TECHNICAL MANUAL

NIKE I SYSTEMS

MISSILE-TRACKING RADAR CIRCUITRY (U)

TM 9-5000-21
CHANGES No. 1

DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C., *21 December 1956*

TM 9-5000-21, 15 May 1956, is changed as follows:

1. The following pen and ink changes are to be inserted:

Page	*Paragraph*	*Line*	*Changes*
1	2	2	Change second sentence to read as follows: **The eight major systems, i. e., sync command system, transmitting system, RF system, receiving system, range system, presentation system, and test, monitor, and calibrating system, are first discussed from a block level and then a more detailed discussion is given on a functional schematic circuitry basis.**
2	5	Title	Change reference to read: (**Fig. 1–3.1**).
2	5	14	Change "transmitter" to read: **transponder.**
3	6	13	After the word "missile" insert simultaneously.
3	6	32–34	Change sentence to read as follows: **The radar pulse follows the preknock pulse by a period equal to range zero minus the missile response time and the coder pulse precedes the radar pulse by the coding interval which is the period determined by the missile code plus 0.1 microsecond.**
4	Fig. 1	--------	The caption on the dimension line connecting the coder pulse and radar pulse should read missile code plus 0.1 sec. The caption on the dimension line connecting the preknock pulse time with the radar pulse time should read range zero minus missile response time.
5	9	8	Change the word "during" to read: **after**
7	14	Title	After title, add: (Fig. 10–1).
8	14b	2	Change "G_Y" to read **Gp**
8	14d	7–8	Change sentence to read: **This complex wave is applied to the contacts of relay K1, and during the steering phase of the flight of the missile, this complex wave passes through the combining amplifier.**
8	14e	5	Change "90" to read **80.**
9	14f	7, 9–10	Change "2-microsecond, pulse, 40 volts in amplitude" to read: **1-microsecond pulse, 45 volts in amplitude.**
9	14f	8	Change "24.4 microseconds" to read: **a period equal to range zero minus missile response time.**
9	14f	11	Add: (**missile code plus 0.1 sec**) between "interval" and the period.
9	15	2	Change "generators" to read: **generator.**
10	16d	10	Change "Z1 charge" to: **Z1 discharges.**
11	18c	8	Change "V2 charges" to: **V2 discharges.**
11	18c	9	Change "would charge" to: **Would discharge.**
12	20	3	Change "Relay K1 is energized" to: **Relay K1 is deenergized.**

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Page	Paragraph	Line	Changes
12	20	5	Change "R6" to read: **R11.** Delete the word: half.
13	22b(2)	4	Change "calibrator" to read: **combining amplifier.**
13	22b(2)	5	Change line to read: **is 100 volts peak-to-peak with either a pitch or yaw steering order or 200 volts peak-to-peak burst signal.**
14	22b(2)	14	Change "greater" to read **less.**
16	23b(3)	18	Change "charges" to: **discharges.**
16	23b(3)	19	Change "charge" to: **discharge.**
18	23b(4)	5	Change "90 volts" to: **50 volts.**
18	23b(5)	5	Change "Zero volts are" to read: **Ground is.**
19	24a	1	Change "V5B" to read: **V5A.** and insert new sentence: The signal is a negative pulse followed by a positive pulse. before continuing with next sentence as printed.
19	24a	6	Delete all of sentence after word "for" and substitute the following: the correct coding interval between the radar and coder pulses. The coding interval is equal to the average missile code pulse 0.1 microsecond.
19	24a	7–10	Delete all of line 7, 8, and 9, and first two words "by T4" of line 10.
19	24a	13	Change "40 volts in amplitude" to read: **are 1 microsecond in width and 45 volts in amplitude.** Starting with the sentence "The radar pulse occurs 24.4" delete remainder of subparagraph 24a.
20	24b(2)	11	Change "2-microsecond" to read: **1 microsecond.**
20	24b(3)	6	Delete "24.4 microsecond" and substitute HR1.
20	24b(4)	1 & 5	Delete "24.4 microseconds" and on line 5 add HR1 after the word "network".
23	25	23	After the first word "system" on this line, insert during actual operation. The command calibrator duplicates these voltages during calibration.
25	26a(2)	1	Change title to read: **Frequency divider and frequency generator.** Change "This unit generates" to read **These units generate.**
27	27d	Title	Change to read: **Divider-Clamper V4.**
28	28a	26	Change "80 volts" to read: **105 volts.**
28	28b	1	Change "80-volts" to read: **105-volt.**
28	28b	7	Change "cut off" to read: **conducting.**
29	28c	3	Delete the period after "coupling".
29	28c	8	Change "divider V4" to read: **divider-clamper V4.**
29	28d	1	Change title to read: **Divider-Clamper V4.**
31	28f	1, 2, & 4	Change "V10A" to read: **V10B.**
32	28g	8 & 10	Change "V10B" to read: **V10A.**
32	28h	6	Change "200 volts" to read: **approximately 220 volts.**
33	29b	2	Change "60" to read: **100.**
33	30c	2	Change "grid" to read: **cathode.**
34	31a(2)	1	Change "200 volts peak-" to read: **220 volts peak.**
34	31a(2)	6	Change "18 volts" to read: **20 volts.**
34	31a(2)	7	Change "182" to read: **200.**
35	31a(3)	3, 4, & 6	Change "18 volts" to read: **20 volts.**
35	31a(3)	13–15	After "V2A" on line 13, change the **comma** to a **period.** Beginning with "since" on line 13, delete the remainder of this sentence to include "V1B" on line 15.
35	31a(3)	18	Delete the word "all" and insert in its place a constant portion.

Page	*Paragraph*	*Line*	*Changes*
35	31a(3)	19	After the first word "waveform", insert as compared to the action of the previous divider stages.
36	31c	8	Delete remainder of sentence after "voltage drops".
36	31c	18	Change "170 volts" to read **130 volts.**
36	31d(2)	1	Delete "of equal amplitude".
38	31g(2)	4	Change "–51.7 volts" to **–100 volts.**
39	31g(2)	2	Change "–51.7 volts" to **–100 volts.**
39	32	14	Change the word "In" to **For.**
45	35e	3	Change "V3B" to **V3A.**
45	35f		Change "V3B" to **V3A to V3B** every place where they occur in this paragraph.
45	35f	3	Insert the word supply between the words "plate" and "potential". Change "V7B" to read **V3A.**
45	35f	4	Change "–30" to read **-13.**
45	35f	17	Change "left" to **right.**
48–59	39, 40		Change switch S1 decknumbers **1 through 7** to **A through G.**
49	39c	10	Change "P2" to **J4.**
49	39c	25	Immediately before "S3" insert **EXP switch.**
50	39d	4	Change "P2" to **J4.**
50	39e	7	Change "P2" to **J4** and "pin 16" to **pin 15.**
51	39f	7	Change "P2" to **J4.**
57	39j	5	Change "P2" to **J4.**
68	44b	6	Delete "24.4 microseconds"; insert in its place a period equal to range zero minus the missile reponse time.
69	45	Title	Change reference in title to **(fig. 11–1).**
69, 70	45b–g		Delete subparagraphs b through g.
70	45h	1	Change "Both pulses" to **Both the radar and coder pulses.**
70	45h	5	Change "4-microseconds" to read **5-microsecond.**
74	50b	4	Change "Transformer T1 in the plate circuit" to read: **An RC network in the output.**
77	51f	5	Delete "at the proper coding interval".
77	51g	18–19	Delete "properly spaced by the coding interval".
77	52a	5	Change "R21" to read **R2.**
78	52c	5	Change "R53" to read **R6.**
79	52e(2)	3	Change "+80" to read **+20.**
81	53		Add. The MTR receiving system is identical to that of the TTR with the exception that the missile AFC unit is normally used instead of the target AFC unit.
86	57	17	Delete "considerably".
86	58b	4	Change "test responder" to read **RF test set.**
87	59a(3)	3	Insert the word will between "frequency" and "be".
88	60e	7	Change "10" to read **15.**
89	60f	5, 6, 7	Change "detecting" to read **integrating.**
90	61b	Title	Add (fig. 23).
90	61b(1)	3	Change "opposite" to **like.**
91	Fig. 23		Those parts of figure 23 now designated as "1" through "5" should be redesignated **a** through **e** respectively.

Page	*Paragraph*	*Line*	*Changes*
92	61b(1)	4	At the right hand margin, opposite the equation add (**1**). Insert the vector sign (——) over "E_1" and "E_2".
92	61b(1)	5	At the right hand margin, opposite this equation, add (**2**). Insert the vector sign (——) over "E_1" and "E_2".
93	61d(1)	3	Change "10" to read **15.**
95	61g(1)	9	Change "explode" to read **fail-safe burst.**
96	Fig. 24	--------	Change the numerical designations of the figure parts 1 through 5 to alphabetical designation **a** through **e.**

2. Remove pages 21, 22, 83, and 84, and insert revised pages 21 and 22, new page 83, and revised pages 84 and 84.1.

cut off until terminal 3 of HR 1 rises from some negative potential, established by the drop of the plate of V3A, to about zero volts. The discharge path which established this time is from C17 and C18 through R76, R75, and R19 to the +250-volt supply and through V3A. Potentiometer R19 is used to adjust the time that V4A is cut off. Since V3A is in the discharge path HR 1, V3A must conduct longer than the maximum delay setting. The conduction time of V3A is determined by the charge path of C6. The delay network is part of HR 1, which is contained in a sealed oven. This oven keeps HR 1 at a constant temperature. The heater is shown on the schematic diagram. Capacitors C21 and C22 suppress arcing which may occur when S1 or S2 opens. Bimetallic heat-control switches S1 and S2 control the current flow through the heaters.

(5) *Switch tube V4A.* Switch tube V4A is a diode-connected triode. The normally conducting tube is cut off at preknock time and remains cut off until terminal 3 of HR 1 rises from its negative potential to approximately zero volts. A small negative pulse will appear across its cathode resistor. This signal is coupled directly to the grid of amplifier V4B.

(6) *Pulse amplifiers V4B and V5A.* This circuit amplifies and differentiates the output from the switch tube. Tube V4B amplifies the negative pulse, and a positive pulse appears at its plate. Stage V5A may be considered a driver for blocking oscillator V5B. Tube V5A is normally cut off by a −20-volt potential appearing at its grid. This voltage is provided by voltage divider R24–R25. The transformer plate load serves to differentiate the output signal. The signal at pin 5 of T2 is a negative pulse followed by a positive pulse. The positive pulse is used to trigger blocking oscillator V5B.

(7) *Blocking oscillator V5B.* Operation of this stage is similar to that of blocking oscillator V1B. Tube V5B is normally cut off by a bias supplied by voltage divider R29–R30–R32. For the blocking oscillator to operate, a positive trigger must appear on the grid. A positive pulse at the grid will cause the grid to rise, starting the regenerative action. When V5B reaches saturation, the process reverses itself, rapidly cutting off the stage. It remains cut off until another positive pulse appears at the grid. The output signal developed across the cathode resistor is the result of the change in plate current which flows through it. The signal is a 1-microsecond positive pulse with an amplitude of 40 volts, following the preknock pulse. This pulse is applied to V6A.

(8) *Pulse amplifier V6A.* The pulse is amplified and inverted by V6A, and a negative pulse appears at pin 1 of T4. The pulse is inverted by T4 and appears as a positive 1-microsecond pulse at J3.

(9) *Coder pulse channel.* The operation of the coder pulse channel is almost identical to the operation of the radar pulse channel. The major difference is the amount of time that switch tube V8A is held cut off. Tube V8A is held cutoff for a period determined by the setting of R44 and R45. These potentiometers are set so that the coding interval (the time between the radar pulse and the coder pulse) is the same as that required for the missiles being used. The coding interval used in the missile-tracking radar is from 2.6 to 10.1 microseconds for existing missile codes. The signal goes through the remainder of the stages in the same manner as in the radar pulse channel. The negative pulse from V6B is not inverted by T4. The negative pulse from T4 is called the coder pulse and is 45 volts in amplitude. It is mixed with the radar pulse in T4.

(10) *Outputs.* The radar pulse and coder pulse are both approximately 45 volts, 1-microsecond pulses. The preknock pulse is a positive pulse of approximately 1 microsecond in width and 40 volts in amplitude. The radar pulse is fixed at some time interval after the preknock pulse. The coder pulse is variable in time relationship to the preknock pulse and the radar pulse. From J1, on the output of the pulse generator, the missile preknock pulse is applied to terminal C of E3, which is located to the rear of the range indicator. From E3, it is applied to P32 on the range indicator, to test jack J23 in the upper inclosure of the missile console, and to J29. It is also applied to pin 4 of S1C, the TARGET-STANDBY-MISSILE switch, where it may be used to trigger the test delay unit if S1 is in the MISSILE position. From J29, the preknock pulse goes to the range and receiver cabinet over cable 6 to E21. A coaxial terminating resistor is connected from E21–B to ground. From E21–D, the preknock pulse goes to the range unit assembly.

triode amplifiers. An additional input to the sum IF amplifier is the 60-megacycle input from the AFC channel of the converter. This signal, as well as the sum signal, is filtered in the sum IF preamplifier and supplied as a current output for the crystal current meter. A delay line is available in this preamplifier to provide 2,000-yard pulses to check the missile ranging system.

d. Elevation and Azimuth IF Preamplifiers. The purpose and functioning of the elevation and azimuth IF preamplifiers are the same as the sum IF preamplifier, except that the AFC signal is not an input and there is no delay line.

e. Slip Ring Assembly. The slip ring assembly electrically connects the rotating pedestal and the stationary trailer. Three adjacent slip rings pass each IF signal. The center ring of the three carries the IF signal and the ring on each side is for isolation to prevent crosstalk loss.

f. The 250-Foot Triple Coaxial Cable. The 250-foot triple coaxial cable carries the IF signals from the missile antenna trailer to the radar control trailer. It consists of three RG-9/U-type coaxial conductors. The main requirement of this cable is to allow no more than 10 electrical degrees of phase shift between any two signals. This cable is 250 feet long and has a power loss of approximately 4 db through any 1 of the 3 conductors.

g. Sum, Azimuth, and Elevation IF Main Amplifiers. The sum, azimuth, and elevation IF main amplifiers are physically located in the radar range and receiver cabinet of the radar control trailer. Signals from the IF preamplifiers reach the IF main amplifiers through the 250-foot triple coaxial cable. Each unit has a grounded-grid amplifier as an input stage and six succeeding stages of amplification. Of these 6 stages, the first 5 have a voltage applied to the control grids to automatically control the gain. The over-all gain of each IF main amplifier is about 111 db. The output of each amplifier is applied to the video and phase unit.

h. Video and Phase Unit. The video and phase unit is located in the radar range and receiver cabinet of the radar control trailer. The video and phase unit compensates for any relative phase shift between the three channels of IF signals. Each channel is shifted about 15,000° in the receiving system, but any relative phase shift must be compensated for. The video and phase unit also serves as second detector for each channel and provides monitor circuits for test purposes. The sweep expansion pulse gates this unit to allow the passage of only the signals from the missile being tracked. The video and phase unit has six main outputs. The sum signal, after being detected, is amplified and applied to the range error detector for use in automatic range tracking and to be displayed on the range tracking indicator. The detected sum signal is also applied to the AGC unit to automatically control the gain of the IF main amplifiers. The azimuth and the sum signals are applied to the azimuth angle error detector to provide azimuth tracking information. The elevation and sum signals are applied to the elevation angle error detector for elevation tracking information. An additional output is applied to the test panel to enable maintenance men to monitor the average signal strength of each of the three channels.

i. AGC Unit. The AGC unit provides a biasing voltage to the IF main amplifiers to control the gain of the receiver. The AGC unit is located in the radar range and receiver cabinet of the radar control trailer. The receiver gate from the range error detector gates the AGC unit to allow automatic gain control action on only the target or missile being tracked. The three outputs from this unit (one for each IF channel) are applied to the control grids of the second through the sixth amplifiers of the IF main amplifiers. Means are provided in this unit to allow maintenance men to monitor the outputs from this unit on the test panel.

j. Missile AFC Unit. The AFC unit, located in the radar range and receiver cabinet of the radar control trailer, controls the frequency of the local oscillator in the converter. The AFC unit, located in the RF unit on the missile-tracking antenna, controls the local oscillator frequency for the missile radar. The AFC units and the method used to control the frequency of the local oscillator are the main differences between the two tracking receivers. The AFC used with the missile radar controls the

repeller voltage of the local oscillator, while the target AFC controls the grid voltage of the tuning triode of the local oscillator tube. Because of a rapid change in beacon frequency when the missile is launched, it is necessary to have an AFC unit and local oscillator combination that will follow this fast change. The controlling of the repeller voltage allows much faster response from the local oscillator than controlling the voltage on the tuning triode. This method is not used with the target radar because the band of frequencies that can be covered by this method is much less. The output of the missile AFC unit is applied through the test panel and slip ring assembly to the local oscillator in the converter.

j.1. (Added) *Angle Error Detectors.* Two angle error detectors are used in the receiving system, but, since the two are identical, only the azimuth unit will be discussed. The received azimuth error IF signal and a portion of the received sum signal are applied to the angle error detector. This unit uses these signals to produce a video pulse signal which represents the direction and magnitude of the antenna azimuth pointing error. In ideal radar operation, if the antenna is pointed off the missile in azimuth in one direction, the azimuth error IF signal will be 180° out of phase with the sum IF signal. If the antenna is off the missile in azimuth, the amplitude of the output video pulse is proportional to the amount of azimuth error. If the antenna on the missile in azimuth, no azimuth error IF signal is applied to this unit; thus results in no output from the unit. As the missile moves in one direction increasingly away from the antenna azimuth on-missile position, the output of this unit will be negative video pulses of increasing amplitude. If the missile moves in the opposite direction in the same manner, the output of the unit will be positive video pulses of increasing amplitude. The 3-microsecond expansion pulse from the ranging system is also applied to the angle error detector; this signal is used to gate the output video pulses which insures that only the received IF signals from the missile being tracked are utilized. The angle error detectors are located in the radar range and receiver cabinet.

j.2. (Added) *Error Pulse Rectifiers.* Two error pulse rectifiers are used in the missile tracking radar; one for the elevation channel and one for the azimuth channel. They are located in the radar range and receiver cabinet. The error pulse rectifiers accept the angle error video pulses from the respective angle error detectors and converts the information contained in the pulses into dc signals. These dc signals are then applied to the antenna positioning systems. When the antenna is pointing on-missile no angle error video pulses are applied to the error pulse rectifier and its output is a zero dc signal with respect to ground. If the antenna is pointing off-missile such that positive video pulses are applied to the unit, a positive dc signal will be its output; and for negative input pulses, its output will be a negative dc signal. Since the amplitude of the dc signals varies proportional with the peak amplitude of the video signals applied, they are proportional to the magnitude of the antenna pointing error. The error pulse rectifiers are gated by the 0.4-microsecond receiver gate from the ranging system. This gate permits only the error video from the missile being tracked to affect the output of the unit.

k. Test Panel. The test panel provides meters, switches, and controls that allow certain test procedures and system checks to be made. The coarse tuning voltage for the missile local oscillator is also supplied from this test panel. This voltage is applied to the control grid of the tuning triode of the local oscillator to determine the section of the frequency band that the missile AFC unit will cause the local oscillator to cover. This test panel is located on the left door of the radar range and receiver cabinet of the radar control trailer.

l. IF Test Unit. The IF test unit, located just above the test panel, provides a 60-megacycle pulse, variable in range, to check the receiving system beginning at the input of the IF main amplifiers. This unit is essentially a built-in IF generator. To use this unit, it is necessary to operate the ON-OFF switch on the unit

[AG 413.44 (24 Oct 56)]

By Order of *Wilber M. Brucker*, Secretary of the Army:

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Chief of Staff.

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NG: None.

USAR: None.

For explanation of abbreviations used, see SR 320–50–1.

TM 9-5000-21

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

NIKE I SYSTEMS

MISSILE-TRACKING RADAR CIRCUITRY (U)

HEADQUARTERS, 213th AAA GROUP
Pennsylvania National Guard
15th & Allen Streets
Allentown, Pennsylvania

DEPARTMENT OF THE ARMY • MAY 1956

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DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C., *15 May 1956*

TM 9-5000-21, NIKE I SYSTEMS, Missile-Tracking Radar Circuitry (U), is published for the use of all concerned.

The special texts in the TM 9-5000-series are training supplements to those in the TM 9-5001-series which are the basic Army directives for the operation and maintenance of the NIKE I Guided Missile System. In the event of conflict, technical manuals in the basic TM 9-5001-series will govern.

[AG 413.44 (25 Apr 56)]

By Order of *Wilber M. Brucker*, Secretary of the Army:

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Chief of Staff.

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44-445R, AAA Msl Bn, NIKE, Continental (17)

NG: None.
USAR: None.
For explanation of abbreviations used, see SR 320-50-1.

CONTENTS

CHAPTER 1

INTRODUCTION TO THE MISSILE-TRACKING RADAR

Section I. INTRODUCTION

1. PURPOSE

This text is to present to the officers and technicians who will man the operating structure of Nike units material that will guide them in the proper maintenance and operation of the missile-tracking radar by instilling in them an understanding of its functional operation and its circuitry. This purpose is achieved, mainly, through the breaking down of the over-all radar component structure into a systems structure of five major systems, comprising the entire missile-tracking radar, and presenting block level and detailed function discussions of each of these, followed by a separate chapter on the control circuitry.

2. SCOPE

This text contains a complete discussion of the missile-tracking radar from two viewpoints. The five major systems, i.e.,sync command system, command calibrator system, transmitting system, receiving system, and servo system, are first discussed from a block level and then a more detailed discussion is given on a functional schematic circuitry basis. Each level of discussion is keyed to a pertinent diagram which is explained in the discussion and which, in turn, presents an explanation of the discussion in graphic form.

3. REFERENCES

Unless otherwise stated, a reference in this text will be to TM 9-5000-25, Nike I Tracking Radar Schematics. This schematic book has double-digit figure numbers assigned to the block diagrams and component's schematics, e.g.,"fig 1-3." The systems running sheets will be referred to by sheet number. The principle source of material consulted was Bell Telephone Laboratories' operators and maintenance notes XSAM-A-7. Volume III, chapter VI is the authoritative source of material on the missile-tracking radar.

4. GENERAL

a. As aircraft have become more and more important as a major weapon of war, aircraft research and development has made considerable advance in

a relatively short period of years. Air bombing attacks are now made from such long ranges; with such great velocities, and at such high altitudes that normal methods of detection and defense are rapidly becoming obsolete and ineffective. For this reason, surface-to-air missiles are required. It soon became apparent that the radar equipment already in existence was inadequate to fulfill the requirements of guiding these missiles. As a result, the tracking radars used in the Nike system were developed.

b. The first requirement of such a system is a means of acquiring and identifying the target. This is done by an acquisition radar and its associated IFF (identification, friend or foe) equipment. After the target has been acquired and identified, the next requirement is to track the target and furnish the computer with present position data. The target-tracking radar satisfies this second requirement. When the target is within range, the missile is fired. The next requirement is to track the missile, so present position data of the missile may be furnished to the computer. The missile-tracking radar satisfies this third requirement. The last requirement is to compare missile position and target position and solve the basic intercept problem. The computer satisfies this last requirement and sends steering and burst orders through the missile-tracking radar to the missile.

Section II. BLOCK DISCUSSION

5. GENERAL (fig 1-3)

The missile-tracking radar, as the name implies, tracks the missile and determines missile position data. These data are used in the computer to compute orders which will cause the missile to fly a course to intercept the target. These orders are transmitted to the missile by frequency modulation of the pulse repetition frequency of the missile-tracking radar. The missile-tracking radar is completely automatic in normal operation. Therefore, only one operator is needed. The missile-tracking radar is in many respects identical in operation and components to the target-tracking radar. However, the synchronizing system of the target-tracking radar is replaced in the missile-tracking radar by the sync command system, which is completely different. Other systems are modified to make the missile-tracking radar completely automatic. The missile presents a very small reflecting surface when in flight and does not reflect enough energy for the missile-tracking radar to track on the echo signal. To produce a strong enough signal, the missile carries a transmitter which is triggered by the r-f pulse from the missile-tracking radar. This transmitted signal from the missile, called the beacon, is the signal actually tracked by the missile-tracking radar.

6. SYNC COMMAND SYSTEM (fig 10-1)

The sync command system has three inputs and two outputs. The inputs are the G_Y, G_P, and burst orders from the computer. The outputs (fig 1) are two sync pulses and the preknock pulse. The G_Y and G_P orders from the computer are d-c voltages which continuously vary between +100 volts and -100 volts. The G_Y order causes the missile to climb to the right and to dive to the left. Within the sync command system, this order is converted into a sine wave voltage (fig 2a) at a frequency between 120 and 180 cycles per second. For -5g, 0g, and +5g orders, the voltages from the computer are -100, 0, and +100, and the frequencies are 120, 150, and 180 cycles per second, respectively. The G_P order (fig 2b) produces a sine wave voltage at a frequency between 400 and 600 cycles per second. For -5g, 0g, and +5g orders, it is 400, 500, and 600 cycles per second, respectively. Since both orders must be transmitted to the missile, they are added together and produce a complex wave, which is used to vary the prf of the missile-tracking radar. The prf varies about 2,000 pulses per second in a complex manner (fig 2c). If the two sine waves reach maximum positive at the same instant, the prf is 2,400; if they both reach maximum negative at the same instant, the prf is 1,600. If one reaches maximum positive at the same instant that the other reaches maximum negative, or if both reach zero at the same instant, the prf is 2,000. If one voltage is zero at the instant that the other is maximum positive, the prf is 2,200. If one voltage is zero and the second voltage is maximum negative the prf is 1,800. For the frequencies illustrated, this complex waveform will repeat itself every 10 seconds. When the burst order is given, the prf varies about 2,000 pps at a rate of 880 cycles per second; that is, it varies from 1,600 to 2,400 pulses per second 880 times each second. The final unit of the sync command system is the pulse generator. One of the outputs (fig 1) from this unit is the preknock pulse, which is applied to the testing, monitoring and calibrating, ranging, and presentation systems for timing purposes. The other outputs are the two sync pulses, which are applied to the transmitting system. The first of these sync pulses is a negative pulse called the coder pulse. The second is a positive pulse called the radar pulse. The radar pulse follows the preknock pulse by 24.4 microseconds and the coder pulse precedes the radar pulse by a coding interval which may be from 4 to 22 microseconds. The time between pulses (that is, preknock to preknock) varies between 417 and 625 microseconds, as the prf varies between 1,600 and 2,400 pps.

7. TRANSMITTING SYSTEM (fig 11-1.1)

Each of the sync pulses from the sync command system causes a pulse of r-f energy to be transmitted by the missile-tracking radar. The transmitting

system of the missile-tracking radar is different from that of the target-tracking radar in that 2 trigger generators and 2 modulators are used, while only 1 of each is used in the target-tracking radar. The coder pulse gates circuits in the missile so that, if the radar pulse arrives at the correct time, the radar pulse will pass through, causing the beacon signal to be transmitted and orders to be applied to the missile. By using different coding intervals for batteries situated close to each other, it will not be possible for one battery to gain control of another battery's missile. Reception of the beacon signal by the missile-tracking radar indicates that the transmitted signal (and orders) are being received by the missile. Within the missile, the prf of the missile-tracking radar is converted into a complex wave and the two steering components are filtered out of the complex wave and applied to the fin-control components.

8. RECEIVING SYSTEM (fig 13-1)

The receiving system of the missile-tracking radar differs from the receiving system of the target-tracking radar in that the 60-mc difference frequency must be maintained between the local oscillator and the received beacon signal. The beacon signal shifts frequency when the missile is launched. These factors necessitate a different, faster-acting automatic frequency control circuit. The fast action is obtained by using repeller-plate tuning instead of cavity tuning of the klystron local oscillator. When a missile is first designated, if the received signal from the missile is strong enough, a relay is energized which permits the missile to be fired. If the beacon signal is not strong enough, the missile must be rejected manually or, if it is desired to fire the missile, it must be accepted manually. The strength of the beacon signal is indicated on the RECEIVED SIGNAL meter located on the missile console.

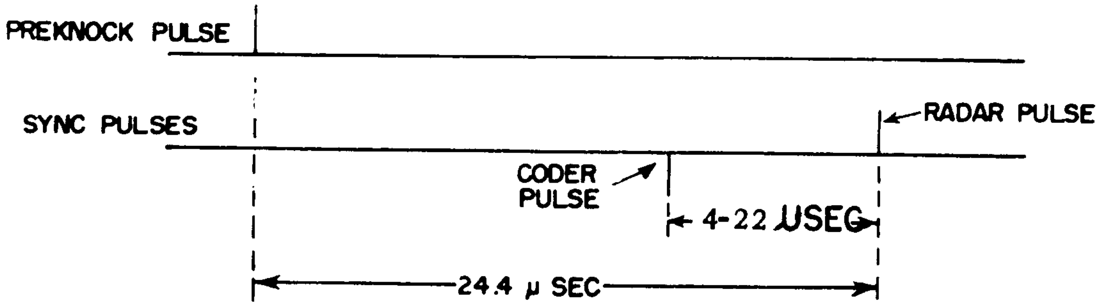


Figure 1. Sync command system outputs.

9. ANTENNA POSITIONING AND RANGING SYSTEMS (figs 15-1.1, -2.1, and -3.1, and 16-1, -2, -4, and -5)

The connections between the units of these systems are different from those in the target-tracking radar so that the missile-tracking radar may be completely automatic. With the TEST-OPERATE switch on the missile console in the OPERATE position, only automatic operation of the missile-tracking radar is possible. When a missile has been designated, information is applied to the antenna positioning and range systems to position the missile-tracking radar to the azimuth, elevation, and range of the designated missile. This preset data continues to position the radar for 3 seconds, during which time the missile-tracking radar locks on the missile signal. The missile-tracking radar will then track the missile during its flight. If the beacon signal becomes unusable, the missile-tracking radar will coast at the existing rates in azimuth, elevation, and range for 3 seconds, at the end of which time the missile-tracking radar will slew to the next designated missile. If the burst signal is given, the radar will slew to the next missile 0.4 second after the beacon signal is lost.

10. PRESENTATION SYSTEM (fig 14-1)

Since the missile-tracking radar is automatic and only one operator is required, it is necessary to have only one indicator. This indicator is the range indicator. The azimuth and elevation of the missile-tracking radar are shown on dials at the indicating panel of the missile-tracking console. Since manual operation is impossible, image spacing is not provided on the indicator.

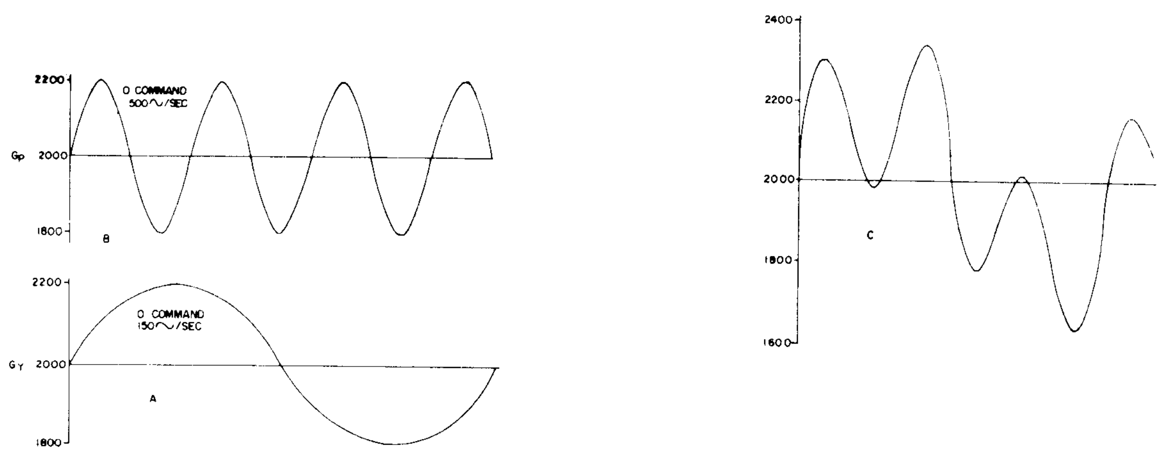


Figure 2. Waveforms

11. TESTING, MONITORING AND CALIBRATING SYSTEM (figs 10-18 and 12-4)

This system is used for testing and calibrating the radar. Besides equipment that is used with both radars, the missile-tracking radar requires certain additional monitoring and adjustment equipment to insure that it is performing correctly. Most important in this respect are the command calibrator and the transmitted pulse monitor. The command calibrator provides a means of adjusting the sync command system to insure that the prf varies in the proper manner with various commands. The transmitted pulse monitor indicates the number of missing pulses from the transmitter. This is important, for if too many pulses are missing from the transmitted energy, a false steering order will be received by the missile. Missing pulses are primarily caused by faulty operation of the magnetron.

CHAPTER 2

SYNC COMMAND SYSTEM

Section I. BLOCK DISCUSSION

12. INTRODUCTION

The missile-tracking sync command system is that portion of the missile-tracking radar which receives the steering and burst orders from the computer and converts them into signals which are used by the transmitting system to control the missile. These orders are sent to the missile by means of the r-f beam. It is possible, because of maladjustment, for the missile to receive a command, even though no order has been given by the computer. Therefore, it is important that the sync command system be well maintained and adjusted at all times to keep the missile from receiving false orders.

13. REVIEW

The transmitting system of the missile-tracking radar transmits pairs of pulses. The frequency at which these pulse pairs vary about 2,000 cycles per second is determined by the order being transmitted to the missile. The first of these pulses is called the coder pulse. The coder pulse causes the circuits in the missile to be gated so that if the radar pulse (the second pulse) arrives at the right time the beacon will be triggered and the orders will be applied to the missile. All the components of the sync command system are located in the upper compartment of the missile console.

