will closely follow any speed and direction variations of the RANGE handwheel.

2. Aided Range Control.

With selector switch S4A/B31 in the AID position, the clutch between B1/B47 and R3/B47 is engaged (fig 15-11).

a. S4A/B41 will cause L1/B47 to be deenergized.

b. With L1/B47 deenergized, the rate clutch is engaged; conversely, if L1/B47 is energized, the clutch is disengaged.

c. The rate clutch will be engaged in both the AID and AUTO positions of range selector S4.

d. The rate potentiometer R3/B47 is connected between 6.3v phase AB and 6.3v phase BA. The center of the potentiometer, therefore, is at zero volts. The wiper arm of this potentiometer is spring-loaded so that, as soon as the clutch disengages, the wiper snaps back to the zero volts position.

e. When the RANGE handwheel is rotated, the engaged clutch will cause the wiper arm of the rate potentiometer to be offset from center in a direction dependent on the direction of handwheel rotation.

f. A voltage variable from 0 to 6.3v of either phase AB or phase BA will be picked up by the wiper arm of R3/B47 and sent through R5 to the input of the R_H amplifier.

g. The R_H amplifier will then drive the range motor tachometer in a manner similar to that which occurs when S4AC/B31 is in the MAN position.

h. Contacts 9 and 2 of K12/B31 are open during MAN and AID operation.

3. SLEW Switch S11/B31.

The range SLEW switch provides a quick method of changing track range without positioning the RANGE handwheel.

a. S11/B31 is a single-pole, double-throw switch with the pole grounded.

b. The operation of the range SLEW switch will cause the slew motor B5/A48 to slew the track-range setting either in or out.

c. Motor excitation is applied to K13/A and K14/A through the upper limit switches.

d. CR6 and CR7 are half-wave detectors for motor excitation whenever their cathodes are grounded by S11/B31.

e. When K13/A is energized, the range servo will slew in.

f. When K14/A is energized, the range servo will slew out.

INSTRUCTOR'S NOTE: Point out motor excitation (motor X) and slew motor B5 on page 15-12. Explain that the series of relays is for controlling the direction of the motor rotation.

g. When K13/A is energized, the circuit operates as follows:

1) Motor X passes through closed contacts 3 and 10 of K11, contacts 9 and 2 of K13, contacts 1 and 9 of K14, contacts 10 and 4 of K13, and through S1 to winding 5 of the slew motor.

2) Winding 3 of the slew motor goes to neutral through closed contacts 10 and 3 of K14 and capacitor C1.

3) This combination of voltages to the windings of B5 will cause the motor to slew in.

h. When K14/A is energized, the circuit operates as follows:

1) Motor X passes through contacts 10 and 3 of K11, contacts 2 and 9 of K14, contacts 9 and 1 of K13, and through S1 to winding 5 of the slew motor.

2) Winding 3 of the motor goes to motor X through contacts 10 and 4 of K14 and C1.

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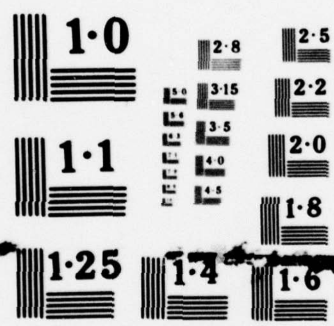

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3) This change of voltage on winding 3 will cause the motor <u>to slew out</u>.

4. <u>Relay Amplifier (fig 15-14).</u>

a. The relay amplifier compares the range setting of two marks (diag 2):

1) The ACQ track-range mark (QTRMK) which represents the range setting of the track-range computer, and

2) The ACQ range mark which represents the setting of the ACQ range computer.

b. The inputs to the relay amplifier are the:

1) Preknock,

2) ACQ track-range mark, and

3) ACQ range mark.

c. V1 is a bistable multivibrator whose cycle of operation is initiated by the preknock pulse.

1) Preknock is coupled through C4 to the grid of V3B.

2) The negative-going plate output of V3B is sent to the grid of V1B. V1B is conducting at this time.

3) The negative-going voltage on the grid of V1B will cause the side of the tube to cut off.

4) The rise in plate voltage at V1B will be felt at the grid of V1A, and this section of the tube will conduct.

5) The multivibrator will stay in this condition—V1B cutoff and V1A conducting—until a negative pulse appears on the grid on V1A and causes the condition to reverse.

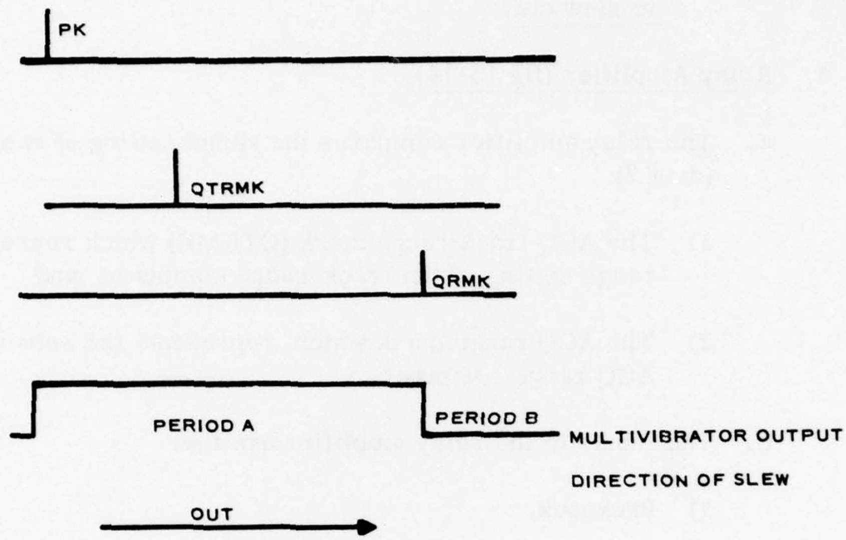

Diagram 2. Time relationships in the relay amplifier.

6) The negative voltage at the grid of V1A is caused by the appearance of the ACQ range mark at the grid of V3A. The negative output of V3A appears on the grid of V1A and causes the section to cut off. At this time V1B will conduct until the introduction of the next preknock pulse.

7) The output waveform of the multivibrator that appears on the grid of the paraphase amplifier V2B will be a square wave beginning at preknock time and going positive for an amount of time determined by the range setting of the ACQ range mark. Since the range of the ACQ range mark is variable, the position of the trailing edge of the multivibrator-output waveform will be variable.

> INSTRUCTOR'S NOTE: Explain that the first part of the multivibrator output will be referred to as period A and the second part as period B.

d. Paraphase amplifier V2B yields two outputs.

1) In the plate output, the waveform will be negative during period A.

2) In the cathode output, period A will be positive.

e. The actual comparison of range between the ACQ range mark and the ACQ track-range mark is done at coincidence tube V6.

> INSTRUCTOR'S NOTE: Discuss with the students the side of V6 that conducts during period A if both cathodes go negative during period A. Do the same for period B. Explain that this action of V6A, conducting more during period B than V6B and conducting less during period A, is the whole secret of the relay amplifier.

f. The QTRMK is introduced to the grid of V2A, and the negative output of the stage is applied to the two cathodes of V6 through transformer T1.

1) If the QTRMK occurs during period A, the track range is too far in and must be slewed out.

2) If the QTRMK occurs during period B, the track range is too far in and must be slewed out.

g. The A section of V6 is negative during period A, and the B section is positive during period A. If the QTRMK occurs during period A, the B section of V6 will conduct, and current will pass through R29 developing a negative voltage at the suppressor grid of V5.

h. If the QTRMK occurs during period B, the conditions on the grids of V6 will be reversed, and the A section of V6 will conduct. Current will pass through R22 to ground, and a negative voltage will appear on the suppressor grid of V4.

i. V4 and V5 are held at control-grid cutoff by a -28v potential which can be removed by activating the ACQUISITION switch on the tracking console.

j. When the ACQUISITION switch is activated, V4 and V5 will conduct according to the voltages applied to their suppressor grids.

k. When V5 conducts, current will flow through K13, and track range will slew in.

l. When V4 conducts, current will flow through K14, and track range will slew out.

m. The conduction of V4 and V5 will operate relays K13 and K14 until the track range approaches the ACQ range setting.

5. Relays K11, K12, K13, and K14.

Assume that relay K13 is energized by the relay amplifier.

a. Contacts 5 and 11 of K13 close and apply ground to one side of K11 through the activated ACQUISITION switch S9/B31.

b. Relay K11 will energize.

c. Motor X will pass through closed contacts 3 and 10 of K12, 2 and 9 of K13, 1 and 9 of K14, and 10 and 4 of K13 to winding 5 of the slew motor.

d. Winding 3 of the slew motor is returned to neutral through C1 and closed contacts 3 and 10 of K14.

e. The motor slews the track-range computer in.

f. The ACQ track-range mark continues in until it occurs in period A.

g. At this time the relay amplifier energizes relay K14 and deenergizes K13.

h. Relay K11 remains energized through its own contacts 2 and 9.

i. As K14 becomes energized, its contacts 5 and 11 close and energize relay K12.

j. Relays K11, K12, and K14 are now energized.

k. Since both K11 and K12 are energized, motor X is removed from the slew motor.

l. A braking voltage of -28v dc is applied from pin Y of J1/A48 through S4/A48, closed contacts 7 and 12 of K11, 12 and 3 of K12, 2 and 9 of K14, 9 and 1 of K13, and S1.

m. This braking voltage serves to slow the motor down after it passes the setting of the ACQ range computer.

n. The slew motor comes to rest about 1,000 yards past the setting of the ACQ range mark.

o. When the slew motor slows down, centrifugal switch S4/A48 opens and removes the braking voltage. The centrifugal clutch, which was disengaged during the slewing operation, will engage.

6. Transformer T24/A.

a. Energizing K11 and K12 will close the primary circuit of T24, and servo X will then be applied.

b. The action of this transformer is as follows.

1) The center of the secondary winding of T24 is grounded.

2) The signal at pin 3 of T24 will be 180° out of phase with respect to the signal at pin 1 of T24.

INSTRUCTOR'S NOTE: Review the condition in which the slew motor was left before the discussion of T24 was begun.

a) It had been slewing in and had just coasted to a stop about 1,000 yards past the setting of the ACQ range mark.

b) Relays K11, K12, and K14 are now energized.

3) Contacts 7 and 12 of K14 close and apply the signal available at pin 3 of T24, through closed contacts 8 and 12 of K13, to the R_H amplifier.

4) The R_H amplifier will then drive motor B1/A48 out in range.

5) The slip clutch and the centrifugal clutch will be engaged at this time, and B1/A48 will drive the range system out.

6) When the QTRMK appears in period B, the relay amplifier will deenergize K14 and energize K13.

7) Contacts 7 and 12 of K13 apply a signal 180° out of phase to the input of the R_H amplifier, causing B1/A48 to slew back in.

8) The relay amplifier will operate K13 and K14 in such a way as to cause the track range to search about 50 yards on either side of the ACQ range setting after the initial 1,000-yard overshoot.

9) The relay amplifier will control the setting of the track-range computer as long as the ACQUISITION switch is held activated.

10) The setting of the range computer is displayed on three dials that are driven by the main drive gear in the range servo. The upper dial makes one revolution every 100,000 yards; the center dial makes one revolution every 2,000 yards; the bottom dial makes one revolution every 400 yards.

11) A system of coarse and fine synchros provides range information at the dials of the range indicator at the tracking console (fig 15-13). The synchro transmitters are located in the track servo computer and are geared in such a way that the coarse-synchro transmitter rotor makes one revolution during 100,000 yards. The fine-synchro transmitter rotor makes one revolution every 2,000 yards. The rotors of both the coarse and fine transmitter are connected

to the rotors of the coarse and fine receivers. The rotors of the two receiving synchros are mechanically coupled to the indicating dials. The range information generated by the coarse- and fine-transmitting synchros is sent to the data junction box, and from there the signals can be sent to any point in which it is necessary to display present range information.

COMMON TROUBLES:

	Symptom	Probable Cause
1.	No control of track range in MAN or AID.	R_H amplifier bad. No servo X being applied to the RANGE handwheel assembly.
2.	Steady creep in range whenever the range SELECTOR switch is put in AID.	Rate pot R3/B47 not being returned to its center.
3.	Track range slews out when ACQUISITION switch is activated but will not slew in.	Switch tube V5 in the relay amplifier bad.
4.	Track range oscillator too far from ACQ range setting.	Relays K11 and K12 not operating (probably because of a broken ground connection).
5.	Track range constantly follows ACQ range mark even when the ACQUISITION switch is not activated.	No -28v disabling voltage going to V4 and V5.

PRACTICAL EXERCISE

RANGE SERVO

AAFCS M33 SETUP: Energized to standby.

EQUIPMENT NECESSARY:

1. Multimeter,

2. Test amplifier, and

3. Trouble light.

PRELIMINARY TROUBLE:

Disconnect the cable going into the track if attenuator.

DEMONSTRATION:

1. Track Range Computer.

   a. Open the track range computer.

   b. Place the range servo in MAN.

   c. Take the cover off the clutch assembly on the RANGE handwheel.

   d. Let one of the students rotate the RANGE handwheel while the others watch what happens in the track range computer.

   e. Have the schematic (fig 15-12) on hand in case questions on data flow arise.

   f. Point out the drive motor B1.

   g. Pull out the R_D amplifier. Explain why it has no effect on B1.

   h. Pull out the R_H amplifier. Explain why B1 stopped.

i. Point out the handwheel motor tachometer.

j. Flip the range SELECTOR switch from AID to MAN several times and have the students listen for the click when the clutch engages. Also make sure they notice the operation of the spring-loaded potentiometer when the SELECTOR is returned to MAN.

k. Set the multimeter to 10v ac. Show the voltage picked off by the wiper arm of rate pot R3/B47 when the servo is in AID.

l. Mention the phase of the voltage appearing at the two ends of R3 (phases AB and BA, 6.3v).

m. Connect a jumper between one side of balance potentiometer R4 and pin 7 of V1A in the R_H amplifier. Explain that this check is used to check quickly the operation of the R_H amplifier.

n. Point out that the R_H amplifier and the R_D amplifier are interchangeable.

2. <u>ACQUISITION switch S9.</u>

a. Designate a target or point on the PPI.

b. Activate ACQUISITION switch S9 and have the students notice the action of the slew motor in the track range computer.

c. Point out relays K11, K12, K13, and K14.

d. Point out the centrifugal clutch, the UPPER and LOWER LIMIT switches, and the slip clutch.

3. <u>Relay Amplifier.</u>

a. Quickly run over the purpose of the relay amplifier and monitor the input waveforms with the test amplifier.

b. Monitor the output waveform of V1. Explain why the trailing edge varies as the ACQ range circle is moved in range.

c. Go through a complete waveform check of the relay amplifier including the -28v bias on the two switch tubes.

SUGGESTED TROUBLES AND ACTIVITIES:

1. Primary.

a. Place a nonconducting 12AX7 in the first stage of the R_H amplifier.

b. Disconnect terminal 5 of E1/B47 in the RANGE handwheel assembly (fig 15-12).

c. Disconnect terminal 219 in the radar cabinet (fig 15-12).

d. Switch the QTRMK and QRMK inputs to the relay amplifier.

e. Disconnect terminal 220 in the radar cabinet (fig 15-11).

f. Replace V1 in the relay amplifier with a bad tube.

g. Replace either V4 or V5 in the relay amplifier with a bad tube.

2. Review.

Have the secondary group adjust the track AFC.

Caution: Turn the ROOF SAFETY switch to OFF and do not turn on the high power servos.

LESSON PLAN

RANGE TRACKING SYSTEM
(Part II: Complete Block Diagram)

OBJECTIVE:

To explain the function of all the components that make up the range tracking system.

INTRODUCTION:

Any system used for the measurement of radar range must be an extremely precise timing device. To arrive at an estimation of range, this timing device must measure the time it takes a pulse of rf energy to make a round trip to the target. If this measurement can be made with a reasonable amount of accuracy, the range of the target can be determined.

Radio-frequency energy travels through space at a fixed velocity of 328 yards per microsecond. If we measure the time it takes for a signal to make a round trip to the target, we can find the target's range by dividing the total distance by two. We can also say that for every increase of 1 microsecond in the time of the round trip the target has moved away by 164 yards.

PRESENTATION: (figs 15-1 and 15-2).

> INSTRUCTOR'S NOTE: One of the most difficult ideas for the student to grasp is how the range measurement is accomplished in the AAFCS M33. It is for this reason that the following example is suggested.

Example: On the blackboard, draw 2 points separated by about 30 inches and discuss how the distance between them can be measured by a ruler. Call attention to the fact that the end of the tape is placed on one mark, and the distance between the two can be read off the scale opposite the other mark.

Now consider that one of the marks is moving. If the end of the tape is kept on the moving mark, the distance, or range, between the two can be read off the scale opposite the fixed mark.

> INSTRUCTOR'S NOTE: Explain that this is, essentially, how the range measurement is accomplished in the AAFCS M33. A movable range mark is produced in the range computer along with a dc voltage that is proportional to the range of the mark.

A servo system is used to position the movable mark continuously at the range of the target's echo, and the dc voltage that is proportional to the range of the mark will then be proportional also to the range of the target.

1. Timing-Wave Generator (fig 15).

   a. The timing-wave generator develops a chain of 51 sine waves during a period of 620 μsec. This sine wave chain can be shifted in phase through 360°.

   b. The period of each sine wave is 12.2 μsec.

   c. The frequency of the sine wavetrain is 81.95 kc.

   d. The sine wavetrain is developed during each prt of the system, and each cycle corresponds to 2,000 yards radar range.

2. Pip-Generator Channel.

   a. The pip generator receives the wavetrain from the timing-wave generator and develops a positive spike at the time the sine wave input goes through zero in a negative direction.

   b. The amplitude of the spikes is 10v and 20v.

   c. The 20v spikes are sent to the TRMK channel.

   d. The 10v spikes are sent to the pip-selector channel.

3. Pip-Selector Channel.

a. Three signal inputs are used in the pip-selector channel.

1) The 10v spikes from the pip-generator channel.

2) A dc voltage from the pip-selector potentiometer is variable between 8v and 144v.

3) The output waveform of the phantastron channel is a negative-going waveform.

a) This waveform, starting at 150v, takes a sharp 20v drop and then begins a linear decrease at the rate of 0.2v per μsec.

b) The linear decrease will continue for 620 μsec, at which time the waveform will return quickly to 150v.

b. The purpose of the pip selector is to develop a waveform with a negative-going, trailing edge whose time of occurrence can be controlled by any one of the 51 input spikes.

c. Since the spikes are developed every 2,000 yards and can be varied through 360°, it follows that the output waveform of the pip selector will be smoothly varied in range.

d. A positive spike is developed at the negative-going trailing edge of the pip-selector output waveform and sent to the 5,000-yard multivibrator.

e. The positive spike will be referred to hereafter as the selected pip.

4. 5,000-Yard Multivibrator.

The 5,000-yard multivibrator receives the selected pip and produces a positive square wave 30 μsec in duration (5,000 yd) with its leading edge coincident with the selected pip. The 5,000-yard square wave is sent to the TRGA cathode follower, QTRMK channel, and TRMK channel.

5. TRGA Cathode Follower.

a. The TRGA cathode follower acts as an isolation stage between the 5,000-yard multivibrator and the circuits using the track-range gate (TRGA), and

b. Further shapes the output of the 5,000-yard multivibrator.

c. The track-range gate is sent to the video-and mark-mixer channel, the precision-indicator sweep and unblanking channels, and the bias channel in the trial-fire indicator.

6. QTRMK Channel.

a. The QTRMK channel receives the output of the 5,000-yard multivibrator, and

b. Produces a positive 16v spike, 15 μsec after it receives the leading edge of the 5,000-yard multivibrator output.

c. This spike is called the ACQ track-range mark and goes to the video-and-mark mixer and relay-amplifier channels.

7. TRMK Channel.

a. The TRMK channel receives the output of the 5,000-yard multivibrator, and

b. Produces a positive 12v spike 12.2 μsec after it receives the leading edge of the 5,000-yard multivibrator output.

c. This spike is called the track-range mark and is sent to the expansion-pulse channel.

PRACTICAL EXERCISE

TRACK-RANGE COMPUTER BLOCK DIAGRAM

AAFCS M33 SETUP: Completely energized. Transmitter OFF.

EQUIPMENT NECESSARY:

1. Test amplifier,
2. Multimeter, and
3. Trouble light.

PRELIMINARY TROUBLE: Place a bad 2C51 in V1 of the relay amplifier.

DEMONSTRATION:

1. Timing-Wave Generator.

   a. Raise the lid of the track-range computer.

   b. Have the students open their schematics to figure 15-1.

   > INSTRUCTOR'S NOTE: The demonstration portion of the practical exercise will consist of the instructor's monitoring waveforms and discussing them while the students make appropriate notations on the block diagram.

   c. Monitor the main gate at TP1 on the range computer.

   d. Monitor the 81.95-kc sine wave at pin 1 of Z1.

   e. Remove V2 while the 81.95 kc is being monitored. Explain the results.

f. Monitor the phase of the four inputs to phase-shift capacitor C8. Be sure the students see the 90° relationship between all of the inputs (have the sweep-length control on the face of the A-scopes fully clockwise).

g. Use the crank on the range computer to vary the range setting of the range computer. Have students notice the effect on the timing wave.

Caution: Make sure nobody tries to slew the range servo while the crank is being used.

2. Pip-Generator Channel.

a. Point out the stand-off insulator at the end of the coaxial cable carrying the timing wave.

b. Monitor the signal at the end of the cable.

c. Monitor the signal at the grid of V1. Explain the clipping action.

d. Monitor the grid- and plate-waveforms of V1 and V2.

e. Demonstrate the two outputs of V2B (10v and 20v).

3. Pip-Selector Channel.

a. Monitor the phantastron output at TP2.

b. Check the 10v spikes appearing at the control grid of V12.

c. Use the multimeter and demonstrate how the dc voltage appearing on the control grid of V12 varies with range.

d. Monitor the output of V14 on pin 5. Explain that this is the selected pip.

INSTRUCTOR'S NOTE: End the demonstration by monitoring the selected pip. Answer any questions.

SUGGESTED TROUBLES:

> INSTRUCTOR'S NOTE: Since the student is acquainted only with the range computer at block level, it would be best not to trouble-shoot it in this lab. Insert troubles in the range servo.

1. Primary.

   a. Disconnect both terminals 216 and 217 in the radar cabinet (fig 15-12).

   b. Lift the range-coupling network out of its socket until the range servo is disabled.

   > INSTRUCTOR'S NOTE: Make sure the students know how to check the operation of the LPSA by inserting the 6.3v from one side of the BALANCE potentiometer on the RANGE handwheel assembly.

   c. Remove the QRMK input to the relay amplifier.

   d. Disconnect terminal 167 in the radar cabinet (fig 15-12).

   e. Place additional troubles in the range servo. The troubles should concern only that portion of the range servo that has been covered in detail to date.

2. Review.

   Have the secondary group time themselves on adjustment of the sweeps on the tactical control console PPI.

LESSON PLAN

RANGE TRACKING SYSTEM
(Part III)

OBJECTIVE:

To explain the operation of the:

1. Main-gate generator, and

2. Timing-wave generator.

INTRODUCTION:

One of the first requirements of the track-range computer is that it develops a mark that is smoothly variable between zero and maximum range.

This is accomplished by first developing a series of 51 sine waves in a period of 620 μsec. The series of sine waves is developed once during each prt of the system.

A phase-shifting capacitor is used to vary the phase of the sine waves smoothly through 360°. A timing spike is developed by each sine wave, and, since each sine wave is variable through 360°, it follows that the spikes will be variable in time.

The smoothly variable range mark is acquired by shifting the phase of the first timing spike through 360°, or 2,000 yards, then picking up the second timing spike at 0° phase shift and following it out for another 2,000 yards.

The process of following one spike for 2,000 yards and then shifting to the next spike continues out to maximum range and results in a range mark that is smoothly variable in range.

PRESENTATION:

INSTRUCTOR'S NOTE: Explain the detailed block diagram of the timing-wave generator, pip generator, and main-gate generator (fig 15-1).