14. BLOCK DIAGRAM DISCUSSION

a. Yaw oscillator (fig 10-2). The yaw oscillator has one input. It is the d-c voltage from the G_Y amplifier of the computer and may vary continuously between +100 and -100 volts. The voltage is applied to a cathode follower and the output of the cathode follower controls a free-running multivibrator. The multivibrator has a frequency of 150 cycles per second when the input from the computer is zero volts. With this input, a 0g command is being transmitted to the missile. If the input is a positive voltage, the frequency of the multivibrator is greater than 150 cycles per second and the missile will climb to the right. If the input is a negative voltage, the frequency is less than 150 cycles per second and the missile will dive to the left. The output of the multivibrator is applied to a cathode follower. The output of the cathode follower is

a symmetrical 34-volt square wave, with a frequency varying about 150 cycles per second. It is applied to the combining amplifier.

b. Pitch oscillator (fig 10-4). The pitch oscillator is nearly identical to the yaw oscillator. It has a similar input, which comes from the G_Y amplifier of the computer. Its center frequency is 500 cycles per second. If the input is a positive voltage, the frequency of the multivibrator is greater than 500 cycles per second and the missile climbs to the left. For a negative input, the frequency of the multivibrator is less than 500 cycles per second and the missile dives to the right. The output is similar to the output of the yaw oscillator except that the center frequency is 500 cycles per second. The output is also applied to the combining amplifier.

c. Burst oscillator (fig 10-6). The burst oscillator is nearly identical to the yaw and pitch oscillators. It does not have an input and oscillates continuously. Since there is no input, the first cathode follower stage is not necessary. The multivibrator runs at a frequency of 880 cycles per second and does not vary from this frequency. The output is taken from a cathode follower and applied to the combining amplifier.

d. Combining amplifier (fig 10-8). The combining amplifier has four inputs. They are the outputs of the yaw, pitch, and burst oscillators and the burst order from the computer. The outputs of the oscillators are applied to the low-pass filters which filter out the higher harmonics of the square waves and allow only the fundamental frequencies to appear at the output. These voltages are sinusoidal at the frequencies of the various oscillators. The yaw and pitch signals are combined and produce a complex wave. This complex wave is applied to contacts of a relay, and during the steering phase of the flight of the missile, this complex wave passes through the combining amplifier. The burst frequency is also applied to contacts of this same relay. The burst order from the computer causes the relay to be energized, removing the steering signals and allowing the burst signal to pass through the combining amplifier. The remainder of the combining amplifier consists of a cathode follower and two amplifier stages. Negative feedback is used from the output amplifier to the cathode follower to insure faithful reproduction of the input signal and to prevent instability. The output of the combining amplifier is either a complex wave or a sine wave, which is applied to the repetition rate oscillator.

e. Repetition rate oscillator (fig 10-10). The repetition rate (rep-rate) oscillator is almost identical to the yaw and pitch oscillators. Its input is a complex wave or a sine wave from the combining amplifier. The center frequency of the multivibrator is 2,000 cycles per second. The final stage is an amplifier rather than a cathode follower. The output is a 90-volt, symmetrical

square wave with a frequency varying about 2,000 cycles per second. The output is applied to the pulse generator.

f. Pulse generator (fig 10-12). The first stage of the pulse generator is a single-swing blocking oscillator. The output of this stage is the preknock pulse, 1 microsecond in duration and 40 volts in amplitude. It is coincident with the positive-going edge of the signal from the rep-rate amplifier. This pulse is used to time various circuits in the missile-tracking radar and also is used to trigger two channels in the pulse generator. The first of these channels is the radar pulse channel, which produces a positive 2-microsecond pulse 40 volts in amplitude, following the preknock pulse by 24.4 microseconds. The second channel is the coder pulse channel which produces a negative 2-microsecond pulse, 40 volts in amplitude. This pulse precedes the radar pulse by the coding interval. Both the coder pulse and the radar pulse are applied to the transmitting system.

Section II. DETAILED DISCUSSION OF YAW, PITCH, AND BURST OSCILLATORS

15. INTRODUCTION

The sync command system includes the yaw, pitch, and burst oscillators, the combining amplifier, the repetition rate oscillator, and the pulse generators. The inputs to the sync command system are the orders from the computer in the form of d-c voltages. The outputs are the preknock pulse; and the coder and radar pulses, spaced at a predetermined interval and repeated at a frequency varying around 2,000 cycles per second. The outputs trigger various circuits of the missile-tracking radar and cause two pulses which are separated by a predetermined time interval to be transmitted. The yaw, pitch, and burst oscillators develop frequencies, according to commands from the computer, which control the pulse repetition rate of the missile-tracking radar transmitter.

16. DISCUSSION (fig 10-3)

a. General. What is said in the following paragraphs regarding the yaw oscillator is equally applicable to the pitch oscillator, except for the frequency. The burst oscillator is so similar to the yaw and pitch oscillators that only one paragraph will be needed to point out the differences.

b. Relay K1. The input to the yaw oscillator is a d-c voltage from the computer. It is applied through the contacts of K1 to a resistor network. This relay is deenergized for normal operation. For calibrating purposes, the relay is energized and a calibrating voltage is applied in place of the computer signal.

A potentiometer, the deviation control, in the resistor network picks off a portion of the input voltage and applies it to V1A. The setting of the deviation control determines the maximum amount the frequency of the oscillator may vary from the center frequency.

c. Cathode follower V1A. The voltage picked off by the deviation control is applied to the grid of cathode follower V1A. This stage isolates the computer from the multivibrator. Since the input may be a negative voltage, the cathode is returned to -250 volts. This permits the cathode to follow the input voltage, regardless of its polarity. The cathode voltage of V1A controls the frequency of the multivibrator.

d. Multivibrator (V2, V3, and K2). The multivibrator circuit includes V2, V3, and K2. Pentodes V2 and V3 are used for greater frequency stability. The coil and a pair of contacts of K2 are included in the plate circuit of V2. The relay insures that the multivibrator operates by opening the plate circuit of V2 if both V2 and V3 conduct exactly the same amount. Relay K2 in the yaw oscillator is energized when the pitch oscillator is being calibrated. This causes the multivibrator to become inoperative by opening the plate circuit of V2; thus, there is no output from the yaw oscillator. The control grids of V2 and V3 are returned to the cathode of V1A through the 0g potentiometer network. The coupling capacitors in Z1 charge toward the voltage appearing at the cathode of V1A. If this voltage is varied, the time needed for the grids to rise to the cutoff potential is changed accordingly and the frequency of the multivibrator is thereby controlled. The center frequencies of the yaw, pitch, and burst oscillators are 150, 500, and 880 cycles per second, respectively. The output of the multivibrator is applied to the grid of V1B through C3.

e. Cathode follower V1B. Cathode follower V1B isolates the multivibrator from the input network of the combining amplifier. The output is a symmetrical, 34-volt square wave which varies about the center frequency according to the commands from the computer.

17. RELAY K1

For normal operation, relay K1 is deenergized. This applies the computer signal through contacts 5 and 6 to resistor network R1, R2, and R3. The pick-off arm of R2 applies a portion of the input voltage to the grid of V1A. The setting of R2 determines the maximum frequency deviation of the multivibrator from its center frequency. Relay K1 is energized for calibration purposes. Plug P1-9 is at ground potential for the adjustment of R7 and at -100 volts for the adjustment of R2.

18. CATHODE FOLLOWER V1A, AND MULTIVIBRATOR, V2, V3, and K2

a. The input to V1A is approximately four-fifths of the signal from the computer. Thus the grid varies between +80 and -80 volts. The cathode attempts to follow the grid and, because of biasing conditions, swings from approximately +90 to -70 volts. This voltage controls the frequency of the multivibrator.

b. This multivibrator uses an inverted power supply, that is, the cathodes are connected to -250 volts while the plates are connected to ground. The plate of V2 is grounded through the coil of K2 and the plate of V3, through R8. If, when power is applied, the conduction of V2 and V3 is so nearly the same that the multivibrator does not start to oscillate, the current flow through V2 will be heavy enough to momentarily energize K2 and the multivibrator will start. When the multivibrator has started, the current flow, which is halved because of multivibrator operation and filtered by C1, is not great enough to energize K2. The signal appearing at the plate of the multivibrator is 244 volts peak to peak.

c. The control grids of the multivibrator are returned to the cathode of V1A through Z1 and R7. The cathode voltage of V1A controls the frequency of the multivibrator (fig 3). The cathode of V1A is at about +10 volts for no command or a 0g command from the computer. The cathode of V2 is at -250 volts. When V2 is conducting, its grid is also at -250 volts. When the multivibrator flops over, the grid of V2 is driven to -494 volts. The grid will always be driven to this voltage, since the plate signal is always of constant amplitude. The coupling capacitor from the plate of V3 to the grid of V2 charges toward the voltage appearing at the cathode of V1A and would charge to this voltage in five time constants. At time t_1, the grid of V2 reaches the cutoff potential and the multivibrator flops over. The time needed for the grid to reach the cutoff potential depends upon the voltage appearing at the cathode of V1A, and upon the time constant of the coupling circuit. For a +5g command, the cathode of V1A is at about +90 volts and the grid of V2 rises from -494 volts towards this voltage, reaching cutoff at t_2. Since the grid reaches cutoff in a shorter time, the period of the multivibrator output decreases and the frequency increases. For a -5g command the cathode of V1A is at about -70 volts. The grid of V2 rises toward this voltage, reaching cutoff at t_3. The period of the output of the multivibrator now increases and the frequency decreases.

d. When the yaw oscillator is being calibrated, K2 in the pitch oscillator is energized, thereby stalling the pitch oscillator, and only the output of the yaw oscillator passes through the combining amplifier. Similarly, when the pitch oscillator is being calibrated, K2 in the yaw oscillator is energized. When the burst oscillator is being calibrated, the relays in the combining amplifier are energized. This removes the output of the yaw and pitch oscillators and allows only the output of the burst oscillator to pass through the combining amplifier.

19. CATHODE FOLLOWER V1B

The output of the multivibrator is divided by the action of resistors R13 and R8 from ground to V3 pin 8. This produces a 38-volt a-c signal at the junction of C3 and R8, which is coupled across C3 and applied to the grid of V1B. The grid of V1B is normally at a +87-volt potential because of the voltage divider action of R9 and R10. The cathode follower isolates the multivibrator from the combining amplifier. The output is a 34-volt square wave.

20. BURST OSCILLATOR (fig 10-7)

Since there is no input, the first cathode follower stage is not necessary and the grids of the multivibrator are returned to a voltage divider, R2, R3, and R4 between plus 250 volts and ground. Relay K1 is energized when the burst oscillator is being calibrated. The input to V3 is taken from the junction of R5 and R6, and is half the normal amplitude. The output frequency is 880 cycles per second.

Section III. DETAILED DISCUSSION - COMBINING AMPLIFIER, REP RATE OSCILLATOR, AND PULSE GENERATOR

21. INTRODUCTION

In the previous section, the operation of the yaw, pitch, and burst oscillators was discussed. It was shown how a d-c voltage from the computer was used to control the frequency of the outputs of the yaw and pitch oscillators. The signals must now be prepared so that the presentation system, range system, and transmitting system will be pulsed at a rate determined by the orders being sent to the missile. This is because orders are sent to the missile by the transmitting system. The orders are sent by the modulating frequency at which the pulses of r-f energy are sent by the transmitting system. The combining amplifier, repetition rate oscillator, and pulse generator are the circuits which convert the frequency variations of the yaw and pitch oscillators and the burst signal into pulses which will be used as timing pulses in the range, presentation, and transmitting systems. For proper operation of the missile-tracking radar, these components must operate properly. Trouble in any one of these units puts the missile-tracking radar out of action. It is, therefore, very important that the maintenance men understand the operation and adjustment of the combining amplifier, repetition rate oscillator, and the pulse generator.

22. COMBINING AMPLIFIER (fig 10-8)

a. General. The combining amplifier combines the yaw and pitch orders and amplifies them for application to the repetition rate oscillator. At the

proper time, the burst order from the computer is applied to the combining amplifier, and the steering orders are removed. The combining amplifier is located on slide number 3 in the upper inclosure of the missile console assembly (fig 10-8). The outputs of the yaw, pitch, and burst oscillators are applied to filter network Z1, which is a low-pass filter. In Z1, the higher harmonics are filtered out and only the fundamental frequencies appear at the output terminals. The signals are sine wave voltages at the frequencies of the various oscillators. They are applied to the input selector and mixer network. Here, the yaw and pitch signals are combined and a complex wave (fig 2c) containing the frequency components of the yaw and pitch orders is produced. This complex wave is applied to the contacts of relay K1. During the steering phase of missile flight, this complex wave passes through the combining amplifier to the repetition rate oscillator. The burst frequency is also applied to contacts of the same relay. The burst order from the computer causes relay K1 to energize, removing the steering signals and allowing only the burst signal to pass through the combining amplifier. Either the complex wave or the burst signal, depending on the condition of relay K1, is applied to cathode follower V1A. The cathode follower matches impedances of the oscillators to the amplifier which follows. From the cathode of V1A, the signal goes through two stages of amplification, V1B and V2. Negative feedback from the output of V2 to the cathode follower insures faithful reproduction of the input signal and prevents instability. The output of the combining amplifier is either a complex wave or a sinusoidal wave, which is applied to the repetition rate oscillator.

b. Schematic discussion (fig 10-9). The inputs at J1, J2, and J3 come from the yaw, pitch, and burst oscillators, respectively. The yaw and pitch inputs are square wave voltages at frequencies determined by the orders being sent to the missile. The burst input is a square wave voltage at a constant frequency of 880 cps.

(1) Filter network Z1. The three inputs are applied to filter network Z1. In Z1, the higher frequency components of the signals are removed and sine wave voltages appear at its output terminals 3, 6, and 9.

(2) Input selector and mixer network. The sine wave voltages appear across potentiometers R7, R8, and R9. These potentiometers are the yaw, pitch, and burst potentiometers. They are adjusted, during calibration of the sync command system, so that the output of the calibrator is 100 volts peak-to-peak with either the steering orders or burst signal applied to V1A. During the flight phase of the missile, relay K1 is deenergized and a complex wave, which results from the mixing of the yaw and pitch inputs, is applied to cathode follower V1A. When the burst order is applied to pin 3 of P1, relay K1 is energized and the

burst signal is applied to the grid of V1A and the yaw and pitch inputs are removed. The values of R10, R11, R12, C1, and C6 are chosen so that the same degree of modulation for either flight or burst orders is obtained. For proper operation, the prf must cover the same range of frequencies for either a steering order or burst signal. For this condition to exist, the maximum signal amplitude at the grid of V1A must be the same for either the burst signal or the steering orders. Since the yaw and pitch signals are mixed together, but the burst signal is not added to another signal, R12 is equal to the parallel combination of R10 and R11. The difference in frequency of the yaw and pitch inputs accounts for the difference in size of R1 and R3, and R2 and R4. Since the impedance of C1 is greater at 150 cps than at 500 cps, the values of R3 and R4 are selected so that the signal which appears at pin 3 of R8 is greater than the signal which appears at pin 3 of R7. Relay K2 is controlled by the FUNCTION switch in the command calibrator. When K2 is energized, its contacts 4 and 6 provide a ground for terminal 7 of K1, causing K1 to energize. This removes the steering order input to V1A and applies the burst order. Relay K2 is energized when using the command calibrator to adjust the burst oscillator and the burst input to V1 in the combining amplifier. Resistor R13, in parallel with the coil of relay K1, is a damping resistor. Resistors R14, R15, and R16, in series with the coil of relay K1, are current limiters.

(3) Cathode follower V1A. Either a sinusoidal voltage wave or a complex wave is applied to the control grid of V1A. A d-c voltage of about 150 volts is applied to the grid of V1A, causing it to operate class A. Resistors R23 and R24 are connected to C1 and C6 so that they are charged to the same potential, whether K1 is energized or deenergized. Capacitors C1 and C6 prevent the d-c potential at the grid of V1A from being affected by R10, R11, R12, and the preceding circuit components, since the grids must be at a high d-c level for V1A to operate class A. The output of V1A is cathode coupled to amplifier V1B.

(4) Amplifier V1B. The signal developed across R21 is injected into the cathode circuit of amplifier V1B. The grid of V1B is grounded for a-c signals by the low-impedance path to ground presented by capacitor C2. Grounded grid amplifier V1B obtains its bias from the junction of voltage divider R19-R20. The output of V1B is coupled by C3 to power amplifier V2. No inversion takes place in V1B, since the signal is applied to its cathode.

(5) Amplifier V2. Amplifier V2 is a conventional parallel-connected triode amplifier. A fixed bias is supplied to V2 from voltage divider R26-R27.

Coil L1 is the plate load for V2. The input at the grid of V2 is amplified and inverted by V2. A portion of the signal developed across V2 is applied to the grid of V1A through C4 and R17. This inverse feedback reduces distortion and any tendencies toward instability. The output of V2 is also coupled to J4 and J5 through C5. From J4, the signal is applied to the repetition rate oscillator. From J5, the signal is applied to the command calibrator for use when adjusting the sync command system.

23. REP RATE OSCILLATOR (fig 10-10)

a. General. The repetition rate oscillator changes the output of the combining amplifier to a symmetrical square wave which varies about 2,000 cycles per second at a rate determined by the frequency of the input. The repetition rate oscillator is located on slide number 3 of the upper inclosure of the missile console, just in front of the combining amplifier. The repetition rate oscillator is similar to the yaw and pitch oscillators. The inputs are applied to selector relay K1. Normally, the output from the combining amplifier is applied to the repetition rate oscillator and controls the output. However, during alinement procedure, relay K1 is energized and an input is applied to the repetition rate oscillator from the command calibrator. This input is a d-c voltage which will cause the repetition rate oscillator to produce certain output frequencies which are observed on the oscilloscope of the command calibrator. From relay K1, the input is applied through cathode follower V1A to free-running multivibrator V2. The multivibrator has a center frequency of 2,000 cycles per second when there is no input from the combining amplifier. As the input changes, the frequency of the output of the multivibrator also changes. The instantaneous amplitude of the input of V2 controls the frequency of the output of V2. If the input is positive, the frequency of the multivibrator is greater than 2,000 cycles per second. If the input is negative, the output frequency is less than 2,000 cycles per second. The rate at which the voltage varies is controlled by the inputs to the combining amplifiers. The output of V2 is a square wave voltage which varies in frequency at a rate determined by the frequency of the input and over a range of frequencies determined by the maximum amplitude of the input. The output of V2 is applied to amplifier V1B. From V1B, the signal is applied to the pulse generator and to the command calibrator.

b. Schematic discussion (fig 10-11).

(1) Selector relay K1. The input to the repetition rate oscillator at J1 is either a complex wave or a sine wave. This input is applied through

the contacts of K1 to a voltage divider. This relay is deenergized for normal operations. For calibrating, the relay is energized and a calibrating voltage is applied in place of the input from the combining amplifier. A potentiometer, the deviation control, in the voltage divider picks off a portion of the input voltage and applies it to cathode follower V1A. The setting of the deviation control determines the maximum amount that the frequency of the oscillator may vary from the center frequency.

(2) Cathode follower V1A. The voltage from the brush arm of potentiometer R2 is applied to the grid of V1A. This stage isolates the combining amplifier from the multivibrator. The signal at the cathode of V1A controls the frequency of the multivibrator.

(3) Multivibrator V2, V3, and K2. The cathodes of V2 and V3 are connected to the -250-volt supply. The plate of V2 is grounded through R11 and R8. If, when power is applied, the conduction of V2 and V3 is so nearly the same that the multivibrator does not start to oscillate, the current flow through V2 will be heavy enough to momentarily energize K2 and the multivibrator will start. When the multivibrator has started, the current flow, which is halved by multivibrator operation and filtered by C1, is not great enough to energize K2. The signal appearing at the plate of the multivibrator is 244 volts peak to peak. The control grids of the multivibrator are returned to the cathode of V1A through Z1 and R7. The cathode voltage of V1A controls the frequency of the multivibrator (fig 3). The cathode of V1A is at about +10 volts when zero voltage is applied to the grid of V1A. The cathode of V2 is at -250 volts. When V2 is conducting, its grid is also at -250 volts. When the multivibrator flops over, so that V3 is conducting, the grid of V2 is driven to -494 volts. The grid will always be driven to this voltage, since the plate signal is constant. The coupling capacitor, connected from the plate of V3 to the grid of V2, charges toward the voltage appearing at the cathode of V1A and would charge to this voltage in five time constants. At time t, the grid of V2 reaches the cutoff potential and the multivibrator flops over. The time needed for the grid to reach cutoff potential depends upon the voltage appearing at the cathode of V1A, and upon the time constant of the coupling circuit. The maximum amplitude signal at the cathode of V1A is 160 volts peak-to-peak. This signal is at a level of +10 volts. This means that during one cycle, the cathode of V1A may vary from +90 volts to -70 volts. When +10 volts appears at the cathode of V1A, the grid of V2 rises from -494

volts toward this voltage, reaching cutoff at t_2. At period represented by t_2, the output will be at a frequency of 2,000 cps. With +90 volts at the cathode of V1A, the grid of V2 rises from -494 volts toward +90 volts, reaching cutoff at time t_1. Since the grid reaches cutoff in a shorter time, the period of the multivibrator output is decreased and the frequency is increased. When the cathode of V1A goes to -70 volts, the grid of V2 rises toward this voltage, reaching cutoff at t_3. The period of the output of the multivibrator is now increased and the frequency decreased. With the burst signal appearing at the input of the repetition rate oscillator, the voltage at the cathode of V1A varies between the limits of +90 volts and -70 volts sinusoidally at a rate of 880 cps. This will cause the period of the waveforms to change at a rate of 880 cps, and thus the frequency of the output will vary around 2,000 cps at an 880-cps rate. When steering orders are applied, the input to the repetition rate oscillator is a complex waveform which contains the mixed frequencies of the yaw and pitch orders. The instantaneous voltage at the cathode of V1A will determine the frequency of the output. The output frequency will vary at a rate determined by the complex wave and will retain the frequency components of the yaw and pitch orders.

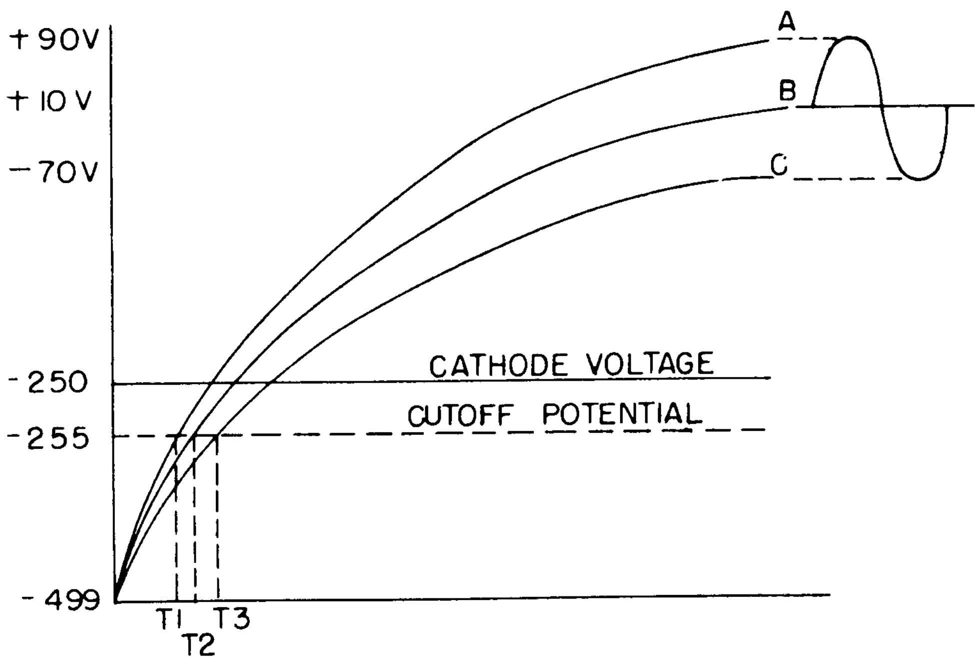


Figure 3. Period of a multivibrator.

(4) Amplifier V1B. The square wave output of the multivibrator is applied directly to amplifier V1B. The output of V1B is applied to jacks J2 and J3. From J3, the output is applied to the pulse generator. From J2, the output is applied to the command calibrator. The output is 90 volts in amplitude and is at a frequency determined by the amplitude of input to the repetition rate oscillator.

(5) Calibration. When the command calibrator is used to adjust the repetition rate oscillator, relay K1 is energized by a ground provided in the command calibrator. A potential is then applied from the command calibrator to pin 9 of P1 on the repetiton rate oscillator. For zero deviation, zero volts are applied. With zero volts, the ZERO DEV control, R7, is adjusted so the center frequency of the oscillator is 2,000 cycles per second as observed on the scope in the command calibrator. For maximum negative deviation, -100 volts are applied at pin 9 of P1, and DEV control R2 is adjusted for the correct pattern. The DEV control adjusts the amplitude of the signal at the grid of V1A, and thereby controls the limits between which the cathode of V1A varies. This sets the spread of frequencies covered by the multivibrator. For a plus deviation, a positive voltage is supplied and the pattern on the command calibrator is used to check the frequency. No adjustment can be made for a plus deviation.

24. PULSE GENERATOR

a. General (fig 10-12). The pulse generator acts as the timer for the missile-tracking radar. Output pulses are generated at a frequency dependent upon the frequency of the input from the repetition rate oscillator. The pulses generated are the missile preknock pulse, the coder pulse, and the radar pulse. The pulse generator is located on slide number 2 of the upper inclosure of the missile console (fig 10-12). The square wave output from the repetition rate oscillator is applied to the preknock pulse generator in the pulse generator. The preknock pulse generator produces a positive 40-volt pulse, which is used as a timing pulse in the missile-tracking radar presentation and range systems. The preknock pulse is also applied to the radar pulse channel and the coder pulse channel. The preknock pulse is amplified and inverted by pulse amplifier V2A and applied to multivibrator V3. When the pulse occurs, the multivibrator is triggered and electronic switch tube V4A is cut off. The length of time that V4A is cut off is controlled by a delay network. The negative square wave output of V4A is amplified and inverted by pulse amplifier V4B and again by pulse amplifier V5A. The signal is differentiated in the transformer plate load of

V5B. The positive pulse that appears in the output of V5A triggers blocking oscillator V5B, which produces a positive output pulse. The pulse is amplified and inverted by pulse amplifier V6A and applied to transformer T4, where it is inverted and mixed with the output of the coder pulse channel. The coder pulse channel operates in a similar manner to the radar pulse channel. The delay network in the coder pulse channel is adjusted for each group of missiles that have a different coding interval. The coder pulse may be adjusted to occur from 4 to 22 microseconds after the preknock pulse. The output of the coder pulse channel is applied to transformer T4. It is not inverted by T4. The output of the pulse generator, taken from the secondary of T4, is applied to the two trigger generators of the missile-tracking radar transmitting system. The output consists of a negative coder pulse followed by a positive radar pulse, both 40 volts in amplitude. The radar pulse occurs 24.4 microseconds after the preknock pulse, and the coder pulse occurs at a time after the preknock pulse determined by the 2.4- to 20.4-microsecond delay network. The radar pulse and coder pulse may be separated by from 4 to 22 microseconds, depending on the setting of the 2.4- to 20.4-microsecond delay network.

b. Schematic discussion (fig 10-13).

(1) Pulse amplifier V1A. The square wave output from the repetition rate oscillator is applied to J2. It is coupled by C1 to the grid of V1A. The signal is amplified and inverted by V1A and is transformer-coupled to V1B. A fixed, -23-volt bias is applied to V1A by voltage divider R1-R2. Resistor R33 is a parasitic suppressor.

(2) Blocking oscillator V1B. Blocking oscillator V1B is normally held cut off by a fixed bias from voltage divider R6-R7-R8. The negative-going edge of the waveform at pin 6 of T1 causes a positive change at pin 3 of T1. This change appears at the grid of V1B and is large enough to cause V1B to conduct. This current flow causes a magnetic field to be developed about the plate winding of T1. The expanding field cuts the conductors in the grid winding of the transformer, inducing a voltage across it. The transformer secondary is terminated at the oscillator grid in a manner which drives the grid positive at this time. The blocking oscillator plate current increases because of the increasing potential at the grid. This regenerative action causes plate current to rise quickly to saturation. During this action, grid current is drawn, and capacitors C3 and C8 become more negatively charged. When the blocking oscillator reaches saturation, plate current ceases to increase, and the magnetic field about the plate winding of T1 no longer expands. Since the voltage across the grid winding is a function of an expanding magnetic field, no voltage will be induced in the grid winding of T1.

This drop of potential at the grid results in a decrease in plate current. Since the magnetic field about an inductor is a function of current through the inductor, the field about the plate winding will begin to collapse because of the decrease in current through the winding. This collapsing magnetic field will produce a pulse of the reverse polarity, driving the grid in a negative direction. The stage is driven rapidly below cutoff, and plate current ceases. The negative potential of charged capacitors C3 and C8 is applied to the grid of V1B through the grid winding of T1. The tube is cut off and remains cut off until the next positive-going edge of the input from V1A. A 40-volt, 2-microsecond pulse appears at the cathode of V1B. The output is applied to J1. It is called the missile preknock pulse and starts the presentation systems of the missile-tracking radar. In the unmodified systems it triggers the range unit. The output of V1B is also applied to V2A to initiate the radar pulse channel, and to V2B to initiate the coder pulse channel.

(3) Pulse amplifier V2A. This stage is normally biased below cutoff by a -27.5-volt potential obtained from voltage divider R9-R11, which is connected between -250 volts and ground. The positive signal from blocking oscillator V1B is coupled through capacitor C4 and is developed across the voltage divider, causing V2A to conduct. The negative-going plate waveform is coupled directly to the 24.4-microsecond delay network and multivibrator gate V3.

(4) Multivibrator gate V3 and 24.4-microsecond delay network HR1. Tube V3A is normally held cut off by the -27-volt bias established on its grid by voltage divider R13-R14, which is connected from ground to -250 volts. Tube V3B is conducting with its grid returned to +250 volts through R18. The capacitance of the 24.4-microsecond delay network, C17 and C18, will charge to approximately 245 volts. The conduction of V2A, during the preknock pulse input, triggers multivibrator V3. The drop at the plates of V2A and V3A is coupled across C6 to the grid of V3B, decreasing the conduction of V3B and causing a rise in potential at its plate. This rise is coupled across C5 to the grid of V3A, allowing V3A to conduct, decreasing the potential at the plate of V3A even more. This action soon causes V3B to be cut off completely and V3A to conduct. This state will continue until V3B is again able to conduct because of its rising grid potential. This rise will result in decreased conduction in V3A, causing a rise in plate potential. Capacitor C5 charging toward -27 volts causes the decreased conduction of V3A. The drop at the plate of V2A and V3A is also coupled across the capacitance of the delay network, cutting off tube V4A. Tube V4A will remain

cut off until terminal 3 of HR1 rises from some negative potential, established by the drop at the plate of V3A, to about zero volts. The charge path which established this time is from C18 through R76, R75, and R19 to the +250-volt supply and through V3A. Potentiometer R19 is used to adjust the time that V3B is cut off. Since V3A is in the path, V3A must conduct longer than 24.4 microseconds. The conduction time of V3A is determined by the charge path of C6. The 24.4-microsecond delay network is part of HR1, which is contained in a sealed oven. This oven keeps HR1 at a constant temperature. The heater is shown on the schematic diagram. Capacitors C21 and C22 suppress arcing which may occur when S1 or S2 opens. Bimetallic heat-control switches S1 and S2 control the current flow through the heaters.

(5) Switch tube V4A. Switch tube V4A is a diode-connected triode. The normally conducting tube is cut off at preknock time and remains cut off until terminal 3 of HR1 rises from its negative potential to approximately zero volts. A small negative pulse will appear across its cathode resistor. This signal is coupled directly to the grid of amplifier V4B.

(6) Pulse amplifiers V4B and V5A. This circuit amplifies and differentiates the output from the switch tube. Tube V4B amplifies the negative pulse, and a positive pulse appears at its plate. Stage V5A may be considered a driver for blocking oscillator V5B. Tube V5A is normally cut off by a -20-volt potential appearing at its grid. This voltage is provided by voltage divider R24-R25. The transformer plate load serves to differentiate the output signal. The signal at pin 5 of T2 is a negative pulse followed by a positive pulse. The positive pulse is used to trigger blocking oscillator V5B.

(7) Blocking oscillator V5B. Operation of this stage is similar to that of blocking oscillator V1B. Tube V5B is normally cut off by a bias supplied by voltage divider R29-R30-R32. For the blocking oscillator to operate, a positive trigger must appear on the grid. A positive pulse at the grid will cause the grid to rise, starting the regenerative action. When V5B reaches saturation, the process reverses itself, rapidly cutting off the stage. It remains cut off until another positive pulse appears at the grid. The output signal developed across the cathode resistor is the result of the change in plate current which flows through it. The signal is a 2-microsecond positive pulse with an amplitude of 40 volts, following the preknock pulse. This pulse is applied to V6A.

(8) Pulse amplifier V6A. The pulse is amplified and inverted by V6A, and a negative pulse appears at pin 1 of T4. The pulse is inverted by T4 and appears as a positive 2-microsecond pulse, which occurs 24.4 microseconds after preknock time, at J3.

(9) Coder pulse channel. The operation of the coder pulse channel is almost identical to the operation of the radar pulse channel. The major difference is the amount of time that switch tube V8A is held cut off. Tube V8A is held cut off for some period between 4 and 22 microseconds. The delay time is determined by the setting of R45 and R44, the coder coarse and coder fine potentiometers. These potentiometers are set so that the coding interval (the time between the radar pulse and the coder pulse) is the same as that required for the missiles being used. The coding interval used in the missile may be set from 2 to 12 microseconds. The signal goes through the remainder of the stages in the same manner as in the radar pulse channel. The negative pulse from V6B is not inverted by T4. The negative pulse from T4 is called the coder pulse and is 40 volts in amplitude. It is mixed with the radar pulse in T4.

(10) Outputs. The radar pulse and coder pulse are both 40 volts in amplitude. The preknock pulse is 40 volts in amplitude. The radar pulse is fixed at some time interval after the preknock pulse. The coder pulse is variable in time relationship to the preknock pulse and the radar pulse. From J1, on the output of the pulse generator, the missile preknock pulse is applied to terminal C of E3, which is located to the rear of the range indicator. From E3, it is applied to P32 on the range indicator, to test jack J23 in the upper inclosure of the missile console, and to J29. It is also applied to pin 4 of S1C, the TARGET-STANDBY-MISSILE switch, where it may be used to trigger the test delay unit if S1 is in the MISSILE position. From J29, the preknock pulse goes to the range and receiver cabinet over cable 6 to E21. A coaxial terminating resistor is connected from E21-B to ground. From E21-D, the preknock pulse goes to the range unit assembly.