1. Main-Gate Generator (fig 15-4).

a. The main gate is used in the timing-wave generator to interrupt the flow of current through a normally conducting tube. It is extremely important that the interruption lasts for 620 μsec. Since the waveform is applied to the grid of the conducting tube, a negative-going, square wave 620 μsec in duration is necessary.

b. V8 and V9 form a cathode-coupled multivibrator, a quick-recovery tube, and a cathode follower.

c. In the quiescent condition, the A section of V8 is cutoff, and the B section is conducting heavily. The current passing through the B section raises the potential at both cathodes to a sufficient level to maintain the A section at cutoff. The plate of the A section is connected to the grid of the cathode follower V9B. Since V8A is cutoff, V9B has 250v applied to its grid and will also be conducting heavily during quiescence. V9A functions as a diode with its plate connected to the grid of V8B.

d. Upon introduction of the preknock (PK) pulse, the A section of V8 begins to conduct. The drop in plate voltage at V8A is felt on the grid of V9B and results in V9B's being cut off. As V9B cuts off, the drop in its cathode potential is coupled to the grid of V8B through C23 and results in V8B's conducting less. When V8B conducts less, the cathode potential of the stage drops so that V8A continues to conduct after the preknock pulse has expired.

e. At this time C23 will begin to discharge, and the grid of V8B will start to rise in potential. When C23 discharges to a sufficient level to allow V8B to conduct, a switching action will occur which ends with the B section conducting and the A section of V8 cut off.

f. The output of the main-gate generator is taken from R67 and is a negative-going, square wave 100v in amplitude and 620 μsec in duration.

g. The waveform is then sent to V1 in the timing-wave generator.

> INSTRUCTOR'S NOTE: Explain to the class that the main-gate generator is located on the cover of the track-range computer instead of on the separate chassis where the rest of the timing-wave generator is located.

2. Clamper Oscillator V1.

a. V1A clamps the grid of V1B at nearly ground potential.

b. Upon introduction of the main gate, the grid of V1B goes well below ground potential and cuts the B section of the tube off.

c. At the time V1B cuts off, tuned circuit Z1 begins to oscillate at a frequency of 81.95 kc. These oscillations are then coupled to the grid of quadrature tube V2.

d. A signal which is in phase with the oscillations developed in Z1 is coupled from the cathode circuit of V2 to the center of the inductance in Z1.

e. This feedback voltage is used to prevent the oscillations developed in Z1 from being damped out because of resistance losses in the oscillating circuit.

f. The oscillations developed in Z1 are therefore at a constant amplitude during the 620-μsec period in which they occur.

3. Quadrature Tube V2.

a. Four sine-wave signals separated from each other by 90° are necessary at the plates of phase-shift capacitor C6. The following stages, V2 (quadrature tube) and V3 (paraphase amplifiers), are used to split the sine wave generated in Z1 into four sine-wave signals whose phase relationships are 0°, 90°, 180°, and 270°.

INSTRUCTOR'S NOTE: Briefly explain the operation of the quadrature stage without the vectors.

b. V2 receives the oscillations developed in Z1.

c. The variations in the cathode circuit of V2 will follow closely the signal at the grid of V2. For purposes of simplicity, we will refer to the signal developed at the cathode of V2 as 0° since the signal follows the grid signal so closely that the phase has not been shifted.

d. The plate signal of most tubes is 180° out of phase with the grid input signal, but V2 has an inductance in its plate circuit that introduces a 90° lag.

e. C3 is an adjustment that introduces a lead to the cathode signal which will reestablish the plate-to-cathode relationship to 90° in case they vary.

4. Paraphase Amplifiers.

a. The two paraphase amplifiers V3A and V3B receive the two signal phases: 0° and 90° from the quadrature tube.

b. The outputs of V3A and V3B are the four voltages necessary in the operation of phase-shift capacitor V6.

c. A sine wave shifted in phase by 90° is introduced at the grid of V3A.

1) The voltage appearing at the plate of V3A is shifted 180° with respect to the grid signal; therefore, the plate signal is shifted in phase by 270° with respect to the oscillations developed in Z1.

2) The voltage at the cathode of V3A will follow the grid input variations of the stage; therefore, the phase of the signal at the cathode of V3A will be shifted by 90° from the oscillations developed in Z1.

d. V3B operates in the same manner as V3A: The input waveform is in phase with the oscillations developed in Z1; therefore, the outputs will be 0° at the cathode of V3B and 180° at its plate.

5. Phase-Shift Capacitor C6.

a. The inputs to C6 are as follows:

1) 0° phase to plate 3,

2) 90° phase to plate 4,

3) 180° phase to plate 1, and

4) 270° phase to plate 2.

b. Movement of the rotor on C6 from plate 3 to plates 4, 1, and 2 consecutively, will cause the phase of the sine wave introduced to the grid of V4 to be shifted by 360°.

c. The phase-shift capacitor makes one revolution for every 2,000 yards of range change; therefore, when the range setting of the range computer is changed from 0 to 100,000 yards, C6 will make 50 revolutions.

6. Pip-Selector Potentiometer R8 (fig 15-6).

a. A system of gears positions the pip-selector potentiometer at the same time the phase-shift capacitor is moved.

b. The gear ratio causes the pip-selector potentiometer to rotate once for every five revolutions of the phase-shift capacitor.

c. Therefore, when going from 0 to 100.000 yards in range, the pip-selector potentiometer rotates 10 times, and the phase-shift capacitor rotates 50 times.

d. The voltage picked off by the wiper arm of R8 can vary between +8v and +144v and is sent to the control grid of V12.

7. Feedback Amplifiers V4 and V5.

a. The timing wave experiences a very large attenuation in the phase-shift capacitor.

b. Feedback amplifier V4 amplifies the weak output of C6.

c. The capacitor C6 acts as a high-impedance source, and to prevent the timing wave from being unnecessarily distorted, the input impedance of V4 is made very high by the use of a degenerative feedback voltage.

> INSTRUCTOR'S NOTE: Explain the degnerative effects of the two unbypassed cathode resistors and the coupling between the plate of V5 and the cathode of V4.

d. The signal appearing at the plate of V4 is coupled to the grid of V5 where it is further amplified.

e. The output of V5 is a string of 51 sine waves with a peak-to-peak voltage of 30v and is referred to as the timing wave.

f. The timing wave is coupled through C10 and sent to the pip generator.

COMMON TROUBLES:

	Symptom	Probable Cause
1.	No expanded sweep and no timing wave at plate of V5.	PK not reaching the grid of V8A. V8A bad. Feedback amplifier V4 bad.
2.	More than 51 sine waves visible on the A-scopes.	Misadjustment of R64/A32, MAIN GATE ADJ.

	Symptom	Probable Cause
3.	Timing wave gradually diminishes in amplitude.	Quadrature tube V2 not conducting.

PRACTICAL EXERCISE

TIMING-WAVE GENERATOR

AAFCS M33 SETUP: Track filaments, low voltage, and INDICATOR HV on.

EQUIPMENT NECESSARY: Test amplifier and trouble light.

DEMONSTRATION:

1. Monitor the timing wave at one of the connections to C6.
2. While the timing wave is on display, remove the main-gate generator V8. Explain the loss of the timing wave.
3. Monitor the waveform at pin 1 of Z1.
4. Remove V1 while the waveform is being monitored at pin 1 of Z1. Explain why the oscillations are still developed.
5. Monitor the waveforms at E3, E4, E5, and E6.
6. Locate E8 and monitor the waveform present at this point. Explain why the amplitude is so much lower than the input to C6.
7. Monitor the timing wave through V4 and V5.
8. Follow the timing wave through J1 to the stand off insulator at the end of the coaxial cable going along the left side of the range computer lid.
9. Demonstrate the method used in adjusting the length of the main gate by monitoring the timing wave and counting 51 sine waves.
10. Point out the pip-selector potentiometer R8.

SUGGESTED TROUBLES:

1. Primary.

   a. Remove preknock from the track-range computer.

   b. Replace main gate MV with a bad tube.

   c. Use a piece of gremlin wire and short pins 2 and 3 of the timing-wave oscillator.

   d. Replace quadrature tube V2 with a nonconducting tube (make sure grid pin is intact).

   e. Replace V3 in the timing-wave generators with a bad tube.

Caution: Caution the students about getting their heads too close to the lid of the range computer while they are looking for tube pins in the timing-wave generator.

   f. Replace V5 in the timing-wave generator with a bad tube.

   g. Short across CR1 with a piece of gremlin wire.

   h. Insert a thin piece of wire between the plates of C1.

2. Review.

   While the primary group is working on the range computer, have the secondary group busy troubleshooting the RANGE handwheel assembly. The following troubles are recommended.

   a. Disconnect terminal 1 of E1 on the RANGE handwheel assembly. (Rate clutch will not disengage.)

   b. Disconnect terminal 5 of E1 on the RANGE handwheel assembly (no aided rate).

   c. Misadjust BALANCE potentiometer R4 (range creep in MAN).

   d. Place a bad tube in the R_H amplifier.

e. Insert in the RANGE handwheel assembly any other troubles that will not interfere with the group working on the range computer.

LESSON PLAN

RANGE TRACKING SYSTEM
(Part IV)

OBJECTIVE:

To discuss the operation and repair of the pip generator, pip selector, and phantastron.

INTRODUCTION:

A timing wave has been developed at the frequency of 81.95 kc in the timing-wave generator. The period of each cycle corresponds to 2,000 yards radar range. The pip generator will develop a positive timing spike at the leading edge of each cycle; therefore, 51 timing spikes will be developed.

Since the phase of each cycle of the timing wave is variable through 360°, each timing spike will vary through 2,000 yards.

The purpose of this discussion is to explain how the timing wave, in conjunction with a dc voltage from pip-selector potentiometer R8, and the output of the phantastron are used to produce the smoothly variable range mark.

PRESENTATION (fig 15-5):

1. CR1 and CR2.

   a. The timing wave is applied to the junction of CR1 and CR2. The two crystals act as positive clippers.

   b. When the timing wave goes through its positive alternation, CR1 will conduct since its plate is positive with respect to its grounded cathode; as a result, very little of the positive alternation of the input is developed across R4.

   c. When the timing wave goes through its negative alternation, CR2 will conduct since its cathode is driven negative. As a result, current passes through R4, and a negative voltage will be felt at the grid of V1.

2. Shaper V1.

a. V1 is biased near cutoff.

b. V1 is driven through cutoff by the extreme negative alternations of the positively clipped timing wave applied to its grid.

c. The output waveform appearing on the plate of V1 is a square wave.

3. Differentiating Amplifier V2A.

a. The output of shaper V1 is applied across capacitor C3 and resistor R13 which constitute a peaking circuit (differentiator).

b. The action of this peaking circuit is to pass only the quick changes in the output of V1 to the control grid of V2A.

c. Since all the quick changes in a square wave are on the steep edges, the differentiator will pass a series of positive and negative spikes (diag 3).

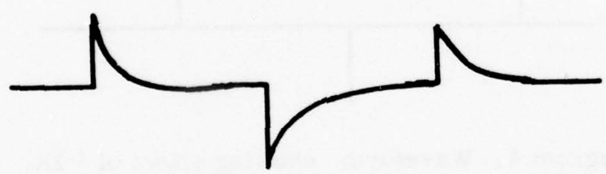

Diagram 3. Output of V1.

d. It will be noticed that the spikes developed at the edges of the square wave do not have a sharp trailing edge. This is because C3 does not charge or discharge instantly because of the resistance in its discharge path.

e. Differentiator amplifier V2A serves to bypass R13 during the charge and discharge of C3.

4. Peaking Amplifier V2B.

a. When shaper V1 conducts, its plate-voltage drop is felt at the grid of V2A, and C3 will begin to discharge through its normal discharge path. The negative voltage felt on the grid of V2A will cut that stage off, and the plate voltage will rise. Capacitor C5 will begin to charge to the new voltage on the plate of V2. The charge path for C5 includes C3; therefore, the charge of C5 aids the discharge of C3. This causes C3 to discharge much more rapidly, and the waveform applied to the grid of V2 will be much sharper.

b. The differentiator amplifier functions in the same manner when the plate of V1 goes positive, except that this time the discharge of C5 aids the charge of C3.

c. The waveform at the plate of V2A in diagram 4 consists of a series of positive and negative spikes and is coupled through C6 to the positive clipper CR3 and to CR4.

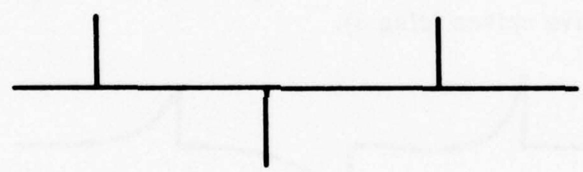

Diagram 4. Waveform showing effect of V2A.

d. The positive clipper is arranged so that only the negative spikes reach the grid of V2B. V2B further amplifies and peaks the waveform by a method similar to that employed in V2A.

e. A series of positive spikes, 20 volts in amplitude, is taken directly off the plate of V2B and sent to the TRMK channel.

f. A series of positive spikes is taken from the junction of R21 and R22 and sent to the pip-selector channel.

5. Phantastron Channel (fig 15-5).

a. The plate of cut off since the cathode if at a more positive potential than the positive four volts appearing at the suppressor.

b. A 25v preknock pulse is introduced to the suppressor grid. The suppressor grid will reach a potential which will allow a certain amount of plate current to flow.

c. The phantastron output, when taken off the plate, will appear as in diagram 5.

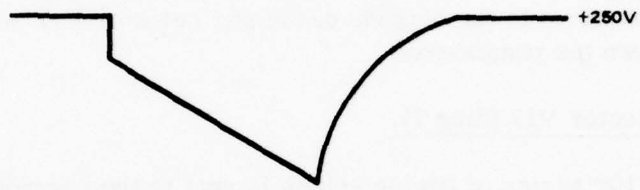

Diagram 5. Phantastron output.

1) It will be noticed that the trailing edge of the waveform represents a gradual rise to B+ voltage.

2) The plate cannot reach B+ until capacitor C1 has charged to that value, and, as a result, the plate reaches B+ exponentially.

INSTRUCTOR'S NOTE: At this time introduce the quick-charge triode. Discuss what it does (diag 6).

Diagram 6. Phantastron-output waveform with quick-charge triode.

d. S1 places C46 in parallel with C25 in the event it is necessary to lengthen the phantastron-output waveform.

e. For finer adjustments of length, the SLOPE 1 adjustment can be made.

f. V7A isolates the suppressor grid of the phantastron from the pulse synchronizer.

g. V7B clamps the output waveform of the phantastron at +150 volts.

h. Cathode follower V10A is used in order to couple the phantastron waveform to the cathode of the pip selector V12 without loading down the phantastron.

6. Pip Selector V12 (diag 7).

a. A 10v series of timing spikes is sent to the control grid of the pip selector.

b. These 10v timing spikes are riding on a dc level determined by the setting of the pip-selector potentiometer R8 which is varied by the setting of the range servo.

c. When track range is set at 100,000 yards, the dc voltage picked off by the wiper arm of R8 is 8 volts.

d. When track range is at minimum, the voltage picked off R8 is 144 volts.

e. The voltage from potentiometer R8 can be considered as a variable bias applied to the control grid of V12.

f. The cathode of V12 receives the phantastron output.

INSTRUCTOR'S NOTE: Draw the voltage relationships of the signals applied to the pip selector.

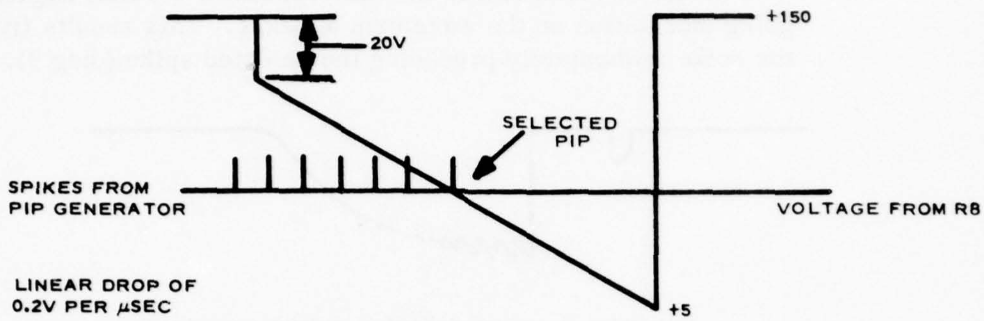

Diagram 7. Pip-selector inputs.

Explain that one spike is going to cause the tube to conduct, and that the time the tube conducts will be a function of the range-servo setting and the phase of the spike. Also explain the action of the pip selector during changes of range as in diagram 8.

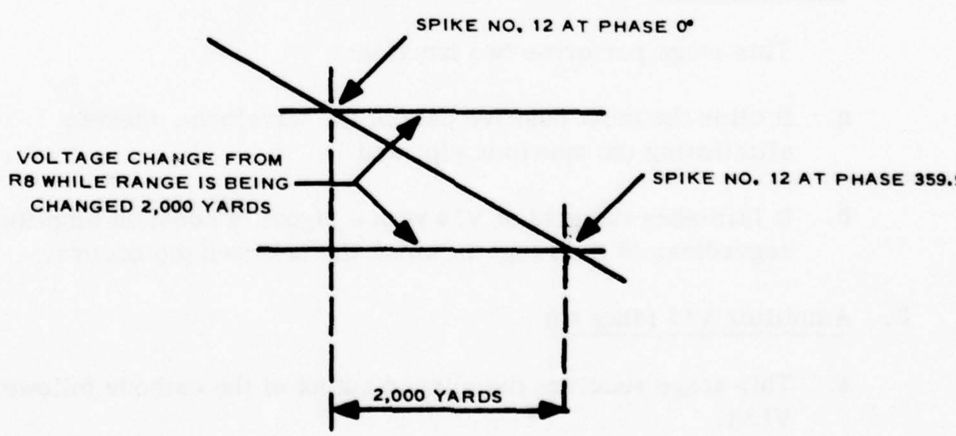

Diagram 8. Pip-selector action.

g. The waveform at the plate of the pip selector will go sharply negative whenever the stage conducts.

h. Two thousand yards before the tube conducts, a small negative-going indentation on the waveform appears. This results from the spike immediately preceding the selected spike (diag 9).

Diagram 9. Pip-selector output waveform.

i. The output waveform of the pip selector is coupled to the grid of V13A through capacitor C29.

j. The negative-going edge of the waveform will henceforth be known as selected pip time.

7. Clamper V13B.

This stage performs two functions:

a. It clips the most positive part of the waveform, thereby eliminating the spurious pip, and

b. It furnishes the grid of V14 with a signal of constant amplitude regardless of the range in which the selected pip occurs.

8. Amplifier V14 (diag 10).

a. This stage receives the clipped output of the cathode follower V13A.

b. Part of the positive-going output of V14 is sent back to the grid of V12 in order to insure that the pip selector continues to conduct on the selected pip.

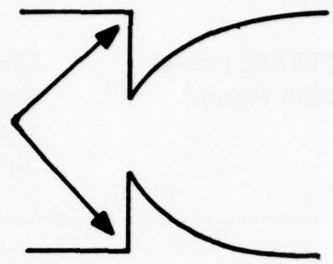

Diagram 10. Signals on grid and plate of V14.

c. A positive-going spike, 140 μsec in duration at the base, appears on the plate of V14 and is used to trigger the 5,000-yard multivibrator.

COMMON TROUBLES:

Symptom	Probable Cause
1. Expanded sweep does not go out in range.	Line from wiper arm of the pip selector open. ZERO ADJ potentiometer R54 open. R55 open.
2. No phantastron output, no expanded sweep.	Isolation clampter V7A bad. Phantastron V11 bad.
3. Phantastron output waveform too short even with SLOPE 1 adjusted all the way to pin 3. Expanded sweep disappears at long ranges.	S1 should be connected to C46.

Symptom	Probable Cause
4. TRGA and QTRMK present, but no expanded sweep.	Check the amplitude of the timing wave on the plate of V2B. Suspect the timing-wave generator.

PRACTICAL EXERCISE

PIP SELECTOR, PIP GENERATOR, AND PHANTASTRON

AAFCS M33 SETUP: Track filaments, low voltage, and INDICATOR HV on.

EQUIPMENT NECESSARY:

1. Test amplifier,
2. Multimeter,
3. Trouble light.

PRELIMINARY TROUBLE: Misadjust the main gate.

DEMONSTRATION:

1. Pip Generator.

   a. Monitor the timing wave at the junction of CR1 and CR2.

   b. Monitor the timing wave at the grid of V1. Explain the clipping action of CR1 and CR2.

   c. Monitor the waveform appearing at pin 3 of V2A. Discuss the peaking action of C3 and R13.

   d. Locate CR4 and CR3. Demonstrate their clipping action with the test amplifier.

   e. Show the 10v and 20v outputs of V2B.

   f. Remind students that the dark line leaving the junction of R14 and R15 and going to one end of R21 is not a signal path.

2. Phantastron.

   a. Monitor preknock appearing at pins 2 and 5 of V7A and pin 7 of V11.

   b. Monitor the phantastron output at the cathode of V10A.

   c. Demonstrate the method of adjusting the duration of phantastron pulse by adjustment of SLOPE 1.

3. Pip Selector.

   a. Locate the ZERO and SLOPE 2 adjustments. Review their effect on the voltage picked off by the wiper arm of R8.

   b. Use the multimeter to show the dc voltage at pin 1 of V12.

   c. Use the test amplifier to monitor the phantastron output at pin 7 of V12 and the timing spikes at pin 1 of V12.

   d. Monitor the plate waveform of V12. Discuss the combined action on the waveform at the plate of V12 of the shift in phase of the spikes and the dc voltage from the pip-selector potentiometer. Point out the spurious pip.

   e. Monitor the plate waveform of V14.

SUGGESTED TROUBLES:

1. Primary.

   a. Tie pins 5 and 6 of V7 together with a piece of gremlin wire.

   b. Replace V1 with a bad tube.

   c. Replace V2 with a bad tube.

   d. Misadjust SLOPE 1 control R69.

   e. Tie pins 1 and 6 of V12 together with a piece of gremlin wire.

f. Replace V14 with a bad tube.

g. Replace V12 with a bad tube.

h. Misadjust SLOPE 2 control R1. Call attention to the effect on the 500-yard expansion pulse.

2. Review.

a. Place a bad crystal in the ACQ signal mixer.

b. Lower the capsule voltage in the ACQ modulator.

c. Disconnect terminal 93 in the radar cabinet (fig 7-4).

LESSON PLAN

RANGE TRACKING SYSTEM
(Part V)

OBJECTIVE:

To explain the operation and repair of the 5,000-yard multivibrator and the TRGA, QTRMK, and TRMK channels.

INTRODUCTION:

A waveform with a variable trailing edge has been developed in the pip-selector stage.

It is now necessary to differentiate the waveform and to produce a spike that can then be used to trigger a multivibrator. The multivibrator produces a 5,000-yard, square wave which is sent through a cathode follower and emerges as the track-range gate.

The 5,000-yard multivibrator output is also instrumental in producing the ACQ track-range mark and the track-range mark.

PRESENTATION:

1. 5,000-Yard Multivibrator (fig 15-6).

   a. This stage operates as a conventional, cathode-coupled multivibrator.

   b. The A section of the tube is normally conducting since its grid is returned to 250v through R32, and RANGE ADJUST R31.

   c. When V14 is cut off, its rise in plate voltage will cause C32 to charge.

      1) During the time C32 charges, current will flow through CR5 and R23 and R26.

2) The flow of current through R23 will develop a positive voltage which will be felt at the grid of V3B.

d. The positive-going voltage on the grid of V3B will correspond in time to the selected pip and will initiate the multivibrator's cycle of operation.

e. A positive-going, square wave 30 μsec in duration will be developed at the plate of V3A and coupled through C12 to the grid of cathode follower V4A.

2. Cathode Follower V4A.

a. This stage receives the output of the 5,000-yard multivibrator.

b. Since the control grid of V4A is biased at -24v, the waveform will be clipped, thereby improving its squareness.

c. The cathode follower isolates all the circuits that use the track-range gate from the 5,000-yard multivibrator.

d. The track-range gate can be monitored at J2/B.

3. TRMK Channel (fig 15-7).

a. Network driver V15A receives an output from the 5,000-yard multivibrator.

b. The grid of V15A is returned to -37v appearing at the junction of R92 and R91.

c. The positive-going, 30-μsec, square wave from the 5,000-yard multivibrator is applied to the grid of V15A.

d. This positive signal overcomes the bias on the grid, and the tube conducts.

e. As V15A conducts, the drop in its plate is immediately coupled to the grid of V15B and cuts off this stage.

> <u>INSTRUCTOR'S NOTE:</u> Explain the operation of a quarter-cycle oscillator as used for obtaining a time delay.

f. Fourteen µsecs after the shaper V15B is cut off, its grid will rise above cutoff, and the tube will begin conducting.

g. A positive-going, square wave appears at the plate of V15B and is coupled through C36 to the suppressor grid of V16. This waveform is called the <u>track-range mark gate</u>.

h. V16 is at suppressor grid cutoff because of a -67v potential at the junction of R98 and R97.

i. The control grid of the stage is at -18v because of the potential from voltage divider R103 and R102.

j. This stage will not conduct unless the negative bias potential at both grids are overcome by the simultaneous introduction of the positive-going pulse from the shaper V15B and one of the timing spikes from V2B.

k. The timing spike that appears in coincidence with the leading edge of the track-range mark gate will not cause V16 to conduct as it does not appear completely within the track-range mark gate.

l. The following spike, occurring 12.2 µsec later, will cause the tube to conduct. The negative-going spike appearing at the plate of V16 will always occur 12.2 µsec after the selected pip.

m. The spike is inverted by transformer T3.

n. The positive spike is known as the track-range mark.

o. The track-range mark is used in the pulse demodulator to produce the 500-yard expanded sweep, 100-yard notch, 35-yard gate, and clear-out pulse.