CHAPTER 3

COMMAND CALIBRATOR SYSTEM

Section I. BLOCK DISCUSSION

25. GENERAL DISCUSSION (fig 10-18)

The Nike missile is guided by commands transmitted by the missile radar. These commands appear as a modulation of the pulse repetition frequency. This modulation is controlled by d-c voltages developed in the computer. Accurate guidance of the missile can be obtained only if the modulation of the pulse repetition frequency is an exact and precise function of the magnitude and polarity of the d-c voltages developed in the computer. This modulation of the prf in accordance with the applied computer voltages is the function of the sync command system of the missile-tracking radar. This system has four oscillators whose frequencies are controlled by the applied voltages. These are the yaw, pitch, burst, and repetition rate oscillators. For accurate guidance, the frequency of the signal generated by each of these oscillators must be a direct function of the applied voltage. Because of this requirement, the command calibrator has been provided for calibrating the oscillators. The command calibrator receives 4 low-frequency reference signals against which the operating frequencies of the 4 critical sync command oscillators may be compared and, if necessary, adjusted. The frequencies of the four reference signals must be extremely stable if calibration of the oscillators is to be reliable. The 4 reference signals are generated by the combined operation of 2 units, the frequency divider and the frequency generator. These components are in two chassis for efficient utilization of the available space. Electrically, the 2 units may be considered as 1. D-C voltages from the Y and P amplifiers in the computer are applied to the yaw and pitch oscillators of the sync command system. The d-c voltages may vary within the limits of ±100 volts. These voltage limits correspond to 5g fin orders. When zero voltage is applied, the signal frequency of the yaw oscillator is 150 cycles per second. With +100 volts applied (the equivalent of a +5g fin order), the frequency of the yaw oscillator is 180 cycles per second. With -100 volts applied (the equivalent of a -5g fin order), the frequency of the yaw oscillator is 120 cycles per second. The center frequency of the pitch oscillator is 500 cycles per second. With +100 volts applied (the equivalent of a +5g fin order), the frequency of the pitch oscillator is 600 cycles per second. With -100 volts applied (the equivalent of a -5g fin order), the frequency of the pitch oscillator is 400 cycles per second. The

output signals of the yaw and pitch oscillators are applied together to the combining amplifier. The output of this stage is applied, in turn, to the repetition rate oscillator. The output of the repetition rate oscillator is a signal which varies about a center frequency of 2,000 cycles per second. The frequency limits are 1,600 and 2,400 cycles per second. This output signal, which is applied to the pulse generator, ultimately controls the pulse repetition frequency of the missile-tracking radar. Unlike the other oscillators, the burst oscillator produces an output signal at a fixed frequency. The output frequency of the burst oscillator is 880 cycles per second. This signal causes the missile to burst. These 10 signal frequencies, tabulated in table I, are used in calibrating the sync command system of the missile-tracking radar.

Table 1. Frequencies used in command calibration.

Oscillator	Signal frequency	Reference frequency	Ratio of sig frequency to ref frequency
Yaw	120 150 180	30 30 30	4 5 6
Pitch	400 500 600	100 100 100	4 5 6
Burst	880	220	4
Repetition rate	1,600 2,000 2,400	400 400 400	4 5 6

26. BLOCK DISCUSSION (fig 10-18)

a. Over-all purpose.

(1) Command calibrator system. The over-all command calibrator system provides the means whereby the oscillators of the sync command system may be calibrated to develop the correct signal frequencies.

(2) Frequency divider. This unit generates a stable master frequency which is used to produce 4 stable reference frequencies of 30, 100, 220, and 400 cycles per second after frequency division in the frequency divider and frequency generator.

b. Frequency divider. The frequency divider is located in the missile console. Figure 10-18 is a block diagram of the command calibrator system. This unit contains a crystal-controlled oscillator whose output is a 20.58-kc sine wave. The oscillator is followed by two frequency-divider circuits which divide by 7 to obtain a 420-cycle output. For the two frequency-divider circuits to function properly, the signals are shaped by a limiter stage. Each divider triggers a pulser (blocking oscillator), which develops 1 output pulse for every 7 pulses applied to the divider. The 420-cycle output signal is applied to the frequency generator.

c. Frequency generator. The frequency generator receives the 420-cycle output of the frequency divider and divides this signal by 7 to obtain an exact 60-cycle signal. This signal is used to drive a synchronous 60-cycle clock motor. The motor speed is 600 rpm, or 10 revolutions per second. The motor drives a slotted tone wheel. The perforations of the tone wheel form 4 concentric rings, through which light is applied to 4 photosensitive transistors. The four rings of perforations contain 3, 10, 22, and 40 evenly spaced holes. Because the motor speed is 10 revolutions per second, the transistors are illuminated at frequencies of 30, 100, 220, and 400 cycles per second and produce output signals of these frequencies. The 4 outputs of the transistor assembly are applied through 4 cathode followers to the switching circuit of the command calibrator.

d. Command calibrator. The command calibrator provides a means whereby the output signals of the yaw, pitch, burst, and repetition rate oscillators of the sync command system may be observed on a 3-inch oscilloscope in the calibrator. These signals are applied to the vertical deflection plates of the oscilloscope. The horizontal sweep of the oscilloscope may be obtained from the frequency generator. The resulting waveshapes which appear on the oscilloscope have definite requirements with respect to the number of complete cycles and their shapes. The adjustment of the oscillator being tested will satisfy these requirements. Also, a meter is provided to indicate the amplitude of the signal being tested. The yaw, pitch, and burst oscillators of the sync command system transform a d-c order voltage, applied from the computer, into an a-c command signal with a certain frequency. The frequencies vary in accordance with the d-c order voltages. When the waveshapes of these a-c signals on the calibrator oscilloscope are being observed, the calibrator (in place of the computer) provides standard d-c order voltages to produce the correct

frequency being tested. The signal frequencies which are tested are listed in table I, together with the reference sweep frequency employed in each case. The number of complete cycles which must appear on the calibrator oscilloscope is indicated in the right column of the table. When the signal frequency is correct, the desired number of waveshapes appears on the oscilloscope, and these waveshapes are motionless. Any movement of the waveshapes in excess of 1 cycle in 10 seconds indicates the need for adjustment of the oscillator being tested.

e. Adjustment of calibrator. If the desired standard frequencies are to be generated, the voltage applied to the motor of the frequency generator must be 60 cycles per second. This, in turn, requires that each of the 3 frequency dividers must divide by 7. To insure that division by 7 takes place in all 3 dividers, the stairstep signal present at each divider is applied to the calibrator switching circuit. These 3 signals, 2 from the frequency divider and 1 from the frequency generator, may be monitored on the calibrator oscilloscope so the dividers may be adjusted. The 20.58-kc master frequency generated in the frequency divider is stable within 0.01 percent tolerance. If frequency division is correct, the 60-cycle signal applied to the motor and the 4 reference frequencies developed in the photosensitive transistor assembly will all be stable within the same 0.01 percent tolerance.

Section II. FREQUENCY DIVIDER

27. BLOCK DISCUSSION (fig 10-14)

a. Master oscillator V1 (fig 4). This stage consists of the two sections of a 12AU7 dual-triode and associated circuit components. The circuit has a quartz crystal in the feedback circuit to obtain an output frequency of 20,580 cycles per second. The frequency tolerance of the oscillator, 0.01 percent, is made possible by crystal control. The output of the oscillator is a somewhat distorted sine wave. This signal is applied to limiter V2 in the first frequency division channel.

b. Limiter V2. For the divider circuit to function properly, the applied signal should be in the form of a square wave. Limiter V2 clips the positive and negative portions of the oscillator output so as to deliver an output square wave.

c. Cathode follower V3. This stage matches the high output impedance of the limiter to the low input impedance of the divider stage. The cathode follower delivers a 195-volt square wave to divider V4.

d. Divider V4. For each input pulse applied to the divider, a small charge is added to a capacitor. After seven pulses, the capacitor is charged to a voltage level which triggers the following stage. When the pulser is triggered, the capacitor is discharged. The capacitor then starts charging again, and the cycle is repeated. Tube V4 is a 6AL5 dual-diode. The two sections of this tube deliver an increment of charging current to capacitor C10 for each negative alternation of the applied square wave. A stairstep waveform appears across the capacitor as the negative charge on the capacitor is increased with each succeeding pulse. The voltage across C10 is applied directly to pulser V5A and to cathode V10A.

e. Pulser V5A. The pulser tube is a single-swing blocking oscillator consisting of one section of a 12AX7 dual-triode and associated circuit components. The tube is biased to cutoff under no-signal conditions. The negative stairstep voltage which appears across capacitor C10 is applied to the cathode of V5A. Tube V5A is biased so that the seventh increase in the charge across C10 produces a cathode voltage negative enough to permit conduction. Pulser V5A then produces a single output pulse. At the same time, the conduction of V5A discharges capacitor C10 to allow another cycle of division to begin. Because tube V5A pulses only once for each 7 cycles of the 20.58-kc signal applied to the divider stage, the frequency of the output signal of V5A is 2,940 cycles per second.

f. Cathode follower V10B. The stairstep voltage across C10 is applied directly to the grid of V10B, half of a 12AU7 dual-triode. This stairstep waveform is reproduced at the cathode of V10B and transmitted to the calibrator. This makes it possible for the calibrator oscilloscope to monitor the operation of the first frequency division channel to insure that division by seven takes place.

g. Second frequency division channel. As is apparent from the block diagram of the frequency divider shown in figure 10-14, the stages of this second frequency division channel are analogous to the stages of the first channel, which has already been discussed. The output of pulser V5A provides the input. This channel divides the 2,940-cycle applied signal by 7 to produce a 420-cycle pulse signal at its output. Limiter V6, in addition to its function as a clipping stage, converts the pulse input to a balanced rectangular waveform. This is done by the grid-leak bias provided by the R-C circuit in the grid of V6.

h. Third frequency division channel. Only the first two stages of this channel are physically located on the frequency divider chassis. The remaining stages of the channel are on the frequency generator chassis (fig 10-16). This

channel receives the 420-cycle output pulses of V5B in the second divider channel and divides by 7 to produce a 60-cycle signal. However, the division does not take place until the signal reaches the stages located on the frequency generator chassis. As a result, the output of V7B is a 420-cycle square wave. Limiter V9 operates in a manner similar to V6 to convert the applied pulse signal to a balanced square wave.

28. DETAILED DISCUSSION (fig 10-15)

a. Master oscillator V1. Master oscillator V1 is essentially a two-stage, R-C coupled amplifier with a positive feedback loop between the output of the second amplifier and the input of the first amplifier. The oscillator consists of the two triode sections of V1, quartz crystal Y1, and associated circuit components (fig 4). The positive feedback maintains oscillation, and the frequency is controlled by crystal Y1 in the feedback circuit. Assume that a signal exists at the grid of tube V1A. This signal is amplified and inverted by V1A and applied through capacitor C1 to the grid of tube V1B. This section also amplifies and inverts the signal. The signal at the plate of V1B appears at the junction of resistors R8 and R9 and is coupled back to the grid of V1A through crystal Y1. The constants of the circuit components are such that the phase shift of the 2 stages is 360° at 20,580 cycles per second. A phase lag introduced by C25 and the crystal is corrected by the circuit consisting of C24, R8, and R9. This circuit introduces a phase lead equivalent to the lag resulting from the presence of C25 and crystal Y1. At the resonant frequency of 20,580 cycles, the positive feedback path has a resistance equal to the resonant impedance of the crystal (minimum). Thus, the original signal is reinforced and the circuit oscillates. Because of the high Q of the resonant crystal circuit, the impedance of Y1 rises rapidly for frequencies on either side of 20,580 cycles. The quartz crystal has a very low temperature coefficient, and stable operation is obtained without the use of temperature control. The crystal is mounted in an evacuated enclosure to prevent frequency changes caused by dirt, pressure variations, or oxidation of the plated crystal electrodes. Negative feedback is introduced by unbypassed cathode resistors R2 and R6. The output of the oscillator is a somewhat distorted sine wave with a peak-to-peak amplitude of about 80 volts. The frequency stability of this signal falls within the required 0.01 percent tolerance.

b. Limiter V2. The 80-volt output of the master oscillator is coupled to the grid of limiter V2 through the R-C circuit consisting of capacitor C4 and resistor R10. This circuit provides grid-leak bias for the operation of V2. The 50-microsecond time constant of C4 and R10 causes V2 to deliver an output square wave having positive and negative alternations of approximately equal duration. The plate voltage is approximately 50 volts when the tube is cut off. The peak-to-peak amplitude of the square wave is approximately 200 volts.

c. Cathode follower V3. This stage uses the two sections of tube V3 in parallel. The output of limiter V2 is coupled to the grids of V3 through the coupling

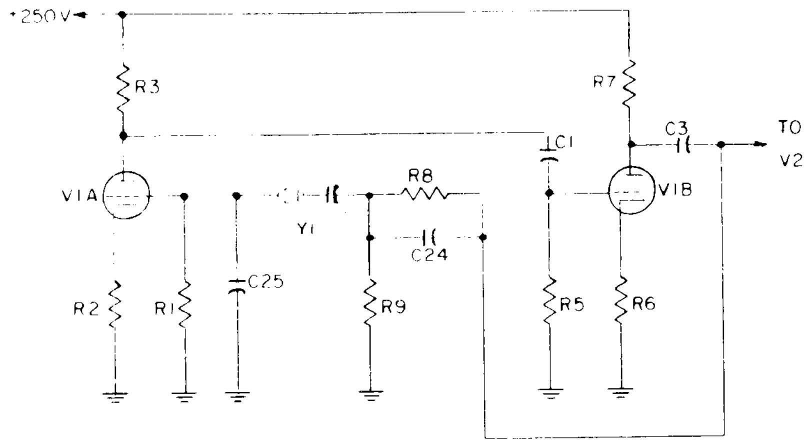


Figure 4. Master oscillator V1, simplified schematic.

circuit consisting of capacitor C6 and resistor R37. Resistor R37 is returned to a -90-volt potential, obtained at the junction of voltage divider R13-R14. The cathodes are returned to the -250-volt supply through parallel resistors R15 and R38, which afford a 19,500-ohm cathode load. As previously stated, V3 serves as an impedance-matching device between limiter V2 and divider V4. The signal at the cathodes, which may be monitored at test point TP1, is a rectangular waveform with an amplitude of approximately 195 volts.

d. Divider V4. The divider stage consists of capacitors C9 and C10 and the two diode sections of V4. Figure 5 is a simplified schematic of the divider and pulser. Assume initially that capacitors C9 and C10 are uncharged. (The potential at the cathodes of V3 is close to zero during the positive alternation of the waveform.) When a negative alternation appears at the cathodes of V3, a voltage appears across V4A (pins 1 and 7) which causes V4A to conduct. Thus, for the negative leading edge of the 195-volt signal, a series circuit to ground exists. This circuit consists of C9, V4A, and C10. Capacitor C10 charges to a fraction of the applied voltage, as determined by the ratio of C9 to the sum of C9 and C10. When the positive trailing edge of the signal appears, V4B (pins 2 and 5) conducts and discharges C9. Because V4A is then cut off, the negative

charge on C10 is retained. On succeeding pulses, V4A does not conduct until the instantaneous amplitude of the negative pulse exceeds the charge on C10. For that reason, the applied voltage toward which C10 charges is, in each case, the difference between the peak amplitude of the pulse and the charge on C10 immediately before the appearance of the pulse. The ratio of C9 to the sum of C9 and C10 is approximately 1:14, so the charges added to C10 by any 2 successive pulses must differ by approximately 7 percent. As the charge on C10 increases with each pulse, the charge that can be added by the next pulse decreases, and the voltage across C10 builds up more and more slowly. The addition of charge to C10 by each pulse produces a stairstep waveshape across C10. Each horizontal tread (and, similarly, each vertical riser) in this stairstep waveform corresponds to one input pulse. Because the amplitude of the applied pulses is constant, a given voltage height on the stairstep waveform corresponds to a definite number of input pulses.

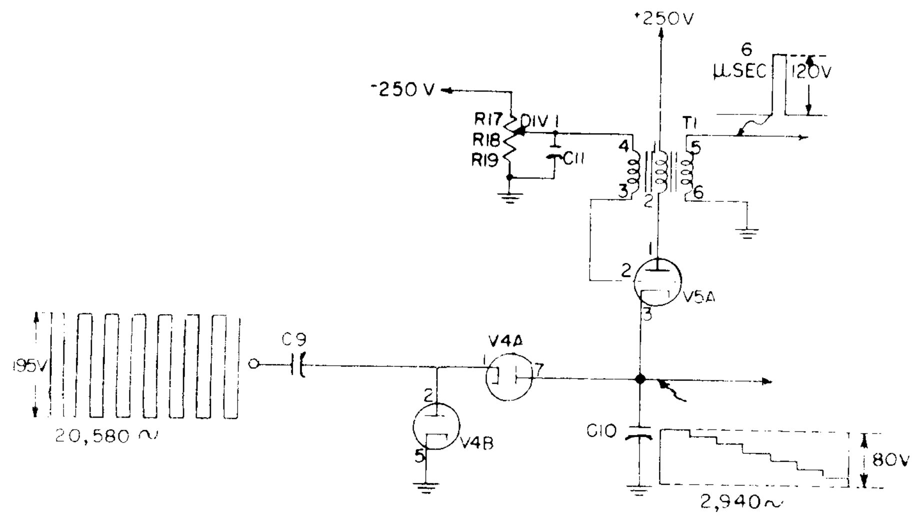


Figure 5. Divider and pulser, simplified schematic.

e. Pulser V5A. The pulser stage, consisting of tube V5A, transformer T1, and associated circuit components, is a single-swing blocking oscillator. When the charge on C10 is zero, V5A is held cut off by the negative voltage applied to the grid from the brush arm of DIV 1 potentiometer R18. As the negative charge on C10 increases in a stairstep fashion, the cathode of V5A approaches the potential which will allow the tube to conduct. The effect is the same as the application of a positive stairstep voltage to the grid. Potentiometer R18 is adjusted so that the charge on C10 will reach the critical voltage, and permit V5A to conduct,

at a point on the seventh vertical riser one-third of the way from the seventh to the eighth tread. The conduction of V5A discharges C10 to zero voltage. Plate current, increasing from zero, causes a voltage decrease at terminal 2 of T1. Terminals 2, 4, and 6 of T1 have a common voltage polarity, as do terminals 1, 3, and 5. Consequently, the decreased voltage at terminal 2 causes a voltage increase at terminal 3 and at the grid of V5A. Since the grid becomes more positive, plate current increases. The action is cumulative and continues until plate current reaches saturation. When that condition is reached, plate current no longer increases, and the magnetic field existing in transformer T1 no longer expands. A positive voltage no longer appears at the grid, and plate current begins to decrease. The resulting collapse of the field within T1 causes an opposite (negative) voltage to appear at the grid. This causes decreased conduction, thus hastening the collapse of the magnetic field. This second cumulative action continues until the grid is driven below cutoff, at which time the negative biasing voltage keeps the tube cut off until, after seven more pulses are applied to the divider, the charge on C10 again reaches the triggering level. As a result of this action, output pulses at a repetition frequency of 2,940 cycles per second appear at terminal 5 of T1. These pulses are applied to limiter V6, the first stage of the second frequency division channel. The output pulses are approximately 120 volts in amplitude and 6 microseconds in duration.

f. Cathode follower V10A. The voltage across C10, in addition to being applied to V5A, is also applied directly to the grid to V10A. Tube V10A is a linear cathode follower. It is used to permit monitoring of the stairstep waveshape without adding stray capacitance in parallel with C10. The output of V10A goes to the command calibrator. By this means, the waveform across C10 may be monitored to adjust DIV 1 potentiometer R18 in the grid circuit of V5A.

g. Second frequency division channel. The only difference between this channel and the one discussed above is that the values of certain components have been changed to allow this divider to function properly at 2,940 cycles per second. The R-C circuit consisting of C12 and R20 provides grid-leak bias for limiter V6. The positive pulse from T1 causes the grid of V6 to draw current. When the 6-microsecond pulse terminates, C12 discharges through R20, developing a negative voltage at the control grid. The time constant of C12 and R20 is such that the grid is held below cutoff for approximately half the period of the 2,940-cycle input. The grid potential then rises above cutoff, and V6 resumes conduction. Tube V6 continues to conduct until the appearance of the next input pulse, at which time C12 is again charged negatively by control-grid conduction. This action produces a distorted rectangular waveform at the plate of V6. The positive and negative alternations are of approximately equal duration, and the peak-to-peak amplitude of the waveform is approximately 200 volts. As in the first channel, cathode follower V7A provides a low-impedance source for divider V8. The operation of

this divider is almost identical to the first divider. Only the values of C17 and C18 are different. Seven steps of voltage appear across C18, which triggers the pulsing circuit of V5B. The output of the channel (at terminal 5 of transformer T2) is 1 positive pulse for every 7 pulses applied to the divider stage. This output is approximately 120 volts in amplitude, and the frequency is exactly 420 cycles per second. DIV 2 potentiometer R28 is used to adjust the bias voltage in the grid circuit of V5B so that the critical voltage across C18 will be reached between the seventh and eighth treads of the stairstep waveshape on C18. Tube V10B is a cathode follower whose input is the stairstep voltage appearing across C18. The output of V10B is monitored on the command calibrator oscilloscope when DIV 2 potentiometer R28 is adjusted.

h. Third frequency division channel. The positive 120-volt, 420-cycle pulses from transformer T2 are applied to limiter V9. This stage is similar in operation to limiter V6. The time constant of C20 and R30 is such that the conduction period of V9 is approximately equal to the cutoff period. The output of V9 is a balanced square wave at 420 cycles per second. The peak-to-peak amplitude of the square wave is 200 volts. This signal is applied to cathode follower V7B, which has a low output impedance. The output of V7B is applied through J1 to the frequency generator, discussed in section III. The remaining stages of the third frequency division channel are contained on the frequency generator chassis.

Section III. FREQUENCY GENERATOR

29. INTRODUCTION

a. General. In the sync command system, the yaw, pitch, and burst oscillators put out signals which frequency modulate the pulse repetition frequency of the missile-tracking radar so that commands can be sent to the missile. These oscillators each have a specified center frequency, which must be maintained if the Nike system is to do its job. Adjusting and checking the oscillators requires a test system, preferably built in, because this is done frequently. So far in the study of this test system, the frequency divider has been covered. The frequency divider consists of a crystal-controlled oscillator, accurate to 0.01 percent, and two dividers. The first divider reduces the signal to 2,940 cycles per second and the second divider produces a 420-cycle-per-second signal. The 2,940-cycle and 420-cycle signals are the outputs from the frequency divider. Only the 420-cycle signal is sent to the frequency generator, but both go to the command calibrator.

b. Frequency generator. The frequency generator is one of the components of the sync command test system and its function is to deliver four precise signals to the command calibrator. These four signals are of different frequencies.

The frequency of each signal must not vary from the specified standard. The four frequencies are: 30 cps, 60 cps, 220 cps, and 400 cps.

30. BLOCK DIAGRAM DISCUSSION (fig 10-16)

a. General. The frequency generator is located in the upper portion of the missile console on slide number 2. It uses several vacuum tubes, a tone wheel, and a photocell assembly to produce four frequencies which are sent to the command calibrator. This chassis is a continuation of the frequency divider system discussed in paragraphs 27 through 29. Physical limitations prevented its being on the same chassis with the frequency divider.

b. Frequency divider V1, V2A. The basic principle of dividers was discussed in paragraphs 27 and 28. The operation of this circuit differs slightly. In previous dividers, the stairstep changes exponentially. In this circuit, the addition of a clamper tube permits each negative pulse of the input wave to give an equal amount of change in the stairstep. The incoming 420-cycle input is divided by 7, to give a resulting 60-cycle signal.

c. Pulser V9. This stage is a blocking oscillator which is triggered each time the capacitors in the grid circuit are charged by the seventh step of the input waveform. The output is a large positive pulse of short duration occurring at a frequency of 60 cycles per second.

d. Multivibrator V3. This circuit is a one-shot multivibrator. It is triggered by the positive pulse from the pulser and the output is a square wave with a frequency of 60 cycles per second. The amplitude of this square wave is approximately 170 volts peak-to-peak.

e. Paraphase amplifier V2B. This stage is referred to as the inverter on some schematics. It receives the signal from V3 and produces two signals 180° out of phase. One signal is taken from the plate and the other is taken from the cathode.

f. Push-pull amplifier V4 and V5. These two tubes and their associated circuitry make up a push-pull amplifier which changes the input square waves into slightly distorted sine waves. These sine waves are then used as the driving voltages for synchronous motor B1.

g. Tone wheel. This wheel is connected to the shafts of B1 and is rotated at 10 revolutions per second. The wheel has four concentric rings of holes through which light shines. Because of the rotation of the wheel, the light shines on the photocell at intervals determined by the speed of the wheel and the number of holes in the wheel.

h. Photocell assembly. There are four photocells, one for each of the concentric rings of holes in the tone wheel. Each time the light shines on the photocell it reduces the resistance of the cell, which permits a cathode follower to conduct and produce an output. The output frequency is determined by the number of times per second the light shines upon the photocells. The following frequencies are the outputs from this stage: 30 cps, 100 cps, 220 cps, and 400 cps. These outputs are sent to the command calibrator.

31. DETAILED DISCUSSION (fig 10-17)

a. Frequency divider.

(1) This circuit is almost identical in operation to the frequency dividers discussed in paragraphs 27 and 28. The most important change is the addition of clamper V2A, which permits the output to be a linear stairstep waveform instead of the exponential stairstep by previous dividers. Figure 6 is a schematic diagram of the frequency divider and pulser.

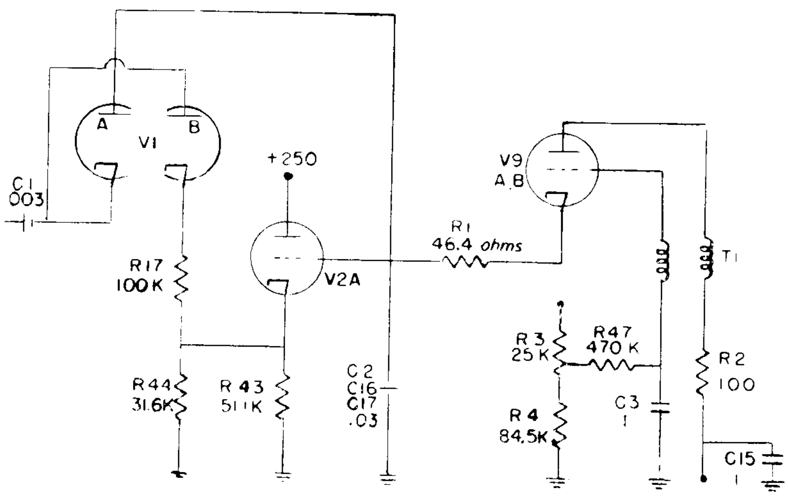


Figure 6. Frequency divider and pulser, schematic diagram.

(2) The input signal is a 420-cycle per second square wave, 200 volts peak-to-peak. Each time this signal goes negative, it causes V1A to conduct and a charge is accumulated on C2, C16, and C17. Capacitor C1 and the combination of C2, C16, and C17 act as a capacitor voltage divider. The combination of capacitors is 10 times the value of C1; therefore, the combination accepts one-eleventh of the charge or 18 volts. Capacitor C1 accepts the remainder of the charge, or 182 volts. When the input signal goes positive, the cathode of V1A goes positive with respect to the plate and conduction through the tube stops. Since the input waveform is now going positive, the right side of C1 is going positive, and

this raises the plate potential of V1B so that V1B will conduct and reduce the potential on the right side of C1 to whatever value of voltage is present on the cathode of V2A.

(3) A brief explanation of the action of V2A should show how this tube permits the divider to develop a linear stairstep waveform. As the combination of C2, C16, and C17 accepts its first 18-volt charge, it makes the grid of V2A more negative by this 18 volts. This change, when plotted on a graph, shows that the cathode changes by almost the same amount, assuming operation on the most linear portion of the tube curve. An 18-volt change on the cathode of V2A will also be seen at the cathode of V1B, and with the positive portion of the input wave on its plate, V1B will conduct until the right side of C1 is at the same potential as the cathode of V1B. The stage now waits for the next alternation with the cathode of V1A slightly positive with respect to its plate (2 to 12 volts, depending on the point of operation of V2A). This slight difference is the result of the bias on V2A, since the plate of V1B is connected to the grid of V2A and the cathode of V1A is connected to the cathode of V2A through V1B. The small difference between the plate and cathode potentials of V1A means that this tube will conduct almost as soon as the input wave goes in a negative direction, with the result that the combination of C2, C16, and C17 accepts almost all of the change brought about by the input waveform. The result is a stairstep waveform with the steps of equal amplitude, for all practical purposes.

(4) Stage V2A also operates as a cathode follower and the 60-cycle stairstep is taken from the cathode and sent to the command calibrator. The stairstep charge on C2, C16, and C17 overcomes the bias on V9 when the seventh step begins to go negative.

b. Pulser.

(1) The pulser stage is a blocking oscillator. When the stairstep charge on C2, C16, and C17 overcomes the bias on V9, the tube conducts and, through the action of T1, is driven quickly to saturation and back to cutoff. This blocking-oscillator action produces a positive pulse on the cathode which is coupled through C4 to the multivibrator. The pulse occurs at a frequency of 60 cycles per second.

(2) Potentiometer R3 is adjusted so that, about one-third of the way down the seventh negative excursion of the stairstep, the tube is driven into conduction. If the arm of R3 is moved toward terminal 1, there is less bias on V9 and the division will be by less than 7. Moving the arm toward terminal 3 increases the bias and division will be by more than 7.

c. Multivibrator. The stage consisting of V3 and its circuit components is a one-shot multivibrator. During the quiescent period, V3B is conducting because of the grid return to +250 volts. The current through V3B establishes a high enough potential on the common cathode to keep V3A from conducting. There is approximately 7 volts bias on V3A at this time, more than enough to hold the tube cut off. The positive pulse from V9, which occurs at a frequency of 60 cycles per second, drives V3A into conduction. When V3A conducts, its plate voltage drops and the common cathode voltage also decreases. The drop in plate voltage is coupled to the grid of V3B, and it ceases conduction with a resulting rise in plate voltage. C5 now has a charge which must leak off until the grid of V3B rises to a level where the tube will again conduct and return the stage to stable operating condition The time that it takes C5 to return the grid to cutoff is determined primarily by C5 and R10. The effect of this path and the parallel paths of R8, R9, and V3A permit the grid of V3B to rise to cutoff in approximately one-half the period of a 60-cycle wave. Plate voltage on V3B drops, and the stage returns to quiescent condition and remains there until the next pulse from V9 drives V3A into conduction. The output from V3B is a 60-cycle square wave approximately 170 volts in amplitude.

d. Paraphase amplifier.

(1) Coupling network. The square wave from the plate of V3B is coupled through C6 and developed across R13 and R16 in series. This combination forms a coupling network with an R-C time constant four times as large as the width of each alternation of the 60-cycle square wave. If computed against the universal time constant curve, it will be seen that this network couples a wave with a trailing edge 25 percent shorter than its leading edge. For idealized waveforms, this network (fig 7) succeeds in coupling the multivibrator waveform across with a trapezoidal slope on the negative leading edge. The waveform which is sent to the grid of V2B begins to assume a shape remotely similar to a 60-cycle sine wave.

(2) Amplifier circuit. Tube V2B produces two signals of equal amplitude, 180° out of phase. The cathode signal is inphase with the grid signal and the plate signal is 180° out-of-phase with the grid signal. The combination of R15 and R16 permits the grid signal to go negative without cutting off the tube. As the grid potential decreases, the cathode potential also decreases, but the bias changes only slightly so tube conduction does not vary as much as it would if a fixed grid potential were used. The outputs from this stage are square waves with rounded edges, but not round enough to be called sine waves.

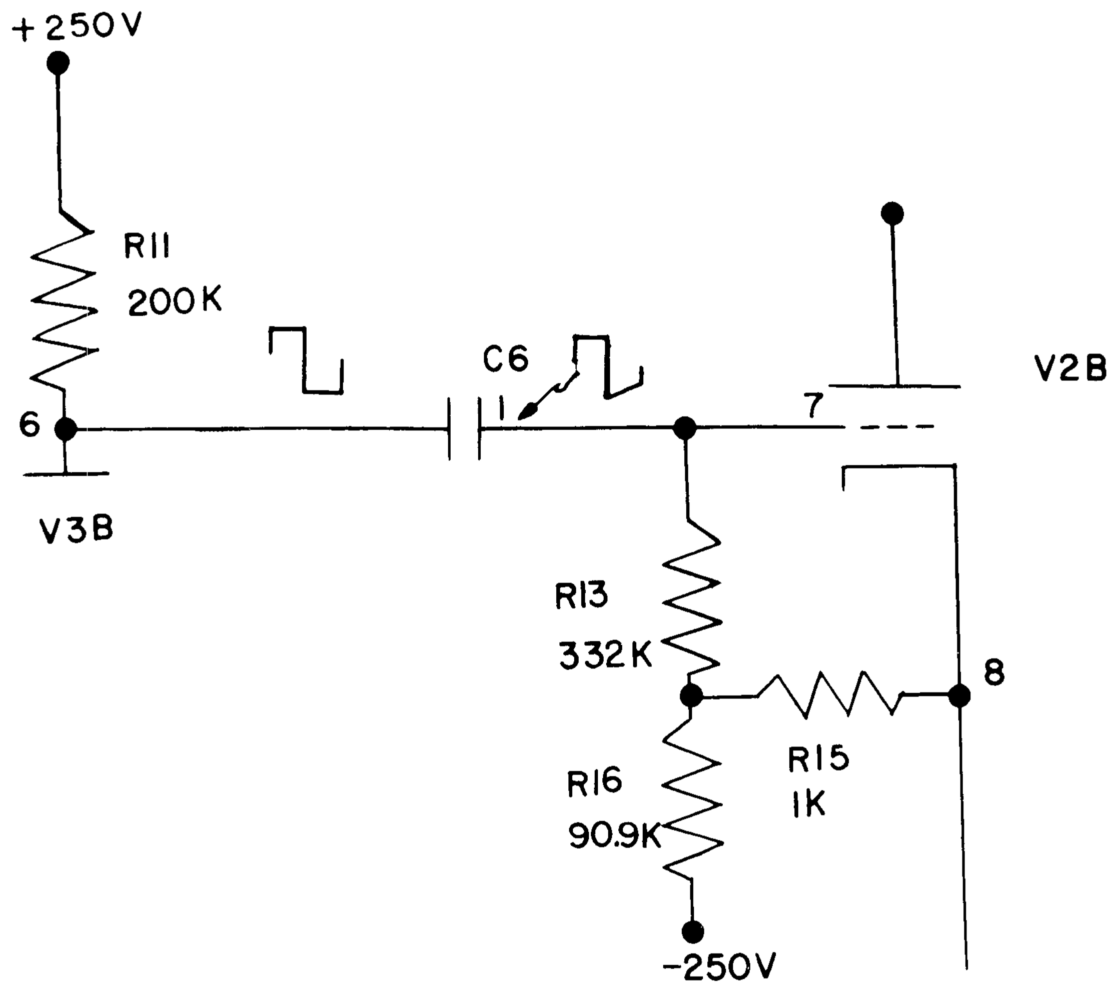


Figure 7. Coupling network.

e. Push-pull amplifier. Tubes V4 and V5 make up a power amplifier for synchronous motor B1. Another function of this stage is to make a 60-cycle sine wave out of the input before applying the signal to the motor. The tank circuit composed of BL1 and C11 provide the necessary action to smooth the square waves into slightly distorted sine waves. These sine waves drive the synchronous motor at 10 revolutions per second.

f. Tone wheel. The tone wheel is mounted on the shaft of the synchronous motor and rotates at the same speed as the motor, 10 revolutions per second. There are four concentric rings of square holes in the wheel. The smallest ring has 3 holes, and the others have 10, 22, and 40, respectively. Four lamps are mounted behind the tone wheel, each placed so as to shine through one ring of holes onto its corresponding photocell in the photocell assembly.