INSTRUCTOR'S NOTE: Review the time relation between the TRMK and TRGA (diag 11).

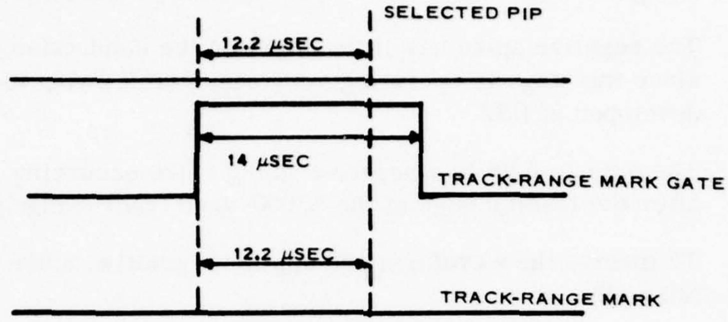

Diagram 11. Time relation between TRMK and TRGA.

4. QTRMK Channel (fig 15-7).

   a. The output of the 5,000-yard multivibrator is also applied to the grid of network driver V4B.

   b. The grid of V4B is biased at -41 volts.

   c. The bias appearing at the grid of V4B is overcome by the positive-going, square wave from the 5,000-yard multivibrator.

   d. When V4B conducts, the drop in its plate voltage is immediately felt at the grid of shaper V5A and cuts this stage off.

   e. The time V5A remains cutoff is a function of the resonant frequency of Z1.

   f. A positive-going waveform is developed at the plate of V5A with a trailing edge occurring 15 μsec after the leading edge of the 5,000-yard track-range gate.

   g. This waveform is shaped by V5B whose grid is at a -44v bias from the junction of R46 and R45.

h. The negative-going 15-μsec square wave appearing at the plate of V5B is differentiated by R49 and C20.

i. The waveform appearing at the control grid of V6 consists of a negative spike followed 15 μsec later by a positive spike.

j. The negative spike has little effect on the conduction of the tube since the stage is operating very near cutoff owing to bias developed at R52.

k. The output of V6 is a negative-going spike occurring 15 μsec after the leading edge of the 5,000-yard track-range gate.

l. T2 inverts the waveform and applies a positive spike to J5 (diag 12).

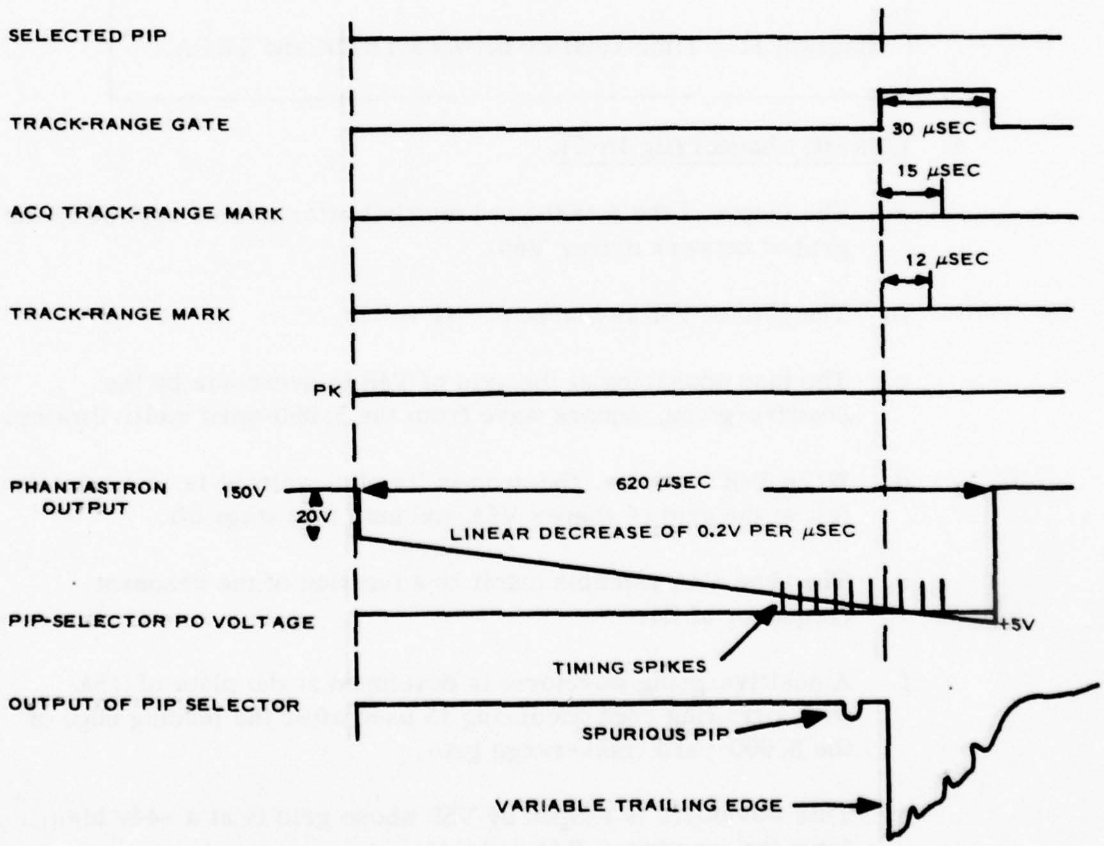

Diagram 12. Time relationship in track-range computer.

COMMON TROUBLES:

	Symptom	Probable Cause
1.	No track-range gate, acquisition track-range mark, or track-range mark. No arc on cross, no expanded sweep, no range sweep on PI with selector in TRACK.	5,000-yard multivibrator V3 either bad or not receiving an input (selected pip).
2.	QTRMK and TRMK present but no TRGA. No range sweep on PI in track.	Cathode follower V4A bad.
3.	TRGA and TRMK present but no QTRMK. No arc on electronic cross.	Trouble is in the QTRMK channel: V4B, V5, or V6.
4.	Fifty-one expanded sweeps on the track indicators.	Bias on suppressor grid of V16 missing.
5.	TRGA and QTRMK present but no TRMK and no expanded sweep.	No output from peaking amplifier V2B.

PRACTICAL EXERCISE

5,000-YARD MULTIVIBRATOR, TRGA, QTRMK, AND TRMK CHANNELS

AAFCS M33 SETUP: Track filaments and low voltage on.

EQUIPMENT NECESSARY:

1. Test amplifier,
2. Trouble light, and
3. Multimeter.

PRELIMINARY TROUBLE:

Misadjust the MAIN GATE ADJ and SLOPE 1 controls on the range computer and the SWEEP LENGTH controls on the three track indicators.

DEMONSTRATION:

1. 5,000-Yard Multivibrator.

   a. Monitor the signal at pin 7 of V3.

   b. Monitor the multivibrator output at pin 1 of V3. Quickly review the operation of the multivibrator.

   c. Locate and explain the purpose of RANGE GATE ADJ R31.

   d. Monitor the waveform appearing at the cathode of V4A.

   e. Locate E12, E15, and E5.

2. ACQ Track-Range Mark Channel.

   a. Monitor all the pertinent waveforms in the QTRMK channel.

   b. Discuss briefly the operation of the quarter-cycle oscillator.

c. Monitor the QTRMK at J5 and discuss the QTRMK distribution.

3. Track-Range Mark Channel.

   a. Monitor all pertinent waveforms in the TRMK channel. Mention that the delay in this channel is 14 μsec.

   b. Monitor square wave input to pin 7 of V16.

   c. Show the 20v timing spikes on pin 1 of V16.

   d. Use multimeter to show the bias at the junction of R98 and R97.

   e. Show plate-output waveform of V16 and demonstrate the inversion encountered in T3 by the track-range mark.

   f. Discuss the distribution of the track-range mark.

   g. Discuss and demonstrate the ZERO ADJ R54.

SUGGESTED TROUBLES:

1. Primary.

   a. Misadjust RANGE GATE ADJ R31.

   b. Replace V3A with a bad tube.

   c. Replace V15 with a bad tube.

   d. Tie pins 7 and 2 of V16 together with a piece of gremlin wire.

   e. Remove the screw in the coaxial connector going to J7 on the range computer. Insert a small nut or bolt in such a way that the center conductor is shorted to the shield. Replace the screw.

   f. Loosen P2 so that main gate does not get to oscillator V1B.

2. Review.

   Have the secondary group work at the barbette with the frequency power meter measuring power frequency and standing-wave ratio.

LESSON PLAN

RANGE TRACKING SYSTEM
(Part VI)

OBJECTIVE:

To discuss the operation and repair of the:

1. Pulse generator, and

2. The range-error channel.

INTRODUCTION:

The track-range computer has produced outputs that are movable in range out to 100,000 yards. Though these marks are variable in range with respect to preknock, they retain their time relationship with each other. Therefore, the track-range gate is always 5,000 yards long, and the track-range mark and ACQ track-range mark will occur 12.2 and 15 μsec, respectively, after the leading edge of the track-range gate.

This discussion will deal with the method in which the track-range mark is used to produce the expansion pulse, 100-yard notch, 35-yard gate, and clear-out pulse.

The second part of the discussion will deal with the range-error channel in which the error signals are developed that cause the track-range servo to follow the target-range variations.

PRESENTATION:

INSTRUCTOR'S NOTE: Explain the detailed block of the range tracking system, part II (fig 15-2).

1. Expansion-Pulse Multivibrator, VI (fig 15-8).

   a. The track-range mark is coupled to the grid of V1A through capacitor C1.

b. V1 is a 3-μsec, one-shot multivibrator, whose cycle of operation is initiated by the track-range mark.

c. R11 controls the width of the pulse and is adjusted for 3 μsec or 500 yards.

d. R5 is adjusted to insure stable operation of the multivibrator or to compensate for circuit changes caused by tube replacement.

e. A positive-going, 3-μsec, square wave is developed at the plate of V1B and coupled to the grid of V4B through C9 and R26.

2. Cathode Follower V4B.

V4B is a conventional cathode-follower. The cathode circuit of the stage furnishes a 45v pulse to network driver V2 and to inverter V4A.

3. Inverter V4A.

a. Inverter V4A receives the 45v square wave from the cathode follower.

b. The output of this stage is a negative 15v pulse which is coupled through C6 to a 75-ohm terminating resistor.

c. A negative 12v pulse is developed across the terminating resistor. This pulse is the expansion pulse.

4. Driver V2.

a. This stage also receives the positive 45v square wave from the cathode of V4B.

b. V2 is normally cut off by a -36v potential applied to its grid from the junction of R13 and R14.

c. The positive 45v cathode pulse of V4B overcomes the negative 36v bias on the control grid of V2, and the stage conducts.

d. A drop in plate voltage will occur when V2 conducts. This drop is immediately felt at the control grid of V3, and V3 will then become cut off.

e. The time V3 remains cutoff is a function of the resonant frequency of Z3.

f. Z3 is tuned so that V3 will resume conducting 1.2 μsec after it has been cut off.

g. A positive-going, 1.2 μsec pulse is developed at the screen grid of V3 and sent to the lobing-error channel. This is the clear-out pulse.

5. Driver V3.

a. A positive-going, 1.2 μsec pulse is also developed at the plate of V3 and sent to Z4.

b. When the plate of V3 initially goes positive, the capacitor in Z4 begins to charge. CR1 will conduct at this time; as a result, very little of the plate-voltage rise will be felt at the grid of V8A.

c. When the plate voltage of V3 drops, the capacitor in Z4 will begin to discharge. At this time CR1 will block the flow of current, forcing current to flow through the inductance in Z4.

d. At the time current begins to flow through the inductor, a negative voltage will be felt at the grid of V8A.

> INSTRUCTOR'S NOTE: Stress the fact that the drop in voltage at the grid of V8A is felt 1.2 μsec after the initial rise in the plate voltage of V3, and that the time at which the negative voltage is applied to V8A is a function of the frequency to which Z4 is tuned.

6. Shaper V8A and Cathode Follower V8B.

a. Shaper V8A will remain cut off for 0.6 μsec because of the action of Z4.

b. A positive-going, square wave 0.6 μsec in duration will appear on the plate of V8A. The leading edge of this pulse will occur 1.2 μsec after the beginning of the expanded sweep.

c. This positive-going waveform is coupled to the grid of V8B through C16 and R47.

d. A negative, 15v is applied to the grid of V8B from the junction of R48 and R45 and holds the tube near cutoff.

e. When the positive, 0.6 μsec pulse from the plate of V8A arrives, the 15v bias on the grid of V8B is overcome, and the cathode follower conducts.

f. When the voltage applied to the grid of V8B surpasses ground potential, CR4 will conduct limiting the voltage at the grid of V8B to ground potential.

g. The output of cathode follower V8B will be the 100-yard notch. It is sent to the track receiver system.

7. Driver V5.

a. By referring back to the plate circuit of driver V2, you will notice that one of the outputs of V2 is going to the 35-yard gate channel.

> INSTRUCTOR'S NOTE: The output is erroneously marked as a 1.3 μsec pulse. This should be changed to 3 μsec (fig 15-8).

b. The output of V2 is applied to terminal 3 of Z2, which is tuned so that a quarter cycle of oscillation has a duration of 1.3 μsec (fig 15-9).

c. When the plate potential of V2 decreases, the drop will be felt at the grid of the normally conducting driver V5 and will cut it off.

d. The driver remains cutoff for 1.3 μsec because of the action of Z2.

e. A positive-going, 1.3 μsec pulse is developed at the plate of V5 and is sent to Z5.

f. Z5 operates in the same manner as Z4 and holds V6 cut off for 0.2 μsec starting 1.3 μsec after the beginning of the expanded sweep.

8. Amplifier V6 and Power Amplifier V14 (fig 15-9).

a. The output of V6 is a positive-going, 0.2-μsec pulse beginning 1.3 μsec after the leading edge of the expanded sweep.

b. The plate signal of V6 is coupled to the grid of V14. V14 is held at cutoff because of a negative, 27v potential appearing on its grid from the junction of R100 and R98.

c. Power amplifier V14 develops a negative-going, 0.2-μsec pulse across R100. This pulse is the 35-yard gate.

9. Delay and Nondelay Channel.

a. The 35-yard gate developed across R100 is applied to the cathodes of V9 and V11 through resistors R74, R70, and R85.

b. The nondelay video is applied to the control grid of V9.

c. The delayed video is applied to the control grid of V11.

INSTRUCTOR'S NOTE: At this time establish the time relationships between the delay and nondelay video and the 35-yard gate. Mention that with the relationships shown in diagram 13, V9 will conduct a given amount, and V11 will conduct the same amount 0.22 μsec later. Mention also that the conditions shown above represent a range error of 0 since the 35-yard gate appears equally in coincidence with the delay and nondelay video.

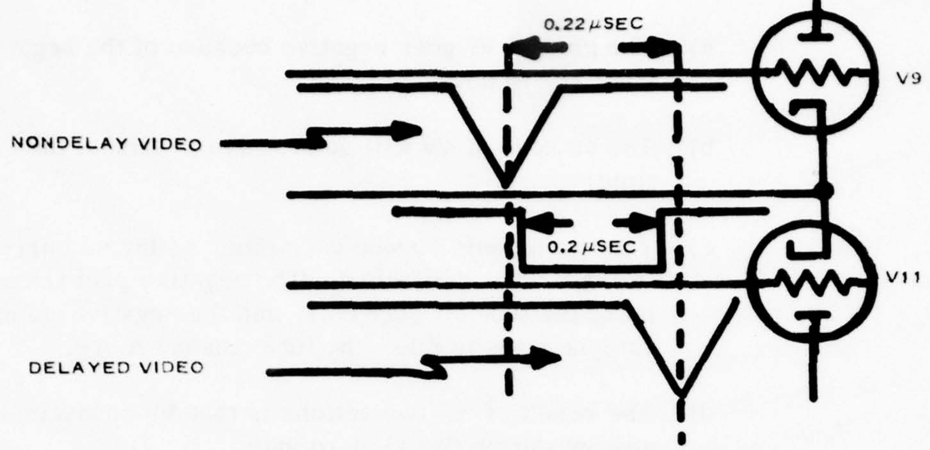

Diagram 13. Inputs to V9 and V11 with zero range error.

d. Assume that the 35-yard gate occurs more in coincidence with the nondelay video.

> INSTRUCTOR'S NOTE: Explain that this is an under-range condition, and that an error signal must be developed which will move the 35-yard gate out in range to the point where it occurs in equal coincidence with the delay and nondelay video.

1) At this time the conditions in diagram 14 exist.

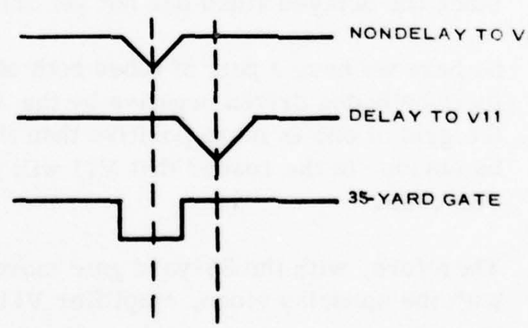

Diagram 14. In-range condition.

a) The grid of V9 goes negative because of the negative, nondelay video.

b) The cathode of V9 will go negative at almost the same time.

c) The two signals oppose each other as far as current through V9 is concerned. The negative grid tries to make the tube conduct less, and the negative-going cathode tries to make the tube conduct more.

d) The result of the two actions is that V9 conducts a small amount during the 35-yard gate.

2) Consider now the conditions surrounding the operation of V11.

a) The cathode of V11 went negative at the same time that the cathode of V9 went negative.

b) Since V11 receives delayed video, its grid will go negative 0.22 μsec after the grid of V9 has gone negative. By this time the cathode of V11 will have returned to its quiescent level.

c) Therefore, at the time of the 35-yard gate, the grid of V11 is quite a bit more positive than the grid of V9 since the delayed video has not yet driven it negative.

d) So here we have a pair of tubes both of which have had their cathodes driven negative by the 35-yard gate, and the grid of one is more positive than the other. It will be obvious to the reader that V11 will conduct more in this case.

e) Therefore, with the 35-yard gate more in coincidence with the nondelay video, amplifier V11 will conduct more than V9.

f) With the 35-yard gate more in coincidence with the delayed video, amplifier V9 will conduct more than V11.

g) With the 35-yard gate appearing equally in coincidence with the delay and nondelay video, both V9 and V11 will conduct equally.

e. Assume that V9 is conducting harder than V11.

1) The plate voltage on V9 will be lower than on V11.

2) The voltage variations on the plates of V9 and V11 will be felt at the cathodes of V10A and V12A.

3) The cathode of V10A will be more negative than the cathode of V12A.

4) If both tubes are allowed to conduct, V10A will conduct the most.

a) At this time consider the two capacitors C19A and C19C.

b) One side of each capacitor is grounded.

c) The other side of each capacitor is returned through a 1.2-megohm resistor to the potential of approximately 25 volts existing at the junction of R66 and R68.

d) During the time between 35-yard gates, both capacitors will have charged equally toward 25 volts. Therefore, the voltage difference between the two is zero.

e) The two capacitors will discharge at some rate determined by the conduction of V10A and V12A.

5) Since we assumed that V10A was conducting harder than V12A, it follows that C19A will be discharged more than C19C.

6) The discharge path for C19A is from its bottom plate to ground, from ground through V14, C27, R74, R70, V9, C18, and C10A, and to the top plate.

> INSTRUCTOR'S NOTE: Let the class find the discharge path for C19C.

7) Since C19A was discharged more than C19C, the output marked A is negative with respect to output C (fig 15-9).

8) With this polarity of output from the delay and nondelay mixer channel, the range servo will operate to move the 35-yard gate in range.

> INSTRUCTOR'S NOTE: Go through the operation of the range-error channel when the 35-yard gate appears more in coincidence with the nondelay video. Discuss the effect of adjusting R74.

9) The TEST OPERATE switch is used to short out the error signal from the range-error channel whenever the following stage (range modulator) is being balanced.

COMMON TROUBLES:

	Symptom	Probable Cause
1.	TRMK present but no expanded sweep on all three track indicators.	500-yard expanded-sweep multivibrator V1 either bad or not operating properly.
2.	Expanded sweep missing on all indicators.	V4A bad. Broken coaxial cable between P64/A and J8/B.
3.	Expanded sweep jitters at all ranges.	MV BIAS I control improperly adjusted.

	Symptom	Probable Cause
4.	Expanded sweep on all three indicators badly distorted.	Open coaxial terminating resistor on E13/B.
5.	No 100-yard notch.	Driver V3 bad. V8 bad. Filaments on trial-fire indicators ON.
6.	System will not track in automatic.	V5, V6, or V14 bad. S2A in TEST position. V9, V10, V11, or V12 bad.
7.	A steady drift in range with the system in automatic and no target gated.	Bad adjustment of range balance R74.

PRACTICAL EXERCISE

PULSE GENERATOR AND RANGE ERROR CHANNEL

AAFCS M33 SETUP: Track filaments and low voltage on.

EQUIPMENT NECESSARY:

1. Test amplifier,
2. Trouble light, and
3. Multimeter.

PRELIMINARY EXERCISE:

Devote about 45 minutes to a demonstration of the complete adjustment of the track-range computer. If possible, let all the students participate.

DEMONSTRATION:

1. Pulse Generator.

   a. Use the test amplifier to monitor the input to the multivibrator V1A.

   b. Monitor the output of the multivibrator. Discuss the method used in adjusting R11.

   c. Use the test amplifier to monitor the progress of the expansion pulse through V4B and V4A.

   d. Discuss the distribution of the expansion pulse, and locate E3, E8, E13, and the coaxial terminating resistor.

   e. Monitor the waveform at the plate of V2 and V3 and at the screen grid of V3.

   f. Monitor the 100-yard notch at the plate of V8A.

g. Monitor the 3-μsec waveform appearing at pin 3 of Z2.

h. Use the test amplifier to follow the progress of the 35-yard gate as far as possible.

> <u>INSTRUCTOR'S NOTE</u>: Since it is usually impossible to have the use of a vacuum-tube voltmeter for this demonstration, it will be necessary to conduct the class with only the multimeter. The 20,000-ohm scale of the multimeter will attenuate the voltages on C19A and C19C to such a level as to be useless for purposes of demonstration. However, if the range modulator is completely disconnected from its Jones plug, a considerable portion of the load for the two capacitors is removed; the multimeter can then be used for demonstration of the effect that range errors will have on the polarity of the charges appearing on these capacitors. It must be remembered that the meter readings will be much lower than the actual voltages appearing on C19A and C19C.

2. <u>Range-Error Channel.</u>

a. Connect the multimeter for use.

b. Connect the meter between pin 2 of V10 and pin 2 of V12.

c. Turn on the track transmitter.

d. Activate the RANGE CALIBRATE switch.

e. Place the 100-yard notch on one of the weaker range-calibrate marks.

f. Place the elevation and azimuth servos in AUTO and the range servo in AID.

g. Move the 100-yard notch to each side of the range-calibrate mark.

h. Explain that the voltage being read on the meter is the error signal that positions the range servo in AUTO.

i. Operate switch S2A to TEST. Point out the deflection on the meter.

j. Monitor the video signals appearing at the control grids of V9 and V11.

k. Show the effect of adjusting RANGE BAL 2 control R74.

SUGGESTED TROUBLES:

1. Primary.

a. Replace V3 in the range modulator with a bad tube.

> INSTRUCTOR'S NOTE: On some sets it is possible to see the 35-yard gate on the track indicators by turning the receiver gain all the way down. If such is the case, have the students use this as a check for the 35-yard gate channel. Another check for the presence of the 35-yard gate (providing the range modulator is intact and functioning correctly) is to vary the RANGE BAL 2 control R74. If the range servo can be made to move in and out in range, the 35-yard gate is present.
>
> Have the student notice the effect on automatic tracking before proceeding with troubleshooting. Explain that the multimeter check of the range-error channel can be used to determine if the channel is working properly.

b. Replace either V9 or V11 with a bad tube (fig 15-9).

c. Place TEST OPERATE switch in TEST.

d. Misadjust RANGE BAL 1 and 2 controls.

e. Replace V6 (fig 15-9) with a bad tube.

f. Replace V5 (fig 15-9) with a bad tube.

INSTRUCTOR'S NOTE: Finish the period by inserting troubles anywhere in the range tracking system including pulse generator and its distribution and the handwheel assembly.

2. Review.

While the primary group is troubleshooting, start a question and answer session with the secondary group.

LESSON PLAN

RANGE TRACKING SYSTEM
(Part VII)

OBJECTIVE:

To explain the operation and repair of the:

1. Range modulator, and

2. Automatic track-indicator channels.

INTRODUCTION:

The range-error channel has furnished an error signal whose polarity is governed by the position of the 35-yard gate with respect to the delay and nondelay video. The amplitude of the error voltage will be determined by the position of the 35-yard gate relative to the two video signals.