As the wheel rotates 10 revolutions per second, light shines intermittently through the holes of the smallest ring 30 times per second. This light falls upon a photocell and causes responses which will be described later. Light shines through the 10-hole ring 100 times per second, through the 22-hole ring 220 times per second, and through the 40-hole ring 400 times per second.

g. Photocell assembly and cathode followers.

(1) This assembly consists of 4 photocells and 4 cathode followers. Before light falls upon the photocell, its resistance is high and there is little or no conduction. As soon as light falls upon the photocell, its resistance decreases and conduction begins. The shape of the holes in the tone wheel and the intensity of the light cause the resistance of the photocell to be overcome so rapidly that the leading and trailing edges of the waveform produced by conduction of the photocell are only slightly sloping and square on top. Figure 8 shows the relation of light intensity and current flow through a typical photocell. As light intensity increases, current also increases until saturation is reached. At this saturation point, a large change of light intensity causes only a slight change in current flow.

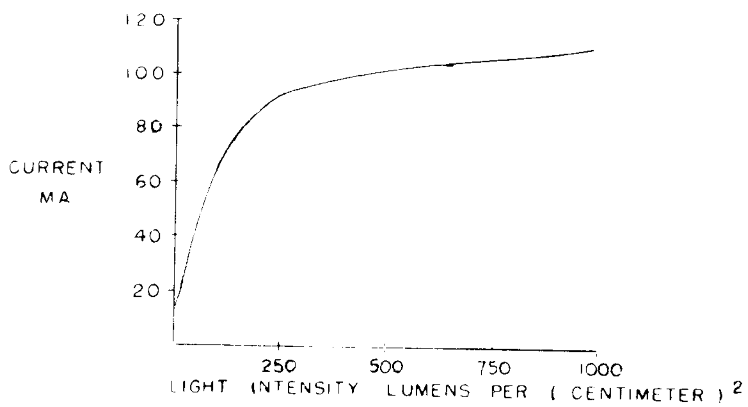


Figure 8. Photoconductivity graph, selenium phototransistor.

(2) To better understand the action of the photocells with relation to the cathode followers, assume that no light shines upon the photocell connected to the grid of V7A. Stage V7A is cut off by the bias established by R24 and R25, approximately -51.7 volts. As soon as light falls upon the photocell, it decreases the resistance and grounds the grid of V1A.

This tube conducts until light no longer shines on the photocell and the -51.7-volt potential is again applied to the grid. This action occurs for V7A 30 times per second. Since the output is taken from the cathode, the output is positive and has a frequency of 30 cycles per second. The other cathode followers and photocell combinations have the same action as the combination just discussed and differ only in the frequency output. Stage V7A has a 30-cps output, V7B has a 100-cps output, V8A has a 220-cps output, and V8B has a 400-cps output. These four outputs are all sent to the command calibrator.

Section IV. COMMAND CALIBRATOR

32. INTRODUCTION

The command calibrator (fig 10-18) is used to check and calibrate the units which comprise the sync command system of the missile-tracking radar. Great accuracy is essential in the missile-tracking radar; the many complicated circuits involved must be tested frequently to insure optimum performance. Many of the important test facilities are built into the missile-tracking radar. Built-in test equipment has several advantages; one is that the quick and accurate testing of important circuits is possible with the operation of only a few switches and controls. Another is that the need to carry large, bulky, and heavy test equipment from one trailer to another is decreased, and finally, this test equipment is much more stable than similar mobile equipment would be. The missile-tracking radar not only tracks the missile in flight, but it also transmits steering orders and the burst order to the missile. Steering and burst orders are the link between the missile and the ground guidance system. This link must not weaken at any time and should be checked often. In the sync command system, the command calibrator is the major piece of test equipment. The calibrator provides the maintenance men with an oscilloscope and a vacuum tube voltmeter, which may be used to check the frequency and amplitude of all of the important waveforms of the sync command system under various test conditions. It is very important that the maintenance men understand the use and operation of the command calibrator to adjust and check the sync command system.

33. FUNCTIONAL OUTLINE

a. General. The frequency divider provides a 420-cycle square wave voltage to the frequency generator. The frequency generator uses this input to provide outputs which control the sweep frequency of the oscilloscope in the command calibrator. These signals are very accurately controlled in frequency since the correct adjustment of the sync command is dependent upon their accuracy.

Signals from the frequency divider and frequency generator may be applied to the command calibrator so that the test equipment may be checked and adjusted before the sync command system is checked.

b. Checks on test equipment. The command calibrator may be used to check the following things in the test equipment:

(1) The zero set of the vacuum tube voltmeter in the command calibrator. This must be accurate to measure the amplitude of the selected signals.

(2) The first frequency division in the frequency divider. The output frequency must be 2,940 cycles per second.

(3) The second frequency division in the frequency divider. The output frequency must be 420 cycles per second.

(4) The third frequency division in the frequency divider. The output frequency must be 60 cycles per second.

(5) The motor speed of the synchronous motor in the frequency generator. The motor speed must be 10 rps.

c. Checks on the sync command system. The command calibrator may be used to check the following things in the sync command system:

(1) The amplitude and frequency of the output of the burst oscillator.

(2) The linearity of the combining amplifier.

(3) The frequency and amplitude of the outputs of the yaw and pitch oscillators with 0g order input, -5g order input, and +5g order input.

(4) The frequency of the output of the repetition rate oscillator for zero, maximum negative, and maximum positive signal input.

34. BLOCK DIAGRAM DISCUSSION (fig 10-18)

a. General. With the command calibrator, the output waveforms of the yaw, pitch, burst, and repetition rate oscillators may be observed on an oscilloscope which is mounted on the command calibrator chassis. The horizontal sweep for the oscilloscope can be synchronized with one of four fixed frequencies from the frequency generator. These standard or reference frequencies are applied to the sweep circuit in the calibrator. The signals to be tested are applied to the

vertical deflection plates of the oscilloscope. The resulting waveforms appearing on the oscilloscope have definite requirements with respect to the number of complete cycles and their shapes. An adjustment in the unit being tested may be used to satisfy these requirements. A meter which checks the amplitude of test signals is also provided in the calibrator. To insure that the reference frequencies used to produce the horizontal sweep on the oscilloscope are accurate, means are provided in the calibrator for checking the operation of the frequency generator and the frequency divider. The main circuits of the calibrator are the oscilloscope with its horizontal sweep circuit and its vertical sweep amplifier, the meter and its associated circuits, the system of switching and relays which connect the necessary inputs to the oscilloscope, and interconnections of the units being tested.

b. Horizontal sweep circuit. Tubes V4, V5, V6, and V7B, sweep capacitors C5 through C13, and associated circuit components form the horizontal sweep generating circuit for the horizontal deflection plates of the oscilloscope. The circuit produces a sawtooth voltage output whose frequency is determined by the frequency of the input signal. Seven sweep frequencies are generated by this circuit in the course of the testing procedure with the calibrator unit. The reference frequencies are applied to the sweep circuit from the selecting circuit. The input is applied to slicer V4. The input to V4 may be either positive square pulses cr negative-going stairstep waveform. The negative-going staircase is differentiated in the grid circuit of V4A. Tube V4A, which is normally held cut off, is caused to conduct by the positive pulse resulting from the differentiation. The negative pulse from V4A is coupled to V4B and cuts V4B off. A positive square wave appears at the output of V4B. The square wave has a very steep leading edge. If a square wave is applied to V4A, it is caused to bypass the differentiator by the selecting circuit. The positive square wave causes V4A to conduct, the negative output of V4A cuts V4B off, and a positive square wave appears in the output of V4B. With either a positive square wave input or a negative-going staircase input, V4 produces a positive square wave. The square wave is differentiated and applied to pulse amplifier V5A, which is normally cut off. The positive pulse, which results from the leading edge of the square wave causes V5A to conduct. A negative pulse appears at the output of V5A. The output of V5A is applied to pulser V6. Tube V6, tube sections V7B and V5B, and the sweep capacitors make up the actual sweep generating circuit in the calibrator. Pulser V6 is a blocking oscillator which conducts for short periods of time when triggered by the output of V5A. Sweep capacitors, selected by the operation of S1 in the selecting circuit, (figs 10-19 and 10-19.1) are discharged when tube V6 conducts. During the interval between times when V6 conducts, the capacitors charge negatively. A negative sawtooth appears in the output of V6. Positive clamper V7B and negative clamper V5B clamp the sawtooth between ground and -20 volts. The sawtooth is amplified and inverted

by sweep amplifier V7A. The output of V7A is applied to horizontal amplifier V3, which provides push-pull sawtooth voltages. These voltages are applied to the horizontal deflection plates of the cathode-ray oscilloscope, V2. The electron beam is thus caused to move from left to right across the face of the scope.

c. Vertical amplifier. The test signals selected by S1 in the selecting circuit are amplified by V1. Tube V1 provides push-pull signals to the vertical deflection plates of the oscilloscope. The signals are applied directly to V1 or to V1 through cathode follower V8, depending on the position of S1.

d. Cathode-ray oscilloscope. Tube V2 is a 3-inch, electrostatic deflection, cathode-ray tube. It is mounted on the chassis of the command calibrator. The test signal~~s~~ are displayed on V2, where the frequency of the test signal may be checked.

e. Metering circuit. Tubes V8, V9, and V10 and meter M1 form a vacuum-tube voltmeter which is used to indicate peak-to-peak amplitudes of the input signals. The signal to be measured is selected by the position of FUNCTION switch S1 in the selecting circuit. The input signal is applied to V8, which is connected as a cathode follower. Tube V8 isolates the metering circuit from the signal-producing circuit. The signal from V8 is applied through clamper V9 to cathode follower V10. Tube V10 is a dual-triode, connected as a cathode follower. Meter M1 is connected between the cathodes of V10A and V10B. The cathode of V10B is at a fixed potential and the cathode of V10A varies as the input signal. The voltage difference between the two cathodes produces a proportional current through meter M1, which reads zero at its center position, and indicates the peak-to-peak amplitude of the input signal.

f. Selecting circuit (figs 10-19 and 10-19.1). The selecting circuit of the calibrator provides the switching action necessary for performing checks and adjustments on the sync command system of the missile-tracking radar. It distributes signals to the vertical amplifier, the horizontal sweep circuit, or the metering circuit, depending upon the position of FUNCTION switch S1. The reference frequencies are applied through the selecting circuit to the horizontal sweep circuit. Slicer V4 prepares the signal for use as a trigger. The output of V4 is applied to a pulse amplifier, V5A. The output of V5A triggers V6, which discharges the sweep capacitors selected by S1. During the interval after the pulse, the capacitors charge negatively, producing a negative-going sawtooth voltage which is clamped between 0 and -20 volts. The sawtooth is amplified and inverted by V7A and applied to horizontal amplifier V3, which provides a push-pull output to the horizontal deflection plates of the cathode-ray tube.

The test signal is applied either directly or through cathode follower V8 to vertical amplifier V1, depending on the position of S1. Amplifier V1 produces a push-pull output which is applied to the vertical deflection plates. The signals displayed are used to check and adjust the frequency of various components. To check the amplitude of various signals, a metering circuit is provided. With a 100-volt peak-to-peak signal input, the meter will read zero. The signal is applied to cathode follower V8. The output of V8 is applied to a clamper circuit. The clamper circuit charges a capacitor to the peak-to-peak amplitude of the signal. The d-c voltage on the capacitor controls the current flow through cathode follower V10A. Meter M1 is connected between the cathodes of V10A and V10B. The current flow through V10B is fixed. Any change in voltage from 100 volts at the grid of V10A will cause a current flow through M1, which will provide an indication of the peak-to-peak amplitude of the signal. Switch S1 has 16 positions, each of which is for an important check (table II). The following is a list of the checks and a general statement on each of the checks.

(1) The SYS NORM position is for calibrating meter M1 with a standard d-c voltage. In this position there is no display on the oscilloscope.

(2) The DIV 1, DIV 2, and DIV 3 positions are for checking the oscilloscope, the frequency generator, and the frequency divider. In each case, seven treads of the staircase waveform should appear on the oscilloscope.

(3) The MOTOR SPEED position is for checking the slippage of the synchronous motor of the frequency generator.

(4) The BURST position is for checking the frequency and amplitude of the burst oscillator.

(5) The AMPLIFIER LINEARITY position is for checking the output of the combining amplifier on meter M1. There is no presentation on the oscilloscope.

(6) The remaining positions are for checking the yaw, pitch, and repetition rate oscillators with zero, +5g, and -5g commands.

35. DETAILED DISCUSSION HORIZONTAL SWEEP CIRCUIT (fig 10-19.1)

a. General. Tubes V4, V5, V6, V7B, sweep capacitors C5 through C13 and associated circuit components form the horizontal sweep circuit for the oscilloscope. The circuit produces a push-pull sawtooth voltage at a frequency determined by the input frequency. The input, as selected by FUNCTION switch S1, may be a square wave of 30 cps, 100 cps, 220 cps, or 400 cps, or a negative-going staircase voltage of 2,940 cps, 420 cps, or 60 cps.

b. Slicer V4. Normally, V4A is cut off by -15 volts applied to its grid from voltage divider R46-R47-R45 from -250 volts to +250 volts. Stage V4B is normally conducting, with its grid at approximately ground. Two types of waveforms are applied to V4, positive square waves or negative-going stairstep waveforms. The square waves are applied to V4A and cause V4A to conduct. The negative signal at the plate of V4A is applied to V4B and V4B is cut off. The negative square wave at the grid of V4B produces a positive square wave at the plate. A negative-going stairstep voltage is applied to V4A in other tests. The stairstep is differentiated by C1 and R28 before application to V4A. The positive pulse resulting from the trailing edge of the negative-going staircase acts in the same manner as the square wave when applied to the grid of V4A. With either the negative-going stairstep or positive square wave applied to V4A, a positive square wave appears at the plate of V4B.

c. Pulse amplifier V5A. Normally, V5A is held cut off by -30 volts on its grid. When a positive pulse is produced at the plate of V4B, R-C network C20-R53 acts as a differentiator. Therefore, a positive pulse followed by a negative pulse appears at the grid of V5A. The positive spike causes V5A to conduct and a current to flow through winding 2-1 of transformer T1. This action triggers the blocking oscillator. The negative pulse which appears on the grid of V5A does not affect this stage, since it is already below cutoff.

d. Pulser V6. Dual-triode V6 is parallel-connected as a blocking oscillator to discharge a sweep capacitor (or capacitors). Plate current is cut off by the -50 volts applied to the grids of V6 from the voltage divider consisting of R57, R58, and R59. The sweep capacitors are selected for a particular sweep rate by switch S1. For a very short time, V6 conducts and is then cut off. Assume that V6 has just conducted and the sweep capacitor has no charge on it. When V6 becomes nonconductive, the sweep capacitor begins charging negatively through resistor R66. The R-C time constant of the sweep capacitor and R66 determines the charging rate of the capacitor. Therefore, for a fast sweep on the scope, the sweep capacitor is small, and for a comparatively slow sweep, the sweep capacitor is made large. FUNCTION switch S1 obtains the proper value of capacitance by using parallel combinations of capacitors C5 through C13. Sometime during the negative charging process of the sweep capacitor, a positive pulse is applied to V5A, and current flows through winding 1-2 of T1. This current induces a positive voltage with respect to ground on the grids of V6. This tube then acts as a conventional blocking oscillator and neutralizes the charge that has built up on the sweep capacitors. The cathode potential of V6 cannot become positive with respect to ground, since V7B acts as a positive clamper. If the cathode potential of V6 tends to become positive with respect to ground, V7B conducts. This feature allows the sweep capacitor to begin charging at

ground potential for every sweep. Shortly after the complete discharge of the sweep capacitors, they start to charge negatively again and a new sweep cycle is started. The potential applied to the plate and grid of diode-connected triode V5B is -20 volts. This voltage is obtained from voltage divider R67-R68. If the voltage at the cathode of V6 becomes more negative than -20 volts, V5B conducts. This negative clamping action insures that the sweep capacitors will never charge to a voltage of more than -20 volts, thus preventing self-triggering of V6. The output sweep voltage is a negative-going sawtooth voltage which is applied to sweep amplifier V7A.

e. Sweep amplifier V7A. The negative sawtooth voltage from V6 is applied to the grid of V7A. As a result, a positive sawtooth is developed at the junction of R25 and R65, and is coupled through C3 to the grid of V3B (pin 2).

f. Horizontal amplifier V3. Voltage divider R20-R21 connected from +250 volts to ground applies approximately +108 volts to the grid of V3B. However, the plate potential of V7B is +450 volts and a small current through the cathode resistance is sufficient to develop a bias of approximately -30 volts. The positive-going sawtooth voltage from V7A is applied to the grid of V3B and produces a negative-going sawtooth at the plate of V3B. The sawtooth is applied directly to the left horizontal deflection plate of V2. The positive-going sawtooth at the cathode of V3B is coupled to V3A (pins 6, 7, and 8) through HOR GAIN potentiometer R40. The amplitude of the signal coupled to V3A is controlled by R40. As the resistance of R40 is increased, the signal coupled to V3A is decreased in amplitude. The setting of R40 determines the length of the horizontal sweep. The grid potential of V3A is adjusted by the HOR CTR potentiometer, R72. The setting of R72 controls the d-c potential present at the plate of V3A, and thus the horizontal centering of the sweep on V2. The waveform coupled to the cathode of V3A produces a positive- going sawtooth at the plate of V3A coincident with the negative-going sawtooth at the plate of V3B. The output of V3A is applied directly to the left horizontal deflection plates. As a result of the waveforms applied to the deflection plates, a left-to-right sweep is displayed on the cathode-ray tube, V2. Increasing the positive grid voltage of V3A with R72 causes the entire sweep to move to the left of the scope, while decreasing the grid voltage causes the reverse.

36. VERTICAL AMPLIFIER V1

The vertical amplifier prepares the signal selected by the position of switch S1 for display on the oscilloscope. The amplifier functions in the same general manner as the horizontal amplifier. The test signal is coupled through C2 and applied to the grid circuit of V1A. Normally, +120 volts is applied to the grid of V1A from voltage divider R7-R8-R9. However, conduction through the cathode

resistance of V1A is such that the bias on V1A is -30 volts. Capacitors C23 and C24 form a voltage divider which reduces the effect of the capacitance introduced by the contacts of relay K5 in the selecting circuit. EXP switch S3, part of the selecting circuit, is used to enlarge and raise the display on the scope, so some of the fine frequency adjustments of the sync command system may be made. Two signals 180° out of phase are produced by V1. These signals are applied directly to the vertical deflection plates of V2 and cause the signal to be presented on the scope. The amplitude of the signal displayed on the scope is controlled by VERT GAIN potentiometer R14. If the resistance of R14 is increased, the amplitude of the displayed signal decreases. VERT CTR potentiometer R71 determines the bias on V1B, and this adjustment is used to vertically center the sweep on the scope. When EXP switch S3 is operated, an enlarged section of the signal is displayed. Pressing this switch energizes relay K11. Relay K11 causes the bias on V1A to be reduced to about -10 volts and causes shunting capacitor C23 to be removed so the full amplitude of the signal is applied to the grid. The effect of the more positive bias and larger signal amplitude is to move the presentation upward so that an enlarged display of the negative portion of the test signal is presented.

37. CATHODE-RAY TUBE V2

The accelerating grid voltages of V2 are obtained from voltage divider R12-R13, which applies approximately +360 volts to the grid (pin 8) of V2. This is a fixed voltage and may be measured at test point TP1. Voltage divider R18-R19 supplies three potentials to V2. The cathode potential is normally -175 volts. INTENSITY potentiometer R18 varies the bias on V2 and thus its intensity. FOCUS potentiometer R19 provides for focusing of the display on the scope. There is no blanking circuit associated with V2, but since the flyback is fast, it does not interfere with the use of the scope.

38. METERING CIRCUIT

a. General. Tubes V8, V9, V10, meter M1, and associated components make up a vacuum-tube voltmeter, which is used to measure peak-to-peak amplitudes of input a-c voltages selected by FUNCTION switch S1.

b. Cathode follower V8. Voltage divider R39-R27-R48-R38-R37-R36 provides a fixed voltage of -90 volts to the two grids of tube V8 through contacts of relay K12. The two sections of V8 are connected in parallel, and normal conduction through the tube produces a bias of -2.5 volts. All of the input signals are applied through C14. Assume relay K12 to be energized. The test signals are applied to the grids of V8, which is connected as a cathode follower to isolate the metering circuit from the signal-producing circuits. If the input signal is of correct

amplitude, the signal at the grids of V8 will be 100 volts, peak-to-peak. A signal of correct amplitude at this point will cause meter M1 to read zero volts (midscale). The output of V8 is coupled by R15 and C15 to pin 6 of relay K14. Resistor R15 is used to present a correct load to the cathode follower when C15 is grounded through the contacts of K14. This is necessary because the meter circuit is not used in some of the tests, but the output signals from V8 are applied to the vertical amplifier for display on the oscilloscope. Relay K14 is controlled by FUNCTION switch S1 and applies the signals to the meter circuit if they are to be measured, or ground the signal before application to the meter circuit if they are not to be measured.

c. Clamper V9. Figure 9 is a schematic of the clamper circuit. The signal appears on the plate of clamper V9A (pins 1 and 7) and on the cathode of clamper V9B (pins 2 and 5). All of the signals which are applied to V9 are sine waves. In the quiescent condition, C15 is not charged. When the first negative half-cycle of the sine wave occurs, the cathode of V9B is driven negative with respect to the plate. Electrons leave the right plate of C15, charging C15. Capacitor C16 is charged to -90 volts in the quiescent condition. The cathode of V9B must go more negative than 90 volts before V9B can conduct. After a few cycles, C15 will charge enough to clamp the waveform negative, with respect to ground. Negative clamper V9A maintains the charge on C15. Each time the cathode of V9B goes negative in respect to the plate, V9B conducts, changing the charge of C16. After a few cycles, C16 will charge to the peak-to-peak amplitude of the applied signal. If the signal is of the correct amplitude, C16 will charge to 100 volts. The charge is maintained on C16 between the negative swings of the input signal, since the leak-off current through R32 is negligible from one cycle to the next. If the signal becomes greater than 100 volts, C16 will charge proportionally. If the signal becomes smaller than 100 volts, C16 will discharge to the peak-to-peak amplitude of the applied signal through R32. Capacitor C16 will not discharge below 90 volts.

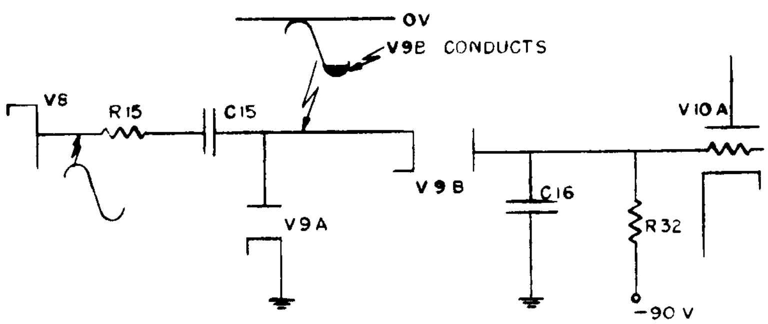


Figure 9. Clamper circuit, simplified schematic.

d. Meter circuit V10 and M1. Tube V10 is a dual-triode connected as a cathode follower. Meter M1 is connected between the cathodes of V10A and V10B. The current flow through V10A is controlled by the charge on C16, while the current flow through V10B is controlled by the d-c potential present on its grid. The grid potential is selected by the ZERO potentiometer, R36. The meter is calibrated with 100 volts present on the grid of V10A so that a midscale reading appears on M1 by adjusting R36. The 100 volts from the junction of R48 and R38 is applied to the clamper circuit through contacts of K13, which is energized when calibrating the meter. Capacitor C16 is charged to 100 volts. The meter is calibrated when FUNCTION switch S1 is in the SYS NORMAL position. In this condition, K13 and K14 are both energized. When the amplitude of a signal is to be measured, K13 and K14 are deenergized. If the signal is of correct amplitude, 100 volts is applied to the grid of V10A and the meter will read midscale. If the signal deviates from the correct amplitude, the voltage difference between the two cathodes produces a proportional current through the meter and R33. Meter M1 is a center reading meter and has 10 divisions on either side. If the signal is too small, the needle on M1 will move to the left. If the signal is too large, it will move to the right. Adjustment may be made in the unit being tested to cause M1 to read zero or midscale.

39. TEST EQUIPMENT CHECKS AND ADJUSTMENTS (figs 10-19 and 10-19.1)

a. General. Before adjusting the sync command system, the test equipment must be checked and alined. Five positions of FUNCTION switch S1 are used only in the checking and adjusting of the frequency divider. the frequency generator, and the command calibrator. To apply power to the command calibrator, TEST-OPERATE switch S12 on the control drawer of the missile console must be in the TEST position. This places a ground at pin 12 of P1 in the calibrator. Pin 12 is labeled SEC, which stands for security. Unless the system is in test, it is impossible to energize the command calibrator. To energize relay K1, S12 must be in TEST position and ON-OFF switch S2 must be in the ON position. Relay K1 is located on the apparatus slide which is located in the upper enclosure of the missile console between slides 1 and 2. When relay K1 is energized, all plate and bias voltages are applied to the calibrator, frequency divider, and frequency generator. The FUNCTION switch may then be used to control the command calibrator. FUNCTION switch S1, a 7-deck, 16-position switch, is shown in position 1, the SYS NORMAL position. It is necessary to place S1 in position 1 to start the tests.

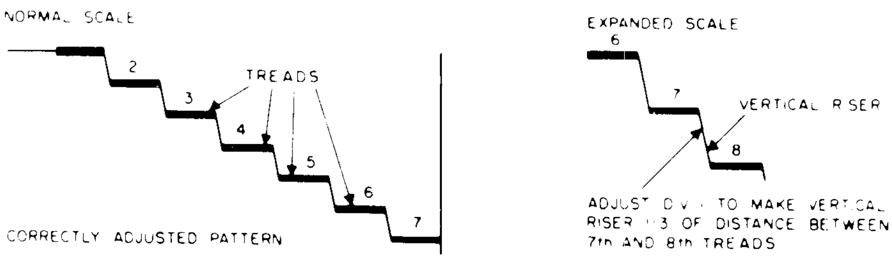
b. Calibrator operation with S1 in the SYS NORM position. When FUNCTION switch S1 is placed in the SYS NORM position, the circuits in the calibrator are prepared so that meter M1 may be adjusted to zero (midscale) with no input signal applied to the meter circuit. Ground is applied to relays K13 and K14 through

contact 7 of S1. Relay K14 removes the input to the meter circuit. Relay K13 removes ground from the cathode of V9A and applies -100 volts from the junction of R38 and R48. The -100 volts appears at the grid of V10A, in the same manner as if a signal of correct amplitude were being applied to the circuit. Meter M1 should read zero (midscale). If M1 does not read midscale, ZERO potentiometer R36 should be adjusted for the correct reading on M1. Also, -250 volts is applied through R1 by deck 1 to the control grid of cathode-ray tube V2. This voltage blanks the tube since it is not used in this position.

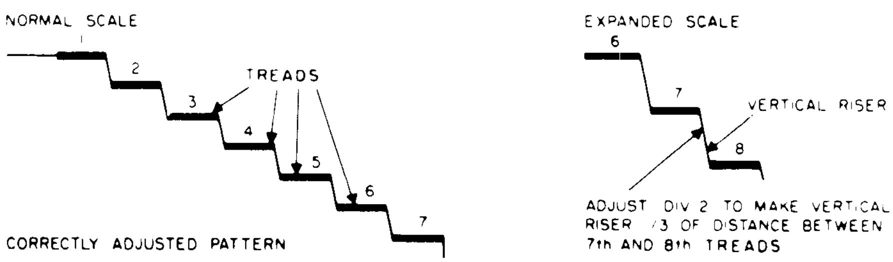
c. Calibrator operation with S1 in the DIV 1 position. The DIV 1 position of S1 is used when adjusting the first frequency division in the frequency divider unit for correct division. The first frequency divider divides the 20,580-cps output by 7 to obtain a signal with a frequency of 2,940 cps. In this position, the oscilloscope is used, but the voltmeter is not. Contact 2 of deck 1 of S1 is not connected to the oscilloscope circuit, so the -250 volts which blanks the scope is not applied and a display will appear on the scope. Sweep capacitor C5 is the only one used in the horizontal sweep circuit, since none of the others are affected by S1 in the DIV 1 position. Deck 5 of S1 energizes relay K6. Deck 6 energizes relay K1. Inputs are then applied from pin 3 of P2 to the vertical amplifier and horizontal sweep circuits. The input to the vertical amplifier is applied from pin 3 through contacts 4 and 6 of K1, 5 and 6 of K2, 5 and 6 of K3, 5 and 6 of K4, and 5 and 6 of K5 to input capacitor C2. The input to the horizontal sweep circuit is applied from contact 6 of K3 to differentiator C1-R28. The positive pulse which results from differentiation of the trailing edge of the staircase waveform is used to start the operation of the sweep circuit. Deck 7 of S1 energizes K13 and K14, which removes the meter circuit. The waveform which should be displayed on the scope is shown in figure 10 (divider 1 stairstep pattern). Seven treads should appear. If seven treads do not appear, DIV 1 potentiometer R18 in the frequency divider should be adjusted until they do. Pressing EXP switch energizes relay K11. Relay K11 places a more positive voltage on the grid of V1A, causing the waveform to move up. The gain of V1A is increased and the displayed signal becomes larger. The waveform that should appear on the scope is shown in figure 1b. If the correct pattern does not appear, S3 should be held and R18 adjusted until the last vertical riser is 1/3 of the distance between the seventh and eighth treads.

d. Calibrator operation with S1 in the DIV 2 position. When the FUNCTION switch is placed in the DIV 2 position, the calibrator is prepared for adjustment of the second frequency divider in the frequency divider unit. The output frequency of this divider should be 420 cps. In this position, the oscilloscope is used, but the voltmeter is not. The oscilloscope is unblanked and sweep capacitors C5 and

C6 are connected in parallel for the proper sweep frequency by deck 2, position 3, of S1. Relay K6 is energized by deck 5 of S1 and relay K2 is energized by deck 6 of S1. The 420-cps staircase is applied to the vertical amplifier from pin 7 of P2 through contacts 4 and 6 of K2, 5 and 6 of K3, 5 and 6 of K4, and 5 and 6 of K2 to C2 in the grid circuit of V1. The input to the sweep circuit is taken from contact 6 of K3, differentiated, and applied through contacts 6 and 4 of K6 to V4, where it is used to start the horizontal sweeps. The waveforms displayed in the normal and expanded conditions are shown in figure 10 (divider 2 stairstep pattern). Adjustment of DIV 2 potentiometer R28 is done in the same manner as adjustment of DIV 1 potentiometer R18. The voltmeter is not used in this adjustment. Deck 7 of S1 energizes K13 and K14, which remove the meter from operation.



Divider 1 Stairstep Pattern



Divider 2 Stairstep Pattern

Figure 10. Calibration patterns for DIV 1 and DIV 2 positions of FUNCTION switch S1.

e. Calibrator operation with S1 in the DIV 3 position. Position 4 of switch S1 is used in adjusting the third frequency divider, V1, in the frequency generator unit. The output of this divider should be a 60-cps staircase voltage. The oscilloscope is used to check this. Deck 2 of S1 connects sweep capacitors C5 and C11 in parallel for the correct sweep frequency. Deck 5 energizes relay K6 and Deck 6 of S1 energized relay K3. The input to the vertical amplifier comes from pin 16 of P2. It is applied through contacts 4 and 6 of K3, 5 and

6 of K4, and 5 and 6 of K5 to C2 in the grid circuit of V1. The input to the horizontal sweep circuit is taken from pin 6 of K3 and applied to differentiator C1-R28. The output of the differentiator is applied through contacts 4 and 6 of K6 to slicer V4. It is used to start the sweep in the same manner as the signal previously discussed. The patterns that should appear on the scope are shown in figure 11. With S3 pressed, DIV 3 potentiometer R47 in the frequency generator should be adjusted so that the last vertical riser is 1/3 of the distance between the seventh and eighth treads. Relays K13 and K14 are energized through deck 7 of S1. This removes the meter circuit from operation.