The small error signal from the range-error channel will eventually position the range servo by controlling the direction of rotation of a servo motor. The motor uses a 400-cycle control voltage.

It then becomes necessary to produce a 400-cycle control voltage whose amplitude is determined by the range-error voltage amplitude and whose phase is determined by the polarity of the error voltage.

PRESENTATION (fig 15-10):

1. Range-Modulator Channel.

   a. If a target is gated and the 35-yard gate is correctly positioned (zero range error), the voltage at pins 1 and 5 of P1/A37 of the range modulator will be approximately 14 volts.

   b. When the 35-yard gate is underrange, the voltage at pin 1 of P1/A37 of the range modulator rises, and the voltage at pin 5 drops.

c. When the 35-yard gate is overrange, the voltage at pin 1 of P1/A37 drops, and the voltage at pin 5 rises.

d. The voltage at the junction of R1 and R2, which are connected between pins 1 and 5 of P1/A37, will be the average voltage difference between the charges on C19A and C19C with respect to ground.

e. This average voltage will be greater when a target is gated than when a target is not gated.

 1) With a target gated, the voltage at the junction of R1 and R2 is approximately 14 volts.

 2) With no target gated, the voltage at the junction of R1 and R2 is approximately 10 volts.

 3) The rise or drop in voltage at the junction of R1 and R2 furnishes the input to the automatic tracking indicator (ATI) channel.

f. A voltage proportional to the rate of the target's range change is available at terminal 7 of K1.

 1) When the system is not in automatic, relay K1 is de-energized, and capacitor C1A will charge to the voltage appearing at terminal 7 of K1. (Contacts of K1 will be in the condition shown on fig 15-10.)

 2) When the system is placed in AUTO, relay K1 will energize; contacts 8 and 6 and contacts 5 and 4 will close.

 3) This placed the voltage at C1A across the input terminals 1 and 5 of P1/A37 of the range modulator.

 4) The action of C1A will eliminate any unnecessary jerking of the range servo whenever the system is initially placed in automatic.

g. Bridge-Balancing Circuit.

1) The bridge-balancing circuit consists of R5 through R10 in addition to potentiometer R11.

2) The purpose of this circuit is to provide a push-pull balancing voltage to the grids of the balanced modulator without affecting the charge on C19A and C19C.

3) Terminals 1 of R11A and 3 of R11B are connected to the junction of R12 and R13. The voltage at this junction is +2.6v.

4) Terminals 3 of R11A and 1 of R11B are connected to -2.6 volts at the junction of R14 and R15.

5) Adjustment of R11 will move both wiper arms either up or down schematically and apply to the grids of the balanced modulator a push-pull balancing voltage which will compensate for unequal output because of circuit inequalities. In simpler terms, this means that R11 is adjusted until zero signal input yields zero signal output.

6) There are three conditions under which there is zero error input to the range modulator:

a) When the system is not in AUTO and relay K1 is de-energized and removed any input to the range modulator.

b) When the system is in AUTO and the 35-yard gate is properly ranged, and

c) When no target is gated.

7) In either of the above cases, the potentials at the grids of the range modulator will be equal, and the range modulator will yield no output.

8) The introduction of an error signal from the range-error channel will unbalance the range modulator in some direction and by some amount determined by the polarity and amplitude of the error signal.

h. The balanced modulator used in the range modulator is very similar to the balanced modulator previously discussed.

1) Two, 400-cycle signals of opposite phases are introduced to the cathodes of V1 and V2.

2) By causing the modulator to be unbalanced in one direction or the other, a phase reversal can be accomplished in the output of the balanced modulator.

3) Two phase-equalizing networks are used in the balanced modulator.

a) In the cathode circuit of the balanced modulator, resistors R18 through R21 and C2 form a network that introduces a phase lag to servo-excitation voltage.

b) In the output end of the balanced modulator, R24 through R27 and PHASE potentiometer R28 form a network that introduces a phase lead to servo-excitation voltage. R28 is adjusted so that this phase lead introduced by the network equals the phase lag introduced in the cathode circuit.

c) The effect of the two equalizing networks introduces a phase lead for frequencies below 400 cycles and a phase lag for frequencies above 400 cycles. This allows the range modulator to compensate for certain frequency versus phase-shift characteristics which are inherent in the range modulator.

i. The outputs of the range modulator are sent to the grids of push-pull cathode followers V3A and V3B.

1) The cathodes of V3A and V3B are returned to -250 volts through the centertap of transformer T1.

2) The primary of transformer T1 is paralleled by capacitor C5 which enables the cathode followers to work into an almost purely resistive load. This prevents an undesirable phase shift which might be caused by an inductive load.

3) The voltage induced in the secondary of the transformer is sent to the range-servo channel.

INSTRUCTOR'S NOTE: The transformer in the cathode circuits of V3A and V3B is not labeled. It should be marked T1.

2. Automatic-Tracking Indicator (fig 15-11).

a. The AAFCS M33 will track a target indefinitely as long as the target return is of sufficient amplitude to control the automatic-track circuits (ATC).

b. If, for any reason, the return from the target drops below a certain prescribed limit, the system will discontinue automatic operation and return to aided operation.

c. At this time, a lamp on the tracking console will light and warn the operators that automatic tracking has ceased.

d. In the discussion of the range modulator, it was found that the voltage at the junction of R1 and R2 was 14v with a target gated and 10v with no target gated. This rise and fall constitutes the input to the ATI channel and is applied to the grid of V4B.

e. The grid of V4A is returned to the wiper arm of potentiometer R30 and can be varied from 0 to approximately 19v.

f. Under normal operation, R30 is set for approximately 12 volts.

g. Operation with no target gated.

1) Grid of V4B is at 10 volts.

2) Grid of V4A is at 12 volts.

3) V4A conducts more than V4B; therefore, its plate voltage is lower than the plate voltage of V4B.

4) The plate voltage variations of both halves of V4 are coupled to the grids of both sections of V5.

5) V5B will conduct more than V5A since its grid voltage is more positive.

6) The current passed through V5B will not pass through K2.

7) K2 is set so that the current passed at this time by V5A will not quite energize it.

8) Contacts 5 and 6 of K2 remain open.

<u>INSTRUCTOR'S NOTE:</u> Assume that all three MAN-AID-AUTO switches are in the AUTO position and that DISABLE switch S7/B31 is in its upper position (contacts 3 to 2 and 6 to 15 are made).

9) Since K3 is deenergized, the COAST indicator I1/B31 will be lit.

10) All the relays permitting automatic tracking will be de-energized.

<u>INSTRUCTOR'S NOTE:</u> Explain the function of all the auto-track relays. Also explain that, with the previously mentioned conditions, the system will be in AID and coasting at the previous rate of the target.

h. Operation with a target gated.

1) V4B will now have 14v applied to its grid.

2) V4A will have 12v applied to its grid.

3) Since V4B is conducting more than V4A, its plate voltage will be the lower of the two.

4) V5A will conduct more than V5B since its grid is more positive.

5) The current flowing through V5A will energize K2.

6) Contacts 5 and 6 of K2 will close and apply -28 volts to K3.

7) K3 will then energize.

8) Contacts 1 and 2 of K3 break, removing ground from the COAST IND 1 lamp, and the light goes out.

9) Contacts 5 and 4 of K3 close and apply ground to all the relays permitting auto tracking.

10) The system will now resume automatic operation.

11) C6B, CR2, R44, C6A, CR1, and R43 introduce a delay in the response of V5A and V5B which permits the system to track in AUTO for one second after the target has become ungated.

COMMON TROUBLES:

	Symptom	Probable Cause
1.	Continual range creep in AUTO	Bad adjustment of R11.
2.	No range response in AUTO.	V1, V2, or V3 in range modulator bad.
3.	Unable to track in AUTO while using the auto-track indicator.	Bad adjustment of R30 in AT1. Relay K3 stuck in the deenergized position. V4 or V5 bad.

5) The current flowing through V5A will energize K2.

6) Contacts 5 and 6 of K2 will close and apply -28 volts to K3.

7) K3 will then energize.

8) Contacts 1 and 2 of K3 break, removing ground from the COAST IND 1 lamp, and the light goes out.

9) Contacts 5 and 4 of K3 close and apply ground to all the relays permitting auto tracking.

10) The system will now resume automatic operation.

11) C6B, CR2, R44, C6A, CR1, and R43 introduce a delay in the response of V5A and V5B which permits the system to track in AUTO for one second after the target has become ungated.

COMMON TROUBLES:

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3.	Unable to track in AUTO while using the auto-track indicator.	Bad adjustment of R30 in AT1. Relay K3 stuck in the deenergized position. V4 or V5 bad.

PRACTICAL EXERCISE

RANGE TRACKING SYSTEM
(Part VII)

AAFCS M33 SETUP: Track filaments on.

EQUIPMENT NECESSARY: Test amplifier and trouble light.

PRELIMINARY TROUBLE:

Misadjust the complete range tracking computer. Devote no more than 45 minutes to the adjustment.

DEMONSTRATION:

1. Range Modulator.

   a. Locate and discuss RANGE BAL 1 control R11.

   b. Monitor the 400-cycle signal at pin 3 of the output transformer with the test amplifier.

   c. Briefly run through the operation of the range modulator.

2. ATC Channel.

   a. Go through the adjustment of the COAST IND.

   b. Use the multimeter to measure the bias on V4A.

   c. Briefly run through the operation and purpose of the ATC channel.

SUGGESTED TROUBLES:

1. Primary.

   a. Misadjust RANGE BAL 1 control R11 and RANGE BAL 2 control R74. Have each man make the adjustment.

b. Replace V3B in the range modulator with a bad tube.

c. Disconnect terminal 188 in the radar cabinet (fig 15-12).

d. Misadjust COAST IND control R30. Have each man make the adjustment.

e. Disconnect terminal 198 in the radar cabinet (fig 15-11).

f. Replace V5 in the ATC channel with a bad tube.

2. Review.

While the secondary group is waiting, the instructor should quiz the group on all of the range tracking system adjustments made so far. The adjustments should be stressed so much that the students should not need any reference material to perform them.

LESSON PLAN

TROUBLESHOOTING REVIEW
(Range Tracking System)

OBJECTIVE:

To explain and review the various methods employed in troubleshooting the range tracking system.

INTRODUCTION:

The coverage of the range tracking system has been necessarily brief—ranging from detailed explanation in some cases to mere exposure in others. The student may at this time be overcome with an overwhelming feeling of bewilderment because of the vast amount of material covered in a few short weeks.

Since it is humanly impossible to absorb and retain all that has previously been covered, it has been decided to include this conference in which troubleshooting is of first importance. Only as much theory as is needed to understand the various methods is used.

The finer points in understanding the operation of the system will come later. Right now, let us fix it!

PRESENTATION:

1. Track-Range Computer.

   a. Main-Gate Generator (fig 15-4).

      1) The quickest place to check the operation of the main-gate generator is at TP1.

      2) Although the main gate appears at TP1, we cannot assume it will also appear at the grids of V1 in the timing-wave generator.

3) The surest check is at the grids of V1A and V1B.

b. Oscillator V1B.

If it has been determined that the main gate is appearing at the grids of V1B, and a waveform check of the oscillator cathode pin 8 reveals the absence of the timing wave, the trouble has been localized to either V1 or Z1.

c. Quadrature Tube V2.

1) The following stages in the timing-wave generator will have to be checked by the appearance or absence of the timing wave since there is no accurate method available for checking phase shift.

2) If a waveform check of the timing wave reveals a sine wave-train of gradually diminishing amplitude, it can be assumed that V2 is not functioning properly.

d. Phase-Shift Capacitor C6.

1) Very little goes wrong with the phase-shift capacitor.

2) The operation of the preceding circuits can be checked by monitoring the input waveforms to C6 at E3, E4, E5, and E6.

3) The feedback amplifiers can be checked by the appearance or absence of the timing wave.

e. Differentiating Amplifier V2A.

1) The junction of CR1 and CR2 is a very good place to check the operation of the timing-wave generator since the lid to the range computer is already up.

> INSTRUCTOR'S NOTE: Make sure the class knows the physical location of this check point. Explain that this check makes it unnecessary to go through the time-consuming job of removing the cover from the timing-wave generator.

2) If V2B is not conducting, a waveform check at its plate will sometimes reveal the presence of timing spikes. This is because of the grid-to-plate coupling through R20 and C8, and the fact that the gain of the test amplifier is set too high.

Caution: While checking the plate outputs of V2B, be certain you know how much deflection a signal of 10v and 20v will give on the A-scopes. This will eliminate unjustified assumptions regarding the operation of V2B.

f. Pip Selector V12.

1) The voltages and waveforms on the pip selector can be used to check the operation of the timing-wave generator, the phantastron, and the pip-selector potentiometer.

2) A dc check at the control grid of V12 will determine whether the variable bias from potentiometer R8/A33 is present on the pip selector.

3) A test-amplifier check at the control grid will determine whether the timing-wave generator and pip generator are operating properly.

4) A test-amplifier check at the cathode of V12 will determine whether the phantastron is operating properly.

5) The presence of the selected pip input to the 5,000-yard multivibrator does not necessarily indicate that the timing-wave generator is operating since a selected pip can be produced with no timing spikes.

6) If the 5,000-yard multivibrator is yielding a proper output, the operation of the QTRMK, TRMK, and TRGA channels can be checked by the presence of their respective outputs.

g. Points To Remember:

1) The junction of CR1 and CR2 can be used as a check point for operation of the main-gate and timing-wave generators.

2) The track-range computer will yield a QTRMK and TRGA with the timing-wave generator inoperative.

3) The inputs to the pip selector V12 can be used to check the following stages:

a) Main-gate generator,

b) Timing-wave oscillator,

c) Phantastron channel, and

d) Pip-selector potentiometer R8.

2. Pulse Generator.

a. The 500-yard expanded pulse and the 100-yard notch outputs from the pulse generator can be seen on the tracking indicators. If any of the outputs are absent from the indicators, the operator will have a clue to the location of the trouble.

b. Sometimes the 35-yard gate can be seen on the track indicators by turning down the track-receiver gain and looking closely at the 100-yard notch for a small, positive-going pip almost in the center.

c. If the 100-yard notch is present, it is generally safe to assume that the clear-out pulse is also present; but if a definite check is desired, it can be made at pin 6 of V3 with the test amplifier.

3. Range-Error Channel.

a. It is sometimes very hard to see the 35-yard gate even with the synchroscope.

b. If it is required to definitely establish the presence of the 35-yard gate, proceed as follows:

1) Vary R74 (fig 15-9) all the way in one direction.

2) Watch the range indicator on the tracking-range computer.

3) If the range indicator creeps out in range for a setting of R74 in one direction and in for a setting of R74 in the other direction, it can be assumed that the 35-yard gate is present.

4) The video signals on the grids of V9 and V11 can be checked with the test amplifier.

4. Range-Modulator Channel.

a. The operation of the range modulator can be checked by placing S2A in the TEST position and moving the setting of R11.

b. If range can be made to creep in or out with R11, it can be assumed that the range modulator is working correctly.

5. Range Tracking System.

a. The operation of the R_D and R_H low-power servo amplifiers can be checked with an artificial error signal of 6.3 volts of either phase AB or phase BA.

b. A multimeter lead can be used by connecting one end of it to one side or the other of BAL 2 ADJ R4/B47 and placing the other end of it on the grid of the first stage of the amplifier under check.

6. Relay Amplifier (fig 15-14).

a. The operation of this channel can be checked simply by designating a given range and azimuth on the PPI, and

b. Depressing the ACQUISITION switch until the range and azimuth servos stop slewing.

c. If the electronic cross comes to rest at the intersection of the range circle and the flashing azimuth line, it can be assumed that the relay amplifier is working properly.

7. Automatic-Tracking Control.

This stage can be checked as follows:

a. Turn on the track transmitter.

b. Activate the RANGE CALIBRATE switch.

c. Activate the DISABLE switch to its upper position.

d. Place the system in AID.

e. Starting from about the 4th or 5th range calibrate mark, slowly move the track range out, and watch the coast indicator.

f. Every time the 100-yard notch passes through one of the calibrate marks, the coast indicator should go out.

g. If this happens even on the weaker range calibrate marks, it can be assumed the ATC is working properly.

PRACTICAL EXERCISE

TROUBLESHOOTING REVIEW
(Range Tracking System)

AAFCS M33 SETUP: Track filaments on.

EQUIPMENT NECESSARY: Test amplifier and multimeter.

PRELIMINARY TROUBLE:

Loosen P66/A in the pulse demodulator so that the expanded sweep disappears.

DEMONSTRATION:

1. Since the nature of this laboratory session is a review, the demonstration by the instructor will be omitted.

2. It is suggested, however, that the complete adjustment of the range tracking system including RANGE BAL 1, RANGE BAL 2, and the coast indicator be done by the group.

3. Allow two men to work on the adjustment and check their results by energizing the track transmitter and tracking a target in AUTO.

4. Conduct a question and answer session with the secondary group on all the material covered to date.

LESSON PLAN

ANTENNA POSITIONING
(Part I)

OBJECTIVE:

To explain the operation of the antenna-positioning system.

INTRODUCTION:

Since the transmitted beam of the track radar is only nine mils wide at the half-power points, it will be necessary to employ an extremely accurate method of positioning the antenna. It must be remembered that a slight pointing error of the antenna with respect to the target will result in loss of target video.

This class will be concerned primarily with how the antenna is positioned or directed under manual and aided operation. Some of the superficial aspects of automatic tracking will of necessity also be covered but only in as much detail as is necessary for explaining aided and manual operation.

PRESENTATION:

1. General.

The antenna-positioning system (APS) can be looked upon as nothing more than two large servo systems that are constantly trying to correct themselves with respect to a given reference point.

a. In the case of manual operation, the reference point that controls the system is the position of the associated handwheel motor tachometer.

b. In aided operation, the reference point is a reversible phase voltage whose phase and amplitude are determined by the direction and amount of handwheel rotation.

c. In automatic operation, the reference point to which the system tries to correct is the target itself.

d. The principle of conical scanning is utilized in automatic operation to provide the error voltages which will position the antenna on the target.

e. Conical scanning results from rotating the scanning horn about the focal point of the antenna so that the transmitted beam will also be caused to rotate.

2. Simplified Block of Antenna-Positioning System (fig 16).

a. The outputs of the lobing-error channel are the error signals which control the antenna in automatic only.

b. The outputs of the lobing-error channel is an ac signal whose frequency is, roughly, 30 cps.

c. The phase and amplitude of this error signal represent direction and amount of antenna-pointing error.

d. The error signal is sent to the azimuth- (az) and elevation- (El) angle detectors, and, since the signal bears a definite relationship to the strength of the target return, it is also sent to the AGC channel where it is used to automatically control the gain of the track receiver.

e. The motor that rotates the scanning horn is also directly connected to the lobing-reference generator which yields four-voltage outputs.

f. As the scanning horn traces a circle about the focal point of the antenna, the outputs of the lobing-reference generator will rise and fall very much as the outputs of the acquisition-azimuth resolver B2 rise and fall when the ACQ antenna rotates.

INSTRUCTOR'S NOTE: Explain the similarity between the lobing-reference generator and acquisition-azimuth resolver B2. Draw the two windings on the board and label them L1D and LR.

g. The left-right output of the lobing-reference generator is sent to the azimuth-angle detector, and the up-down output is sent to the elevation-angle detector.

h. At this point, it must be remembered that the elevation-and azimuth-angle detector both receive the same output of the lobing-error channel.

i. The left-right, lobing reference voltage and the output of the lobing-error channel are compared in the azimuth angle detector, and a 400-cycle signal is developed whose phase and amplitude are proportional to the direction and amount of antenna-pointing error in azimuth. The elevation-angle detector compares the same lobing-error channel output with the up-down outputs of the lobing-reference generator and develops an error signal proportional to the antenna-pointing error in elevation.

j. The two 400-cycle signals are then sent to their corresponding servo channels where they are used to position the track antenna when in automatic.

k. The student should always keep the following in mind:

1) The lobing-error channel controls the position of the track antenna through the azimuth and elevation angle detectors only while the system is in automatic;

2) The tachometer output from the handwheel assemblies will control the position of the antenna in manual;

3) In AID the antenna is positioned by a reversible phase voltage whose phase and amplitude are controlled by the direction and amount of handwheel rotation; and

4) In addition to the above-mentioned control possibilities, it is also possible to control only the azimuth servo by a setting on the ACQ azimuth channel. In this case, the track-azimuth servo will be caused to come to rest at a point that coincides in azimuth to the azimuth setting of the steerable azimuth line on the PPI's.

3. Manual Operation of the Azimuth Servo (fig 16-2).

a. In manual operation, it is desired to control the operation of drive motors V1A/D1, B3A/D1, B5A/D1, and V7A/D1 by rotating the AZIMUTH handwheel which is shown at the lower left-hand corner of the page.

b. In MAN and AID, relays K3 and K5 will be deenergized.

c. Turning the handwheel will also turn the handwheel tachometer since they are mechanically linked.

1) As the tachometer is turned, it will yield a 400-cycle signal whose phase is determined by the direction of rotation and whose amplitude is determined by the speed of rotation.

2) The tachometer output is then sent to the azimuth-coupling network Z2/B38.

> INSTRUCTOR'S NOTE: Call attention wherever possible to the similarities between the range servo which has already been covered and the azimuth servo.

d. The input network electrically prepares the tachometer output for introduction to the A_H LPSA.

e. The A_H LPSA amplifies the signal appearing at its input and yields a controlling voltage which is sent to intermediate motor B6/B51.

1) As B6 is caused to turn by the controlling voltage from the A_H LPSA, the tachometer and the 25-speed control XMTR will also turn.

2) One of the tachometer inputs is sent back to coupling network Z2/B38 where it is used to cancel out any oscillations of B6/B51.

f. This completes the discussion of the low-power servo loop for the azimuth servo while in manual.

g. It will be remembered that as B6 rotated it also caused the 25-speed control XMTR rotor to turn. This is where the control signal for the high-power loop is produced.

   1) A voltage is induced in the rotor of B5 (erroneously labeled B6 on fig 16-2) as soon as the mechanical angle of the rotor deviates from the electrical angle set up by the stator of B5.

   2) The student should keep in mind that the electrical angle produced by the stator of B5 is a direct result of the antenna's present position in azimuth.

h. The signal appearing at the rotor of B5 is then sent to the azimuth-coupling network through closed contacts 6 and 11 of relay K5 where it is prepared for introduction of the azimuth, high-power servo preamplifier which is called the A_P amplifier.

i. The input to the A_P amplifier is a 400-cycle signal whose phase is determined by the direction in which the rotor of B5 was turned.

j. The output of the A_P amplifier is a dc voltage whose polarity is determined by the phase of the signal appearing at its input.

k. The dc output of the A_P amplifier is sent to four high-power servo amplifiers (HPSA), which converts the signal into a powerful 400-cycle control voltage for use in the drive motors.

l. The control voltage leaving the four HPSA will drive the four drive motors in synchronism thereby turning the antenna in azimuth and, at the same time, turning the 25-speed control transmitter B9/D1.

m. B9/D1 is the unit that determines the position of the electrical angle set up in the stator of B5. Therefore, the antenna will continue to turn until B9 transmits to B5 an electrical angle which corresponds to the mechanical angle of the rotor of B5. At this time, since both electrical and mechanical angles coincide, there will be no voltage induced to the rotor of B5, and the antenna will come to rest.

4. Operation of the Azimuth Servo in Aided (fig 16-2).

a. When the MAN-AID-AUTO switch is placed in AID, the magnetic clutch between the handwheel motor tachometer and the rate potentiometer R3/B46 becomes engaged.

b. The rate potentiometer is so arranged that 6.3 volts of phase AB appear at one end, and 6.3 volts of phase BA appear at the other end. The wiper arm is spring loaded so that when the magnetic clutch is disengaged, the arm will always return to the center or zero-volt position.

c. With the magnetic clutch engaged, the wiper arm of the rate potentiometer will be offset from zero in one direction or the other depending on the direction of handwheel rotation.

d. The antenna will then turn in a direction and speed corresponding to the phase and amplitude of the voltage appearing at the wiper arm of the rate potentiometer.

e. The operation of the HP loop and the LP loop is identical in MANUAL and AID from this point on.

5. Detailed Operation of the Azimuth Servo In Manual (figs 16-7 and 16-8).

a. Motor excitation is not applied to motor B1 since contacts 2 and 9 of K3/B31 are open at this time.

b. Rotation of the handwheel will cause the tachometer to rotate and to generate a voltage of a phase and amplitude determined by the direction and speed of rotation. The phase of tachometer excitation can be varied by the phase adjustment R2/B46. (This is an ordnance adjustment.)

c. BAL control R4/B46 is used to eliminate any tendency of the system to creep when it is at rest.

d. The tachometer-output voltage is applied across R15, through R14 and R16 in the azimuth-coupling network, to the input of low-power servo amplifier A_H.

e. From this servo amplifier the amplified error signal is applied to motor B6 through terminals 8 and 12 of relay K3 which is deenergized in manual operation.

f. Motor B6 turns tachometer B6 and the rotor of control transformer B5.

g. The speed-feedback voltage from intermediate tachometer B6 has two μsec.

1) It is used for damping the response of the intermediate motor B6. This is also called intermediate shaft. In this use, it is applied across R11 and through R10 in the coupling network, the input of servo amplifier A_H, where it is mixed with the handwheel signal coming through coupling resistor R14.

2) It is also used as a forward-feed voltage to decrease the lag of the system. In this use, it is applied to the input of the high-power servo preamplifier through terminals 3 and 10 of relay K5 and through resistor R4 in the coupling network. The movement of the rotor of the control transformer B5 from the null position causes an error voltage to appear across the rotor. (Motor B6 causes this displacement when the control signal is applied.)

h. The error voltage at the rotor of the control transformer is applied through terminals 6 and 11 of relay K5, and through the coupling network, to the input of the high-power servo preamplifier.

i. The output of the preamplifier, which is a dc voltage, is sent to the high-power servo amplifier. There are four HPSA in the azimuth servo system, each controlling one drive motor.

j. As the drive motors turn, they cause the antenna to turn. Four tachometers mechanically connected to the antenna have an output that is used as feedback. The antenna is also mechanically connected to the rotor of the control transmitter B9. This will cause the antenna to turn until the rotors of B5 and B9 are positioned to such a point as to have no output from B5.

6. Elevation Servo in Manual and Aided.

a. The operation of the elevation servo in manual and aided is exactly the same as in the azimuth servo.

b. Relay K5 of the azimuth servo is replaced by K1, and azimuth relay K3 is replaced by K2.

c. Since it does not require so much power to move the antenna in elevation as it does in azimuth, only one drive motor is required here. Also, there is need for only one high-power servo amplifier.

d. The antenna cannot move through 360° of elevation, so some method of limiting its movement is needed. A limit stop is incorporated to reverse the polarity or phase of the input to the HPSA. An arrangement of an upper- and lower-limit stop does this.

e. A slew circuit is used to move the antenna without the use of the handwheel. It taps off one phase of servo X when moving in a given direction. If it is desired to cause the antenna to move in the opposite direction, a different phase of servo X is tapped off by the SLEW switch.

f. The low-power servo amplifiers, high-power servo preamplifiers, and the high-power servo amplifiers are all interchangeable with those in the azimuth-servo system.

7. Operation of the Azimuth Servo During ACQUISITION.

a. Some method of referring target positions from the ACQ radar to the track radar is necessary.

b. To get the antenna to slew to the proper azimuth, a group of synchros are used. A synchro transmitter B2 is located in the antenna housing. Its rotor will always correspond to the azimuth of the track antenna.

c. The differential synchro B2 is located on the tactical-control console. Depressing the ring at that location will cause a stationary sweep to appear on the PPI. Turning this ring will cause the steerable azimuth line to move to the azimuth desired in order to intersect the target.

d. With this condition, there will be an output from the control transformer B8. When the SLEW switch is operated, K4 will energize allowing the 400-cycle output of B8 to be applied to the high-power servo preamplifier.

e. This same thing can be accomplished by turning the RING DEPRESS switch of B8, located on the tracking console, and thereby designating a target azimuth. Operating the SLEW switch will then also apply an input to the high-power servo preamplifier.

f. The 400-cycle voltage from the ACQ AZIMUTH control replaces the signal from the low-power servo loop when the ACQUISITION switch is operated.

g. The antenna is geared to the rotor of transmitter B2 causing it to turn. This continues until the rotors of all three units are properly alined to give no output from control transformer B8.

8. Miscellaneous Information.

a. Relay K13 is energized by the AIR SURFACE switch. This adds a resistor into the rate circuit, decreasing the maximum aided rate than can be set in.

b. TEST OPERATE switch S17 located in the control drawer is used to keep the antenna from moving from a preset position. It sends the output of the low-power servo amplifier A_H back to the input of the handwheel motor. This will put torque on the handwheel motor so it cannot be turned.

PRACTICAL EXERCISE

ANTENNA POSITIONING
(Part I)

AAFCS M33 SETUP: Fully energized except for transmitters.

EQUIPMENT NECESSARY:

1. Test amplifier,
2. Multimeter, and
3. Trouble light.

DEMONSTRATION:

1. Place the azimuth servo in MAN.
2. Use the test amplifier with maximum gain and minimum attentuation to monitor the signal appearing at pin 7 of the azimuth handwheel motor tachometer. Mention that this is the signal that controls the azimuth of the antenna while in MAN.
3. Use figure 16-7 to trace the path that the tachometer output takes on its way to the A_H amplifier.
4. Point out the A_H amplifier and mention that it is interchangeable with any of the other LPSA.
5. Call attention to the red dot on the shaft of B5. Show how it rotates when the handwheel is turned.
6. Disconnect the A_H amplifier, rotate the azimuth handwheel, and call attention to the red dot.
7. Explain that all troubles in the LP servo loop will show up as a lack of rotation of the red dot when the handwheel is rotated.

8. Demonstrate the use of the 6.3 volts appearing at either end of balance control R4 in checking out the operation of the LPSA.

> INSTRUCTOR'S NOTE: It would be best not to show the students the use of tachometer X in checking out the power amplifiers of the LPSA. The students get accustomed to using tachometer X for signal injection, and the first thing they do is inject it somewhere and blow a phase potentiometer.

9. Disconnect the A_p amplifier. Have the students notice that, this time, the red dot moves, but the antenna remains stationary.

10. Demonstrate the use of signal injection in checking out the A_p amplifier.

11. Demonstrate the purpose of shorting either pins 3 and 2 or 7 and 8 of V5 in the A_p amplifier.

12. Return to the handwheel assembly and take the cover off the rate potentiometer. Use the multimeter to show how the voltage picked off the wiper varies with the number of handwheel rotations.

13. Flip the MAN-AID-AUTO switch from MAN to AID several times. Have students watch the clutch and the spring mechanism.

SUGGESTED TROUBLES:

1. Replace either V1 or V2 of the A_H amplifier with a bad tube (12AX7).
2. Remove tachometer X from the handwheel motor tachometer.
3. Disconnect terminal 1 of the intermediate shaft motor tachometer.
4. Short S1 on Z2 in the azimuth-input network (use heavy wire, or the student will unwittingly correct the trouble when he injects 6.3 volts to the grid of the first stage in the preamplifier).
5. Disconnect terminal 5 of E1/B46.

6. Disconnect either terminal 1 or 2 of E1/B46.

7. Disconnect terminal 211 in the radar cabinet.

LESSON PLAN

ANTENNA POSITIONING
(Part II)

OBJECTIVE:

It will be the purpose of this discussion to show how the error signals which position the antenna automatically are developed as well as how these signals actually control the position of the antenna.

INTRODUCTION:

In the preceding discussion, it was shown how the antenna is controlled by manipulation of the AZIMUTH and ELEVATION handwheels while the system is in manual or aided.

PRESENTATION:

1. General.

The lobing-error channel is located on the pulse-demodulator chassis in the radar cabinet.

a. The lobing-error channel is composed of pulse amplifier V13, diode detector V12B, charging triode V15B, cathode follower V15A, lobing amplifier V16A, and cathode follower V16B, all of which may be found on figure 16-5.

b. In understanding the operation of the lobing-error channel, it is first necessary to understand the source and makeup of the channel's inputs (refer to fig 15-9).

1) On figure 15-9, a heavy line will be seen leaving the common cathode connection of V9 and V11 and proceeding to the right edge of the page where it is terminated in an arrow and labeled MOD VIDEO and 35-YD GATE to V12.

INSTRUCTOR'S NOTE: V12 should be changed to read V13.

2) An examination of the signal appearing at this point will reveal a series of video pulses which are 35 yards in duration and which occur at the prf of the system. Since the beam pattern is constantly rotated at a 30-cycle rate, the reflection from most targets will be rising and falling at a 30-cycle rate. This rise and fall in reflected-video amplitude will cause a 30-cycle modulation to appear on the video spikes that appear at the common cathode-connections of V9 and V11. This series of spikes will constitute one of the inputs to the lobing-error channel (fig 16-5).

3) The clear-out pulse is sent to the grid of V15A. Its function will be covered in a later paragraph.

4) The nondelay video is sent to the grid of V13.

2. Lobing-Error Channel Detailed Operation.

a. Since the delay and nondelay video signals being applied to V9 and V11 are modulated at 30 cps, the cathode signal of both tubes will vary at 30 cps when they conduct (fig 15-9).

b. Therefore, the signal applied to the cathode of V13 (fig 16-5) will consist of 35-yard pulses of video, also modulated at 30 cps.

c. At low elevations of the antenna, a spurious lobing-signal develops in the cathode signal introduced to V13. The grid circuit consisting of CR2, R19, and C22 together with the incoming nondelay video serves to cancel the spurious lobing-error components of the signal being introduced to the cathode of V13. This results in the lobing-error channel's developing an error signal based only on the amplitude of the target's reflection and not the reflection from ground clutter.

INSTRUCTOR'S NOTE: Explain that when no video occurs during the time interval of the 35-yard gate, tubes V9 and V11

INSTRUCTOR'S NOTE (continued)
conduct more heavily than they do when video does occur. With no target in the 35-yard gate, V13 will have a more positive voltage on its cathode than when a target is gated.

d. With no target gated, the operation of V13 and V12B is as follows:

1) V9 and V11 conduct at their highest level.

2) The voltage at the cathode of V13 is at its most positive value.

3) V13 conducts a small amount during the period of the 35-yard gate, and a corresponding voltage drop will occur at the plate of V13.

4) The drop is coupled to the cathode of V12B through C23. The cathode of V12B is normally held at a positive 25v from the junction of R68 and R66.

5) V12B will conduct when its cathode goes negative, and a discharging current will flow into the ungrounded plate of C24.

6) The amount of discharge of C24 is proportional to the conduction of V12B which, in turn, is directly proportional to the amplitude of the target reflection.

7) The discharging action of the 35-yard gate upon C24 is 0.2 μsec in duration. The voltage to which C24 has discharged remains almost constant until the charging triode V15B conducts because of the positive-going clear-out pulse being applied to its grid. The conduction of V15B will recharge C24 to a fixed reference level.

8) Study of the pulse generator showed that the clear-out pulse started at TRMK time and lasted for 1.2 μsec. The 35-yard gate started 1.3 usec after TRMK time and lasted for 0.2 μsec. In other words, the clear-out pulse ends 0.1 μsec before the 35-yard gate begins.

9) The clear-out pulse is used to return the charge on C24 to a fixed level before it is discharged by another 35-yard gate. Thus, the discharge of C24 is governed solely by the amplitude of the video within the 35-yard gate.

10) The waveform on the ungrounded plate of C24 will appear as in diagram 15.

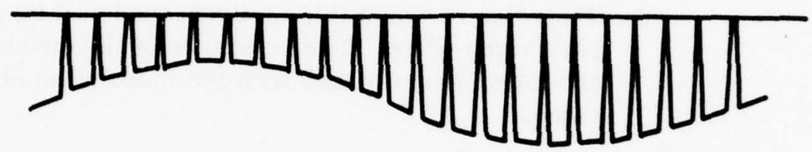

Diagram 15. Voltage across C24 with video.

11) When no target is gated, — when no video occurs during the 25-yard gate — C24 discharges to a fixed level.

e. The clear-out pulse is applied to the grid of the charging triode V15B. V15B conducts, charging C24 to a fixed reference level.

f. The operation of V13, V12B, and V15B with a target gated is as follows.

1) At this time, the amplitude of the voltage reaching the cathode of V13 will be varying at a 30-cps rate.

2) The voltage coupled to the cathode of the diode detector, V12B, will also vary at a 30-cycle rate.

3) The value to which C24 will discharge will be different at each video pulse, and because of the action of the clear-out pulse, it will always return to a fixed level 0.1 μsec before the introduction of the following 35-yard gate.

4) The waveform on the ungrounded plate of C24 with no video will appear as in diagram 16.

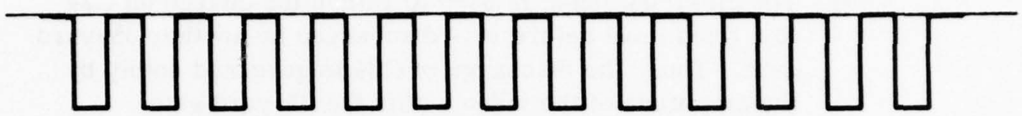

Diagram 16. Voltage across C24 without video.

5) The value to which C24 is discharged will be different for each video pulse. The amplitude of the envelope rises and falls in accordance with the modulation of the target video.

3. Cathode Follower V15A.

a. This stage is a conventional cathode follower which isolates the lobing capacitor from the lobing amplifier.

b. One of the outputs of V15A is the 30-cps envelope of the gated video pulses which is applied to the lobing amplifier.

c. A voltage proportional to the average dc value of the lobing signal is taken from the junction of R104 and R105 and sent to the automatic-gain control channel.

d. The 30-cycle envelope is coupled through C28 and R111 to pin 3 of R112. The voltage at the wiper arm of R112 is then sent to the grid of V16A. R112 can be varied to control the amount of lobing gain in the lobing amplifier.

e. R111 and C30, R106, and C29, and R118 and C32 form a low-pass filter that removes the spikes caused by the clear-out pulse.

f. The output of V16A is fed to the grid of V16B.

g. The output of V16B is taken from the cathode and coupled to the primary of T1 through C33 and C34.

h. The unbypassed cathode resistance of V16B improves the fidelity of the stage.

i. The centertap of the secondary of T1 is grounded.

j. The signal at pins 1 and 3 of J53/A is a push-pull ac voltage varying in amplitude at 30 cps.

k. The push-pull, lobing-error signal is then sent to both the azimuth- and elevation-angle detectors.

4. AGC Amplifier V17.

a. The input to this stage is obtained from the junction of resistors 105 and 104 (fig 16-5).

b. Resistors R119, R120, R121, and capacitors C35, C36, C37, C38A, and C38B act as a filter circuit to filter the 30-cycle variations in the output of the lobing detector.

c. V17 is arranged so that the conduction of the B section controls the gain of the A section.

> INSTRUCTOR'S NOTE: Discuss the common-cathode resistors R123 and R124 and the divider which establishes the grid voltage at V17B.

d. The static voltage on the grid of V17B is established by the setting of R132 which may be adjusted between +16v and +33v.

e. C39 bypasses R128 and whatever part of R132 is in parallel with it. This is done so that the signal voltage coupled to the grid of V17B from the plate of V17A will not vary as the AGC 2 adjustment is changed.

f. The setting of R132 will determine the conduction level of V17B.

g. Conduction of V17B will cancel some of the degenerative effect of R123 and R124.

h. During periods of weak video, V17B does not cancel any of the degeneration produced by R123 and R124. The result is a negative voltage on the grid of V18A.

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AAFCS M33 TECHNICIAN TRAINING PROGRAM VOLUME IV. TRACK RADAR.(U)
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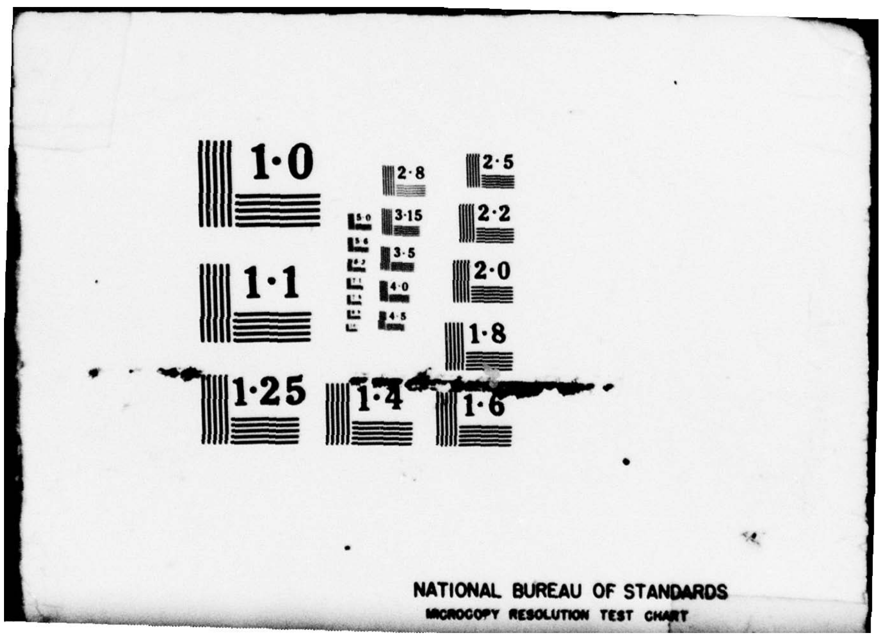
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i. V18A does not conduct, and the AGC voltage will be about zero volts. Therefore, the gain in the preamplifier is high.

j. During periods of high-amplitude video, the bias on V17B will be overcome by the signal from the plate of V17A and, as V17B conducts, it will cancel part of the degenerative effect of R123 and R124. As a result, the gain of V17A increases, and a positive-going voltage is fed to the grid of V18A.

k. V18A will conduct, and the current will pass through R139 to ground, and as a result the AGC voltage will go negative, and the gain of the preamplifier will be lowered.

l. AGC 1 control R141 will determine the amount that V18A conducts for a given input.

m. In simple terms, AGC 1 adjusts for how much the gain of the preamplifier will be reduced.

n. AGC 2 adjusts for how strong the video signal has to be before AGC action commences.

5. Angle Detector (fig 16-6).

a. The lobing-error voltage is introduced to pins 3 and 1 of PI on each angle detector.

b. In the azimuth-angle detector, the E-W output of the lobing-reference generator is applied to the grids of V1.

c. In the elevation-angle detector, the N-S output from the lobing-reference generator is applied to the grids of V1.

d. The lobing-reference amplifier serves to square the 30-cycle voltage variations from the lobing-reference generator.

1) The squaring action results from the use of both grid- and plate-saturation limiting.

2) The push-pull square wave developed at the plate of V1 is coupled to the grids of V2 through C2 and C1.

e. V2 is a dual triode connected as a conventional push-pull cathode-follower stage. The square-wave reference voltage is coupled through the cathode follower V2 and T1 to V3 and V4.

6. Phase Detector V3 and V4.

a. The phase of the azimuth-reference voltage continuously represents the instantaneous position of the rf beam with respect to the mean azimuth (lens axis). The phase of the lobing-error signal represents the direction to a target from the lens axis (direction of pointing error). A phase comparison of these two voltages is made by a phase-sensitive detector consisting of tubes V3 and V4. The result of this phase comparison is the development of a voltage with dc level proportional in polarity and magnitude to the direction (left or right) and distance to the target from the lens axis. When the target is to the right of the lens axis, the dc level is positive. When the target is to the left, the dc level is negative. The magnitude of the dc level is a function of the magnitude of the azimuth component of the pointing error. The farther the target is from the lens axis, the greater will be the magnitude of the dc level.

b. Miscellaneous Information.

1) The push-pull lobing error signal from the secondary of T1 in the lobing-error channel is fed to terminals 2 and 5 of Z1 in the phase detector. The push-pull azimuth-reference square wave is fed to the tubes of the phase detector from the secondary of T1 in the angle-detector channel. The amplitude of the reference voltage is considerable greater than that of the error signal. The effect of the reference voltage is such that, for one half-cycle of the reference voltage, tubes V3A and V4A are allowed to conduct. The effect of the error signal on the circuit is to control the conduction of each tube section that is being permitted to conduct.

2) Consider the current flow in the circuit in the absence of an error signal. When the reference voltage at terminal 1 of the reference-voltage transformer is positive with respect to terminal 3, current flows through tubes V4B and V3B

and the secondary of the reference-voltage transformer. Any output from the circuit is developed across R16. In order for an output to be produced, current must be caused to flow through R16. This is accomplished by application of an error signal to the circuit. When an error signal is induced into the secondary of the error-signal transformer, a difference in potential is created. Thus, current is caused to flow through the centertap of the secondary of T1 and through R15 and R16. The relative phase of the error signal determines the direction of current flow through R16, and, hence, determines the polarity of the output voltage.

INSTRUCTOR'S NOTE: Explain the similarities of this demodulator with the one covered in ACQ.

Only the azimuth-angle detector need be discussed in detail since the elevation-angle detector is identical to the azimuth-angle detector. Emphasize that these chassis are interchangeable.

7. Equalization Network and Relay K1 (fig 16-6).

When the proper conditions for automatic tracking are established, relay K1 is energized. When the relay is energized, the output of the phase detector is fed through contacts 4 and 5 to the equalization network, and contacts 6 and 8 connect capacitor C8 in the circuit. Resistor R19 and capacitor C5A form the filter circuit which averages out the 60-cycle pulsations in the output of the angle detector. Resistor R18 and capacitor C8 bypass any sudden fluctuations in the dc level to ground. Resistor R17 serves as a bleeder resistor for C8 when relay K1 is deenergized. The dc voltage at the output of the filter circuit is applied as a control voltage to the balanced modulator.

8. Balanced Modulator and Cathode Follower.

This circuit is conventional in every respect. The output of this circuit is fed from pins 7 and 9 of P1 to either the azimuth or the elevation automatic relays, K5 or K1, respectively, for application to the high-power servo preamplifiers. The output is a 400-cycle voltage the phase and amplitude of which are proportional to the azimuth or elevation component of the pointing error.

COMMON TROUBLES:

	Symptom	Probable Cause
1.	Antenna continually jerks while tracking a target in AUTO.	Lobing gain adjusted too high.
2.	Antenna will not follow a target in AUTO.	No lobing-reference voltage. (Check SCANNER switch on power-control panel. Make sure it is on.) Activate selector switch on either the track elevation or azimuth indicator to SEL SIG. If the split signal appears, the lobing-reference generator is operating properly. No 35-yard gate is being developed. Lobing gain adjusted too far counterclockwise.
3.	Steady creep in either elevation or azimuth while system is in AUTO and no target gated.	Incorrect adjustment of MOD BAL control in the angle detector is associated with the drift.
4.	No track video while receiver is in AGC.	Bad adjustment of AGC 1 and AGC 2.

IT-P17

PRACTICAL EXERCISE

ANTENNA POSITIONING
(Part II)

AAFCS M33 SETUP: Energized to standby.

EQUIPMENT NECESSARY:

1. Test amplifier,
2. Multimeter,
3. Trouble light, and
4. Synchroscope.

PRELIMINARY TROUBLE:

V1 in the track trigger generator replaced with a bad tube.

DEMONSTRATION:

1. Point out C24.
2. Monitor the nondelay video appearing at pin 1 of V13.
3. Monitor the modulated video and 35-yard gate appearing at pin 7 of V13.
4. Mention that the video appearing within the 35-yard gate will eventually determine the amount of charge on C24.
5. Connect the synchroscope for use and set to START, STOP, SLOW, and EXT SYNC, and use the jumper between the sync-input jack on the synchroscope and J1 on the track console.
6. Monitor the signal appearing at pin 6 or 7 of V12.

7. Use the test amplifier or synchroscope to monitor the clear-out pulse on the charging triode at pin 7 of V15.

8. Monitor the signal at pin 3 of R112.

> INSTRUCTOR'S NOTE: From this point on, correct operation of the lobing-error channel can be demonstrated by the injection of the 30-cycle up-down or left-right reference voltage.

9. Demonstrate that if the AGC cuts down the receiver sensitivity when a range-calibrate mark is gated, it can be assumed that stages V13, V12B, and V15B in the lobing-error channel are functioning correctly.

10. Demonstrate that the operation of V16 can be checked by injection of one of the reference voltages.

11. Mention the purpose and adjustment of R112.

12. Inject the up-down reference voltage to either grid of V1 in the azimuth-angle detector to check out the operation of V1, V2, and the phase detectors V3 and V4.

13. Inject the left-right reference voltage to either grid of V1 to check out the corresponding stages in the elevation-angle detector.

14. Demonstrate that if the balanced modulator can be balanced by means of MOD BAL adjustment on either angle detector, it can generally be assumed that the balanced modulator is functioning properly.

> INSTRUCTOR'S NOTE: Make sure your servos are in AUTO.

SUGGESTED TROUBLES:

1. Replace V13 with a bad tube.

2. Run the LOBING GAIN control all the way counterclockwise.

3. Replace V16 with a bad tube.

4. Replace V1 in either angle detector with a bad tube.

5. Replace either V3 or V4 in either angle detector with a bad tube.

6. Replace V7 in either angle detector with a bad tube.

7. Disconnect terminal 183 or terminal 185 in the radar cabinet (figs 16-7 and 16-10).

8. Replace V15 with a bad tube (fig 16-5).

INSTRUCTOR'S NOTE: Make sure the student is familiar with making the LOBING GAIN and angle detector MOD BAL adjustment.