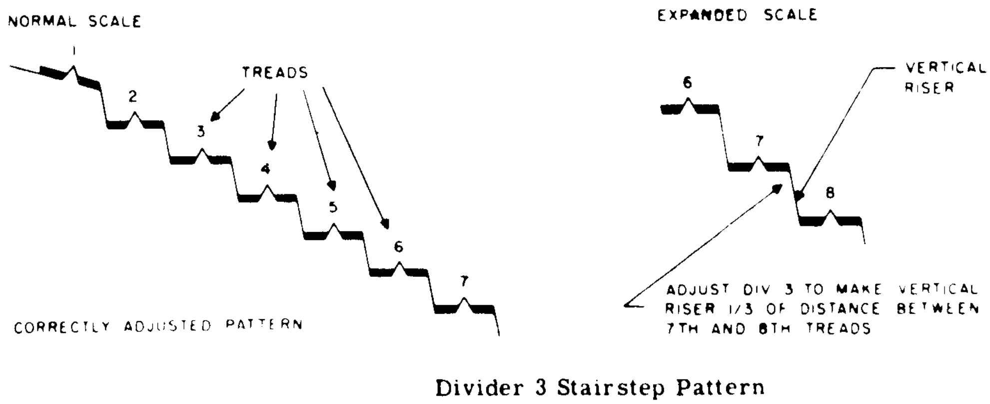
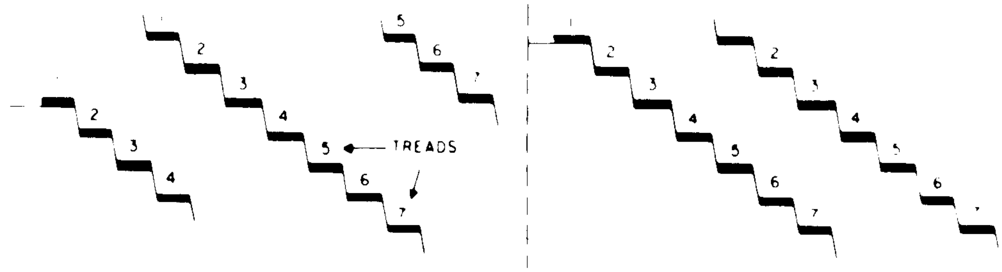


Figure 11. Calibrator patterns for DIV 3 position of FUNCTION switch S1

f. Calibrator operation with S1 in the MOTOR SPEED position. In the MOTOR SPEED position of S1, the calibrator is set up so the speed of the synchronous motor in the frequency generator may be checked. The correct speed of the motor is 10 rps. In this position, meter M1 is not used. Deck 2 of S1 connects sweep capacitors C5, C12, and C13, in parallel so that a sweep of the correct frequency is obtained. Deck 5 energizes relay K7. A 30-cps square wave, from the frequency generator, is applied from pin 2 of P2 through contacts 4 and 6 of K7 to the grid of slicer V4. This signal causes a sweep voltage to be generated at a rate of 30 cps. Deck 6 energizes K3 and the 60-cps staircase voltage is applied to vertical amplifier in the same manner as in the DIV 1 position of S1. The calibrator patterns, one of which should appear on the scope, are shown in figure 12. If this pattern does not appear correctly, there is no adjustment which may be made to correct the condition. If the motor proves defective, as shown by a moving waveform, the frequency generator unit must be replaced. The meter circuit is made inoperative by relays K13 and K14, which are energized by deck 7 of S1.



Motor Speed Double Stairstep Pattern

Figure 12. Calibrator patterns for MOTOR SPEED position of FUNCTION switch S1.

40. SYNC COMMAND SYSTEM TESTS AND ADJUSTMENTS

a. General. In paragraph 39, the tests and adjustments of the command calibrator were covered. These should be checked each time before checking and adjusting the components of the sync command system. In this paragraph, the action of the relays of the selector circuit in the remainder of the positions of S1 will be discussed.

b. Calibrator operation with S1 in the BURST position. The BURST position of FUNCTION switch S1 is used when adjusting the frequency of the burst-signal output of the burst oscillator, and the amplitude of the burst signal applied to V1 in the combining amplifier. Both the voltmeter and the oscilloscope are used in this position. Deck 2 of S1 connects sweep capacitors C5 and C7 in parallel. Deck 4 energizes relay K2 in the combining amplifier. Relay K2 provides a ground to burst relay K1 in the combining amplifier for energizing it. Relay K1 in the combining amplifier disconnects the yaw and pitch signals, and applies the burst signal. The output at J5 on the combining amplifier is applied to J2 on the calibrator. Deck 5 of S1 energizes relay K8. The 220-cps square wave input from the frequency generator is then applied through contacts 6 and 4 of K8 to the horizontal sweep circuit where it is used to generate the sweep voltages. Deck 6 energizes relay K4. The input at J2 should be 200 volts peak-to-peak when adjusted correctly. Meter M1 is calibrated so that a 100-volt peak-to-peak signal will cause it to read zero. The amplitude of the input may be read on M1. It is applied to voltage divider R29-R30, where it is divided by 2. The signal from the junction of R29 and R30 is applied to cathode follower V8. In this position of switch S1, K13, and K14 are both deenergized and the meter circuit is operative. If the signal is of the correct amplitude, the meter should read zero. If the meter does not read zero, adjust BURST potentiometer R9 in the combining amplifier for the correct meter reading. The signal from the cathode of V8 is applied to the vertical amplifier through contacts 4 and 6 of K4. The pattern which should appear on the scope is shown in figure 13.

Since the input to the vertical amplifier is at a frequency of 880 cps and the sweep is at a frequency of 220 cps, 4 sine waves should appear. If the frequency is correct, the pattern will be stationary. If the pattern is drifting, BURST FREQ potentiometer R3 on the burst oscillator should be adjusted for a stationary pattern. A small tolerance is allowed. One cycle may drift off the scope in 10 seconds without interfering with the operation of the sync command system.

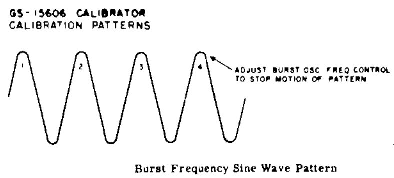
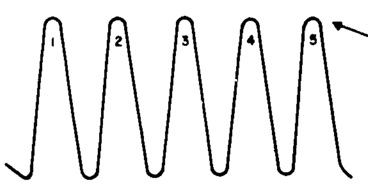


Figure 13. Calibrator pattern for BURST position of FUNCTION switch S1.

c. Calibrator operation with S1 in AMPLIFIER LINEARITY position. Position 7 of FUNCTION switch S1 is used to check the linearity of the combining amplifier. In this test, the burst signal is halved in the burst oscillator and applied through the combining amplifier to V8 in the calibrator. Meter M1 should again read zero. A zero reading will indicate linear operation of the combining amplifier. If the amplifier proves nonlinear, replacement of tubes or unit will be required. The oscilloscope is not used in this check, so deck 1 of S1 provides a negative voltage to the grid of the cathode-ray tube to blank it. Deck 4 holds relays K1 and K2 on the combining amplifier energized so that only the burst signal is applied. Deck 7 energizes relay K12 so that the full input at J2 is applied to the meter circuit. Deck 7 also provides ground to pin 2 of P1 which connects to relay K1 in the burst oscillator. Relay K1 halves the output of the burst oscillator. If the meter again reads zero, the amplifier is linear. This check will show that with an input signal of smaller amplitude, the gain of the combining amplifier remains the same.

d. Calibrator operation with S1 in the 0G-YAW position. Position 8 of S1 is for checking the frequency and amplitude of the output of the yaw oscillator with a 0g order input. The frequency of the output should be 150 cps. Deck 2 of S1 connects C5, C12, and C13 in parallel for use in the horizontal sweep circuit. Deck 5 energizes relay K7. The 30-cps square wave from the frequency generator is then applied to V4 to trigger the sweep circuit. A horizontal sweep of 30 cps is produced. Deck 1 energizes relay K2 on the pitch oscillator. This disables the pitch oscillator so the yaw oscillator may be checked and adjusted. Deck 3 grounds input D in the yaw, pitch, and repetition rate oscillators. Deck 4 energizes relay K1 on the yaw oscillator. Relay K1 disconnects the input

to the yaw oscillator and connects the grounded input from the calibrator. The yaw oscillator then provides an output which represents a 0g order. Deck 6 of S1 energizes relay K4 in the calibrator and relay K12 is energized by deck 7. The full output of the combining amplifier, which enters the unit at J2, is applied to V8 through contacts 4 and 6 of relay K12. This signal should be a 100-volt peak-to-peak signal and meter M1 should read zero. If M1 does not read zero, YAW potentiometer R7 in the combining amplifier should be adjusted until the meter reads zero. An output from the cathode of V8 is applied to the vertical amplifier through the contacts of relay K4. The waveform which should appear on the scope is shown in figure 14. The sweep frequency is 30 cps and the test signal frequency is 150 cps, so 5 stationary sine waves should appear in the pattern. If the correct pattern does not appear, the 0g potentiometer, R7, in the yaw oscillator should be adjusted for the correct pattern. This adjustment insures that the center frequency of the yaw oscillator is 150 cps.



Yaw Oscillator Zero G Sine Wave Pattern

Figure 14. Calibrator pattern for 0G YAW position of FUNCTION switch S1.

e. Calibrator operation with S1 in the -5G YAW position of S1. Position 9 of FUNCTION switch S1 is used to check the frequency of the output of the yaw oscillator when a -5g order input is applied. The output frequency should be 120 cps. The circuits are set up in the same manner as in position 8, except that deck 3 provides -100 volts to input D on the yaw oscillator instead of ground, as in position 8. With the sweep at a frequency of 30 cps and the test signal at a frequency of 120 cps, 4 stationary sine waves should be displayed. The correct waveform is shown in figure 15. If the correct pattern does not appear, -5g potentiometer R2 in the yaw oscillator should be adjusted. This adjustment will insure that the yaw oscillator output is correct for a -5g order. Meter M1 should read zero if the amplitude is correct.

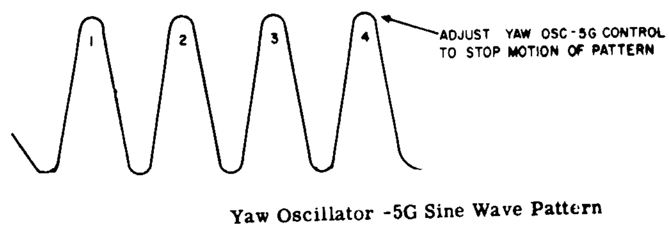


Figure 15. Calibrator pattern with S1 in the -5G YAW position.

f. Calibrator pattern with S1 in the +5G YAW position. Position 10 of S1 is used when checking the frequency of the output of the yaw oscillator with a +5g order input. Again the relay configuration is the same as in position 8. Deck 3 of S1 applies +100 volts to input D on the yaw oscillator. The output of the yaw oscillator should be 180 cps. With a sweep frequency of 30 cps and a test signal of 180 cps, 6 stationary sine waves should be displayed on the scope. The pattern which should appear is shown in figure 16. If the pattern moves across the scope, the frequency is not correct, and ERROR potentiometer R3 should be adjusted to stop the pattern from moving. If the pattern can be stopped with error potentiometer indicating within the scale markings, the frequency is within tolerance. Potentiometer R3 varies the voltage applied to input D on the yaw oscillator from 98 volts to 102 volts.

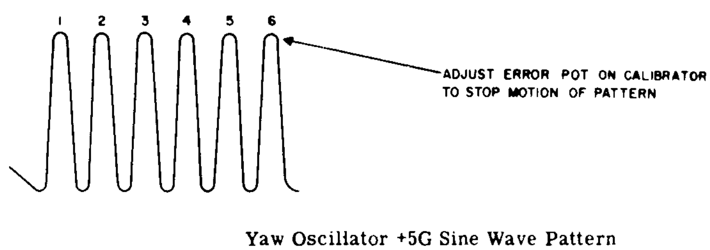
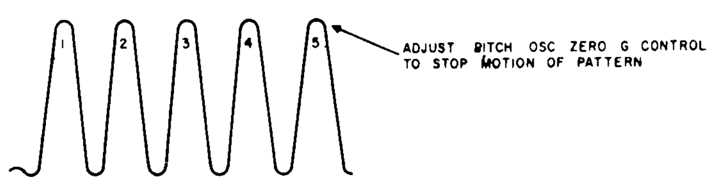


Figure 16. Calibrator pattern for +5G YAW position of S1.

g. Calibrator operation with S1 in the 0G PITCH position. Position of S1. FUNCTION switch S1 is for checking the output of the pitch oscillator with a 0g order input. Deck 1 of S1 energizes relay K2 on the yaw oscillator, disabling the yaw oscillator so the pitch oscillator can be checked and adjusted. Deck 2 connects sweep capacitors C5, C8, C9, and C10 in parallel for the proper sweep frequency.

Deck 5 of S1 energizes K9 and the 100-cps square wave is applied as a synchronizing voltage from pin 10 of P1 to the horizontal sweep circuit. Deck 4 of S1 energizes K1 on the pitch oscillator. This disconnects the input from the computer and applies input D from the calibrator. Input D is placed at ground potential by deck 3 of S1. This should cause the pitch oscillator to provide a 500-cps output, which is applied to the combining amplifier. The output of the combining amplifier is applied to J2 on the calibrator. Relay K12 is energized by deck 7 of S1 and the full input at J2 is applied to cathode follower V8. Meter M1 should read zero, since the input at J2 should be 100 volts peak-to-peak. If M1 does not read zero, PITCH potentiometer R8 in the combining amplifier should be adjusted until the meter reads zero. An output from the cathode of V8 is applied through contacts 4 and 6 of K4 to the vertical amplifier. Relay K4 is energized by deck 6 of S1. A pattern of 5 sine waves should appear on the calibrator, since a 500-cps test signal is applied to a 100-cps sweep. The correct pattern is shown in figure 17. If the pattern is incorrect, adjustment of the 0g potentiometer, R7, in the pitch oscillator will give the correct pattern. This adjustment will insure a 500-cps output from the pitch oscillator for a 0g order.

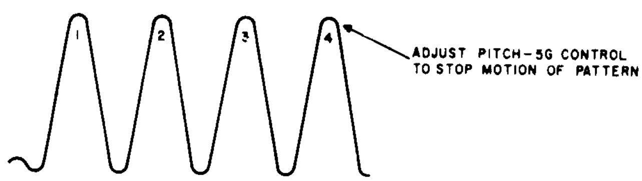
h. Calibrator operation with S1 in the -5G PITCH position. In position 12 of S1, the output of the pitch oscillator is checked when a -5g order is applied as an input. The relay action is the same as in position 11. In the -5G PITCH position, deck 3 of S1 applies −100 volts to input D on the pitch oscillator. The input at J2 is then applied to the metering circuit. Meter M1 should read zero. The output from V8 is applied to the vertical amplifier. The test input should be 400 cps and the sweep frequency is 100 cps, so 4 sine waves should appear on the scope as shown in figure 18. If the pattern is not correct, adjust -5g potentiometer R2 in the pitch oscillator. This adjustment insures that the output of the pitch oscillator for a -5g order input is 400 cps.



Pitch Oscillator Zero G Sine Wave Pattern

Figure 17. Calibrator pattern for 0G PITCH position of switch S1.

i. Calibrator operation with S1 in the +5G PITCH position. Position 13 of S1 is for checking the output of the pitch oscillator with a +5g order input. The relay action is the same as in positions 11 and 12. Deck 3 of S1 applies a positive voltage to input D of the pitch oscillator. This voltage may be varied from 98 to 102 volts by ERROR potentiometer R3. If the correct pattern can be displayed on the scope within the range of the scale of R3, the frequency is within tolerance. Meter M1 should read zero and a pattern of 6 sine waves, as shown in figure 19, should be displayed. This check insures that the output of the pitch oscillator is 600 cps with a +5g order input.

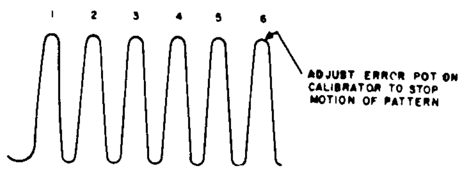


Pitch Oscillator -5G Sine Wave Pattern

Figure 18. Calibrator pattern with S1 in -5G PITCH position of S1.

j. Calibrator operation with S1 in 0 DEV-REP RATE position. The 0 DEV-REP RATE position is for checking the frequency of the output of the repetition rate oscillator with a zero deviation signal input. In this position, meter M1 is not used. Deck 5 of S1 energizes relay K10, which applies a 400-cps input to the horizontal sweep circuit from pin 11 of P2, through contacts 4 and 6 of K10. Sweep capacitors C5 and C6 are connected in parallel by deck 2 of S1. Deck 4 energizes relay K1 on the repetition rate oscillator, disconnecting the input from the combining amplifier and connecting input D from the calibrator. Deck 3 of S1 grounds input D. The output of the repetition-rate oscillator which should be a 2,000 cps square wave is applied to J1 in the calibrator. From J1, the test signal is applied through contacts 4 and 6 of relay K5, which is energized by deck 6, to vertical amplifier V1. With a 2,000-cps signal displayed on a 400-cps sweep, 5 square waves should appear in the pattern as shown in figure 20. If the pattern is not correct, 0 DEV potentiometer R7 in the repetition-rate oscillator should be adjusted. Meter M1 is not used in this position. Deck 7 of S1 energizes relay K13 and K14. This adjustment insures that the center frequency of the repetition-rate oscillator is correct.

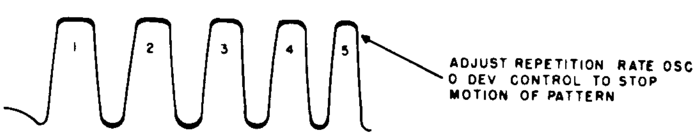
GS-15606 CALIBRATOR
CALIBRATION PATTERNS



Pitch Oscillator +5G Sine Wave Pattern

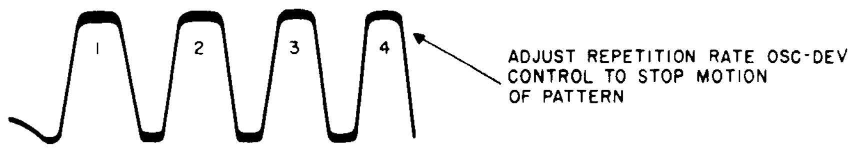
Figure 19. Calibrator pattern with S1 in +5G PITCH position.

k. Calibrator operation with S1 in the -DEV-REP RATE position. Position 15 of S1 is used when checking and adjusting the frequency of the output of the repetition-rate oscillator with a maximum negative order input. Only the calibrator scope is used in this position of S1. The relays are set up in a manner similar to that in position 14. Deck 3 of S1 supplies -100 volts to input D on the repetition-rate oscillator. The input at J1 should be 1,600 cps. This signal displayed on a 400-cps sweep should provide a pattern of 4 square waves as shown in figure 21. If the correct pattern is not obtained, adjust the -DEV potentiometer, R2, in the repetition-rate oscillator. This adjustment insures that the frequency of the output of the repetition-rate oscillator is correct when a maximum negative order is applied.



Repetition Oscillator Zero Deviation Square Wave Pattern

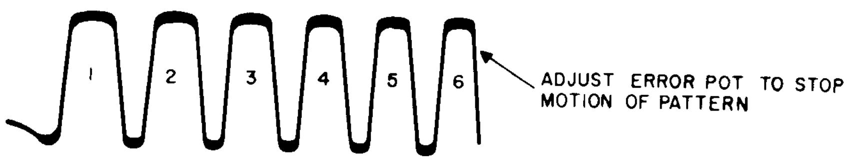
Figure 20. Calibration pattern with S1 in 0 DEV-REP RATE position.



Repetition Oscillator Minus Deviation Square Wave Pattern

Figure 21. Calibrator pattern with S1 in -DEV-REP RATE position.

1. Calibrator operation with S1 in +DEV-REP RATE position. Position 16 of S1 is for checking the frequency of the output of the repetition-rate oscillator with a maximum positive deviation input. The calibrator is set up in the same manner as in positions 14 and 15, except that deck 3 now provides a positive voltage to input D of the repetition-rate oscillator. The input at J1 from the repetition-rate oscillator should be a 2,400-cps square wave. This signal displayed on a 400-cps sweep should produce a pattern of 6 square waves (fig 22). If the correct pattern can be obtained within the range of ERROR potentiometer R3, the frequency is within tolerance. There is no adjustment provided if the correct indication cannot be obtained.



Repetition Oscillator Plus Deviation Square Wave Pattern

Figure 22. Calibration pattern with S1 in the +DEV-REP RATE position.

Table II. Command calibrator FUNCTION switch (S1), position operational data.

Position of S1	Function	Calibrator relays energized by S1 and function	Other relays energized by S1 and function	Other connections made by S1 and function	Desired meter reading	Desired oscilloscope presentation
SYS NORMAL (1)	To adjust for 0 (midscale) reading on M1.	K14 - removes input from meter circuit. K13 - applies standard bias to meter cathode follower V10.	None	Applies -250 volts control grid of CRT to blank the tube.	0 (midscale)	None
DIV 1 (2)	To check and adjust DIV 1 on frequency divider (2,940 cps).	K13, K14 -see position 1.	None	Applies 2,940-cps signal from J4-3 to vertical amplifier V1. Applies ground to bottom of R28. Applies vertical signal to sweep channel. (Top of R28 to top of R46.)	0	7-step stairstep (fig 10).
DIV 2 (3)	To check and adjust DIV 2 on frequency divider (420 cps).	K13, K14 -see position 1.	None	Applies 420 cps signal from J4-7 to vertical amplifier V1. Applies ground to bottom of R28. Applies vertical signal to sweep channel. (Top of R28 to top of R26.) Inserts capacitor C6 in to the sweep generator circuit.	0	7-step stairstep (fig 10).

Table II. Command calibrator FUNCTION switch (S1), position operational data (cont).

Position of S1	Function	Calibrator relays energized by S1 and function	Other relays energized by S1 and function	Other connections made by S1 and function	Desired meter reading	Desired oscilloscope presentation
DIV 3 (4)	To check and adjust DIV 3 on frequency generator (60 cps).	K13, K14 - see position 1.	None	Applies 60-cps signal from J4-15 to vertical amplifier V1. Applies ground to bottom of R28. Applies vertical signal to sweep channel. (Top of R28 to top of R46.) Inserts capacitor C11 in sweep generator circuit.	Not used	7-step stair-step (fig 11).
MOTOR SPEED (5)	To check synchronous motor on frequency generator for correct speed (10 rps).	K13, K14 - see position 1.		Applies 60-cps signal from J4-15 to vertical amplifier V1. Applies 30-cps signal from J4-2 to sweep channel. Inserts capacitors C12 and C13 in sweep generator circuit.	Not used	Two 7-step stair-steps (fig 12).
BURST (6)	To check and adjust frequency and amplitude of burst oscillator output.	None	K2 in combining amplifier, which energizes K1 on same unit. K1 disconnects yaw and pitch signals from input and applies burst signal only.	Applies 880-cps signal from cathode of V8 to vertical amplifier V1. Applies 220-cps signal from J4-6 to sweep channel. Inserts capacitor C7 into sweep generator circuit.	0	Four sine waves (fig 13).

Table II. Command calibrator FUNCTION switch (S1), position operational data (cont).

Position of S1	Function	Calibrator relays energized by S1 and function	Other relays energized by S1 and function	Other connections made by S1 and function	Desired meter reading	Desired oscilloscope presentation
AMPLIFIER LINEARITY (7)	To check linearity of combining amplifier.	K12 - applies input from J-2 directly to V8.	K1, K2 on combining amplifier - see position 6. K1 on burst oscillator to reduce output to one-half.	Applied -250 volts to control grid of CRT to blank the tube. Applies ground to input of vertical amplifier.	0	None
0G, YAW (8)	To check and adjust output frequency and amplitude	K12 - see position 7.	K1 on yaw oscillator connected d-c input from calibrator and removes input from computer. K2 on pitch oscillator disables the pitch oscillator. K1 on burst oscillator is not functional.	Applies ground to in put of yaw oscillator (J3-3). Inserts capacitors C12 and C13 in seeep generator circuit. Applies signal from cathode of V8 to vertical amplifier V1. Applies 30-cps signal from J4-2 to sweep channel.	0	Five sine waves (fig 14).
-5G YAW (9)	To check and adjust output frequency and amplitude of yaw oscillator for -5g order input (d-c).	K12 - see position 7.	See position 8.	Applies -100 volts to yaw oscillator (J-3), a -5g (d-c) order. Sweep capacitors - see position 8. Input to vertical amplifier - see position 8.	0	Four sine waves (fig 15).

Table II. Command calibrator FUNCTION switch (S1), position operational data (cont).

Position of S1	Function	Calibrator relays energized by S1 and function	Other relays energized by S1 and function	Other connections made by S1 and function	Desired meter reading	Desired oscilloscope presentation
+5G YAW (10)	To check output frequency and amplitude of yaw oscillator for +5g (d-c) order input.	K12 - see position 7.	See position 8.	Applies +100 volts to yaw oscillator (J3-3), a +5g (d-c) order. Sweep capacitors - see position 8. Input to vertical amplifier - see position 8.	0	Six sine waves (fig 16).
0G PITCH (11)	To check and adjust output frequency and amplitude of the pitch oscillator for a 0g (d-c) order input.	K12 - see position 7.	K1 on pitch oscillator connects d-c input from calibrator and removes input from the computer. K2 on yaw oscillator - disables yaw oscillator. K1 on burst oscillator - see position 8.	Applies ground to input of the pitch oscillator (J3-3), a 0g (d-c) order. Inserts capacitors C8, C9, and C10 in sweep generator circuit. Input to vertical amplifier - see 8.	0	Five sine waves (fig 17).

Table II. Command calibrator FUNCTION switch (S1), powition operational data.

Position of S1	Function	Calibrator relays energized by S1 and function	Other relays energized by S1 and function	Other connections made by S1 and function	Desired meter reading	Desired oscilloscope presentation
-5G PITCH (12)	To check and adjust output frequency and amplitude of the pitch oscillator for -5g (d-c) input order.	K12 - see position 7.	See position 11.	Applies -100 volts to the pitch oscillator (J3-3), a -5g d-c order. For sweep capacitors and vertical amplifier input - see position 11.	0	Four sine waves (fig 18).
+5G PITCH (13)	To check output frequency and amplitude of the pitch oscillator for +5g (d-c) input order.	See position 12.	See position 11.	Applies +100 volts to the pitch oscillator (J3-3), a +5g d-c order. For sweep capacitors and input to vertical amplifier - see position 11.	0	Six sine waves (fig 19).
0 DEV-REP-RATE (14)	To check and adjust frequency output of the repetition rate oscillator for 0 deviation signal input.	K13, K14 - see position 1.	K1 in the repetition rate oscillator connects d-c input from calibrator and removes input from combining amplifier.	Applies ground to the input of the repetition rate oscillator (J3-3), a 0 deviation signal. Capacitor C6 inserted in sweep generator circuit. Input from J1 applied to vertical amplifier.	Not used	Five square waves (fig 20).

Table II. Command calibrator FUNCTION switch (S1), position operational data (cont).

Position of S1	Function	Calibrator relays energized by S1 and function	Other relays energized by S1 and function	Other connections made by S1 and function	Desired meter reading	Desired oscilloscope presentation
-DEV-REP-RATE (15)	To check and adjust frequency output of the repetition-rate oscillator for maximum negative deviation.	See position 14.	See position 14.	Applies -100 volts to rep-rate oscillator (J3-3), a maximum negative deviation order input. For sweep capacitors and input to vertical amplifier, see position 14.	Not used	Four square waves (fig 21).
+DEV-REP-RATE (16)	To check frequency output of the rep-rate oscillator for maximum positive deviation.	See position 14.	See position 14.	Applies +100 volts to rep-rate oscillator (J3-3), a maximum plus deviation order input. For sweep capacitors and input to the vertical amplifier, see position 14.	Not used	Six square waves (fig 22).

Section V. MODIFIED CALIBRATOR CIRCUIT

41. INTRODUCTION

The modified command calibrator circuitry performs the same functions as the circuitry of section IV in very much the same manner as previously explained. The only appreciable changes, circuitwise, are the elimination of relays K1 through K10 of the calibrator and the rewiring of S1 FUNCTION switch. Switch S1 applies the inputs formerly controlled by relays K1 through 10, directly through the switch to the proper circuit points. Decks E and F of S1, in switch positions 1 through 16, apply the inputs direct to the calibrator instead of switching them in through contacts of relays. In the following paragraphs, the operation of the modified circuit where it differs from the unmodified circuit will be explained.

42. TEST EQUIPMENT CHECKS AND ADJUSTMENTS (fig 10-19.1)

a. Calibrator operation with S1 in the DIV 1 position. The operation of the calibrator with S1 in the DIV 1 position is the same as that of the unmodified calibrator. The input to the vertical amplifier from pin 3 of J4 is applied directly through contact position 2 of S1F; through C2; and through the parallel impedance consisting of R11 and C24, to the grid of V1A. Further operation of the circuit is the same as given in paragraph 39.

b. Calibrator operation with S1 in the DIV 2 position. In the DIV 2 position of S1, the modified calibrator circuit operates like the unmodified circuit, except for the operation of relays and the subsequent signal paths. Position 3 of switch S1 places the 420-cycle, DIV 2, stairstep pattern signal from the frequency divider on to the grid of V1A by connecting path segements B and M (shown in upper left of schematic) together. This connection is made through contacts of deck F of the FUNCTION switch. Deck E of S1 applies the DIV 2 stairstep pattern to the grid of V4, where it will be used to start the horizontal sweeps. The circuit explanation in paragraph 39 applies for the remainder of the circuit operation.

c. Calibrator operation with S1 in the DIV 3 position. In the schematic of the modified calibrator circuitry, the DIV 3 position of the FUNCTION switch, deck F connects input path segments C and M. Deck E connects segments J and L. These connections provide the inputs described in paragraph 39. The function of the circuit is the same as described there.

d. Calibrator operation with S1 in the MOTOR SPEED position. This position of the FUNCTION switch connects input path segments C to M on deck F and D to J on deck E to apply a 60-cycle, stairstep waveform to the vertical sweep channel at V1A, and a 30-cycle signal to the grid of V4A in the horizontal sweep channel to be used for initiating the sweeps. These inputs are directly connected through the FUNCTION switch without recourse to relay switching. The remainder circuit function is as described in paragraph 39 for the unmodified circuit.

43. SYNC COMMAND SYSTEM TESTS AND ADJUSTMENTS (fig 10-19.1)

a. Calibrator operation with S1 in the BURST position. In the modified calibrator circuit, the BURST position of S1 connects input path circuit segments E to J on deck E and I to M on deck F to permit direct application of the 220-cps, frequency generator waveform from pin 6 of J4 to the horizontal sweep channel and the signal from the cathode of V8 to the vertical sweep channel. The remainder of the operation of this switch position of S1 is the same as described in paragraph 40.

b. Calibrator operation with S1 in the 0G YAW position. The operation of the modified calibrator circuit with S1 in position 8 is the same as described in paragraph 40, except that deck E of the FUNCTION switch makes direct connection for applying the 30-cycle square wave from the frequency generator to the horizontal sweep channel for initiating the sweeps and deck F makes a direct connection for applying the output from the cathode of V8 to the vertical amplifier.

c. Calibrator operation with S1 in the 0G PITCH position. In the modified circuit, position 11 of S1 makes direct connections for applying the output from the cathode of V8 to the vertical sweep channel, on deck F, and the 100-cps square wave output from the frequency generator to the horizontal sweep channel on deck E. The remainder of the circuit operation for this position of the FUNCTION switch is described in paragraph 40. The same changes apply to the -5G PITCH position of S1 and the +5G PITCH position.

d. Calibrator operation with S1 in the 0 DEV-REP RATE position. In this position, deck E makes a direct connection to apply the 400-cycle square wave output from the frequency generator to the horizontal sweep channel at grid (2) of V4 to initiate the sweeps. The action of deck F directly connects the REP RATE CAL signal to V1, pin 2 for use in the vertical sweep channel. The operation of the circuit is as described in paragraph 40. The same circuit connection changes apply in the -DEV and +DEV positions of FUNCTION switch S1, with the circuit operation descriptions in paragraph 40.

CHAPTER 4

MTR SYSTEMS BLOCKS; R-F MONITOR, TRANSMITTED PULSE MONITOR AND AFC UNIT

Section I. TRANSMITTING SYSTEM BLOCK

44. INTRODUCTION

a. The student is already familiar with the target-tracking radar transmitting system. He has made a detailed study of the synchronizer, trigger generator, modulator, pulse transformer, magnetron, and control circuitry. The missile-tracking radar transmitting system uses most of the same units, but in a slightly different manner. The method used in the missile-tracking radar is such that mutual interference between the missile-tracking radars of two adjacent batteries or between the missile- and target-tracking radars of the same battery is nonexistent. To keep the missile- and target-tracking radar systems at top operating efficiency, the maintenance man must be thoroughly familiar with both the similarities and differences between the two systems.

b. The target-tracking radar transmitting system is synchronized with the acquisition transmitter at about 1,000 pulses per second. The transmitted pulses originate in the synchronizer. The synchronizer develops two pulses, the preknock pulse and the sync pulse. The preknock pulse is used throughout the system to synchronize various timing circuits. The sync pulse, which follows the preknock pulse by 24.4 microseconds, is used in the radar transmitting system, where it is amplified and shaped to pulse the magnetron. The conduction of the magnetron causes a pulse of r-f energy to be emitted from the feedhorns and radiated into space. The missile-tracking radar transmitting system operates on the same principle, but in a modified form.

c. The missile-tracking radar differs from the target-tracking radar in that it must transmit steering and burst orders to the missile. It transmits pulse pairs at a pulse repetition frequency varying from 1,600 to 2,400 cps. The reason for the extra transmitted pulse is to establish a coding system whereby nearby batteries may not influence the flight of the missile. The first of these pulses is called the coder pulse and the second is the radar pulse. The missile transmitting system amplifies and shapes these pulses and causes the magnetron to fire. The amplification and shaping is done by the trigger generators, the modulators, and the pulse transformer.

45. BLOCK DIAGRAM DISCUSSION (fig 10-1)

a. General. The transmitting system of the missile-tracking radar must do two things. First, it must cause the beacon in the missile to be fired; second, it must transmit orders to the missile. A beacon is necessary because the missile presents such a small reflecting surface that not enough energy is reflected back to permit reliable tracking by the missile-tracking radar at extreme ranges. To prevent mutual interference between missile-tracking radars, the pulses are transmitted in coded pairs. The first of these pulses is called the coder pulse. It causes certain circuits in the missile to be gated so that if the second pulse, the radar pulse, arrives at the correct coding interval, the beacon will be triggered and the steering and burst circuits will receive the orders. The second requirement, the transmission of orders, is done by frequency modulation of the pulse repetition frequency. This causes the pulse repetition frequency to vary between the limits of 1,600 and 2,400 pairs of pulses per second. The rate at which the pulse repetition frequency varies between these limits is dependent upon the commands being sent to the missile. The orders sent to the missile are the steering orders or the burst order, and are determined in the computer.

b. Pitch oscillator. The input to the pitch oscillator comes from the G_P amplifier of the computer. This input is a d-c voltage with a scale factor of 20 volts per g. The orders may vary from zero to a maximum of ±5g. The output of the pitch oscillator is a variable frequency square wave. This output has a center frequency of 500 cycles per second and may vary ±20 percent from the center frequency upon application of maximum g orders. This signal will cause the missile to climb to the left or dive to the right.

c. Yaw oscillator. The yaw oscillator has an input similar to the pitch oscillator. It is also a d-c voltage with a scale factor of 20 volts per g. Its source is the G_Y amplifier in the computer. The output of the yaw oscillator is a square wave which may vary ±20 percent from its center frequency of 150 cycles per second. This signal causes the missile to climb to the right or dive to the left. A combination of yaw and pitch orders may steer the missile in any desired direction to intercept and destroy the target.

d. Burst oscillator. The burst oscillator has no input. It oscillates continuously at its free-running frequency of 880 cycles per second. The output is a square wave and is always available for use in the combining amplifier. When this signal is transmitted, the steering orders are removed.

e. Combining amplifier. There are four inputs available to the combining amplifier. These are the yaw, pitch, and burst oscillator outputs and a burst

signal from the computer. The yaw, pitch, and burst signals are changed into sine waves by low-pass filters in the combining amplifier. The yaw and pitch sine waves are then combined into a complex wave which represents the steering orders. When the computer gives the burst order, a relay in the combining amplifier is energized, removing the steering orders and applying the 880-cycle burst order. These orders are applied to the repetition rate oscillator.

f. Repetition rate oscillator. The repetition rate oscillator receives its input from the combining amplifier. This input may be either the complex wave of the steering orders or the sine wave of the burst order. Regardless of which input it receives, the repetition rate oscillator will oscillate between the limits of 1,600 and 2,400 cycles per second. The orders being received determine the rate at which the frequency of the oscillator varies between these limits. The center frequency of this unit is 2,000 cycles per second. The output is a frequency-modulated square wave of a constantly varying frequency between the limits of 1,600 and 2,400 cycles per second.

g. Pulse generator. The pulse generator is the synchronizer of the missile-tracking radar. The synchronizer in the target-tracking radar is controlled by the acquisition radar synchronizer. The pulse generator in the missile-tracking radar is controlled by the frequency-modulated output of the repetition-rate oscillator, which is controlled by the orders being received from the computer. The pulse generator develops three output pulses. These are the preknock pulse, the coder pulse, and the radar pulse. The preknock pulse triggers various timing and sweep circuits. The coder and radar pulses establish a coding system and trigger the magnetron. The coder pulse precedes the radar pulse by a variable interval known as the coding interval. These two pulses are joined at the output of the chassis and are transmitted through the same cable to the two trigger generators.

h. Trigger generators (fig 11-1). Both pulses are applied to each trigger generator. Because of the different input connections, one trigger generator operates only on the coder pulse and the other operates only on the radar pulse. The output of each trigger generator is a positive pulse of about 230 volts and 4 microseconds in duration. One pulse is coincident in time with the coder pulse and the other is coincident with the radar pulse. They are each applied to their respective modulators (fig 1).

i. Modulators. The missile-tracking radar has two modulators, identical and interchangeable with that of the target-tracking radar. The 400-microsecond charging time of the pulse-forming network establishes the need for the use of two trigger generators and two modulators in the missile radar. Both modulator

pulse-forming networks are charged by a common high-voltage power supply. The pulse-forming networks in the modulators are discharged by the pulse developed in its respective trigger generator. Thus, the output of one modulator will be coincident with the coder pulse and the output of the other will be coincident with the radar pulse. The modulator output is a negative 6.5-kv, 0.25-microsecond pulse. Both modulators apply their output pulses to a common pulse transformer.

j. Pulse transformer. The pulse transformer receives the two negative 6.5-kv, 0.25-microsecond pulses from the modulators. These pulses are stepped up to approximately 30 kv, depending upon the operating voltage of the high-voltage power supply. An L-C network in the modulator puts a step in these pulses so as to ease the magnetron into conduction for a period of 0.18 microsecond. These pulses are applied to the cathode of the magnetron and each causes the magnetron to fire. The firings of the magnetron cause two 0.18-microsecond pulses of r-f energy to be radiated into space.

Section II. R-F MONITOR AND TRANSMITTED PULSE MONITOR

46. INTRODUCTION

The commands transmitted to the missile are established by controlling the frequency of the repetition rate oscillator. The missile-tracking radar transmits two pulses of r-f energy for each cycle of the repetition rate oscillator. These two pulses, separated by the proper coding interval, must both be received by the missile before the guidance system of the missile can decode the orders and respond with a beacon signal. The failure to transmit one of these pulses, or to transmit improperly coded pulses, will result in no response by the missile and no returned beacon signal. A fault in the missile decoder or beacon transmitter will also result in a failure of the missile to respond to the commands or to transmit a beacon signal back to the missile-tracking radar. A means of isolating a malfunction to the faulty component that is at fault is an asset in troubleshooting any equipment. The more complex the equipment being used, the more important this means becomes. In equipment that is as involved, complex, and expensive as the ground guidance and missile components used in the Nike system, a systematic method of determining faulty components is a necessity. The monitor circuits discussed in this section provide a means of determining the operation of the missile transmitting system. The misfiring of the missile-tracking radar transmitter or an improper coding interval may be detected simply by observing a meter on the missile-tracking console. Therefore, simple observation will prevent the firing of a missile when the missile transmitter is not functioning properly. The r-f and transmitted pulse monitors are built-in test equipment and must be properly maintained if they are to do their job.

47. COORDINATION OF COMPONENTS

The sync command system of the missile-tracking radar triggers the missile transmitter. To prevent interferance with another Nike system, the missile-tracking radar transmits a two-pulse code. Since these codes are predetermined and will differ for each system in a defense, no one battery can erroneously gain control of a missile launched by another battery. The combined outputs of the yaw and pitch oscillators are applied to the contacts of a normally closed relay in the combining amplifier. The frequency of these oscillators is controlled by a d-c voltage from the computer. The combining amplifier supplies the repetition-rate oscillator with a complex wave whose frequency components are proportional to the commands to be sent to the missile. The main component of the repetition rate oscillator is a multivibrator. The square wave output from this multivibrator is applies to the preknock channel of the pulse generator. The pulse generator consists of three separate channels; the preknock, coding, and radar pulse channels. The output from the preknock pulse channel triggers the missile range indicator in the missile presentation system, and in some systems, the missile range unit assembly. This preknock pulse also triggers the coder and radar channels of the pulse generator. The coder and radar pulses trigger the trigger generators. The coder pulse is negative in polarity and precedes the positive radar pulse by a time equal to the coding interval. Each trigger generator receives one of the pulses and generates a pulse strong enough to drive the modulator associated with its channel. The two modulators supply a common pulse transformer with a pulse of energy whose amplitude is proportional to the high-voltage supplying the modulator, whose duration is determined by the electrical properties of a network in the modulators, and whose time relationship is determined by the coder and radar pulses. The pulse transformer increases the amplitude of the pulse enough to operate the magnetron. The pulse applied from the pulse transformer to the magnetron causes the magnetron to oscillate for the duration of the pulse. The r-f pulse from the magnetron is applied by the waveguide assembly to the lens antenna. The lens antenna causes the pulse of energy to be radiated into space in a pencil-like beam. TR tubes prevent the transmitter pulse from entering the receiver as it travels out the waveguide to the lens antenna.

48. OVER-ALL PURPOSE

The r-f monitor detects a portion of the two pulses of r-f energy emitted by the missile transmitter. This unit produces a positive output only when both pulses are transmitted. The transmitted pulse monitor records the absence of an output from the r-f monitor. The record is an indication of missing pulses in the missile transmitting system.

49. BLOCK DIAGRAM DISCUSSION, R-F MONITOR (fig 12-2)

a. General. The r-f monitor monitors the output of the missile-tracking radar transmitter. A crystal in this unit detects a small portion of every r-f pulse transmitted. The r-f pulses occur in pairs and the two pulses in each pair are separated by a fixed time interval. This monitor produces a positive pulse output for every pair of pulses transmitted. The r-f monitor is mounted on the feedhorn assembly of the missile-tracking radar.

b. Detector CR1. A small probe protruding through a hole in the antenna feedhorn shield is connected to crystal CR1 in the r-f monitor. The crystal rectifies the small portion taken from each r-f transmission by the probe and applies a positive video pulse to the grid of the first amplifier.

c. Amplifier V1A and V1B. The two triode sections of V1 are R-C coupled video amplifiers. The positive pulse from CR1 is applied to the control grid of V1B. This stage amplifies and inverts the signal and applies it to the control grid of V1A. Here it is amplified again, inverted, and applied to amplifier V5B. This signal is also applied to coincidence gating tube V4.

d. Amplifier V5B. This stage, together with network Z1, forms a quarter-cycle oscillator circuit. The amplified pulse pairs from stage V1 are the inputs to V5B. It is normally cut off by -12 volts bias on the control grid from voltage divider action of resistors R23 and R33 connected from -250 volts to ground. These act as developing resistors for the signals applied to the control grid of V5B. The positive pulses from V1 are amplified and inverted by V5B to present negative signals to network Z1. These negative signals permit network Z1 to discharge like a conventional quarter-cycle oscillator and apply this signal through CR2 to multivibrator stage V2.

e. Multivibrator V2. This stage is a one-shot multivibrator. Crystal CR2 clips the negative portion of the quarter-cycle oscillations it receives from network Z1. The remaining positive signal is applied to the cut-off A-section of V2 to drive it into conduction. Conventional one-shot multivibrator action follows, with V2 delivering a positive gating signal to the suppressor grid of coincidence gating tube V4.

f. Coincidence gating tube V4. This stage uses a pentode tube. It is controlled by both the suppressor and control grids. Bias on this tube is established on both of these grids and is such that a positive signal must be present on both grids, coincident in time, for plate current to flow. If both transmitted pulses are present in the feedhorn shield, the detected radar pulse will appear on the

control grid of V4 at the same time the positive peak from multivibrator V2 appears on the suppressor grid. Plate current will then flow in the plate circuit of V4.

g. Blocking oscillator V5A. Tubes V4 and V5A both use the primary of transformer T1 for a plate load. When plate current is drawn by V4, a change in the magnetic field of T1 occurs. This changing field causes blocking oscillator action to take place in stage V5B. A positive pulse is developed in the cathode circuit of V5B. This pulse is approximately 50 volts in amplitude and 5 microseconds in duration. It is applied through J2 to the transmitted pulse monitor.

50. BLOCK DIAGRAM DISCUSSION, TRANSMITTED PULSE MONITOR (fig 12-4)

a. General. The transmitted pulse monitor provides a meter indication of the missing pulses of the missile transmitter. This unit is located on the missile r-f unit of the missile antenna trailer. The output from the r-f monitor and the radar pulse from the pulse generator are the main inputs to this unit. A combination of these two inputs determines the amount of deflection of a microammeter, which is calibrated to indicate pulses missing from the output of the r-f monitor.

b. Blocking oscillator V1. The radar pulse from the pulse generator triggers this blocking oscillator. The output of this stage is a negative square wave whose leading edge corresponds in time with the radar pulse and whose trailing edge is about 9 microseconds later. Transformer T1 in the plate circuit of V1B differentiates the square wave, thereby producing a negative pulse followed by a positive pulse. These two pulses are applied to gate circuit V4. Since this is a coincidence-type gating circuit, it is necessary, for explanation purposes, to leave this pulse and develop another input for V4.

c. R-F pulse gate generator, V3. The positive pulse from the r-f monitor triggers this stage. This signal is applied through isolating diode V2A to the A-section of V3. The positive trigger causes a negative square wave to be developed at the plate of V3A. This 18-microsecond square wave is applied to the suppressor grid of gating circuit V4.

d. Gate V4. Voltage divider action establishes the control grid bias of V4 at such a potential as to prevent the flow of plate current in this tube. Ideally, there are two inputs to the gate circuit. One of these inputs is the positive pulse generated by the differentiating circuit in the output of blocking oscillator V1. The other input is the negative square wave from gate generator V3A and will be present if both pulses of energy are detected by the r-f monitor. If both signals are applied at the same time, no plate current will flow in V4, since one signal

is negative. However, plate current will flow if the positive pulse from V1 is applied without the negative gate from V3. Since there is a positive pulse from V1 for each radar pulse, and a negative gate from V3 for each pair of transmitted pulses, V4 will only produce an output when the missile transmitter misfires. The output from V4 triggers missing-pulse multivibrator V5.

e. Missing-pulse multivibrator, V5. Sections V5A and V5B of tube V5, with associated circuit components, form a monostable multivibrator. This multivibrator is triggered by the negative pulse from gate tube V4. When triggered, V5B produces a positive square wave as an output. This square wave is adjustable in duration and is about 20 volts in amplitude. To sum up the action of this stage, it can be said that for every missing transmission pulse, a positive square wave appears at the output of the missing-pulse multivibrator, V5.

f. Missing-pulse indicator circuit, V6, V7, V8, V9, and M1. These components make up the circuit to give a visual indication of the pulses missing at the output of the r-f monitor. The gate from the missing-pulse multivibrator is limited and triggers the indicator circuit. This pulse causes current to flow in one triode, V7A, and cuts off a second triode, V7B. The difference in current drawn by these two tubes changes the charge on a capacitor. The charge on this capacitor controls the current drawn by cathode-coupled amplifier V6B. The meters used to indicate missing pulses are located electrically in the plate circuit of V6B. It can be seen that the positive gate from V5B controls the deflection of the meters. There are two meters associated with this circuit. They are in series with each other; one located on the transmitted pulse monitor and the other one on the missile-tracking console.

51. R-F MONITOR, DETAILED DISCUSSION (fig 12-3)

a. Detector CR1. The small probe protruding through the hole in the antenna feedhorn shield couples the transmitted energy to crystal CR1. This crystal rectifies a small portion of each transmitted pulse. Resistor R3 is the load resistor for the crystal. The r-f components are filtered out by stray capacitance. The rectifier pulse is coupled through capacitor C1 to the control grid of V1B.

b. Amplifiers V1A and V1B. The positive signal from the detector circuit is developed across resistor R6 and applied to pin 7 of V1B. The signal is amplified and inverted by V1B and coupled through capacitor C2 to the control grid of V1A. This section of V1 also amplifies and inverts the signal. A positive signal is applied from the plate of V1A through capacitor C3 to the B-section of tube V5 and coincidence tube V4.

c. Amplifier V5B. Tube V5B is cut off between pulses by -12 volts on its control grid from voltage divider action. The -250 volts applied across R23 and R33 in series to ground biases the control grids of V5B and V4 at -12 volts in the quiescent mode. With V5B cut off, network Z1 charges to +150 volts. The arrival on the control grid of V5B, of the positive signal from pin 4 of V1B will cause V5B to conduct. The plate voltage will drop, giving a negative output pulse of the same duration as the positive pulse from V1B. This will cause network Z1 to begin oscillation, starting in a negative direction. The negative portion of the waveform will be of 0.8- to 1-microsecond duration, followed by the positive portion of the oscillator waveform. With the end of the pulse at its control grid, V5B will again be cut off and the plate voltage will rise. This action will damp out the oscillation of Z1 and begin to recharge Z1.

d. Crystal CR2. Crystal diode CR2 is connected so that its plate receives the signal from network Z1. The negative portion of the signal from Z1 network will not permit the crystal to conduct and thus, is clipped. During the positive portion of the signal,the plate of CR2 will be more positive than its cathode and it will conduct, passing the positive portion of the signal. This positive signal is coupled through C6 to pin 3, the control grid of multivibrator tube V2.

e. Multivibrator V2. Tube V2 is a one-shot multivibrator. Before the arrival of the positive trigger pulse from CR2, V2B is conducting heavily, due to the large positive bias on the control grid from the plate supply voltage. The biasing action of the voltage drop across common cathode resistor R31 holds V2A cut off. The positive trigger pulse from CR2 drives V2A into conduction. This signal is amplified and inverted. The amplified negative signal is applied to the grid of V2B, cutting it off. The voltage at pin 6 of V2B, the plate, will rise, and at the end of the trigger pulse, V2A returns to cutoff condition, allowing V2B to conduct again, dropping the plate voltage and completing the positive waveform to be applied to the suppressor grid of coincidence gating tube V4.

f. Coincidence tube V4. In the static condition, this stage is cut off with -12 volts on the control grid from voltage divider network R23 and R33 (between -250 volts and ground) and -22.5 volts on the suppressor grid from divider network R20 and R21 (between -250 volts and ground). For plate current to flow, positive signals must appear on both these grids at the same time. The positive signal from multivibrator V2 is coupled by C7 to the suppressor grid of V4. This signal is delayed 1.5 microseconds by the clipping action of CR2 on the negative portion of that signal, from network Z1. The positive pairs of pulses from the plate of V1B are impressed on

the control grid of V4. The first of these arrives coincident in time with the negative signal, which was eliminated at CR2. The second one (if there are two) will arrive coincident in time with the signal at the suppressor grid. This will cause V4 to conduct. With this arrangement, V4 can conduct only if both the coder and radar pulses have been transmitted at the proper coding interval.

g. Blocking oscillator V5A. This is a plate-synchronized blocking oscillator. It is normally cut off by -8.2 volts bias, applied to the control grid from divider network R27 and R26 (between -250 volts and ground). The 3-4 winding of transformer T1 provides a common plate load for V4 and V5A. When V4 conducts, the plate voltage of both tubes will drop, effectively coupling a negative signal from the plate of V4 to the plate of V5A into the 3-4 winding of T1. This signal will be coupled through T1 to the 5-6 winding with a negative polarity at pin 6 and positive at pin 5. The grid will be driven positive and the cathode more negative. This will cause V5A to go into conduction. The resulting drop in plate voltage is coupled through to the 5-6 windings of T1 and applied to the grid and cathode, respectively, in the correct polarities to drive the tube towards saturation. Resistor R25 will develop the positive pulse output at the cathode to J2, the monitor output. Capacitor C13 will lengthen the pulse. As the tube reaches saturation, there can be no more change in the magnetic field of T1. Once more, the -8.2 volt bias at the grid will be felt and the tube will return to cutoff. The output pulse to J2 is 50 volts in amplitude and 5 microseconds in duration. This output is applied to the transmitted pulse monitor. This pulse appears only if both the coder and radar pulses have been transmitted, properly spaced by the coding interval.

52. TRANSMITTED PULSE MONITOR, DETAILED DISCUSSION (fig 12-5)

a. Trigger delay blocking oscillator V1. Tube V1, transformer T1, and the associated circuit components, make up a blocking oscillator. Section V1A is a trigger tube and V1B is the blocking oscillator section. In static operation, both are normally cut off by approximately -15 volts bias through voltage divider networks R56-R21 to ground and R58-R57 to ground, respectively, from -250 volts. The two sync pulses from the pulse generator are applied to the grid of V1A from J1 through C2. These pulses are, in order of appearance, the negative (coding) pulse followed, after the coding interval, by the positive (radar) pulse. Since V1A is cut off at this time, the negative pulse has no effect on it. Upon the arrival of the positive pulse, V1A will conduct. The plate voltage of V1A will drop and the change of voltage in the 2-1 winding of T1 will cause a voltage to be induced in the 3-4 winding of such polarity that terminal 3 will be positive with respect to terminal 4. This will trigger V1B, the blocking oscillator section into conduction. This circuit acts as a conventional blocking oscillator with a negative pulse output at terminal 6 of T1.

Resistor R53 and capacitor C17 comprise a differentiating network which will differentiate the approximately 9-microsecond negative pulse. This action sends a negative spike, followed by 9 microseconds, by a positive spike, to the control grid of V4.

b. R-F pulse gate generator V2A and V3. This circuit function as a one-shot multivibrator with V2A serving as an isolating diode. Normally, V3B is conducting as the control grid is returned to B+ through resistor R16. The control grid of V3A is returned to the plate of V3B, and because of the conduction of V3B, this point is at about +43 volts. The control grid of V3A is returned through resistor R14 to the junction of R49 and R50. The potential at the junction of these resistors is about -50 volts. The combination of this voltage and the +43 volts at the plate of V3B places the control grid of V3A at approximately -35 volts. The plate and cathode of V2A are at the same potential. The positive pulse from the r-f monitor is coupled through V2A to the control grid of V3A. Multivibrator action takes place and a negative gate is developed at the plate of V3A. Because of the time constants of this circuit, the negative gate is about 18 microseconds in duration. This gate is coupled through capacitor C5 to the suppressor grid of V4.

c. Gate circuit V4. This stage receives the negative and positive pulses from transformer T1 on the control grid, and the negative gate from V3A on the suppressor grid. (Switch S1 is normally in the 10 position.) In the static condition, V4 is biased below cutoff by the voltage divider action of resistors R5 and R53. The negative pulse from transformer T1 will have no effect on V4. The positive pulse from T1 will cause V4 to draw plate current if it does not arrive in time coincidence with the negative pulse from V3A. Note that the positive pulse from T1 occurs 9 microseconds after the radar pulse and the negative gate starts just after the radar pulse, but it has a duration of 18 microseconds. Since the positive pulse at the control grid of V4 occurs once for each radar pulse, and the negative gate occurs only when two pulses are transmitted by the missile transmitter, V4 will produce an output only if the output of the r-f monitor is missing. This circuit could be called a missing-pulse counter.

d. Missing pulse multivibrator V2B and V5. Sections V5A and V5B and associated circuit components, form a one-shot multivibrator. Tube V2B is a triggering or isolating diode and is considered part of this stage. In a static condition, V5A is cut off and V5B is conducting. This condition continues until a negative pulse is applied from V4 through capacitor C10 and tube V2B to the control grid of V5B. This negative pulse causes the plate current to decrease; thereby, increasing the plate voltage. This increase in plate voltage

is coupled through capacitor C12 to the control grid of V5A. A cumulative action takes place until V5B is cut off and V5A is conducting. This condition continues until capacitor C11 discharges to the cutoff voltage of V5B. The length of time during which V5B is cut off is determined by the rate of discharge of capacitor C11 through resistor R26 and PRF potentiometer R25. This potentiometer permits adjustment of the conduction time of V5B. The correct adjusting procedure is discussed in paragraph 52f. The positive square wave output signal is applied from the plate of V5B through capacitor C13 and resistor R30 to the control grid of V7A. To sum up the action of the r-f and transmitted pulse monitors thus far, it can be said that for every missing transmitted pulse, a positive square wave appears at the control grid of V7A.

e. <u>Missing pulse indicator V6, V7, V8, V9, and M1</u>.

(1) Static condition. The static condition of this circuit will be discussed first. The resistor network composed of R41 through R46 forms a voltage divider from +250 volts to ground, for obtaining necessary operating voltages for this circuit. The plate of diode-connected V6A is at +60 volts. The cathode of this stage is connected to the +80-volt tap on the voltage divider. The control grid of V7A receives +60 volts from the voltage divider through resistor R31. The cathode potential of V7A is kept at approximately +75 volts by the normal conduction of V7B and V8. The grid-to-cathode voltage of V7A is about -15 volts, which is enough to cut this stage off. The bias on V7B is about -5 volts, so this section conducts in the static condition. The plate of voltage regulator tube V9 receives +108 volts from the junction of resistors R42 and R43. This tube maintains a constant voltage on the screen grid of constant current generator V8. The constant voltage applied to the screen grid of V8 maintains constant plate current in this tube in spite of plate voltage variations. Tube V6B is cut off a very short time after power is first applied because V7A is cut off and V6B has no d-c return to ground. (Switch S1 is in position 10 during normal operation.) With V6B cut off, no current is flowing through the two missing pulse meters in the plate circuit of this stage. To sum up the static condition, it can be said that stages V8 and V7B are conducting, but V6A, V6B, and V7A are cut off. Tube V8 is a constant current generator with V9 holding the screen grid potential of V8 at +108 volts.

(2) Dynamic condition. Application of the positive 20-volt pulse to the control grid of V7A causes this section to start conducting. The input pulse swings from +60 to +80 volts. An increase of the signal exceeding +80

volts is limited by V6A. The conduction of V7A causes the potential at the cathode to increase. This increase is enough to cut V7B off. The plate of V7B rises to +250 volts immediately. Since the conduction of V7A decreased, the plate voltage of this stage and the plate of V7B increased to +250 volts, a voltage difference appears across capacitor C14, which charges accordingly. The charge path is through V8, V7A, resistors R34 and R37, and potentiometer R39. After the pulse on the control grid of V7A disappears, this section returns to cutoff and V7B again conducts. The plate voltage of V7B drops and capacitor C14 discharges through V6B, R32, and the meters. This capacitor can be considered a filtering capacitance which maintains a constant current through the meters, proportional to the number of pulses appearing at the control grid of V7A. Therefore, the deflection of the meter is proportional to the number of pulses appearing at the control grid of V7A.

f. Adjustments.

(1) Meter calibration. For the indication on the meter to be of any value, the meter must first be calibrated. METER switch S1 is provided in the transmitted pulse monitor to calibrate the missing pulse indicators, and to permit the use of two different ranges of meter scales. The DC and PRF positions of this switch are used for calibrating the meter by using potentiometers R39 and R25, in that order. By placing the switch in the DC position, the suppressor grid of gate tube V4 is grounded by contacts 1 and 6 of S1A. With ground on the suppressor grid, V4 will pass all positive sync pulses applied to the control grid. This operation simulates the condition of 100 percent missing pulses. The DC position of S1B, by use of contacts 1 and 6 and 12 and 7, places the plate circuits of V6B and V7B in parallel in order to provide the proper current through the meters for full scale deflection. If the meters do not have full-scale deflection, adjust DC potentiometer R39 in the cathode of V8 as required. Note that current from both V7A and V7B is flowing through the meters.

(2) Missing pulse adjustment. When S1 is placed in the PRF position, the 100 percent missing pulse condition is again simulated. Contacts 12 and 8 of S1B connect the proper paths for the plate current of V6B so that the current flowing in the meter circuit will cause the meter to indicate 100 percent missing pulses. Contacts 12 and 6 of S1B connect the proper shunts for V7B. In this condition, however, the current through the meters is only the current from V7A and C14. If the meters do not indicate 100 percent missing pulses, adjust PRF potentiometer R25 in missing pulse multivibrator V5 accordingly.

(3) Use of positions of switch S1. Positions 10 and 100 of METER switch S1 are for changing the scale of the meters. In the 10 position, full-scale deflection indicates 10 percent missing pulses. In the 100 position, full-scale deflection indicates 100 percent missing pulses. No connection is made to the suppressor grid of V4 in either of these positions of the switch. In the 10 position, all the current drawn by V6B flows through the meter. In the 100 position, a shunt is provided for the meters by resistor R35, contacts 12 and 9 of S1B, and the +250-volt supply.

(4) Summary. The DC and PRF positions of the METER switch are for calibrating the meter and the adjustments are made in the order indicated, DC and PRF. The 10 and 100 positions are for changing meter scales.

Section III. MTR RECEIVING SYSTEM BLOCK

53. INTRODUCTION

Any pulse-modulated radar system may be divided into a number of basic components. These components are essentially the same in all types of radar systems. The degree of refinement of a specific component depends upon the use for which the equipment is designed. One of the basic components of any radar is a receiver. The receiver accepts the very weak r-f signals returning from a target, amplifies them, detects the pulse envelope, and amplifies these detected pulses. All radar systems use frequencies in the microwave region. Therefore, it is difficult to obtain enough amplification with vacuum tube circuits. To obtain enough amplification, a superheterodyne-type receiver is used. This type of receiver permits double detection of the signal. It changes the frequency of the returned echo to a lower frequency, amplifies at that lower frequency, and then detects the lower frequency signal. The required stability of operation and over-all sensitivity of the receiver are obtained through careful design. In the Nike I system, complete tracking information is available from each received pulse. For the Nike I system to perform the tactical mission assigned properly, the receiving system must be operating at or near peak efficiency. Proper operation of the receiver system is the responsibility of the maintenance men. They must be able to recognize and remedy any system malfunction that might occur. This requires a thorough knowledge of the operation of the separate receiver components, as well as the proper adjustment and tuning of the circuits.

54. OVER-ALL PURPOSE

The receiver system of the missile-tracking radar converts, amplifies, and detects the received signals from the missile beacon. The video output must be

azimuth angle error detector to provide azimuth tracking information. The elevation and sum signals are applied to the elevation angle error detector for elevation tracking information. An additional output is applied to the test panel to enable maintenance men to monitor the average signal strength of each of the three channels.

i. AGC unit. The AGC unit provides a biasing voltage to the i-f main amplifiers to control the gain of the receiver. The AGC unit is located in the radar range and receiver cabinet of the radar control trailer. The receiver gate from the range error detector gates the AGC unit to allow automatic gain control action on only the target or missile being tracked. The three outputs from this unit (one for each i-f channel) are applied to the control grids of the second through the sixth amplifiers of the i-f main amplifiers. Means are provided in this unit to allow maintenance men to monitor the outputs from this unit on the test panel.

j. AFC unit. The AFC unit, located in the radar range and receiver cabinet of the radar control trailer, controls the frequency of the local oscillator in the converter. The AFC unit, located in the r-f unit on the missile-tracking antenna, controls the local oscillator frequency for the missile radar. The AFC units and the method used to control the frequency of the local oscillator are the main differences between the two tracking receivers. The AFC used with the missile radar controls the repeller voltage of the local oscillator, while the target AFC controls the grid voltage of the tuning triode of the local oscillator tube. Because of a rapid change in beacon frequency when the missile is launched, it is necessary to have an AFC unit and local oscillator combination that will follow this fast change. The controlling of the repeller voltage allows much faster response from the local oscillator than controlling the voltage on the tuning triode. This method is not used with the target radar because the band of frequencies that can be covered by this method is much less. The output of the missile AFC unit is applied through the test panel and slip ring assembly to the local oscillator in the converter.

k. Test panel. The test panel provides meters, switches, and controls that allow certain test procedures and system checks to be made. The coarse tuning voltage for the missile local oscillator is also supplied from this test panel. This voltage is applied to the control grid of the tuning triode of the local oscillator to determine the section of the frequency band that the missile AFC unit will cause the local oscillator to cover. This test panel is located on the left door of the radar range and receiver cabinet of the radar control trailer.

l. I-F test unit. The i-f test unit, located just above the test panel, provides a 60-megacycle pulse, variable in range, to check the receiving system beginning at the input of the i-f main amplifiers. This unit is essentially a built-in i-f generator. To use this unit, it is necessary to operate the ON-OFF switch on the unit

c. Sum i-f preamplifier. The sum i-f preamplifier receives a 60-megacycle signal from the sum channel of the converter. The input is obtained by actual physical contact of the input of the sum i-f preamplifier with the crystal holders

triode amplifiers. An additional input to the sum i-f amplifier is the 60-megacycle input from the AFC channel of the converter. This signal, as well as the sum signal, is filtered in the sum i-f preamplifier and supplied as a current output for the crystal current meter. A delay line is available in this preamplifier to provide 2,000-yard pulses to check the missile ranging system.

d. Elevation and azimuth i-f preamplifiers. The purpose and functioning of the elevation and azimuth i-f preamplifiers are the same as the sum i-f preamplifier, except that the AFC signal is not an input and there is no delay line.

e. Slip ring assembly. The slip ring assembly electrically connects the rotating pedestal and the stationary trailer. Three adjacent slip rings pass each i-f signal. The center ring of the three carries the i-f signal and the ring on each side is for isolation to prevent crosstalk loss.

f. The 250-foot triple coaxial cable. The 250-foot triple coaxial cable carries the i-f signals from the missile antenna trailer to the radar control trailer. It consists of three RG-9/U-type coaxial conductors. The main requirement of this cable is to allow no more than 10 electrical degrees of phase shift between any two signals. This cable is 250 feet long and has a power loss of approximately 4 db through any 1 of the 3 conductors.

g. Sum, azimuth, and elevation i-f main amplifiers. The sum, azimuth, and elevation i-f main amplifiers are physically located in the radar range and receiver cabinet of the radar control trailer. Signals from the i-f preamplifiers reach the i-f main amplifiers through the 250-foot triple coaxial cable. Each unit has a grounded-grid amplifier as an input stage and six succeeding stages of amplification Of these 6 stages, the first 5 have a voltage applied to the control grids to automatically control the gain. The over-all gain of each i-f main amplifier is about 111 db. The output of each amplifier is applied to the video and phase unit.

h. Video and phase unit. The video and phase unit is located in the radar range and receiver cabinet of the radar control trailer. The video and phase unit compensates for any relative phase shift between the three channels of i-f signals. Each channel is shifted about 15,000° in the receiving system, but any relative phase shift must be compensated for. The video and phase unit also serves as second detector for each channel and provides monitor circuits for test purposes. The sweep expansion pulse gates this unit to allow the passage of only the signals from the missile being tracked. The video and phase unit has six main outputs. The sum signal, after being detected, is amplified and applied to the range error detector for use in automatic range tracking and to be displayed on the range tracking indicator. The detected sum signal is also applied to the AGC unit to automatically control the gain of the i-f main amplifiers. The azimuth and the sum signals are applied to the

azimuth angle error detector to provide azimuth tracking information. The elevation and sum signals are applied to the elevation angle error detector for elevation tracking information. An additional output is applied to the test panel to enable maintenance men to monitor the average signal strength of each of the three channels.

i. AGC unit. The AGC unit provides a biasing voltage to the i-f main amplifiers to control the gain of the receiver. The AGC unit is located in the radar range and receiver cabinet of the radar control trailer. The receiver gate from the range error detector gates the AGC unit to allow automatic gain control action on only the target or missile being tracked. The three outputs from this unit (one for each i-f channel) are applied to the control grids of the second through the sixth amplifiers of the i-f main amplifiers. Means are provided in this unit to allow maintenance men to monitor the outputs from this unit on the test panel.

j. AFC unit. The AFC unit, located in the radar range and receiver cabinet of the radar control trailer, controls the frequency of the local oscillator in the converter. The AFC unit, located in the r-f unit on the missile-tracking antenna, controls the local oscillator frequency for the missile radar. The AFC units and the method used to control the frequency of the local oscillator are the main differences between the two tracking receivers. The AFC used with the missile radar controls the repeller voltage of the local oscillator, while the target AFC controls the grid voltage of the tuning triode of the local oscillator tube. Because of a rapid change in beacon frequency when the missile is launched, it is necessary to have an AFC unit and local oscillator combination that will follow this fast change. The controlling of the repeller voltage allows much faster response from the local oscillator than controlling the voltage on the tuning triode. This method is not used with the target radar because the band of frequencies that can be covered by this method is much less. The output of the missile AFC unit is applied through the test panel and slip ring assembly to the local oscillator in the converter.

k. Test panel. The test panel provides meters, switches, and controls that allow certain test procedures and system checks to be made. The coarse tuning voltage for the missile local oscillator is also supplied from this test panel. This voltage is applied to the control grid of the tuning triode of the local oscillator to determine the section of the frequency band that the missile AFC unit will cause the local oscillator to cover. This test panel is located on the left door of the radar range and receiver cabinet of the radar control trailer.

l. I-F test unit. The i-f test unit, located just above the test panel, provides a 60-megacycle pulse, variable in range, to check the receiving system beginning at the input of the i-f main amplifiers. This unit is essentially a built-in i-f generator. To use this unit, it is necessary to operate the ON-OFF switch on the unit

c. Sum i-f preamplifier. The sum i-f preamplifier receives a 60-megacycle signal from the sum channel of the converter. The input is obtained by actual physical contact of the input of the sum i-f preamplifier with the crystal holders

to the ON position, and connect the output from the i-f test unit. One or all three i-f channels may be checked.