LESSON PLAN

ANTENNA POSITIONING
(Part III)

OBJECTIVE:

1. To review the operation of the APS in MAN, AID, AUTO, and ACQUISITION.

2. To teach the operation of the high-power servo preamplifier and the high-power servo amplifiers.

INTRODUCTION:

The operation of the antenna-positioning system in MAN and AID was covered in "Antenna Positioning (Part I)." The production of error signals for control of the antenna in AUTO was covered in "Antenna Positioning (Part II)."

The first part of this conference will be a review of the operation of the APS in MAN, AID, AUTO, and ACQUISITION. The second part of the conference will deal with the detailed operation of the high-power servo preamplifiers and high-power servo amplifiers.

PRESENTATION:

> INSTRUCTOR'S NOTE: Since manual and aided operation have already been covered, it should not be necessary to begin this discussion at a block level.

1. Detailed Operation of Azimuth Servo in Manual (fig 16-7).

   a. Rotation of the handwheel assembly shown at the left edge of figure 16-7 will cause the A_p amplifier to produce a dc voltage whose polarity is determined by direction of handwheel rotation and whose amplitude is governed by the speed of handwheel rotation.

b. Four antenna-drive motors will eventually be controlled by the output of the A_p amplifier. The dc output of the A_p amplifier is sent to four high-power servo amplifiers which develop the controlling voltages that cause the four drive motors to turn in synchronism.

c. Rotation of the AZIMUTH handwheel will cause a voltage to be developed at pin 7 of the tachometer. This voltage is then sent to the grid of the first stage of the A_H amplifier. The 400-cycle voltage is amplified and sent to pin 1 of B6/B51 through the TEST OPERATE switch and closed relay contacts 12 and 8 of K3/B31.

d. The azimuth intermediate motor tachometer rotates in accordance with the signal applied to its control winding, and, as it does so, the rotor of the azimuth intermediate-control transformer, B5/B51, is also rotated away from the null position.

1) The null position of B5/B51 can be looked upon as an electrical angle set up by the voltages appearing on the stator of B5.

2) The value of the voltages appearing on the three stator windings of B5 will be determined by the position of the track antenna in AZIMUTH.

3) When the rotor of B5 is moved because of the action of B6, an error voltage is developed on the rotor winding of B5. This rotor voltage is applied to the grid of the first stage of the A_p amplifier through contacts 6 and 11 of K5/B31 and coupling network Z2.

4) The A_p amplifier controls the outputs of the four HPSA which drive the four azimuth-drive motors.

5) The antenna will continue to turn until the electrical angle set up by the stator of B5 corresponds to the new rotor setting of B5.

6) When the two angles are alined, no voltage is induced in the rotor of B5, and the system will come to rest.

e. A speed-feedback voltage is taken from pin 7 of the tachometer section of B6. This feedback has two uses:

1) The voltage is sent back to the input end of the A_H amplifier where it is used to dampen the response of the intermediate shaft, and

2) This voltage is also sent to the input end of the A_P amplifier where it is used as a forward-feed voltage which decreases the lag of the system.

f. An additional feedback voltage is also used in the servo at this time. This voltage comes from the four azimuth-drive motor tachometers and is sent to the A_P amplifier through terminal 102 in the tracking console and R5 in the input network. This voltage is used for damping the response of the HP servo loop.

2. Detailed Operation of the Azimuth Servo in Aided (fig 16-10).

a. One of the main differences in the azimuth servo when it goes from MAN to AID is that the clutch that is connected to the wiper arm of rate potentiometer R3/B46 is engaged. Therefore, movement of the handwheel will cause a corresponding movement of the rate potentiometer.

b. When all sections of the MAN-AID-AUTO switch are in AID, the student can see for himself that the voltage picked off the rate potentiometer will then be sent to the A_H amplifier.

c. The rate voltage from the handwheel assembly and a feedback voltage from the intermediate-shaft motor tachometer constitute two of the three inputs to the A_H amplifier during aided operation.

d. The third input to the A_H amplifier comes from the tachometer assembly. It would seem, at first thought, that as we are in aided operation, we will not need an additional input from the handwheel tachometer since the rate of the system is controlled by the voltage from R3.

1) The voltage generated in the tachometer is used whenever the system is accelerated from one rate to another, or decelerated.

2) Since the output of the tachometer is zero when the handwheel is stationary, its effect is felt on the servo only when the handwheel is rotated. Then it adds or subtracts from the rate voltage to supply the amount of acceleration or braking action required.

e. The operation of the azimuth servo from the A_H amplifier onwards is exactly the same in AID as it was in MAN.

3. Detailed Operation of the Azimuth Servo in Automatic (fig 16-7).

a. In automatic operation, the position of the azimuth servo is controlled by the output of the azimuth-angle detector.

b. The angle detector output appears at the input of the A_P amplifier through contacts 2 and 9 of K5 and contacts 3 and 10 of K4.

c. The A_p amplifier produces a dc output proportional to the ac error signal from the angle detector.

d. The error signal then drives the four HPSA which, in turn, cause the four azimuth drive motors to rotate.

e. The feedback from the azimuth-drive tachometer is again introduced to the input end of the A_P amplifier in order to reduce the response of the HP loop.

f. The signal developed on the rotor of B5/B51 is sent to the input end of the A_S amplifier through closed contacts 7 and 12 of K5/B31.

g. The A_S amplifier then drives the intermediate motor tachometer and the rotor of B5 until the error voltage induced in the rotor of B5 is zero.

h. The feedback voltage from intermediate motor tachometer B6 is applied in the conventional manner to the input of the low-power servo amplifier A_S through network Z2. In addition, this signal appears as an input at low-power servo amplifier A_H. After amplification, it is applied as a driving signal to the azimuth-handwheel motor tachometer B1. The rotation of B1 displaces the brush arm of the rate potentiometer to produce a rate voltage which, when mixed with the feedback voltage from B6, will cause a zero signal to be present at the input to low-power servo amplifier A_H. The rate voltage thus established prepares the system for aided-manual operation in the event that the automatic controller loses the target.

4. Target Acquisition.

a. When the ACQUISITION switch is operated, the azimuth servo system slews automatically to the azimuth designated by the position of the steerable azimuth line on the acquisition indicators.

b. The position of the steerable azimuth line is governed by AZIMUTH LINE control knobs.

c. At the tactical-control console, the AZIMUTH LINE control knob is mechanically coupled to an azimuth-line resolver and to differential synchro B2.

d. At the tracking console, the AZIMUTH LINE control knob is mechanically connected to an azimuth-line resolver and to acquisition-azimuth control transformer B8.

e. Therefore, the position of synchros B2 and B8 is determined by the position of the associated control knobs which also determine the azimuth at which the steerable azimuth line appears.

f. When the ACQUISITION switch is operated, the 400-cycle signal present across the rotor of control transformer B8 is applied through the contacts of acquisition relay K4 and through network Z2 to the high-power servo preamplifier A_P.

g. This signal after amplification causes rotation of the azimuth servo-motors.

h. This rotation is imparted to the rotor of the acquisition-azimuth synchro transmitter B2.

i. The currents flowing in the stator windings of B2 change. As a result, the currents flowing in the rotor windings of differential synchro B2 and in the stator windings of control transformer B8 change correspondingly. Accordingly, the angular position of the magnetic field within B8 rotates in synchronism with the azimuth rotation of the antenna.

j. Movement of the servo continues until the magnetic field within B8 assumes a position 90° displaced from the rotor of B8. At that time, no error signal is induced in the rotor of B8 and the antenna comes to rest at the azimuth designated by the steerable azimuth lines.

INSTRUCTOR'S NOTE: The foregoing discussion should be used as a review for the student, and the amount of detail entered into is left to the discretion of the instructor since he alone can tell if the class is sufficiently familiar with the operation of the APS.

5. High-Power Servo Preamplifier (fig 16-15).

a. The purpose of the HP servo preamplifier is to convert its 400-cycle signal input to a push-pull dc voltage whose amplitude and polarity are dependent on the amplitude and phase of the input.

b. The high-power preamplifier is composed of:

1) Voltage amplifiers V1A and V1B (both amplifying triodes are contained in a single tube envelope),

2) Voltage amplifiers V2A and V2B (again, both triodes are in the same tube envelope),

3) Phase-sensitive demodulator V3 and V4, and

4) Cathode followers V5A and V5B.

c. Voltage Amplifiers V1A and V1B.

1) The 400-cycle signal is sent to the grid of V1A.

2) The operation of V1A and V1B is very similar to the operation of V1A and V1B in the LPSA.

d. Voltage Amplifiers V2A and V2B.

1) These two amplifiers further amplify the 400-cycle signal to the level necessary in the operation of the phase-sensitive demodulator.

2) A selective feedback is used between the cathode of V2B and the grid of V2A, which quickly reduces the gain of the two stages for any frequency other than 400 cycles.

3) R7, C2, C3, and R8 form a bridged "T" network which insures that the feedback sent to the grid of V2A is small at 400 cycles and larger at other frequencies.

e. Phase-Sensitive Demodulator V3 and V4.

1) The 400-cycle output of voltage amplifier V2B is applied to a phase-sensitive demodulator consisting of dual diodes V3 and V4.

2) The demodulator also has applied to it a 400-cycle reference voltage, servo X.

3) These two voltages are compared with each other in the demodulator. Their phase relationships are such that the 400-cycle control voltage from V2B is either in phase, or 180° out of phase, with the reference voltage, depending on the direction of the pointing error of the tracking antenna.

4) The output of the demodulator consists of two pulsating dc voltages of equal amplitude but of opposite polarity.

5) The average amplitude of the output voltage is proportional to the amplitude of the 400-cycle control-voltage output of V2B.

6) The polarity of the push-pull output voltage is determined by the phase relationship of the control voltage and the reference voltage.

7) The pulsating voltages are applied to the output stage consisting of cathode followers V5A and V5B.

f. Cathode Followers V5A and V5B.

1) With no signal applied to the servo preamplifier, the voltage between the cathodes of V5A and V5B is zero, and the voltage between either cathode and ground is essentially zero.

2) The cathode followers provide a means of varying the output voltage in either a positive or a negative direction with respect to ground.

3) When a signal is applied which causes the cathode of V5A to go in a positive direction, the cathode of V5B goes in a negative direction.

4) If the cathode of V5A goes in a negative direction, the cathode of V5B will go in a positive direction.

5) The cathode followers reduce the output impedance of the servo preamplifier to a low value.

6) A low value of output impedance is needed to drive the high-power servo amplifiers. The output of the azimuth servo preamplifier is applied to four high-power servo amplifiers.

7) The output of the elevation servo preamplifier is applied to one high-power servo amplifier.

6. High-Power Servo Amplifier.

a. Five of these units are used in the tracking radar servo systems. Four units, one for each of the four servo-motors are used in the azimuth servo system. A single unit is used with the single servo-motor of the elevation servo system.

b. The high-power servo amplifier consists of a push-pull dc amplifier and a saturable reactor. The output is a 200-watt, 400-cycle signal which is applied to the servo motor with which the amplifier is associated.

c. DC Amplifier V1 and V2.

Tubes V1 and V2 accept the push-pull dc control voltages from the servo preamplifier and translate these control voltages into corresponding direct currents through the control windings of saturable reactor T1.

d. Saturable Reactor T1.

1) Saturable reactor T1 has applied to it a 400-cycle excitation voltage in addition to the dc control currents from V1 and V2.

2) The direct currents control the amplitude and the phase of the 400-cycle output voltage from T1.

3) The amplitude of the output of T1 is proportional to the difference between the currents in the control windings of T1 and will be either in phase, or 180° out of phase with servo excitation depending upon which of the control currents is greater in magnitude.

PRACTICAL EXERCISE

ANTENNA POSITIONING
(Part III)

AAFCS M33 SETUP: Equipment will be energized to standby.

EQUIPMENT NECESSARY: Multimeter and test amplifier.

PRELIMINARY TROUBLE:

Terminal 2 of the azimuth intermediate motor tachometer B6/B51 is disconnected.

DEMONSTRATION:

1. Use the test amplifier to monitor the signal appearing at either pin 9 or 11 of P1/B36 on the azimuth, HP servo preamplifier.

2. While monitoring this signal, depress the ACQUISITION switch. Have the students notice the effect and explain schematically what happened.

3. While monitoring the same point, wobble the AZIMUTH handwheel back and forth. Notice the effects and explain.

> INSTRUCTOR'S NOTE: Unless the handwheel is jerked violently, the signal may not be seen.

4. Discuss the signal-injection method of checking out the HP servo preamplifier and the grid-to-cathode short on V5 in the A_p amplifier.

5. Demonstrate the adjustment of the HP servo preamplifier both with the multimeter and the test amplifier.

6. Locate and discuss the operation of the HP servo amplifiers.

7. Demonstrate the adjustment of the HP servo amplifiers.

8. Lower the cover on the azimuth-drive motors. Point out the friction drive and the terminal strips E1/D1, E2/D1, E3/D1, and E4/D1.

9. Mention that a drive motor or HP servo amplifier that is pulling harder than the other three can usually be detected by extreme heat. Feel the saturable reactor in the HP servo amplifier or the housing on the motor.

10. Locate all the hardware that the student may be required to find, such as B8/B48, B2/C14, K4/B31.

> INSTRUCTOR'S NOTE: Have each student go through the HP servo preamplifier and HP servo amplifier adjustments both with the multimeter and the test amplifier.

Caution: Stress the importance of disconnecting the meter before the BAL switch S22 is turned loose during the HP servo amplifier adjustment. If the meter is not disconnected on a test, the student will lose points.

SUGGESTED TROUBLES:

1. Primary.

   a. Terminal 102 in the radar cabinet is disconnected (fig 16-7). The loss of the feedback causes a distinct azimuth oscillation to develop.

   > INSTRUCTOR'S NOTE: Leave the HP SERVO switch at OFF, except where necessary, to prevent undue wear on the drive ring and rollers.

   b. Short together terminals 211 and 212 in the radar cabinet (fig 16-8).

   c. Replace V1 in the A_S amplifier with a bad tube (fig 16-7). The symptom will be an azimuth jump when the ACQUISITION switch is turned loose after slewing to the designated azimuth.

d. Remove either R1 or R2 of B8/B48 (fig 16-7). There is no azimuth movement of the antenna when the ACQUISITION switch is depressed.

e. Disconnect the spade lug on terminal 20 of the radar cabinet (fig 19-6). This removes motor excitation from the drive motors.

f. Disconnect terminal 51 on E45/A (fig 19-72). Remove neutral from drive motors.

2. Review.

The instructor should spend whatever time he can with the secondary group in the review of all material so far covered in the antenna-positioning system.

LESSON PLAN

ANTENNA POSITIONING
(Part IV)

OBJECTIVE:

1. To explain the operation of:

    a. The optics servo, and

    b. The periscope optics system.

2. To review the operation of the antenna-positioning system.

INTRODUCTION:

For every new weapon, there is an effective counterweapon. In the case of radar, the counterweapon is the different types of jamming and diversive tactics that can be employed.

In one method, jamming of radars consists merely of the aircraft crew's dumping tinfoil strips of different lengths out of the aircraft. The radar will usually cease tracking the plane and "lock-on" the clusters of tinfoil. The tinfoil strips are known as "chaff" or "window." At any rate, the purpose of the operation is accomplished as soon as the radar ceases tracking the plane.

One of the most common diversive maneuvers performed by aircraft is the strategy of flying at extremely low elevations. This usually results in the aircraft's being lost in the ground clutter on the radar indicators.

In both of the above instances, the radar has become confused and is now dependent on human assistance for the accomplishment of its mission.

Since this condition was anticipated, a periscope system was included in the design of the AAFCS M33. With this system the operators can visually position the track antenna on the desired target until the system can again begin automatic operation.

The purpose of the optics system, therefore, is to:

1. Provide a means of optical tracking whenever jamming or diversive action is employed by the target,

2. Provide a means of target identification,

3. Provide a means of determining the accuracy of gun fire, and

4. Provide a means of orienting the track radar.

PRESENTATION:

> INSTRUCTOR'S NOTE: Try to gage your time so that you can cover the optics system in about two periods, use the remaining two periods for a review of APS, and explain the use of the checkout list in "Antenna Positioning (Part V)."

1. Periscope.

The optics servo functions to continually position the periscope line of sight to conform with the axis of the antenna. The upper optics unit is mounted on the antenna pedestal; therefore, alinement of the periscope in azimuth will present no problem. However, a servo system is necessary for the alinement in elevation. This is accomplished by vertically moving a scanning prism by use of a motor tachometer.

2. Upper Optics Unit.

The portion of the periscope system that is mounted on the top of the antenna pedestal is known as the upper optics unit. Optical coverage in azimuth is accomplished as the antenna rotates in azimuth. Elevation coverage is accomplished by means of a scanning prism which is rotated vertically by a motor tachometer over a range of -250 to 1,450 mils. The elevation of the optical line of sight will, therefore, always be in alinement with the elevation of the antenna provided the optics servo is functioning and adjusted correctly.

3. Lower Optics Unit.

The lower optics unit is composed of a beam splitter, three eyepieces with their associated tubes and lenses, and a derotating prism. The function of the derotating prism is to prevent the field of vision from rotating as the antenna is swung about in azimuth. The beam splitter is used to divide the light that comes from the scanning prism into three equal parts so that the three eyepieces can be used simultaneously. The tactical control officer can control the division of light between the three eyepieces by use of a small knob provided on the lower optics unit. The possible control combinations are:

a. One-third to each eyepiece,

b. Half to each of the tracking eyepieces and almost none to the tactical control officer's telescope, and

c. Total amount of light to the tactical control officer's eyepiece and none to the tracking eyepieces.

4. Scanning Prism.

The incoming light passes through the scanning window to the scanning prism. This prism reflects the light back toward the objective lens. The scanning prism has the characteristics of all moving mirrors in that the reflected field travels at twice the angular velocity of the mirror which reflects it. Consequently, the optics servo system, which synchronizes the motion of the scanning prism with that of the antenna, is geared down to a 2:1 ratio. For example, a 100-mil movement of the antenna in elevation will result in a 50-mil inclination of the prism.

5. Pentaprism.

The beam passes through an objective lens to the pentagonal prism (diag 17). This prism reflects the light downward. Numerous inversions of the optical field take place in the various lenses and prisms. Unlike a conventional right-angle prism, the pentaprism does not invert the image. Use of the pentaprism is necessary to obtain an even number of vertical inversions.

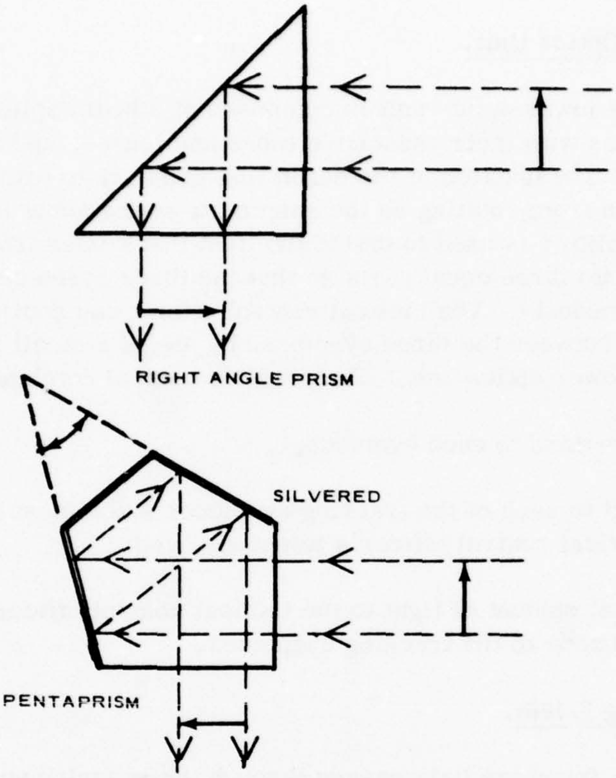

Diagram 17. Pentaprism.

6. Relay Lens.

A relay lens is introduced in order to increase the length of the optical path between objectives without the field-of-vision restriction which otherwise occurs.

7. Reticle.

The reticle is a glass disk located in the focal plane of the objective system. Engraved cross hairs are graduated in 10-mil increments. The image of the reticle coincides with the image of the field. An observer can gage the accuracy of the tracking radar by observing the target image in the cross-hair pattern. Two lamps are provided for night illumination of the reticle. The voltage applied to the lamps is obtained from the filament transformer of the elevation servo. The illumination cannot be seen in daylight.

8. Erecting Prism.

This component, also known as a derotating prism or Z prism (diag 18), serves to keep the image from appearing to rotate. In the absence of such a device, targets would appear normal at one azimuth only, and would appear either canted or upside down at all other azimuths. A prism of this type may be used to stop image rotation by rotating it mechanically about the optical axis at half the angular velocity of the pentaprism. The erecting prism is mounted on ball bearings and rotated by means of a ring gear and worm. The worm is driven by a flexible shaft from a special output fitting on the azimuth drive.

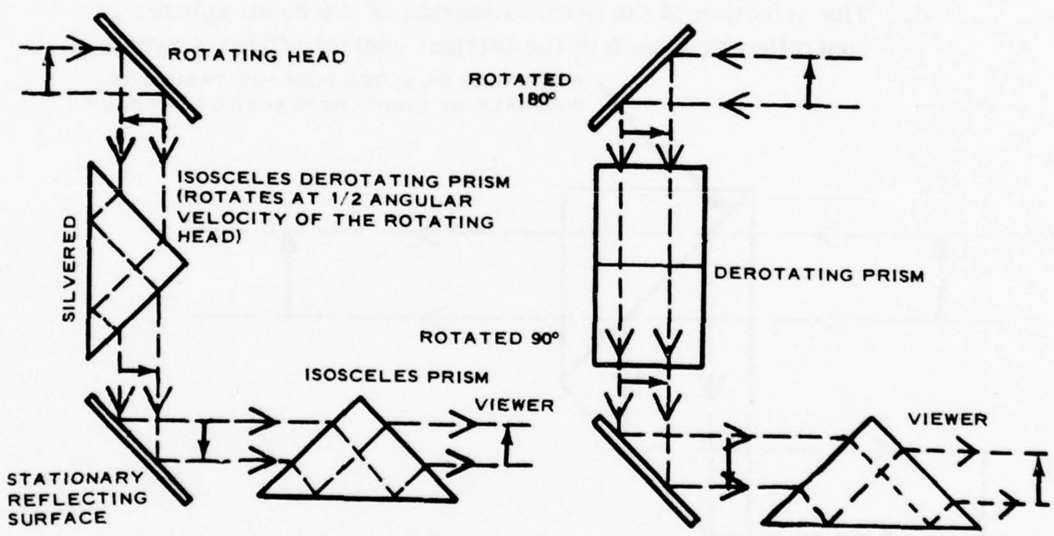

Diagram 18. Block of periscope showing effect of derotating prism.

9. Beam Splitter.

A right-angle prism, immediately below the erecting prism, directs the light horizontally to the beam splitter. The beam splitter (diag 19) provides a means of directing maximum light to the eyepieces in use. It is a plate-glass disk divided into three segments.

a. The first segment is a full mirror which reflects practically all of the light to the eyepiece at the tactical-control console.

b. The second segment, clear glass, passes practically all of the light on to the azimuth and elevation eyepieces. Since this light is divided between two eyepieces, the image is only half as bright as the image reflected to the signal eyepiece by the first segment.

c. The third segment is coated with a very thin reflective coating, sufficient to reflect a third of the total light to the eyepiece at the tactical control console. The remaining light is divided equally between the two tracking eyepieces. Hence, of the total light available, each eyepiece receives a third.

d. The selection of the desired section of the beam splitter is controlled by a knob at the tactical control officer's eyepiece.

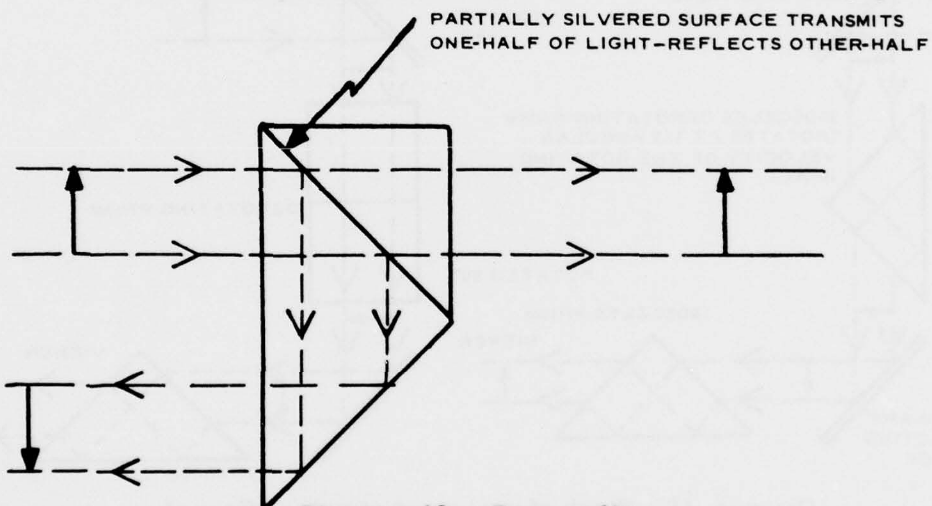

Diagram 19. Beam splitter.

10. Optics Servo Amplifier.

a. The operation of the periscope requires that the scanning prism be positioned in accordance with the elevation position of the tracking antenna (diag 20). The optics servo controls the movement of the scanning prism. To obtain the required accuracy, a 25-speed synchro chain provides the primary error signal.

b. The use of a 25-speed system complicates matters, however, in that it is not completely self-synchronous since there are 25 possible synchronous positions of the output shaft to any one position of the input shaft. To obtain complete synchronism a one-speed system is also used. The one-speed system provides an input signal that insures the correct positioning of the output shaft.

c. The stator windings of the two synchro-control transformers are connected to corresponding control transmitters in the elevation drive. As the antenna is positioned in elevation, error signals will appear across the rotors of the two control transformers. The signals are applied to the input-selector stage of the optics servo amplifier which drives the optics servo in such a way as to eliminate the error. In doing this, the optics servo will drive the scanning prism and keep it in continuous alinement with the axis of the antenna.

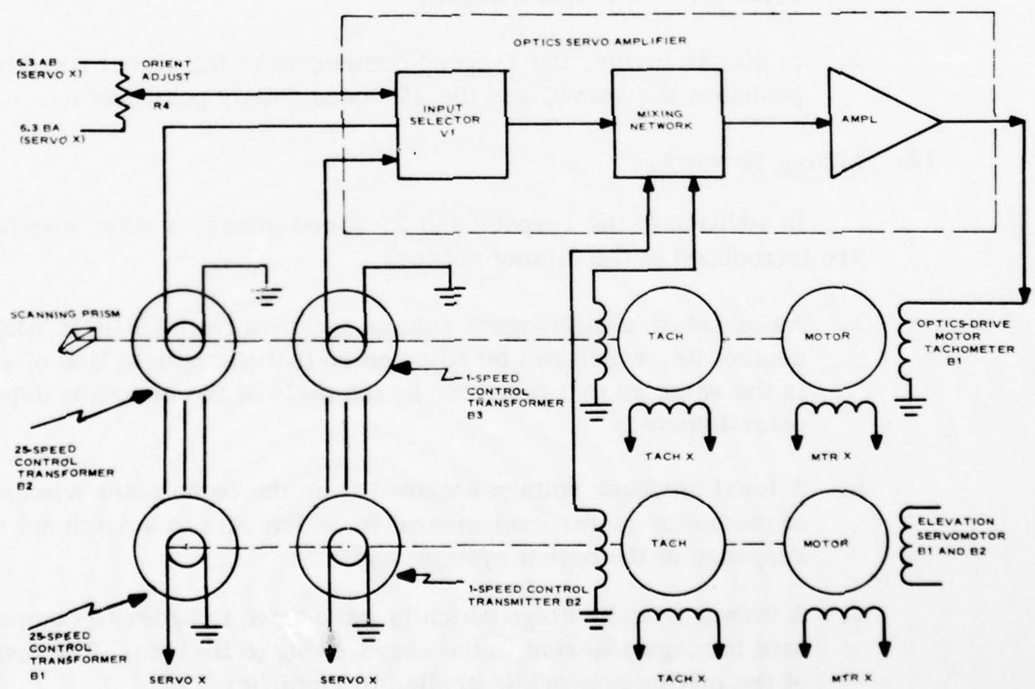

Diagram 20. Optics servo block diagram.

11. Input Selector (fig 16-14).

Dual diode V1 forms the first stage of the optics servo amplifier and has two functions.

a. When the peak value of the 25-speed signal is less than 2.5v, V1 blocks the 1-speed signal, and only the 25-speed signal passes.

b. When the peak value of the 25-speed signal exceeds 2.5 volts, V1 allows a component of the 1-speed signal to pass. This produces a composite signal containing both 25-speed and 1-speed components.

c. When the alinement error of the input shaft is small, the output of the stage consists, primarily, if not entirely, of the 25-speed signal.

d. When the alinement error is large, the signal from this stage is primarily the 1-speed signal.

e. In simple terms, the 1-speed component of the signal roughly positions the servo, and the 25-speed finally positions it.

12. Mixing Network.

In addition to the 1-speed and 25-speed inputs, 3 other signals are introduced to the mixing network:

a. An orientation-adjustment voltage obtained from ORIENT ADJUST control R4, which can be adjusted so that the optical line of sight is the same as that indicated by the dials of the elevation data potentiometer;

b. A local feedback voltage obtained from the tachometer winding of the optics motor tachometer B1 which acts to smooth out the response of the optics system; and

c. A forward-feed voltage which is introduced in order to compensate for lags inherent in the servo owing to its load. The output of the mixing network is applied to amplifier V2A.

13. Amplifier Stages.

The remainder of the stages in the optics servo amplifier are nearly identical to the other servo amplifiers found throughout the equipment. The 400-cycle signal output of the optics servo amplifier is applied to the optics motor tachometer B1. The movement of B1 positions the rotors of the two control transformers and the rearming prism until the error signal is removed, at which time the optics line of sight and the axis of the antenna coincide.

PRACTICAL EXERCISE

ANTENNA POSITIONING
(Part IV)

AAFCS M33 SETUP: Track filaments on.

EQUIPMENT NECESSARY:

1. Test amplifier,
2. Multimeter, and
3. Trouble light.

DEMONSTRATION:

1. Remove the cover from the optics servo amplifier.
2. Show the students the location of the optics servo amplifier.
3. Have the students stand clear and watch the scanning prism when the antenna elevation is changed.
4. Discuss the method used in alining the optics with the azimuth of the track antenna.
5. Discuss the method used in alining the optics with the elevation of the track antenna.

> INSTRUCTOR'S NOTE: Because of the inaccessibility of the optics servo amplifier, the demonstration of this unit will be necessarily brief and superficial. It may be well to mention that this is the only LPSA in the system which is not interchangeable with the rest.

6. Demonstrate the effects of the OPTICS ORIENT control. Mention that the elevation servo should be perfectly balanced when the OPTICS ORIENT control is adjusted, and that, even so, the control should be left alone unless provisions for collimation are available.

7. Spend the rest of the period in a review of the antenna-positioning system. Use any troubles so far listed.

LESSON PLAN

ANTENNA POSITIONING
(Part V)

OBJECTIVE:

1. To present a brief review of all material covered in the APS, and

2. To explain some of the troubleshooting procedures used for localizing troubles in the antenna-positioning system.

> INSTRUCTOR'S NOTE: The first portion of this conference should be of the "helpful hint" category. In addition to reviewing the material covered in APS, the instructor should keep a steady flow of questions moving. The second portion of the conference should be devoted to an explanation of the procedures set forth for troubleshooting the antenna.

INTRODUCTION:

It is the purpose of this discussion to set forth a few basic observations and procedures which are designed to help the repairman localize a trouble within the antenna-positioning system. It should be understood that the procedures outlined below will not work in all cases nor should they be performed exactly as set forth in the text. The checks that are used and the sequence employed will vary with the trouble encountered and the choice of the repairman.

PRESENTATION:

1. Checking Azimuth Servo in MANUAL (diag 21).

   a. Rotate the AZIMUTH handwheel.

   b. If the antenna moves, both the LP loop and HP loop are okay.

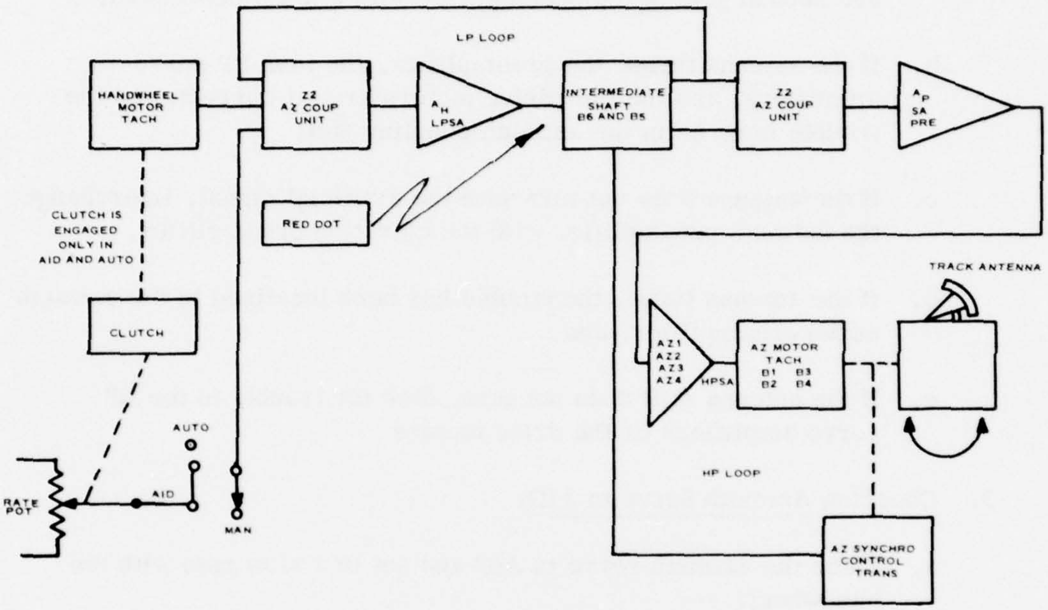

Diagram 21. Azimuth servo in MANUAL.

c. If the antenna does not move and the red dot does turn, look for trouble in the HP loop.

d. If the red dot does not turn, look for trouble in the LP loop or handwheel assembly.

2. Assuming Trouble in the HP Loop.

As mentioned before, if the red dot turns and the antenna does not move when the handwheel is rotated, it can be assumed that trouble exists in the HP loop. The azimuth servo preamplifier A_p, the four high-power servo amplifiers, the four drive motors, azimuth synchro-control transmitter B9, B5, and part of the azimuth coupling network Z2 can all be suspected. To eliminate everything forward of the input to the servo preamplifier, proceed as follows:

a. Inject an artificial error signal of 6.3v to the grid of the first stage of the servo preamplifier. The signal can be taken off one side of the balance potentiometer R4 and applied to the first and second grid of the preamplifier with a multimeter lead,

b. If the antenna turns, the preamplifier, the four HP servo amplifiers, and the four drive motors are all correct, and the trouble must be in the azimuth coupling unit,

c. If the antenna does not turn with the artificial signal, interchange the azimuth preamplifier with the elevation preamplifier,

d. If the antenna turns, the trouble has been localized to the azimuth servo preamplifier, and

e. If the antenna still does not turn, look for trouble in the HP servo amplifiers or the drive motors.

3. Checking Azimuth Servo in AID.

a. Place the azimuth servo in AID and set in a slow rate with the handwheel.

b. If the antenna moves, the rate potentiometer is all correct.

c. Return the servo to MAN and then snap it back to AID. The rate previously set in should disappear.

d. If the rate still exists after the servo is placed in AID for the second time, check the clutch or the return springs on the rate potentiometer.

4. Checking Azimuth Servo in AUTO (diag 22).

a. Misbalance the azimuth-angle detector. Place the azimuth servo in AUTO.

b. The antenna should move continually in one direction.

c. If red dot turns, B9, B5, A5, and the LPSA are all correct.

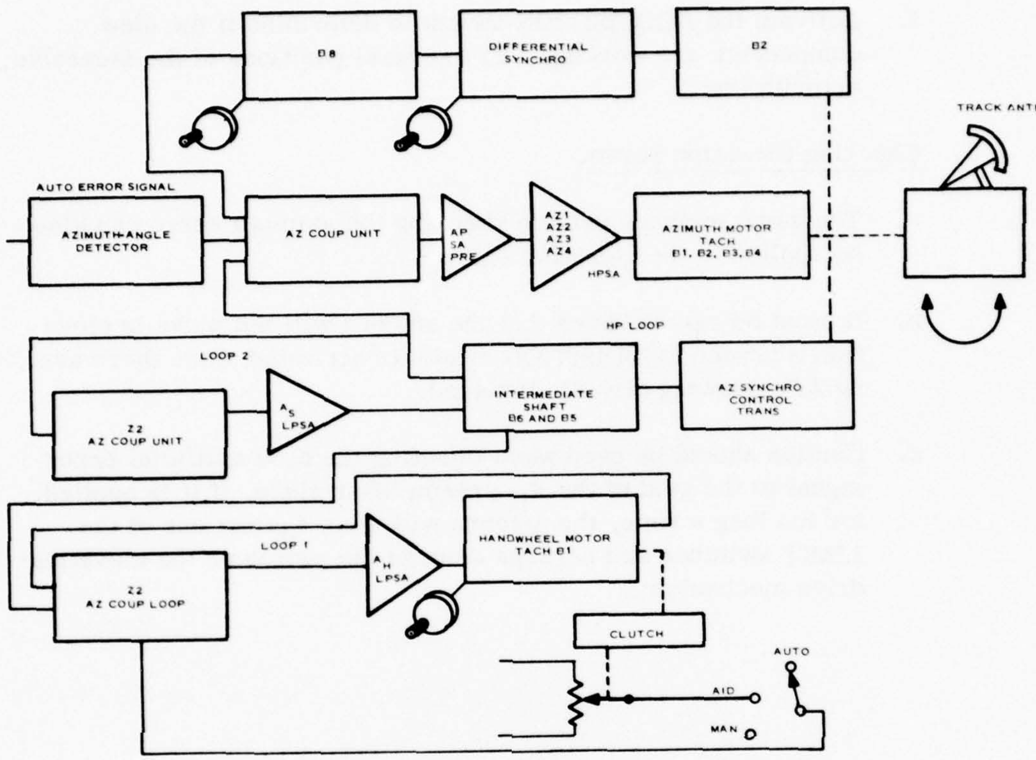

Diagram 22. Azimuth servo in AUTO.

d. Place the azimuth servo in AID. If the antenna continues to move at the previous rate, the A_H amplifier and the azimuth motor tachometer B1 are all correct.

e. When the checks performed in AID and MAN reveal no malfunction, and misbalancing the angle detector in AUTO does not move the antenna, assume the trouble to be in the angle detector.

f. Interchange the azimuth- and elevation-angle detectors.

g. If the antenna moves, the trouble has been localized to the azimuth-angle detector.

h. If the antenna still does not move, check the signal inputs to the azimuth-angle detector.

i. Activate the ACQUISITION switch to determine if the slew components are working. Try several positions of the steerable, azimuth line.

5. Checking Elevation Servo.

a. The same methods used in checking the azimuth servo can also be applied to the elevation servo.

b. It must be remembered that the antenna will not move in elevation when the ACQUISITION switch is activated since there are no ACQ slewing circuits involved.

c. Caution should be used when injecting the 6.3v artificial error signal to the grid of the E_H preamplifier since, if it is applied for too long a time, the antenna will slam against one of the LIMIT switches and perhaps damage the switch or the elevation-drive mechanism.

PRACTICAL EXERCISE

ANTENNA POSITIONING
(Part V)

AAFCS M33 SETUP: Energized to standby.

EQUIPMENT NECESSARY:

1. Multimeter,
2. Test amplifier,
3. Trouble light, and
4. APS check list (lesson plan 20).

> INSTRUCTOR'S NOTE: One of the main differences between a good and a mediocre repairman is the amount of logic or "horse sense" that each applies to his work. Repairmen spend many months in gaining a detailed knowledge of a certain piece of equipment but, in many cases, fail to develop a sensible procedure for applying this knowledge. It will be the purpose of this exercise to help in the development of sensible troubleshooting procedures which, together with detailed knowledge, make a good repairman, but it should be pointed out that he will not always be able to rely on printed material to do his thinking for him. Sooner or later, he will find himself in a position where he must mentally form his own checklist.

DEMONSTRATION:

1. The instructor will demonstrate the use of the checklist in localizing troubles within the APS.

2. Troubles will then be inserted in any part of the antenna-positioning system, and each student will be given a chance to locate and clear the troubles.

SUGGESTED TROUBLES:

Use any of the troubles listed in the practical exercises dealing with the antenna-positioning system.

LESSON PLAN

TRACKING INDICATORS

OBJECTIVE:

To explain the operation and repair of the track indicators.

INTRODUCTION:

Three tracking indicators are used in the track presentation system. The tracking indicators are located on the front of the track console. The elevation scope is on the left, the azimuth scope in the center, and the range scope on the right. The video signals displayed on the three screens are obtained from the track-receiver system. The 500-yard expansion pulse and the 100-yard notch are also displayed. The sweeps on the track screens are made continuously variable from 20,000 to 100,000 yards for better definition of nearby targets. Three pairs of coarse and fine synchros indicate the range in yards and the azimuth and elevation in mils.

PRESENTATION:

INSTRUCTOR'S NOTE: Explain the detailed block diagram of track presentation system (fig 17-1).

1. IMAGE SPACING Switch OFF.

   a. With the IMAGE SPACING switch in the OFF position, the sweep appears as a horizontal base line on the indicator.

   b. Video signals appear as single vertical deflections of the sweep.

   c. The 500-yard expanded section of sweep is presented, as well as the 100-yard range notch.

2. IMAGE SPACING Switch NOR.

   a. With the IMAGE SPACING switch in the NOR position, two base lines appear on the indicator.

b. The base lines are superimposed vertically, but are offset laterally.

c. The video signals, expansion pulse, and range notch appear on both base lines.

d. Hence, signals appear as double images, offset by the displacement of the sweeps (diag 23).

Diagram 23. Sweep configurations.

3. <u>IMAGE SPACING Switch SEL SIG.</u>

a. When the IMAGE SPACING switch is in the SEL SIG position, the indicator is unblanked only for the duration of the 500-yard expansion pulse.

b. Because of the lateral displacement of the sweep, the expansion pulse and the 100-yard notch will again appear as a double image.

c. This is also true of any video signals which appear during the three-microsecond period of the expansion pulse. The lateral displacement in the NOR and SEL SIG positions of the switch is produced, by use of the lobing-reference voltages, to make manual and aided tracking possible in azimuth and elevation.

d. Because in range tracking the range notch is made to coincide with the target video (and not by pip matching as in azimuth and elevation), there is no need for lateral sweep displacement on the tracking-range indicator.

e. Operation of the IMAGE SPACING switch of the tracking-range indicator has no effect upon the position of the sweep on that indicator.

4. Video Amplifier Channel (fig 17-2).

a. The video amplifier is located on the left side of the tracking-indicator chassis.

b. The video amplifier receives the 100-yard range notch and delayed video from the video-and-notch mixer on the pulse-demodulator chassis.

c. At the input to the video amplifier, the negative video signals are normally about 2 volts in amplitude, and the positive notch is 0.6 volt in amplitude.

d. The signals are amplified and fed to a paraphase amplifier.

e. This stage produces:

1) Positive video signals and a negative notch for the top deflection plate of the oscilloscope, and

2) Negative video signals and a positive notch for the lower deflection plate.

INSTRUCTOR'S NOTE: Discuss the effects of varying VERTICAL CENTER control R9 and VIDEO GAIN control R6. Discuss the function of S1 and CR1.

5. Sweep-Generator Channel (fig 17-3).

a. Multivibrator.

1) The preknock pulse is introduced to the grid of multivibrator V1.

2) Multivibrator V1 is almost identical to the main-gate multivibrator in the track-range computer.

3) A negative square wave 615 μsec in duration is taken from the plate of V1A and sent to the grid of cathode follower V2B.

4) Another output, a negative-going, square wave 615 μsec in duration, is taken from the cathode of V1 and is sent to the unblanking channel.

b. Cathode Follower V2B.

This stage is used for isolation of the multivibrator from the sweep generator V3A.

c. Sweep-Generator Circuit V3A, V6, and C3.

1) V3A and V6 are in series between 450 volts and ground.

2) Capacitor C3 is connected to the junction of the plate of V6 and the cathode of V3A.

3) V3A is normally conducting, and, as a result, capacitor C3 charges to some level determined by the resistance in the cathode circuit of V3A.

4) This resistance will include the plate-to-cathode resistance of V6 (which is also conducting), part of R45, and the SWEEP LENGTH and MAX SWEEP LENGTH controls R9 and R3.

5) V3A will cut off when the negative-going, 615-μsec square wave developed in V1 is applied to its grid.

6) The plate current of V6 can no longer flow through V3A but will flow into the ungrounded plate of C3 instead thereby discharging the capacitor.

7) C3 will discharge at a linear rate as long as the plate current through V6 is constant.

8) The current through V6 is held constant by a feedback voltage introduced at its screen grid from the plate of sweep amplifier V4A.

> INSTRUCTOR'S NOTE: *Make sure the class understands the operation of the sweep generator up to this point. Review, if necessary, before proceeding with the introduction of the expanded pulse.*

9) The expanded pulse will be developed at some time after PK and will be introduced to the grid of amplifier V5 as a negative-going square wave three μsec in duration.

10) V5 will amplify and invert the square wave, and the output will be applied to the control grid of V6.

11) Since the current through V6 is constant due to the feedback from the plate of V4, C3 is discharged at a linear rate.

12) When the positive three-μsec square-wave output of V5 appears at the grid of V6, V6 will increase its conduction and thereby discharge C3 at a faster rate. The waveform appearing at the ungrounded plate of C3 will appear as in diagram 24.

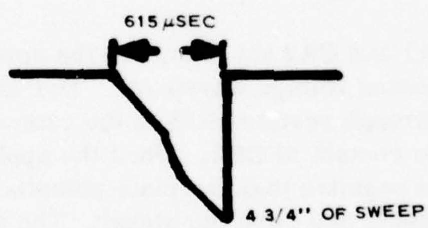

Diagram 24. Voltage input to V3B.

> INSTRUCTOR'S NOTE: Explain the effect that the increase in the rate of discharge of C3 will have on the sweeps.

d. Sweep Amplifier V4.

1) The voltage appearing on C3 is sent to the grid of cathode follower V3B, and the cathode output of this stage is sent to the grid of sweep amplifier V4.

2) V4 is a cathode-coupled paraphase amplifier. The two plate outputs of this stage are push-pull saw-toothed waveforms which are applied to the right and left deflection plates of the cathode-ray indicator tube through A and B of E1.

3) The grid of V4B receives a 30-cycle square wave when the IMAGE SPACING switch is in the NOR position. The sweep amplifier then has a composite output consisting of sweep voltages superimposed on a 30-cycle square wave. When the average voltage at the plate of V4A is positive with respect to V4B, 17 sweeps will occur. These sweeps will be displaced to the right. During the next alternation of the 30-cycle square wave, 17 sweeps will again occur, but these sweeps will be displaced to the left. This action produces the image spacing necessary for pip matching in azimuth and elevation.

4) Crystals CR1 and CR2 act to square the applied 30-cycle lobing-reference voltage waveform. The 30-cycle signal is applied through resistor R35 to the cathode contact of CR1 and the plate contact of CR2. When the applied signal becomes more negative than the plate potential of CR1, that crystal conducts and clips the signal. The conduction of CR2 during the positive alternation has a similar effect. The clipping level is determined by the setting of the IMAGE SPACING switch.

   a) In the OFF position, switch section S1E is open, and the 30-cycle sine wave does not enter the sweep channel.

   b) In the NOR position of the switch, the 30-cycle sine wave enters the unit through switch section S1E. The plate of CR1 is at a negative 0.3v potential, and the cathode of CR2 is at a positive 0.3v potential. Hence, the sine wave is clipped above +0.3 volt and below -0.3 volt.

> INSTRUCTOR'S NOTE: Explain relationships of rotating beam with offset sweeps.

c) In the SEL SIG position of the switch, the crystals are biased between 0.3 and 6.4 volts as determined by the two-section image-spacing potentiometer R2. This control is adjusted to obtain the desired amount of lateral sweep displacement on the screen.

> INSTRUCTOR'S NOTE: Explain the function of all the controls associated with the sweep generator: MIN SWEEP, CENT, EXP WID, SWEEP LENGTH, MAX SWEEP LENGTH, IMAGE SP, MAX SWEEP RANGE, and ASTIGMATISM.

6. Unblanking Channel (diag 25).

a. Rectifier V1.

1) The N-S lobing-reference generator output is applied to the two cathodes of V1 in the ELEVATION indicator.

2) The E-W lobing-reference generator output is applied to the two cathodes of V1 in the AZIMUTH indicator.

3) Since the azimuth- and elevation-unblanking channels are identical, the following discussion will deal only with the elevation-indicator unblanking channel.

4) The 30-cycle signals applied to V1 are 180° out of phase with each other and will cause half of V1 to be conducting at all times.

5) A 60-cycle pulsating negative dc will be developed across R3.

> INSTRUCTOR'S NOTE: Explain to the class how the reference generator four outputs will rise and fall according to which quadrant the scanner horn is passing through.

6) The 60-cycle pulsating dc voltage is coupled through C1 and developed across R6 before application to the grid of V2A.

b. Shaper V2.

1) This stage is a dual triode.