Section IV. MISSILE AFC UNIT

56. INTRODUCTION

For the receiving systems of the Nike I system to be able to function, the local oscillators must operate 60 mc above the frequency of the received signal. The missile-tracking radar receives a beacon signal from the missile. Because the frequency of the beacon is independent of the missile-tracking radar transmitting frequency, some means must be provided for controlling the local oscillator frequency as a function of the beacon frequency. This is done by the missile automatic frequency control (AFC) unit. If the missile AFC unit were to become inoperative, it would be impossible to track the missile, and therefore impossible for the Nike I system to accomplish its mission. For this reason, it is imperative that the reader have a thorough understanding of the AFC unit and its related circuitry.

57. FUNCTION

The missile-tracking radar transmits two high-frequency pulses per repetition period. The frequency of their r-f components is determined by the missile-tracking radar transmitting system. The pulse repetition frequency is determined by the sync command system, which receives signals representing steering orders from the computer. The two pulses have a fixed time relationship, determined by the coding interval. The missile electronic system receives these pulses and determines whether the pulses are separated by the correct coding interval. If the coding interval of the input signal is correct, the pulse repetition frequency is detected to determine steering orders and a single high-frequency pulse is transmitted for each pair of pulses received. The frequency of the r-f components of these pulses is determined by the missile transmitting system and is independent of the missile radar transmitting frequency. These pulses are received by the missile-tracking radar and converted to azimuth, elevation, and sum signals in the waveguide assembly. They are then mixed with the output of the local oscillator in the balanced converter to produce three i-f signals. These signals are amplified by the i-f preamplifiers and i-f main amplifiers and applied to the video and phase unit for phase correction before being used in the video, automatic gain, and servo systems. The sum i-f input to the video and phase unit is also sent to the missile AFC unit. The missile AFC unit requires a signal with a power level far in excess of that of the received signal. Therefore, the input to the missile AFC unit is taken from the system after i-f

amplification. An error voltage is produced when the missile AFC unit compares the intermediate frequency with 60 mc. This error voltage is applied to the local-oscillator repeller plate and causes the local oscillator to change frequency in such a direction as to cause the intermediate frequency to be nearer 60 mc. Therefore, the frequency of the local oscillator of the missile-tracking radar (and target-tracking radar when the missile AFC unit is used during certain test procedures) is a function of the frequency of the received signal. In the target-tracking radar during normal operation, a sample of the transmitted frequency is monitored and mixed with the local-oscillator signal. This produces an i-f signal which is used in the target AFC unit for comparison with 60 mc to produce an error voltage. This error voltage is applied to the control grid of the tuning triode section of the local oscillator, causing the buncher grids to change their separation. This causes the local-oscillator frequency output to change, which brings the intermediate frequency nearer 60 mc. However, this system cannot be used in the missile-tracking radar. The missile beacon (transmitter) frequency is independent of the missile-tracking radar transmitter frequency, preventing the use of the missile-tracking radar frequency as a reference. The missile transmitter frequency will vary considerably during launch, preventing the use of thermal tuning in the local oscillator. Thermal tuning is inherently slower than electronic tuning.

58. OVER-ALL PURPOSE

a. The missile AFC unit monitors the i-f signal, detecting any deviation from the 60-mc intermediate frequency. When a frequency deviation occurs, the AFC unit develops an output signal which causes the local-oscillator frequency to be returned to a frequency 60 mc higher than the missile beacon frequency. In case a few pulses are not received from the missile, the AFC unit will continue to have the same output as from the last received pulse, rather than the zero output as would be expected with zero input. This is necessary to prevent the local oscillator from changing frequency when a few pulses are missed and possibly causing the i-f signal to be outside the bandpass of the receiver when pulses are again received. It also causes the local oscillator to search over a small frequency range (±20 mc) for the frequency of the new missile. This is necessary because frequencies of successively fired missiles vary slightly.

b. This discussion will constantly refer to the missile-tracking radar in its normal configuration (when tracking a missile or the test responder). Most of the discussion will also apply to the target-tracking radar when used in conjunction with the test responder during test and alinement procedures. This discussion is not true of the missile-tracking radar when tracking a target (not a beacon) during certain test procedures.

59. MISSILE AFC LOOP BLOCK DIAGRAM (fig 6-5)

a. Requirements for a closed loop. To have a complete closed loop in the missile AFC system, there are three requirements:

(1) There must be an r-f input (the missile beacon or test responder must be operating).

(2) There must be an i-f input to the AFC unit (the output of the converter must be within the bandpass of the receiver).

(3) The beacon pulse must be gated in range in the AFC unit (the radar range setting and missile range must be the same). When these three requirements are met, the local-oscillator frequency be properly adjusted.

b. AFC loop. In the missile AFC system, if the frequency of the r-f input were to rise, the intermediate frequency would decrease. This would cause a negative output error voltage from the AFC unit, which would cause the local oscillator frequency to rise and return the intermediate freqquency to 60 mc. This closed loop allows very rapid input frequency changes to be followed by the local-oscillator frequency.

60. MISSILE AFC UNIT BLOCK DIAGRAM

a. General. The AFC unit has two inputs, the receiver gate and the sum i-f signal. The receiver gate, an output of the range error detector, allows only the frequency of the gated beacon to affect the output of the missile AFC unit. The i-f signal input has been amplified by the sum i-f preamplifier and the sum i-f amplifier and passed through a 750-ohm isolation resistor in the video and phase unit before application to the AFC unit. The output of the AFC unit is a d-c level, determined by the frequency of the gated input signal. A 60-mc input signal will produce a zero volt output level. This output is applied through a voltage divider network in the test panel to the repeller plate of the local oscillator. A change of d-c level applied to the repeller plate causes a very rapid frequency change of the output of the local oscillator. This ability to change frequency rapidly is necessary for tracking the missile. It has been found that during the boost phase of the missile flight, a change of beacon frequency up to 13 mc is not uncommon because of mechanical stresses upon the missile electronic system. A local oscillator using thermal tuning, such as the target-tracking radar local oscillator, would be incapable of changing frequency rapidly enough to keep the intermediate frequency within the bandpass of the receiver during the rapid acceleration of the

missile. However, a local oscillator using repeller plate tuning would not suffice in the target radar, since this type of electronic tuning can only tune over a narrow band of frequencies (approximately ±25 mc).

b. I-F amplifiers V1, V2, and V3. These three stages are conventional i-f amplifiers which are tuned to 60 mc, and have a 10-mc bandpass. The output from the i-f amplifiers is amplified in these stages to a level sufficient to operate the discriminator. I-F signals at frequencies below 55 mc or above 65 mc lie outside the bandpass of the i-f amplifiers. Such signals will not be passed by V1, V2, and V3, and therefore will not be applied to the discriminator.

c. Discriminator V4. This circuit is tuned to 60 mc. Any deviation in frequency of the applied signal from this value will cause the discriminator to develop an output voltage pulse. The stage consists primarily of the the tuned secondary circuit of transformer T3 and dual-diode V4. When the frequency of the applied signal goes above 60 mc, the polarity of the output pulse is positive. When the i-f signal is exactly 60 mc, the discriminator does not produce an output signal. Also, when no input is applied to the discriminator, no output signal is developed. The latter condition will arise whenever the frequency of the i-f signal deviates so greatly from 60 mc that the signal lies outside the bandpass of the i-f preamplifiers, main i-f amplifiers, and i-f amplifiers V1, V2, and V3 of the missile AFC unit.

d. Cathode followers V6A, V7A, and video amplifier V6B. These stages amplify and invert the output of the discriminator and isolate the discriminator from the succeeding circuits. All three stages are biased to provide equal amplification to both positive and negative inputs. The output of this circuit is a series of pulses occurring at the pulse repetition frequency of the missile transmitter. The polarity and amplitude are determined by the frequency of the input to the AFC unit with respect to 60 mc. This output is applied to the gating circuit.

e. Receiver gate amplifier V5A and cathode follower V5B. Since all received signals within the 10-mc bandpass of the MTR receiver and input i-f amplifiers are able to enter the discriminator, other signals besides the missile beacon may cause the discriminator to have an output. It is necessary that only the missile beacon frequency affect the AFC unit output. This is done by using the receiver gate from the range error detector as a gating pulse. The positive 0.4-microsecond, 10-volt receiver gate is applied through a 0.1-microsecond L-C delay line to the receiver gate amplifier, V5A. This is necessary because at the immediate beginning of each pulse (even for zero error) of the discriminator output, a small positive pip appears. To avoid interpreting this pip as an error signal, the 0.1 microsecond delay is introduced into each gating pulse, preventing that pip from being

gated. Amplifier V5A amplifies and inverts these pulses and applies them to cathode follower V5B. This stage provides a large cathode current to drive the primary of a transformer in the gating circuit.

f. Gating and detecting circuit V8. The gating and detecting circuit prevents the missile AFC unit from having an output resulting from any signal other than the signal from the beacon which is gated in range and produces a d-c error from the video pulse input. The circuit consists of a transformer, a dual-diode, and a detecting capacitor. Neither half of V8 can conduct, except during the period of the receiver gate. At that time, one tube will conduct and charge the detecting capacitor to the level of the input video pulse from cathode follower V6B. Thus, the output of the gating circuit is a d-c level, determined by the level of the gated input pulse. This d-c level is applied to cathode follower V7B.

g. Cathode follower V7B. This stage applies the d-c level output of the gating circuit to the DC amplifier and integrator, without discharging the integrating capacitor.

h. DC amplifier and integrator V9 and amplifier V12. The output of cathode follower V7B is amplified and integrated by V9 and V12. This circuit holds the intermediate frequency extremely close to 60 mc. It provides instantaneous corrections in the local-oscillator frequency when an error signal is developed and, by integrating any small error that remains, corrects the local-oscillator frequency until it is almost exactly 60 mc above the frequency of the missile beacon. This keeps the output of the discriminator very close to zero at all times. Any momentary failure of the missile-tracking radar to receive pulses from the missile beacon then results in little change in the output of the AFC unit. The local oscillator continues to operate at essentially the same frequency until pulses are again received from the missile beacon.

i. Sweep generator V10 and regulator V11. Sweep generator V10 is a phantastron oscillator whose output is applied to the DC amplifier and integrator circuit during missile slew operation. This begins 0.4 second after burst ordered or 3 seconds after the missile is lost and continues until 3 seconds after the ATC unit again provides a ground for automatic tracking circuits. The output of the sweep generator is a negative-going sawtooth waveform, which causes the local oscillator to sweep through a restricted frequency range. This is necessary because successively fired missiles do not have exactly the same transmitted frequencies. Regulator V11 causes the output voltage of the sweep generator to vary above and below zero rather than about +50 volts.

61. DETAILED DISCUSSION (fig 6-6)

a. I-F amplifiers V1, V2, and V3. The input to these stages is a 60-mc signal output of the sum i-f amplifier. Actually the signal passes through a 750-ohm isolating resistor, R21, in the video and phase unit, rather than coming directly from the sum i-f amplifier. This permits interchangeability of the i-f amplifier chassis, without having a spare i-f output jack on the azimuth and elevation amplifiers. Amplifiers V1, V2, and V3 amplify the input to a level that permits operation of the discriminator (about 40 db of amplification). Air core transformers T1 and T2 provide interstage coupling. These transformers and interelectrode and distributed capacitance form circuits resonant at 60-mc and have a 10-mc bandpass due to loading of the resonant circuit by R4, R5, R9, and R10. The input circuit is also tuned to 60-mc by L1 and stray capacitance. Resistor R1 matches the impedance of V1 to the input 75-ohm cable. Operating bias is established by R2, R7, and R12, bypassed by C1, C3, and C5. Unbypassed cathode resistors R6 and R11 are necessary for the grid circuits of V2 and V3 to present an input grid impedance which permits transformers T1 and T2 to be of the same type as used in other i-f circuits of the Nike system. Networks Z1, Z2, and Z3, combined with capacitors C2, C4, C6, and C7, form decoupling circuits to prevent interaction between the stages. Networks Z1, Z2, and Z3 present a high impedance to 60-mc. However, they present a low impedance to the video envelope of the input signal. Resistor R62 and capacitor C34 eliminate the video pulses from the power supply. Inductors L2 through L5 and capacitors C29 through C33 decouple r-f components from the filament supply of V1 through V4, and thus prevent interaction between these stages. The output of V3 is applied to transformer T3 and to the junction of C9 and C10.

b. Discriminator V4.

(1) The primary of transformer T3 is broadly tuned by capacitor C8 to 60 mc. It is loosely coupled to the secondary and is so poled that the primary and secondary voltages are of opposite phase. The secondary circuit is tuned by slug tuning the secondary of the transformer to 60 mc. The input of the primary of T3 (E_1) is also applied to the junction of capacitors C9 and C10 in the secondary circuit of T3. Figure 23 has vector diagrams of these voltages. The signal at the plate of V4A (E_3) is the sum of E_1 and the voltage across capacitor C9. The signal at the plate of V4B (E_4) is the sum of E_1 and the voltage across capacitor C10. Since C9 and C10 are identical, the signal across each capacitor is equal to one-half the voltage developed across the resonant secondary circuit of transformer T3 (E_2). However, the voltage at the plate of V4A due to secondary current (I_s) through C9 must be of opposite

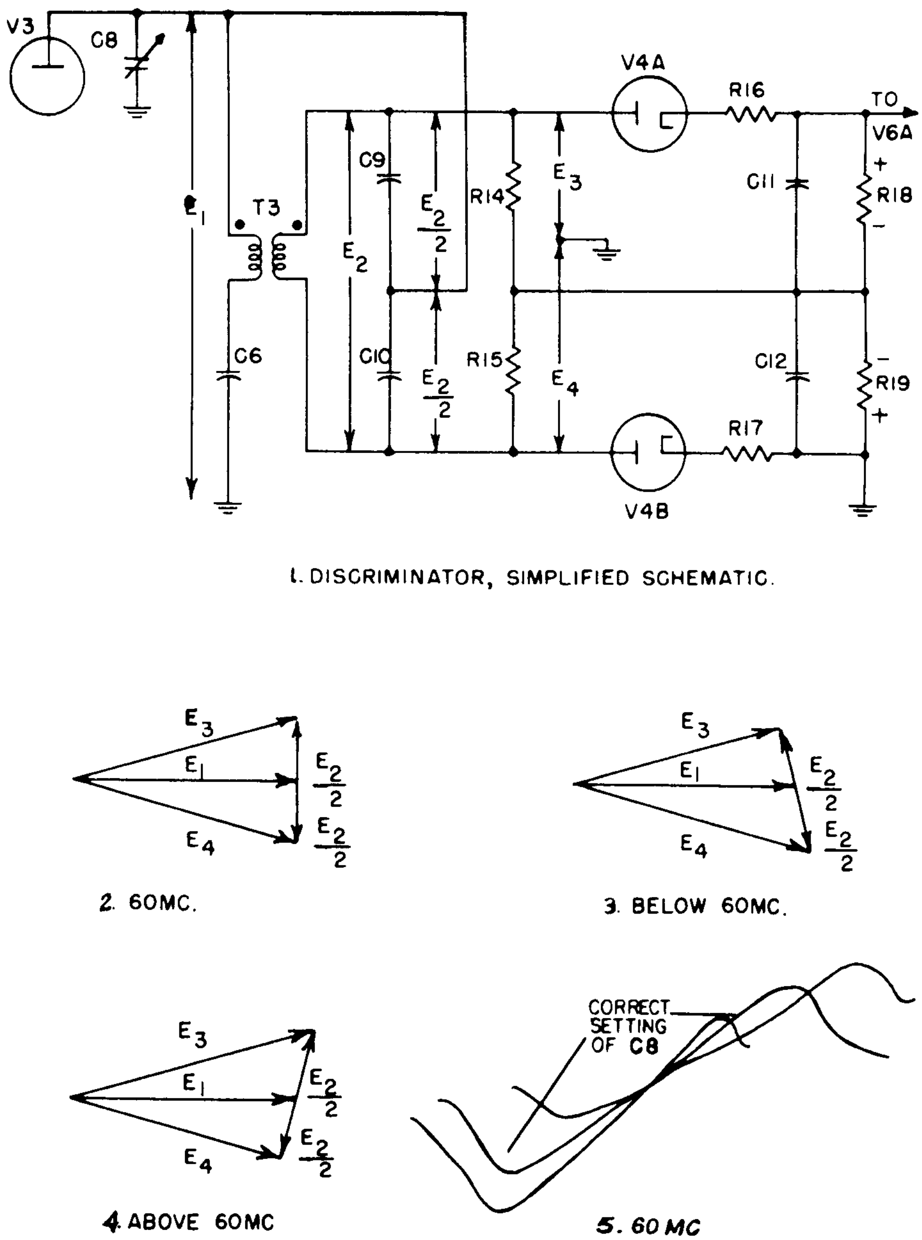


Figure 23. Missile automatic frequency control discriminator circuit, vector diagrams, and discriminator response for various settings of C8.

polarity to that of the voltage at the plate of V4B resulting from the secondary current through C10, since these two points are at opposite ends of the secondary of a transformer. Therefore:

$$E_3 = E_1 + \frac{E_2}{2}$$

$$E_4 = E_1 - \frac{E_2}{2}$$

(2) Consider first the case where the input frequency is 60 mc. In this case, the impedance of the secondary circuit of transformer T3, which is series resonant to 60 mc, appears purely resistive. Therefore, the current in the secondary (I_s) is in phase with the induced secondary voltage. The voltage across a capacitor always lags the current through it by 90° With this condition, the magnitude of E_3 and E_4 are equal, as illustrated by the vector sums $E_3 = E_1 + \frac{E_2}{2}$ and $E_4 = E_1 - \frac{E_2}{2}$ in figure 23b for the 60-mc condition. Stages V4A and V4B conduct equally and the discriminator has no output.

(3) If the input frequency is below 60 mc, the secondary circuit of transformer T3 appears slightly capacitive. In this case, the secondary current will lead the induced secondary voltage. Since the voltage across the two capacitors still lags the current by 90°, the vectors representing $+\frac{E_2}{2}$ and $-\frac{E_2}{2}$ are advanced in phase, relative to primary voltage E_1. This is shown in figure 23c. In this case, E_4 is greater than E_3. Stage V4B conducts more than V4A, producing a negative video pulse as the output of the discriminator.

(4) If the frequency of the input is above 60 mc, the secondary circuit appears slightly inductive. In this case, the opposite of the above discussion is true, E_3 is greater than E_4. Stage V4A conducts more than V4B, producing a positive video pulse as the output of the discriminator.

(5) The output of the discriminator is a positive or negative video pulse, or zero. The pulse amplitude is determined by the difference between the input frequency and 60 mc and the polarity is determined by the direction

of error. This is true within the 10-mc bandpass of the input i-f stages. This is illustrated in the amplitude vs frequency waveforms shown in figure 23e. However, if capacitor C8 is misadjusted, the response of the discriminator to frequencies above and below 60 mc is not equal. Capacitor C8 is factory adjusted to tune the primary of transformer T3 to 60 mc.

c. Cathode followers V6A and V7A and video amplifier V6B. The output of the discriminator is coupled directly to the grid of cathode follower V6A. This cathode follower prevents loading the discriminator, acting to isolate the discriminator from video amplifier V6B. The output of V6A is coupled through capacitor C13 to the grid of V6B. Returning the grid resistor to the cathode circuit provides the desired degeneration for equal amplification of both positive and negative inputs. Tube V6B amplifies and inverts the input and its output is coupled through capacitor C14 to the grid of cathode follower V7A. The grid resistor is returned to the cathode circuit for the same purpose as in V6B. This stage provides less than unity gain, but is able to supply a high-power pulse to the circuit of transformer T4. These three stages amplify and invert the output of the discriminator, isolating it from the gating circuit. The output is coupled through capacitor C15 and developed across resistor R32 for application to the gating circuit.

d. Receiver gate amplifier V5A and cathode follower V5B.

(1) The input at jack J3 is the receiver gate pulse which occurs at a time determined by the range setting of the radar. This 0.4-microsecond, 10-volt pulse from the range error detector is applied to a network consisting of inductors L6 through L8 and capacitors C36 through C38. This network produces a 0.1-microsecond delay. The leading edge of the discriminator output contains a positive pip which should not be interpreted as a frequency error. The delay introduced into the receiver gate prevents gating the leading edge of the discriminator output in the gating circuit.

(2) The output of the delay line is applied to resistors R65 and R26, which match the input impedance of receiver gate amplifier V5A to the impedance of the coaxial cable. Tube V5A amplifies and inverts the pulse. The output of the amplifier is coupled through capacitor C16 to cathode follower V5B. The output of the cathode follower is a negative 30-volt pulse, which is enough to drive the primary of transformer T4 in the gating circuit. This pulse allows only the output of the discriminator which is coincident in time with this pulse to affect circuits which follow.

e. Gating and detecting circuit V8.

(1) This circuit has two inputs; the 30-volt gating pulse from cathode follower V5B to the primary of transformer T4, and the video pulse from cathode follower V7A to the centertap of the secondary of T4. The output is a d-c level determined by the amplitude of the gated video input. Transformer T4 is poled so that during the gating period, a negative pulse is applied to the cathode of V8A and a positive pulse is applied to the plate of V8B. At this time, a video pulse, positive or negative as determined by the discriminator output, is applied to both the cathode of V8A and the plate of V8B. The plate of V8A and cathode of V8B are both tied to an integrating capacitor, C20. Either V8A or V8B will conduct at this time and capacitor C20 will charge to the level of amplitude of the input video pulse. If the input i-f signal has a frequency of 60 mc, the discriminator will have no output and the gating circuit will have no video input. In this case, both V8A and V8B will conduct slightly, but C20 will accumulate no charge.

(2) During the gating period, C18 and C19 charge to the level of voltage drop across R30 and R31. The discharge of these capacitors through R30 and R31 prevents V8A and V8B from conducting during the period between gating pulses.

f. Cathode follower V7B. Cathode follower V7B prevents the discharge of capacitor C20 by the d-c amplifier and integrator. The grid of V7B is tied directly to C20. The plate current at V7B passes from -250 volts through R35, R34, R33, and V7B to +150 volts. Tying this circuit between a negative and positive potential permits the output of this stage to vary above and below zero volts. AMP INPUT potentiometer R34 is adjusted to establish zero volts at the output, monitored at TP2, when there is no video input to the gating circuit. The output of cathode follower V7B is a d-c level determined by the difference between the input i-f frequency and 60 mc.

g. DC amplifier, integrator V9, and amplifier V12.

(1) The Nike I system relies upon the input from the missile beacon to adjust the local-oscillator frequency. The output of the AFC unit must be a d-c level which causes the local-oscillator frequency to be 60 mc above the beacon frequency. However, a certain number of pulses may not be received from the missile. This may be caused by malfunctions in the missile receiving, decoding, or transmitting systems; malfunctions in the missile-tracking radar transmitting or receiving systems; atmospheric conditions; flight angle of the missile with respect to the radar; or any number of uncontrolled variables. With no input, the discriminator

is designed to have no output. If the DC amplifier and integrator were not in the circuit, this could cause the radar to lose the missile when a few pulses are missed. For example, consider a missile which requires the local oscillator to be at a frequency 20 mc above the frequency established by zero output of the AFC unit. If several pulses were missed from the missile, the output of the AFC unit would drop to zero. When pulses reappear, the local oscillator would be 20 mc too low, out of the bandpass of the receiver. The missile could not be retracked and would explode after a few seconds.

(2) To prevent this situation, the integrating circuit within the DC amplifier prevents the output from going to zero immediately, even though the input drops to zero. However, actual changes of beacon frequency must be followed. Therefore, the output of the DC amplifier must be a function of the input signal, as well as the average value of the input. When a few pulses are missed, it is desirable to keep the output of the circuit relatively constant, even though the input drops to zero. To do this, the gain of the DC amplifier is made extremely large to a constant d-c input, although low for higher frequencies. A very small voltage input will give the desired output. Thus, a fraction of a volt at the input of the DC amplifier will keep the local-oscillator frequency 20 mc above the center frequency as in the example above. When a few pulses are missed, the input drops from a fraction of a volt to zero and the integrating network causes the output to remain relatively constant, while the integrating network charges to a new level. The drop has little effect, since it consists of high-frequency components, which are amplified little by the DC amplifier.

(3) The DC amplifier and integrator should have a gain characteristic curve which is very high at zero frequency and drops off rapidly at low frequencies; then remaining relatively constant over the range of operation, the gain must drop off at higher frequencies to prevent oscillation. This characteristic curve is established by capacitors C21 and C23 in conjunction with resistors R37 and R39 (fig 24c).

(4) A positive d-c voltage at the grid (pin 6) of V9 increases the conduction of that stage. This produces a positive voltage on the common cathode, decreasing conduction in the other half of V9. Thus, the voltage at the plate (pin 1) of V9 increases, increasing the potential at the grid (pin 1) of V12. This causes a negative voltage at the plate of V12, the output of the AFC unit. The cathode of V12 is returned to -150 volts, established by regulator V11, permitting the plate signal to vary both postively and negatively about zero volts.

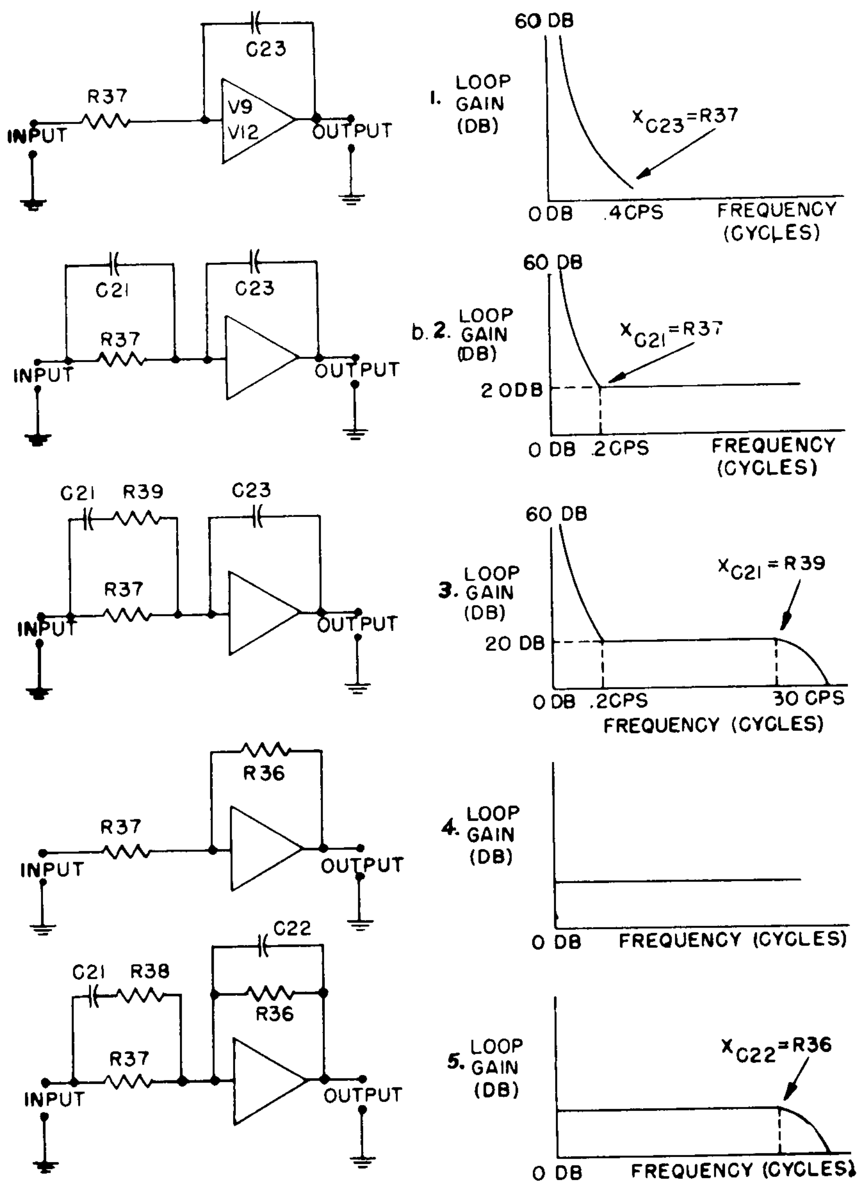


Figure 24. Missile AFC frequency curves of feedback loop.

(5) The gain of this circuit decreases as the frequency of the input increases, because of the decreasing reactance of C23, and thus increasing the amount of degenerative feedback. The gain of a d-c level is highest, since no feedback can pass the capacitor. The gain decreases rapidly as the frequency increases from 0 to 0.2 cycle per second (fig 24a). At 0.2 cycle per second, the impedance of the feedback network is approximately equal to the input impedance of the input network. As the frequency of the input continues to increase, the gain of the circuit becomes relatively constant. This is true because the output amplitude is a function of the product of the input amplitude and the ratio of the feedback impedance to the input impedance. The reactance of C23 is the feedback impedance. The predominant factor in the input impedance network from 0.2 to approximately 30 cycles per second is the reactance of C21. Therefore, the gain of the circuit is predominantly a function of the ratio of the reactances of C23 and C21, which is constant (fig 24b). At approximately 30 cycles per second, the reactance of C21 is approximately equal to the resistance of R39 in series with C21. As the frequency of the input continues to rise, the feedback impedance continues to decrease, increasing the feedback signal. However, the impedance of the input remains relatively constant, since R39 is then the predominant factor of the input impedance (fig 24c). In this manner, the gain of the d-c amplifier and integrator is determined by frequency-selective networks. The gain is approximately 60 db at zero cycles per second, drops to 20 db at 0.2 cycle per second, remaining relatively constant from 0.2 to approximately 30 cycles per second, and dropping off rapidly for frequencies above 30 cycles per second.

(6) Capacitor C22 and resistor R38 have little effect in this configuration because of their high resistance and reactance with respect to the circuits they parallel. Action of this circuit with K1 energized will be discussed in paragraph 58.

(7) The voltage divider network consisting of R42 through R46 in the grid (pin 3) circuit of V9 establishes the potential of that grid. AFC ZERO potentiometer R44 is adjusted to establish zero volts at the output of the AFC unit, monitored at TP1, when the input to the DC amplifier is zero by placing switch S1 in the AFC ZERO position.

(8) The network between the plate (pin 1) of V9 and the grid (pin 1) of V12 produces a slight phase shift, which is necessary to prevent a tendency of the circuit to go into oscillation at higher frequencies.

(9) The output of the DC amplifier is the output of the AFC unit and is a d-c voltage determined by the frequency of the input i-f signal to the AFC unit. This output is positive for an input frequency above 60 mc and negative for an input frequency below 60 mc. The output is applied to a voltage divider in the test panel before application to the repeller plate of the local-oscillator tube.

h. Sweep generator V10 and regulator V11.

(1) When the radar is slewed to a new missile, it is necessary to sweep through a portion of the frequency range of the local oscillator to determine and lock onto the frequency of the new missile. This sweeping is done by phantastron oscillator V10. The operation of this stage is similar to the operation of phantastron oscillator V7 in the target AFC unit. The phantastron of the target AFC unit uses the series of pulses from its screen grid as its output. The phantastron of the missile AFC unit uses the negative-going sawtooth waveform from its plate as its output.

(2) This stage is allowed to oscillate when relay K1 energizes, applying plate voltage to the tube. Relay K1 is energized by contacts 1, 5, and 9 of relay K6, the launcher acquisition control relay, applying ground through closed contacts 6 and 11 of remote control relay K1. Relay K6 is energized as the result of slew control relay K5 of the missile slew control unit being energized. These relays energize 0.4 second after the missile bursts or 3 seconds after the missile is lost and remain energized for 3 seconds after the automatic tracking unit indicates the missile is tracked. Phantastron oscillator V10 oscillates, producing a sawtooth output for this period of time. Relay K1 may also be energized by closing BO SWEEP switch S2. This switch is used for checking the operation of V10 and to force the unit to drive the local oscillator through its search range.

(3) The signal output from the plate of V10 is a negative-going sawtooth, dropping from +90 volts to +10 volts in 1.75 seconds, with 0.25 second required for recovery of the circuit. However, a signal varying from +90 volts to +10 volts applied to the grid (pin 6) of V9 would not sweep above and below the center frequency of the local oscillator. A signal voltage varying above and below zero is more desirable. Therefore, the signal is applied through a resistance network to a regulated -150-volt supply. This voltage is established by current flow from -250 volts through R59 through V11 to ground. A 150-volt potential is always dropped across an 0A2-type regulator tube such as V11, unless

the circuit is excessively or inadequately loaded. Thus, a signal varying between approximately plus and minus 40 volts is applied to the DC amplifier. This will produce a signal at the output of the AFC unit which will produce a plus and minus 20-mc variation of local-oscillator frequency about its center frequency.

(4) It is desirable, while sweeping, to eliminate the sudden drop in gain of the DC amplifier from 0 to 0.2 cycle per second. Therefore, C23 is removed from the feedback circuit and replaced by resistor R36, thus giving a flat gain response for frequencies from 0 to 20 cycles per second (fig 24d). At approximately 20 cycles per second, the reactance of capacitor C22, in parallel with R36, is about equal to the resistance of R36. For frequencies above 20 cycles per second, the gain drops off rapidly, since the reactance of C22 is lower, increasing the feedback signal (fig 24e).

(5) As the AFC unit output causes the local oscillator to sweep through the 40-mc band, it reaches the frequency 60 mc above the missile-beacon frequency. At this time, a signal is fed through the discriminator, producing a d-c voltage which is applied to the DC amplifier. This signal will oppose the sweep voltage. This signal is large enough to reduce the sweep output of the AFC unit from a value which will cause a plus and minus 20-mc variation of local-oscillator frequency for an open loop (no feedback) to a value which will cause a variation of plus and minus 2 mc per second for a closed loop (with feedback).