2) Both sections operate to limit both the positive and negative extremes of the signal appearing at their grids.

3) The signal coupled through C1 is developed across resistors R4 and R6 which are returned to ground; hence, the signal varies about a ground reference.

4) The negative extremes of the waveform at the grid of V2A cut off the tube.

5) When grid rises above ground level, grid current flows. (Cathode is grounded.)

6) Clipping occurs again, but, this time, as a result of the grid-limiting action of resistor R4.

7) The rectangular waveform at the plate of V2A is coupled through C2 and developed across R8.

8) The negative portion of the applied signal is clipped by cutoff limiting and the positive portion by grid limiting.

9) The 60-cycle square wave at the plate of V2B is coupled through C3 to V3A.

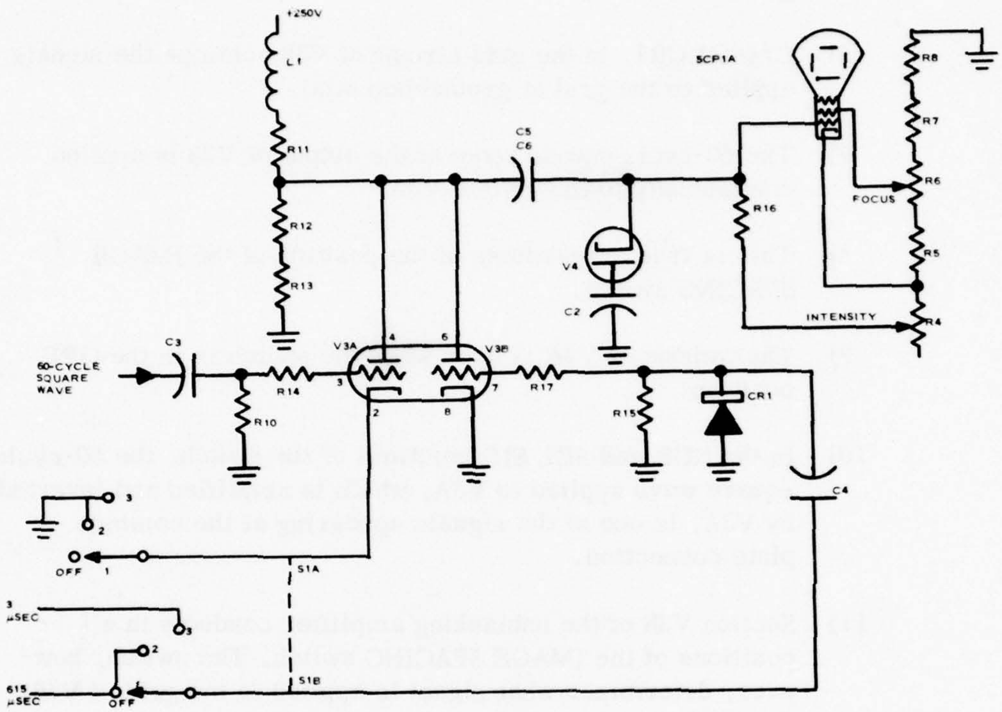

Diagram 25. Unblanking channel.

c. Unblanking Amplifier.

1) The unblanking amplifier is a dual triode with its two plates tied together.

2) Resistors R11, R12, and R13, and inductor L1 provide the proper plate voltage.

3) The signals passed by both sections of V3 are developed across R11 and L1.

4) The inductor sharpens the leading and trailing edges of the rectangular waveforms by improving the high-frequency response of the stage.

5) Conventional RC coupling circuits are employed at both grids.

6) Crystal CR1, in the grid circuit of V3B, clamps the signals applied to the grid at ground potential.

7) The 60-cycle square wave at the output of V2B is applied continuously to the grid of V3A.

8) This is true, regardless of the position of the IMAGE SPACING switch.

9) The cathode of V3A is open when the switch is in the OFF position.

10) In the NOR and SEL SIG positions of the switch, the 60-cycle square wave applied to V3A, which is amplified and inverted by V3A, is one of the signals appearing at the common plate connection.

11) Section V3B of the unblanking amplifier conducts in all positions of the IMAGE SPACING switch. The switch, however, determines what signal is applied to the grid of V3B.

12) With the switch in either the OFF or NOR position, the negative 615-microsecond square wave generated in the sweep channel is applied to V3B 1,000 times per second. The signal is amplified and inverted by V3B and appears as a positive gating signal at the plate.

13) In the SEL SIG position of the switch, the negative, three-microsecond, expansion pulse is applied to the grid of V3B.

<u>INSTRUCTOR'S NOTE:</u> Explain relationship of unblanking pulse with rotating beam.

14) The recurrence frequency of this signal is also 1,000 pulses per second. Again, V3B amplifies and inverts the input, and positive three-microsecond gating signals appear at the plate.

COMMON TROUBLES:

	Symptom	Probable Cause
1.	No range sweep on one of the track indicators.	Multivibrator V1 not operating properly. Sweep amplifier V4 bad.
2.	No sweep, and one side of the indicator appears illuminated.	Loose or broken connection A or B on E1.
3.	No expanded sweep on one indicator.	Discharge diode V6 or amplifier V5 not operating.
4.	No video on one indicator.	Video amplifier V1 bad. Broken coaxial cable between E2/B and grid of V1 (fig 17-2).
5.	No split signal in either scope while in *SEL SIG*.	SCANNER switch OFF.
6.	Split signals on one indicator overlap.	CR1 or CR2 (fig 17-3) shorted.

PRACTICAL EXERCISE

TRACKING INDICATORS

AAFCS M33 SETUP: The equipment will be completely deenergized.

EQUIPMENT NECESSARY: Multimeter and test amplifier.

PRELIMINARY TROUBLE:

Short out E13/B with a small bolt or nut and screw the cap back on (fig 15-8).

DEMONSTRATION:

1. On the sweep generator (either scope), monitor preknock appearing at J1 and explain that the whole purpose of the range-sweep generator is to develop the two sweep voltages that are appearing at A and B of E1.

2. Monitor the expansion pulse at J2 and explain how it affects the range sweep.

3. With the test amplifier, monitor all pertinent waveforms in the range-sweep generator.

> INSTRUCTOR'S NOTE: Use the schematic at all times in order to get the student accustomed to interpreting the symbols into the actual hardware.

4. Connect the synchroscope for use and monitor the waveforms in the unblanking channel.

> INSTRUCTOR'S NOTE: Stay out of the circuitry associated with V4 (-2,000 volts).

5. Put one student at each of the three track indicators and guide them through the adjustment of the indicators. Assume that the MAIN GATE is adjusted correctly. Have the students adjust MAX SWEEP LENGTH RANGE R9, MAX SWEEP LENGTH R9 (right side of the indicator), MIN SWEEP R45, IMAGE SP R2A and B, and CENTER.

SUGGESTED TROUBLES:

1. Primary.

   a. Disconnect either spade lug on the bottom of E1 (fig 17-4). A short sweep appears either at left or right edge of the screen.

   b. Push the crystal connected to J2 on the range-sweep generator over so that one of its leads makes contact with the adjustment lock for the astigmatism control (fig 17-3). No expanded sweep on either indicator.

   c. Replace multivibrator V1 with a bad tube (fig 17-3). No sweep.

   d. Disconnect the preknock input to any scope.

   e. Replace V5 or V6 in the range-sweep channel with a bad tube (fig 17-3). No expanded sweep.

   f. Disconnect the jumper between terminals 150 and 151 in the tracking console (fig 19-18). No sweep on the azimuth and elevation indicators.

   g. Short across CR1 or CR2 with a piece of gremlin wire (fig 17-3). Split signal in SEL SIG will not separate.

INSTRUCTOR'S NOTE: Trouble can be inserted in the unblanking system, but it must be remembered that loss of the unblanking voltage can be overcome by increasing the INTENSITY control and the sweep will appear anyway.

2. Secondary.

> INSTRUCTOR'S NOTE: Disconnect the RANGE indicator and place it on the TCC and reconnect it. It will now be possible for the secondary group to use the synchroscope to troubleshoot troubles in this unit.

a. If more time is needed for familiarization with the adjustments, the reversed scope can be used.

b. Completely disconnect the scope and have the group practice removal and replacement of the CRT.

LESSON PLAN

MONITOR CONTROL AND SIGNAL PANEL
(fig 19-92).

OBJECTIVE:

To explain the operation of the monitor-control system.

INTRODUCTION:

The operation of an AAFCS M33 and associated artillery requires the close teamwork of many men at different positions, both at the guns and the radar.

In a system of men and equipment of this complexity, it is necessary to have some quick method of communication between each station which will enable every man taking part to follow the progress of the engagement. This system is known as the monitor control.

The monitor control uses a series of bells, indicator lights, and a siren to relay information regarding the battery status from the radar to the gun pits. This discussion will deal with the operation of the monitor control in each of its eleven conditions.

PRESENTATION:

1. The following is a discussion of the various conditions which may exist during any engagement:

   a. "Surveillance." The radar is manned with a reduced crew, and the battery is in a standby condition.

   b. "Battery Alert." Information has been received that enemy aircraft are approaching. A siren is sounded which signals the guncrews to ready the guns for firing. The grid coordinates of the enemy aircraft are phoned in from outlying posts and plotted on the long-range plotting board so that radar contact can be made as soon as the target comes within acquisition-radar range.

c. "Guns Ready." The gun commander at each gun has signaled the radar, by an indicator light, that his gun is ready to fire.

d. "First Challenge." As soon as the target comes within acquisition range, it is interrogated by the IFF equipment. The presentation on the PPI will indicate whether the target is friendly or hostile.

e. "Target Designated." If the target has been found to be hostile, the tactical control officer will position the ACQ range circle and azimuth line over the target and press a button which signals the tracking operators to get on target. The button will also ring a bell at each gun thereby signaling the guncrews that the track radar is about to engage a target.

f. "Target Confirmed." When the tracking operators hear the buzzer signaling that a target has been designated, the first operation is to activate ACQUISITION switch S9 which will roughly position the track antenna on the desired target. When S9 is activated, an indicator lamp on the tactical-control console lights and signals the tactical control officer that the tracking operators are searching for the designated target.

g. "Target Tracked." When the tracking operators have placed the system in AUTOMATIC, the TRACKED button is pressed, thereby signaling the tactical control officer that the system is in AUTOMATIC and tracking the designated target. The computer operator is also signaled, at this time, that the computer is receiving target information. He can then place the PLOTTING CONTROL switch in PLOT and activate the plotting-board pens.

h. "Second Challenge." The target is again interrogated by the IFF system. If the target is friendly, a buzzer is sounded at the tracking console, signaling the operators to cease tracking the target. If the target is not friendly, the HOSTILE push-button, which lights the HOSTILE indicator lamp on the tracking console, is depressed.

i. "Computer Ready." When the computer is ready to supply firing information to the guns, the computer operator will so indicate to the tactical control officer by depressing the COMPUTER READY button. At this point in the engagement, the battery is ready to fire.

j. "Fire." The tactical control officer can give the signal to fire, at any time after the target comes within gun range, by depressing the FIRE button. At this time, a horn will sound at each of the guns for a minimum of two seconds, and this is the signal to fire. The FIRE indicator at each gun will light, and a lock on the firing lever will retract thereby allowing the gun to be fired. At the plotting boards, a fire mark will be made at the target position.

k. "Cease Fire." This order is given by depressing the CEASE FIRE switch S7 at the monitor-control panel. The firing lever at each gun is then locked, and the FIRE indicator is extinguished. The CEASE FIRE lamp at each gun is now on. The horn in each gun is sounded for two seconds. At the plotting board, a mark is made indicating the target position where the order to cease fire was given. The system will return to the condition it was in prior to the order to fire.

2. OPERATION (fig 19-92).

a. Surveillance.

1) All relays in the monitor control are deenergized.

2) The CEASE FIRE lamp on the monitor control is lit.

3) The PREDICTION OUT lamp at the TARGET RATE indicator is lit.

4) The CEASE FIRE lamp at each gun is lit.

5) The firing lever at each gun is locked.

b. Battery Alert.

1) When BATTERY ALERT button S1 is pushed, one side of the switch will apply -24v from the batteries to the siren on the roof.

2) The other side of the switch will apply -24v to relays in the switchboard and complete two preset telephone loops within the battery.

3) The CEASE FIRE lamp at the monitor control is lit.

4) The PREDICTION OUT lamp on the TARGET RATE indicator is lit.

5) The CEASE FIRE lamp at each gun is lit.

6) The firing lever at each gun is locked.

7) Two preset telephone loops are complete.

c. Guns Ready.

1) When the siren alerts the battery, the guncrews prepare the guns and ammunition for firing. As each gun and guncrew become ready, the chief of section operates the READY switch at his gun. When the READY switch at gun 1 is closed, the GUN 1 READY relay K1 in the monitor control is energized. Contacts 2 and 3 of that relay close. This completes the circuit through the GUN 1 lamp I1, and the lamp is lit. Similarly, as the READY switches at the remaining guns are closed, corresponding relays K2, K3, and K4 in the monitor control are energized, and indicator lamps I2, I3, and I4 are lit. Although it is not shown on the schematic diagram, closing the READY switch at each gun lights a READY lamp at the gun. Contacts 4 and 5 of the 4 GUN READY relays close and partially complete the circuit to BATTERY READY relay K10.

2) At "Guns Ready," the following conditions exist:

a) The CEASE FIRE lamp at the monitor control is lit.

b) The GUNS 1, 2, 3, and 4 lamps at the monitor control are lit.

c) The PREDICTION OUT lamp at the TARGET RATE indicator is lit.

d) The CEASE FIRE lamp at each gun is lit.

e) The READY lamp at each gun is lit.

f) The firing lever at each gun is locked.

d. First Challenge. When the target appears on the PPI, it is possible to interrogate the target with the IFF by operation of either CHALLENGE switch. Operation of the CHALLENGE switch will not affect the relays in the monitor control.

e. Target Designated.

1) If the target is hostile, the intersection of the range circle and the steerable azimuth line is placed on the target, and the TARGET DESIGNATED pushbutton S2 on the monitor control is operated. Section S2D of the TARGET DESIGNATED switch applied 120v to a bell at each gun. The bell signals the gun personnel that a target is about to be engaged.

2) Section S2A of the switch completes the circuit to the coil of DESIGNATED relay K5, causing it to become energized. A holding circuit for K5 is provided through its own contacts 4 and 10, contacts 6 and 11 of K6, contacts 6 and 11 of K7, and section S3A of the CEASE TRACKING switch. Note that K5 can remain energized only while K6 and K7 remain deenergized. Contacts 2 and 9 of K5 close, causing DESIGNATED lamp I5 at the monitor control and DESIGNATED lamp I2 at the signal panel to light.

3) Section S2B of the DESIGNATED switch completes a circuit through the CEASE TRACKING switch to a buzzer on the high-voltage indicator power supply.

4) The CEASE FIRE lamp at the monitor control is lit.

5) The GUNS 1, 2, 3, and 4 lamps at the monitor control are lit.

6) The DESIGNATED lamp at the monitor control is lit.

7) The DESIGNATED lamp at the signal panel is lit.

8) The PREDICTION OUT lamp at the TARGET RATE indicator is lit.

9) The CEASE FIRE lamp at each gun is lit.

10) The READY lamp at each gun is lit.

11) The firing lever at each gun is locked.

f. Target Confirmed.

1) When a target is designated by the tactical control officer and the buzzer is sounded on the tracking console, the first action of the azimuth operator will be to operate ACQUISITION switch S9. This action causes relay K4/B31 (fig 15-11) in the control drawer to be energized. Contacts 5 and 11 of K4/B31 close and apply -28v through terminal 190 to relay K13 behind the signal panel. This causes relay K13 to be energized. If the range and azimuth radar operators are already tracking the designated target on the precision indicator, the azimuth-radar operator will depress the CONFIRMED pushbutton S4. This action will also result in relay K13 being energized.

2) Contacts 7 and 12 of K13 apply 120v to a bell at each gun, warning the guncrews that a target is about to be engaged.

3) Contacts 2 and 9 of K13 close and energize the CONFIRMED relay.

4) Contacts 6 and 11 of K6 open and break the holding circuit for DESIGNATED relay K5. As a result, both DESIGNATED lamps go off.

5) K6 is held energized through its own contacts 4 and 10, contacts 6 and 11 of K5, contacts 6 and 11 of K7, and the CEASE TRACKING switch.

6) Contacts 2 and 9 of K6 close, and the CONFIRMED lamp lights.

7) The CEASE FIRE lamp at the monitor control is lit.

8) The GUNS 1, 2, 3, and 4 lamps at the monitor control are lit.

9) The TARGET CONFIRMED lamp at the monitor control is lit.

10) The CONFIRMED lamp at the signal panel is lit.

11) The PREDICTION OUT lamp at the TARGET RATE indicator is lit.

12) The CEASE FIRE lamp at each gun is lit.

13) The READY lamp at each gun is lit.

14) The firing lever at each gun is locked.

g. Target Tracked.

1) When the target is being tracked automatically, the azimuth operator depresses TRACKED button S5.

2) Relay K4 in the prediction-control panel energizes and will be held energized through its own contacts 2 and 9 and contacts 6 and 11 of deenergized relay K13. When K4 energizes, the PREDICTION OUT lamp on the TARGET RATE indicator goes out, and the computer can receive target information from the track radar.

3) Another section of S5 energizes TRACKED relay K7.

4) Contacts 6 and 11 of K7 open and deenergize K6. Both CONFIRMED lamps go out.

5) K7 is held energized through its own contacts 4 and 10, contacts 8 and 12 of K5, contacts 8 and 12 of K6, and one section of the CEASE TRACKING switch.

6) Contacts 2 and 9 of K7 close, and the following three lamps light: The TARGET TRACKED lamp, 17, at the monitor control; the TRACKED lamp, 14, at the signal panel; and the ON TARGET lamp, 12, at the TARGET RATE indicator. (When the computer operator sees that the PREDICTION OUT lamp is off and the ON TARGET lamp is lit, he places the PLOTTING CONTROL switch in the PLOT position. The plotting-board pens then drop to the paper and plot.)

7) The CEASE FIRE lamp at the monitor control is lit.

8) The GUNS 1, 2, 3, and 4 lamps at the monitor control are lit.

9) The TARGET TRACKED lamp at the monitor control is lit.

10) The TRACKED lamp at the signal panel is lit.

11) The ON TARGET lamp at the target rate indicator is lit.

12) The CEASE FIRE lamp at each gun is lit.

13) The READY lamp at each gun is lit.

14) The firing lever at each gun is locked.

h. Second Challenge.

1) The target is challenged a second time. If a friendly response is received, the CEASE TRACKING pushbutton can be depressed. This will sound a buzzer in the tracking console.

2) If a hostile response is received, the HOSTILE button S2/B24 is depressed, and HOSTILE relay K8 is energized.

3) K8 is held energized through its own contacts 4 and 10, the normally closed contacts of the FRIENDLY switches, the TARGET DESIGNATED switch, and the CEASE TRACKING switch.

4) As K8 energizes, both HOSTILE lamps light through contacts 2 and 9 of K8.

5) The CEASE FIRE lamp at the monitor control is lit.

6) The GUNS 1, 2, 3, and 4 lamps at the monitor control are lit.

7) The TARGET TRACKED lamp at the monitor control is lit.

8) The HOSTILE lamp at the monitor control is lit.

9) The TRACKED lamp at the high-voltage indicator power supply is lit.

10) The HOSTILE lamp at the high-voltage indicator power supply is lit.

11) The ON TARGET lamp at the target rate indicator is lit.

12) The CEASE FIRE lamp at each gun is lit.

13) The READY lamp at each gun is lit.

14) The firing lever at each gun is locked.

i. Computer Ready.

1) When the computer is ready to supply firing data to the guns, the computer operator depresses the COMPUTER READY pushbutton S8 on the target rate indicator.

2) The circuit to the COMPUTER READY relay K9 is completed through the holding circuit of relay K7 and the contacts of COMPUTER READY switch S8.

3) A holding circuit for K9 is provided through contacts 4 and 10 of K9, the normally closed contacts of COMPUTER NOT READY switch S9, and the holding circuit of relay K7.

4) Contacts 2 and 9 of relay K9 close, lighting COMPUTER lamp I9 at the monitor control and COMPUTER READY lamp I3 at the target rate indicator.

5) At this point in the engagement, the guns are ready (GUN READY relays K1 through K4 are energized), the tracking radar is ready (TRACKED relay K7 is energized), the computer is ready (COMPUTER READY relay K9 is energized), and the target is holtile (HOSTILE relay K8 is energized). In other words, the battery is ready to fire. BATTERY READY relay K10 (lower right corner of the diagram) now becomes energized through parallel contacts of relays K1 through K4 (contacts 4 and 5), contacts 5 and 11 of K9, contacts 5 and 11 of K8, and the holding circuit of K7.

6) Contacts 2 and 3 of BATTERY READY relay K10 close, and BATTERY lamp I10 at the monitor control is lit.

7) The CEASE FIRE lamp at the monitor control is lit.

8) The GUNS 1, 2, 3, and 4 lamps at the monitor control are lit.

9) The TARGET TRACKED lamp at the monitor control is lit.

10) The HOSTILE lamp at the monitor control is lit.

11) The COMPUTER lamp at the monitor control is lit.

12) The BATTERY lamp at the monitor control is lit.

13) The TRACKED lamp at the high-voltage indicator power supply is lit.

14) The ON TARGET lamp at the target rate indicator is lit.

15) The COMPUTER READY lamp at the target rate indicator is lit.

16) The CEASE FIRE lamp at each gun is lit.

17) The READY lamp at each gun is lit.

18) The firing lever at each gun is locked.

j. Fire.

1) When the target comes within range of the guns, and the tactical control officer decides to open fire, FIRE push-button S8 on the monitor control is depressed.

2) FIRE relay K11 is energized through section S8A of the FIRE switch, the normally closed contacts of CEASE FIRE switch S7, contacts 5 and 11 of relay K9, contacts 5 and 11 of relay K8, and the holding circuit of relay K7. This holding circuit includes contacts 4 and 10 of energized relay K7, contacts 8 and 12 of deenergized relay K5, contacts 8 and 12 of deenergized relay K6, and the normally closed contacts of section S2A of the CEASE TRACKING switch.

3) A holding circuit around the contacts of section S8A of the FIRE switch is provided by contacts 4 and 10 of FIRE relay K11.

4) The coil of relay K1 at each gun is in parallel with the coil of FIRE relay K11. Hence, relay K11 at each gun is now energized.

5) Contacts 1 and 9 of K11 open, extinguishing CEASE FIRE lamp I11 at the monitor control.

6) Contacts 2 and 9 of K11 close, lighting FIRE lamp I12 at the monitor control.

7) Contacts 8 and 12 of K11 open, and contacts 7 and 12 of K11 close. This initiates an action in the computer which causes fire marks to be made by the plotting board pens. Through a two-second timer in the computer, a horn is sounded at each of the guns when the FIRE pushbutton is depressed. It continues to sound for a minimum of two seconds and is the signal for the guncrews to fire.

8) At each gun, when relay K1 becomes energized, it extinguishes the CEASE FIRE lamp at the gun, lights a FIRE lamp, and releases the lock on the firing lever. This permits the guns to be fired. (Provision is made at the guns for manually engaging the firing lever in the event of failure of the firing lock.)

9) The GUNS 1, 2, 3, and 4 lamps at the monitor control are lit.

10) The TARGET TRACKED lamp at the monitor control is lit.

11) The HOSTILE lamp at the monitor control is lit.

12) The COMPUTER lamp at the monitor control is lit.

13) The BATTERY lamp at the monitor control is lit.

14) The FIRE lamp at the monitor control is lit.

15) The TRACKED lamp at the signal panel is lit.

16) The HOSTILE lamp at the signal panel is lit.

17) The ON TARGET lamp at the target rate indicator is lit.

18) The COMPUTER READY lamp at the target rate indicator is lit.

19) The READY lamp at each gun is lit.

20) The FIRE lamp at each gun is lit.

21) The firing lock at each gun is released.

k. Cease Fire.

1) The order to cease fire is given by depressing CEASE FIRE switch S7 at the monitor control.

2) The holding circuit for the FIRE relay opens, and FIRE relay K11 becomes deenergized.

3) K1 at each gun is deenergized, the firing lever at each gun is locked, and the FIRE lamp is extinguished. The CEASE FIRE lamp is lit.

4) Contacts 8 and 12 of K11 close, a horn sounds at each gun, and the plotting boards form cease-fire marks.

5) K11 extinguishes the FIRE lamp and lights the CEASE FIRE lamp at the monitor control.

6) The monitor control is returned to the condition it was in just before the order to fire was given.

> INSTRUCTOR'S NOTE: The foregoing discussion was based on operation during a normal engagement. Explain any abnormalities that may occur, such as: COMPUTER NOT READY, OVERRIDE, or the target's identifying itself as friendly at any time before the order to fire is given. Troubleshooting of the monitor control will be covered to a satisfactory degree in the laboratory portion.