(6) For a brief period (3 seconds), both the sweep voltage and discriminator voltage appear at the input of the DC amplifier and integrator. Therefore, the input network must remain in the circuit while sweeping. Resistor R38 prevents capacitor C21 from affecting the gain of the DC amplifier, when using the sweep-generator output.

i. Output distribution. The output of the missile AFC unit is applied through a section of switch S8 (fig 25) of the test panel to a resistor network. Each position of the switch allows the local oscillator to be tuned over a 40-mc frequency range by the output of the missile AFC unit. The center frequency of this 40-mc frequency range is established by the adjustment of R20 and R12, R19 and R9, or R21 and R13. The first resistor in each case establishes the voltage range over which the varying output of the missile AFC unit may vary the repeller plate voltage. The second resistor establishes the space between buncher grids by fixing a certain tuner-grid potential. Successive lots of missiles will have different beacon frequencies. To permit rapid transition from one frequency range to another during an operation, three sets of frequency ranges are preset by use

of the previously mentioned potentiometers. When shifting from one lot of missiles to another, only the switch needs to be changed.

j. Dual site restrictions on frequencies. Operational requirements encountered on dual sites have caused higher command to prescribe that at dual battery sites, one battery use the upper half of the frequency band and the other battery use the lower half, with a guard band of 200 mc maintained between the two halves of the band. The frequency of the missile magnetrons will be placed within this guard band. The missile-tracking radar transmitter and receiver frequencies must be separated by an amount sufficient to prevent large amounts of ground clutter from entering the receiver. To meet this requirement, the missile-tracking radar transmitter frequency must be kept more than 60 megacycles below or more than 180 megacycles above the missile-tracking radar receiver frequency. Since the missile-tracking radar receiver must be adjusted to the same frequency as the missile beacon, the frequency region in which the missile-tracking radar transmitter may be permitted to operate depends upon the frequency to which the missile beacon magnetron is set. In answer to these dual site restrictions, r-f receiver filters are to be incorporated as a part of the Nike I missile, so that the missile receiver r-f bandwidth will be only 50 megacycles. There will be five different filters, with their center frequencies at five different points in the X-band. The combination of filters with the 6 missile codes will make a total of 30 usable missile codes available. When the filters are incorporated, the missile-tracking radar transmitter must be adjusted to the center frequency of the filters in the missile being used by the particular battery. Since the missile-tracking radar transmitter will have to be tuned to the center frequency of the missile filter and the missile-tracking radar receiver will have to be tuned to

Table III.

Missile-tracking radar transmitting and receiving frequencies.

Filter center frequency and MTR transmitter frequency	Allowable missile beacon magnetron frequencies and MTR receiver frequencies
8,550 mc	8,900 to 9,400 mc
8,800 mc	8,900 to 9,400 mc
9,050 mc	9,110 to 9,400 mc
9,300 mc	8,900 to 9,120 mc
9,550 mc	8,900 to 9,370 mc

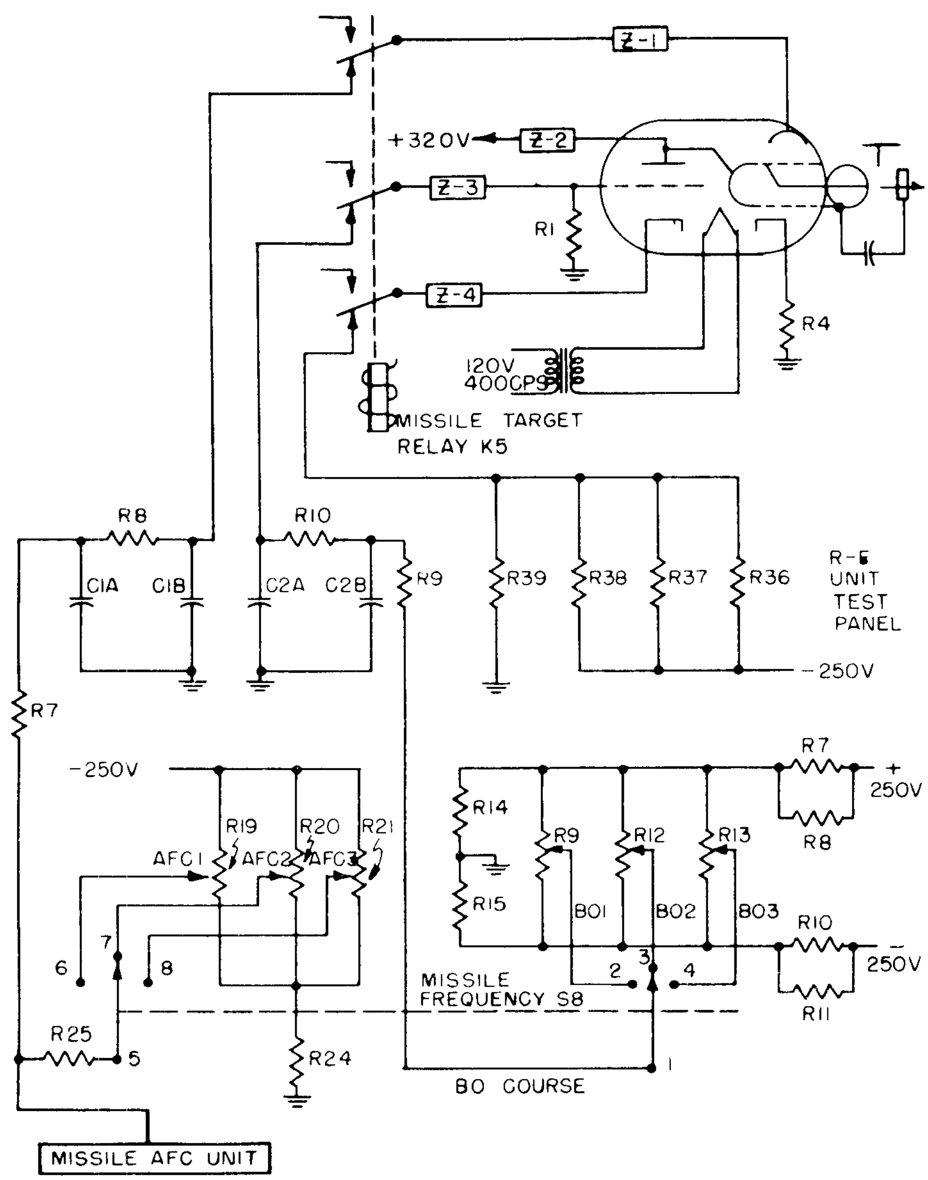


Figure 25. Missile local oscillator, simplified schematic.

the same frequency as the missile beacon magnetron, a specification of the frequencies of the missile receiver and beacon will also specify the frequencies of the missile-tracking radar transmitter and receiver. Table III shows the missile filter center frequencies (which are the missile-tracking radar transmitter frequencies) and the corresponding allowable missile beacon frequencies (which are the missile-tracking radar receiver frequencies). When receiver filter has been incorporated in the missile, the missile beacon magnetron frequency must be restricted to the corresponding range shown in the above table, but may be anywhere within that range.

Section V. MTR RANGE, AZIMUTH, AND ELEVATION SERVO SYSTEM BLOCK DIAGRAM

62. INTRODUCTION

The computer must have smooth and accurate data concerning the position in space of both the target and the missile so that it can compute the control commands to be sent to the missile. The target- and missile-tracking radars, respectively, can supply such data to the computer. If slow or inaccurate missile position data is sent from the missile-tracking radar to the computer, the effectiveness of the entire Nike battery is greatly reduced. The radar range, azimuth, and elevation servo systems are necessary to acquire and transmit this position data, but they can also be a source of inaccurate or slow information. These servo systems were designed to provide the smooth and accurate data required almost immediately, but will do so only if they are properly adjusted and maintained. These servo systems employ both electrical and mechanical principles. The components of the systems are widely separated and need extensive circuitry to connect them. A thorough knowledge of these components and their circuitry is necessary to troubleshoot the servo systems.

63. OVER-ALL PURPOSE

The missile-tracking radar's range, azimuth, and elevation servo systems drive the range unit in range and the missile-tracking radar antenna in azimuth and elevation in accordance with signals obtained from the automatic tracking circuits. During testing or alinement operations, these servo systems may drive the range unit and the antenna in accordance with signals manually applied to the handwheel assemblies, to the range slew control unit, to the launcher acquire circuitry, or to the antenna control unit.

64. RANGE UNIT ASSEMBLY, BLOCK DIAGRAM

a. Composition. The missile-tracking radar range unit assembly is identical to the target-tracking radar range unit assembly. It is located in the lower left hand side of the radar range and receiver cabinet. The range unit assembly consists of two main components, the timing wave generator and the range mark generator (as found in the previous study of the target-tracking range unit). Details of this circuitry may be found in TM 9-5000-19. For complete explanation of the circuits, use this reference.

b. Functional description. The block diagram of the range unit is found on page 127 of TM 9-5000-25. There are switching provisions to use the SYNC pulse for normal operation triggering of the range unit. This switching arrangement provides for the use of the PREKNOCK pulse for triggering of the range unit for special purpose applications.

c. Selective pulse triggering.

(1) To remove that component of range zero drift caused by changes in the delay between preknock and the transmitted pulse, the transmitted pulse triggers the range unit. The transmitted pulse itself is not conveniently available, but the current pulse from the 5C22 thyratron modulator tube is brought out on a jack (TP1) on the high-voltage modulator, so this pulse is used.

(2) It should be clearly understood that this change does not hold the interval between the two transmitted pulses in the missile-tracking radar constant. This coding interval is as free to drift as it has been previously. Drift in this coding interval will not cause a direct range zero error, but it will cause an indirect error because it changes the response time of the missile. This effect is greater at longer ranges, so it cannot be readily detected when the missile is on the launcher. A large enough error in code spacing will cause loss of the missile at long ranges. For these reasons, it should not be thought that this change will remove the necessity for checking range zero and code spacing in the missile-tracking radar.

(3) When the thyratron current pulse is used to trigger the timing wave generator, the minimum theoretical range to which a target can be tracked is about 2,250 yards. This can be understood more readily by referring to TM 9-5000-25, page 127, waveforms. The track range mark occurs 2,000 yards after the first selected pip, and is selected

by a gate which is generated by the first selected pip. If there is no first selected pip, there is no gate and thus no track range mark. If the first pip is being generated by the thyratron current pulse, it cannot occur before the thyratron current pulse, so the closest approach the track range mark can make to zero range is 2,000 yards. The received signal is centered in a 500-yard gate, which is generated by the track range mark, so the closest a received signal can get to zero range is 2,250 yards, even neglecting the effects of the starting transients in the timing wave generator.

(4) There is an additional factor which will restrict the minimum range to which the radar can track. This is the operation of the phantastron delay circuit. A phantastron's delay versus control voltage is quite linear when the delay is long enough. For small delays, the linear relation no longer holds. In the case where the target is at 2,250 yards, if the thyratron current pulse is used to trigger the phantastron, the latter would have to have zero delay, and even then the first selected pip would be falling out of the gate. For this reason, the preknock pulse is retained in the range unit to trigger the phantastron. This relieves the phantastron of the necessity of going down to very short delays. Now, when the preknock-to-transmitted pulse interval drifts, it shifts the positions of the gates slightly with respect to the timing pips, but does not shift the timing pips relative to the transmitted pulse, and thus does not change zero range.

(5) Only the timing wave generator waveforms are different from those in the unmodified range unit.

65. CIRCUIT OPERATION

a. Difference between range units. The missile-tracking radar must be able to track a missile on the launcher, and the minimum distance between the missile-tracking radar and the launcher is 1,000 yards. The theoretical minimum range of 2,250 yards is therefore not acceptable. The solution to this is found in the fact that the 5,000-yard gate for the precision indicator is not needed in the missile-tracking radar. Another range limitation on siting is that the minimum separation of the launching control trailer and missile-tracking radar must be 850 yards (not considering the inherent delay in the test responder of approximately 100 yards (thus the minimum may be 750 yards). It can be seen that the range unit of the missile-tracking radar can be made different from that in the target-tracking radar.

b. First selected pip. If the first selected pip instead of the second is used as the track range mark, the latter can theoretically go down to zero yards, and a target can be tracked to a theoretical minimum range of 250 yards. The waveforms in the missile-tracking radar with this circuit change are shown in 2x, page 127.1. When the first selected pip instead of the second is used, an additional step must be taken for the range unit to give the correct range. Notice at the bottom of figure 8-2.1 that the 500-yard expanded area has been moved in by 2,000 yards. The reading on the dials when the radar is locked on a target will thus be 2,000 yards too great. This anomaly comes about because the first selected pip is not the correct pip. This is corrected by adjusting the ZERO control on the phantastron until the first selector gate surrounds the correct pip; the one which used to be the second selected pip. When this is done, the waveforms will be as illustrated and the range dials will give the correct reading.

66. RANGE SERVO SYSTEM BLOCK DIAGRAM (fig 15-2)

a. General. The missile-tracking radar tracks the missile in range with its ranging system. The range servo circuits in this ranging system:

(1) Drive the missile-tracking radar range unit phase capacitor and selector potentiometer in accordance with error data from the range modulator (or from the handwheel drive during testing procedures).

(2) Automatically and rapidly slew to the range of the next designated launcher.

(3) Provide missile slant range data, up to 55,000 yards, to the computer.

(4) Provide missile slant range information for the dials on the missile-tracking console track range indicator.

(5) Provide for manual range slewing.

Although this system can track in automatic, manual, and manual-aided modes, the automatic mode must be used during missile-target engagement. The other two modes are only for testing. For this reason, whenever the TEST-OPERATE switch on the missile-tracking radar control drawer is in the OPERATE position, the range system will be in the automatic mode of operation, regardless of the position of the range MAN-AID-AUTO switch.

b. Automatic mode.

(1) In automatic operation, the control signals are generated by the range modulator and applied to low-power servoamplifier number 3 through the contacts of deenergized range man-aid relay K12. The output of the low-power servoamplifier drives the servo drive motor which rotates the phase capacitor by mechanical linkages. A velocity-feedback signal is generated by the tachometer associated with the servo drive motor and is fed back to the input of the low-power servoamplifier to stabilize the servo loop.

(2) The circuitry of the automatic coarse and fine slewing systems and the operation of the slew motor are discussed in chapter 5. These circuits provide for automatic slewing to the range of the next designated launcher after burst or in case of a lost missile. Four-tenths second after burst ordered, the slew circuitry provides this automatic range slewing. In case the missile beacon is lost for a short time, tracking operation continues through the range 3-second coast feature. In that case, the range modulator produces, as an output, the charge on its coast capacitors, C2 and C3. This charge is established by the last range information received from the missile. After the 3-second coast, the slew circuitry causes automatic slewing to the range of the next designated launcher, if the system has not again locked on the lost missile.

c. Manual mode (fig 15-1). In manual operation, the control signals are generated by the handwheel drive. The tachometer in the handwheel drive generates a 400-cycle signal, whose amplitude is proportional to the rate at which the handwheel is turned and whose phase angle (with respect to motor excitation) is dependent upon the direction of rotation of the handwheel. This signal is fed through the contacts of energized range man-aid relay K12 to low-power servoamplifier number 3. The output of the low-power servoamplifier drives the servo drive motor-tachometer which, in turn, positions the phase capacitor and provides a velocity feedback signal as an input to the low-power servoamplifier, just as is done in the automatic mode. Manual slewing has been provided and will be discussed in paragraph 76.

d. Manual-aided mode. In manual-aided operation, the control signals are again generated in the range handwheel drive. However, in the manual-aided mode, the arm of the rate potentiometer is positioned through an engaged magnetic clutch and a mechanical linkage to the handwheel. The 400-cycle signal picked off by the rate potentiometer arm is the primary control signal. When

the arm of the potentiometer is centered, zero voltage is picked off. The arm is centered by springs whenever the clutch is disengaged. Approximately six revolutions of the handwheel are required to move the arm from the center position to either end, depending on the direction of rotation of the handwheel. The ends of the potentiometer have 6.3-volt a-c potentials of opposite phase. Therefore, the amplitude of the signal of the potentiometer arm depends upon the number of handwheel revolutions and its phase depends on the position of the potentiometer arm with reference to its center position. One volt of this control voltage causes about 105 yards per second change in range. The maximum aided rate is about 650 yards per second. The control voltage from the rate potentiometer arm is fed through the contacts of energized range man-aid relay K12 to low-power servoamplifier number 3. During rotation of the handwheel, a signal will also be generated by the handwheel drive tachometer and applied to a low-power servoamplifier number 3, as in manual mode. If the handwheel is turned over six revolutions, the potentiometer arm hits a stop, the magnetic clutch slips, and the handwheel can be rotated continuously, permitting the signal from the handwheel drive tachometer to be varied, as in the manual mode. Therefore, this tachometer signal is proportional to the acceleration of the range handwheel and is called the second derivative control signal. It is added to the rate potentiometer control signal at the input to low-power servoamplifier number 3. The output of low-power servoamplifier number 3 drives the servo drive motor-tachometer, which, in turn, positions the phase capacitor and provides a velocity feedback signal to the input to servoamplifier number 3, as is done in the automatic mode.

e. Missile range indication (fig 8-3). A dual-speed synchro chain links the range unit assembly with the dials on the missile range indicator. The rotors of coarse data, 100,000-yard synchro transmitter B2 and of fine data, 2,000-yard synchro transmitter B4 are geared to the shaft of the range servomotor. The stators of these synchro transmitters are connected to the stators of corresponding missile range indicator coarse data synchro transformer B1 and synchro transformer B2, the rotors of which are connected to the range dials. In addition, another set of coarse and fine range dials are on the range unit and are geared to the shaft of the selector potentiometer R19 in the timing wave generator. Provision is made for transmitting the dual-speed range synchro data signals to any remote point where missile range information is desired.

f. Missile slant range data supply for the computer. The arm of range data potentiometer R1 is geared to the shaft of the range servomotor. The arm rotates at a rate corresponding to 128,000.3 or 42,666.7 yards per revolution. The potentiometer has a 2½-turn spiral card (100,000 yards per 2 11/32 revolutions), one end of which is connected to +106.7 volts and the other end, to ground. This voltage is so applied that the potential on the potentiometer

arm becomes more positive as the range increases. The potentiometer arm supplies the computer with missile slant range data. The scale factor is 1 millivolt per yard. A more detailed discussion of this potentiometer is given in TM 9-5000-14.

67. RANGE SERVO SYSTEM, DETAILED DISCUSSION

a. Automatic mode (TM 9-5000-25, fig 15-2 and sheet 43). For automatic operation, TEST-OPERATE switch S1 is in the OPERATE position and range MAN-AID-AUTO switch S10 may be in any position. (Note that regardless of the position of S1, placing S10 in auto will also prepare the system for automatic operation.) Coast relay K1 in the range modulator must be energized for normal operation of the modulator. Therefore, either ATC relay K3 must be energized or disable switch S2 must be in disable. In automatic range tracking, only the range modulator error voltage is coupled through contacts 1 and 9 of deenergized range MAN-AID relay K12 and coupling unit resistor R1 to low-power servoamplifier number 3. The amplified 400-cycle control voltage from this amplifier is applied to the control winding of the range servo drive motor B1. This motor has another stator winding, spaced 90 electrical degrees from the control winding and carrying a 400-cycle fixed amplitude motor-excitation voltage which is 90° out of phase with the control voltage. Rotation of the motor drives the gearing assembly of the range unit, as shown on page 129 of 2x. The torque of the motor is roughly proportional to the applied control voltage. Tachometer B1, an induction generator, is on a common shaft with the motor. Therefore, as the motor rotor rotates, the tachometer rotor rotates. One tachometer stator has 400-cycle, fixed amplitude, tachometer-excitation voltage. Spaced 90 electrical degrees from this stator is the output stator. When the tachometer rotor is driven, a 400-cycle velocity feedback signal is induced in the output stator which is proportional to the rotor speed. Phase potentiometer R1, in series with the tachometer-excitation winding, corrects the phase of the feedback voltage so that it is exactly 180° out of phase with the control signal. (Since the impedance of the tachometer-excitation winding is inductive, the excitation current will lag the excitation voltage. Inserting a resistance in series with this winding will reduce the lag, thus advancing the phase of the generated voltage.) The velocity-feedback voltage is applied across coupling unit load resistor R4. The signal developed across R4 is applied to low-power servoamplifier number 3 through coupling resistor R3. Therefore, in automatic tracking, the phase capacitor is rotated at a rate roughly proportional to the amplitude of the error voltage output of the range modulator, the direction of rotation being such as to minimize the error.

b. Manual mode.

(1) For manual operation, TEST-OPERATE switch S1 must be in TEST position and range MAN-AID-AUTO switch S10, in MAN position. Relays K12, range MAN-AID, and K2, DISABLE, and magnetic clutch coil L1 are thereby energized. Turning the range handwheel mechanically turns the rotors of range handwheel drive motor B1 and tachometer B1, which are coupled mechanically and have the same theory of operation as servo drive motor-tachometer B1. A 400-cycle error signal will be generated in the output winding of tachometer B1. This signal's amplitude is proportional to the rate of rotation of the handwheel and its phase angle is proportional to the motor excitation voltage which is +90° or -90°, depending on the direction of handwheel rotation. Phase potentiometer R2, in series with the tachometer-excitation winding of handwheel drive tachometer B1, zeroes the phase angle between the tachometer excitation voltage and the generated voltage. This potentiometer operates on the same theory as phase potentiometer R1, in series with servo drive tachometer B1 excitation winding, which was described in paragraph 66. Only a control signal appearing between terminal 7 of tachometer B1 and ground, or from the rate potentiometer could pass through the contacts of energized range MAN-AID relay K12. However, magnetic clutch coil L1 is energized and therefore, the clutch is disengaged and the RATE potentiometer arm is centered by springs, so no error signal is picked off. Further, the circuit from the rate potentiometer to the servo drive motor is opened when the range MAN-AID-AUTO switch is in MAN. Therefore, only the control signal from range handwheel drive tachometer B1 is passed through load resistor R8 in the coupling unit. The signal developed across R8 is coupled through resistor R7 to the low-power servoamplifier number 3. The amplified voltage is then applied to servo drive motor B1. The rotor of the motor, the phase capacitor, and servo drive tachometer B1 are all rotated, as in the automatic mode. A velocity feedback voltage generated in this tachometer is coupled through resistor R3 to the input of low-power servoamplifier number 3, again as in the automatic mode. Phase potentiometer R1 has the same function as in the automatic mode.

(2) A phenomenon called "creep" is inherent in this servo system and is caused by the small voltage induced in the output winding of handwheel drive tachometer B1 when the rotor is stationary. This induced voltage is amplified enough to slowly drive servo drive motor-tachometer B1 and, therefore, the phase capacitor, even though the handwheel is stationary. Creep in this system is eliminated by nullifying the induced

voltage with enough 400-cycle voltage of the opposite phase, applied in series with the output winding of the tachometer. Balance potentiometer R4 is connected across the secondary winding of transformer T1, the centertap of which is grounded. The ends of this winding have a 6.3-volt potential of opposite phase and the center, a zero potential. Resistors R1, R4, and R5 make up a voltage divider to reduce the compensating voltage to the proper value. Potentiometer R4 also allows choice of the proper phase. The voltage applied at the junction of R1 and R5 is the nullifying voltage required to eliminate creep.

(3) Since range modulator DISABLE relay K2 is energized, the signals from the range error detector and those on the COAST capacitors are shorted through missile slew control resistor R26.

c. Manual-aided mode.

(1) For manual-aided operation, the TEST-OPERATE switch must be in TEST position and range MAN-AID-AUTO switch S19 must be in AID position. Relays K12, range MAN-AID, and K2, range modulator DISABLE, are thereby energized, maintaining the necessary circuitry for flow of the 400-cycle manual error signal from handwheel drive tachometer B1 to servo drive motor-tachometer B1. Magnetic clutch coil L1 is deenergized, engaging the clutch and mechanically coupling the RATE potentiometer arm to the handwheel. This potentiometer arm will be positioned as described in paragraph 69. The 6.3-volt potentials of opposite phase at either end of rate potentiometer R3 are provided in the same manner as the voltage on balance potentiometer R4. Balance potentiometer R4, handwheel drive phase potentiometer R2, and servo drive phase potentiometer R1 have the same functions as in the manual mode. The 400-cycle error signal on the RATE potentiometer arm is the primary control voltage. Its amplitude depends on the number of handwheel rotations and its phase depends on the position of the RATE potentiometer arm with reference to its center position. This signal is coupled through contacts of switch S10, contacts 4 and 10 of energized range MAN-AID relay K12, contacts 4 and 10 of deenergized CALIBRATE relay K11, and coupling resistor R2.

(2) During rotation of the handwheel, an error signal is generated in handwheel drive tachometer B1, just as in the manual mode. Since the magnetic clutch slips after the rate potentiometer arm has reached either limit, there is no limit to the number of handwheel rotations. The amplitude of this signal depends upon the speed of handwheel rotation. This

error signal is called the second derivative control signal because its amplitude varies with acceleration of handwheel rotation. The second derivative signal is applied through the coupling unit in the same manner as in the manual mode.

(3) The RATE potentiometer error signal and the second derivative signal, if any, are combined in the coupling unit, and this combined signal is applied to the input of low-power servoamplifier number 3. The amplified control signal is applied to servo drive motor B1, rotating the motor, the phase capacitor, and servo drive tachometer B1, as in the automatic and manual modes of operation. A velocity feedback voltage is generated in this tachometer and coupled through coupling resistor R3 to the input of low-power servoamplifier number 3, again as in the automatic and manual modes.

68. ANTENNA POSITIONING SYSTEM BLOCK DIAGRAM (figs 16-1, 16-2, 16-4, and 16-5).

a. General. The missile-tracking radar antenna is moved in azimuth and in elevation by the antenna positioning system. The servo circuits in this antenna positioning system:

(1) Drive the missile-tracking antenna 6,400 mils in azimuth and between -200 and +1,590 mils in elevation, in accordance with steering signals from the angle modulators (or from the handwheel drive during testing procedures). In testing, the antenna positioning system drives the antenna in elevation between -200 and +3,380 mils.

(2) Slew the antenna automatically to the azimuth and elevation of the next designated launcher.

(3) Provide missile position data to the computer.

(4) Provide missile azimuth and elevation data to the missile indicator panel dials on the missile console. Although this system can track in the automatic, manual, and manual-aided modes, the automatic mode must be used during missile-target engagement. The other two modes are only for testing operations. For this, the test-operate switch on the missile control drawer is in the OPERATE position, the azimuth and elevation antenna positioning systems will be prepared for automatic operation, regardless of the positions of the azimuth and elevation MAN-AID-AUTO switches. All the antenna drive motor-tachometers are continuously cooled by separate,

single-phase, capacitor-run, induction blower motors located in the same housings as the motor-tachometers.

NOTE: Second number or groups of numbers refer to the elevation antenna positioning system.

b. Automatic mode.

(1) In automatic operation, the control signals are generated by the azimuth and elevation angle modulators and are applied to the respective servo preamplifiers through the contacts of deenergized azimuth and elevation MAN-AID relays K10 and K4 and the contacts of deenergized azimuth and elevation acquire relays K8 and K2. The push-pull d-c outputs of the servo preamplifiers are applied to the high-power servoamplifiers which furnish control voltages to the antenna Diehl two-phase, induction drive motors. There are 4 high-power servoamplifiers and antenna drive motors in the azimuth antenna positioning system and 2 of each in the elevation antenna positioning system. The drive motors position the antenna in azimuth and elevation. Velocity feedback signals are generated by the tachometers associated with the drive motors. These signals are fed to the input of the azimuth and elevation servopreamplifiers to smooth antenna response, and, as forward feed voltages, to the low-power servoamplifiers, numbers 2 and 1, through the contacts of deenergized azimuth and elevation MAN-AID relays K9 and K3. When the antenna is rotated in azimuth and/or elevation, the shafts of 25-speed azimuth and elevation synchro control transmitters B1 are rotated a corresponding amount, inducing an error voltage in the rotor winding of 25-speed control transformers B1 in the azimuth and elevation intermediate drives. The error voltages from the rotors of these control transformers are applied to the input of the respective low-power servoamplifiers through the contacts of deenergized azimuth and elevation MAN-AID relays K10 and K4. The amplified signals from the low-power servoamplifiers are therefore, combinations of the forward speed signals from the antenna drive tachometers and of the error signals from the rotors of the intermediate drive control transformers. These amplified signals are applied to the intermediate drive motors which rotate the intermediate shaft (rotors of the control transformers) in the direction and by the amount necessary to cancel the error voltages on the intermediate shafts.

(2) A 3-second coast feature is used in the azimuth and elevation positioning systems to permit operation in case the missile beacon signal is

lost for a short time. In that case, the outputs of the angle modulators are derived from the charges on their coast capacitors, C1 and C2. These charges are established by the last azimuth and elevation data received from the missile.

(3) When the antenna is rotated in azimuth or elevation, the rotors of 1-speed missile acquisition control transmitters in the azimuth and elevation data units are rotated correspondingly. Four-tenths second after burst or 3 seconds after a lost missile, the missile track slew control causes energization of azimuth and elevation acquire relays K8 and K2 and, in turn, azimuth and elevation relays K2 and K1 in the launcher position unit for the next designated launcher. When these launcher position unit relays energize, the data units' missile acquisition control transmitter stators are connected to the stators of the 1-speed control transformers in the launcher position unit for the next designated launcher; thereby, inducing error signals on the manually positioned rotors of these control transformers. These error signals are applied through the contacts of deenergized azimuth and elevation star GAZE RELAYS K7 and K1 and of the now energized acquire relays to the servo preamplifiers instead of the angle modulator error signals, which cannot pass through the energized ACQUIRE relays. Therefore, the antenna and the intermediate shafts will be positioned to cancel the error on the rotors of the launcher position unit control transformers, that is, to the azimuth and elevation of the next designated launcher.

c. Manual mode.

(1) In manual operation, the control signals are generated by the azimuth and elevation handwheel drives. These handwheel drives are identical to the range handwheel drive. The 400-cycle control voltages from the azimuth and elevation handwheel drive tachometers are applied to the respective low-power servoamplifiers, numbers 2 and 1, through the contacts of the energized azimuth and elevation MAN-AID relays K9 and K3. The amplified signals are then applied to the intermediate drive motors, turning the intermediate shafts, and inducing error signals on these rotors of the 25-speed intermediate-drive control transformers B1. These error signals are then applied to the servo-preamplifiers through the contacts of the energized azimuth and elevation MAN-AID relays K10 and K4. The signals generated by the tachometers associated with the intermediate shaft drive motors are applied to the inputs of the low-power servoamplifiers as velocity

feedback signals to dampen the response of the intermediate shaft and, through the contacts of the energized azimuth and elevation MAN-AID relays K10 and K4, to the inputs of the servopreamplifiers as forward feed voltages. The amplified signals from the servopreamplifiers are, therefore, combinations of the error signals from the intermediate shafts and of the forward feed signals from the intermediate drive tachometers. These amplified signals are then applied through the high-power servoamplifiers to the antenna drive motors. The drive motors rotate the antenna in azimuth and elevation, and, through mechanical linkages, rotate the rotors of the 25-speed azimuth and elevation synchro control transmitters, B1. Rotation of the control transmitter rotors will reduce the induced error signals on the rotors of the control transformers in the intermediate drives. Velocity feedback signals from the antenna drive tachometers are applied to the inputs of the servopreamplifiers, as in automatic operation.

(2) Manual slewing to the azimuth and elevation of a particular launcher may be done by positioning LAUNCHER ACQUIRE switch S4 and certain associated switches.

d. Manual-aided mode. In manual-aided operation, the handwheel drive tachometer error signals continue to affect the operation of the azimuth and elevation servo systems, just as in manual operation. However, as in manual-aided operation of the range servo system, these error signals are now called second derivative signals. The principal control signals are taken from the azimuth and elevation RATE potentiometer arms. As in the range system, these arms are positioned by the handwheels. The error signals from these potentiometer arms are applied through the AID contacts of azimuth and elevation switches S9C and S8C and the contacts of energized azimuth and elevation MAN-AID relays K9 and K3 to the inputs of the low-power servoamplifiers. Here they are mixed with the second derivative signals, if any, from the handwheel drive tachometers. The remainder of the azimuth and elevation servo systems are connected and operate as described for manual operation. The RATE potentiometers will drive the antenna in azimuth and in elevation at a maximum rate of approximately 705 angular mils per second.

e. Remote antenna positioning (figs 16-2 and 16-5).

(1) The tracking antenna control unit enables the antenna to be positioned in azimuth and elevation by controls at the tracking antenna mount assembly. It is used only for testing and alinement purposes. The unit contains 23-speed azimuth and elevation remote control transformers B1, the rotors of which are manually positioned by knobs on the unit. In addition, there are azimuth (and elevation) slew switches on the unit.

(2) When the track antenna control unit is plugged in at the antenna, azimuth and elevation STAR GAZE relays K7 and K1 are energized; thereby, deenergizing missile slew control LAUNCHER POSITION relay K3, and energizing ACQUIRE relay K6, which energizes azimuth and elevation ACQUIRE relays K8 and K2 and deenergizes azimuth and elevation MAN-AID relays K9, K10, K3 and K4. The range and angle modulator DISABLE relays K2 are energized. Therefore, the angle modulators, the handwheel drive tachometers, the RATE potentiometer arms and the intermediate shafts error signals are prevented from being applied to the antenna positioning servo systems. Further, the range and angle modulators are disabled. Energization of the azimuth and elevation STAR GAZE relays K7 and K1 opens the circuits carrying the launcher position unit control transformer rotor error signals to the servopreamplifiers; thereby, preventing slewing to the coordinates of the next designated launcher. In addition to opening all circuits carrying normal error signals and disabling the range and angle modulators, plugging in the track antenna control unit connects the stator windings of its remote control transformers to the stator windings of the azimuth and elevation synchro control transmitters and stator windings of the intermediate drive control transformers. It also connects the rotors of the control units' remote control transformers to the servopreamplifiers through contacts of energized azimuth and elevation STAR GAZE relays K7 and K1 and deenergized azimuth and elevation MAN-AID relays K10 and K4. In effect, the intermediate drive control transformers have now been replaced by the remote control transformers in the antenna control unit. Turning the knobs that rotate the rotors of the remote control transformers now induces error signals on these rotors. These error signals are applied to the antenna drive motors through contacts of energized azimuth and elevation STAR GAZE relays K7 and K1, contacts of deenergized azimuth and elevation MAN-AID relays K10 and K4, the servopreamplifiers, and the high-power servoamplifiers. The antenna and the azimuth and elevation synchro control transmitters are therefore rotated to reduce the error on the rotors of the antenna control unit azimuth and elevation remote control transformers. Error signals are generated by the tachometers associated with the antenna drive motors. These error signals are applied to the servopreamplifiers as velocity feedback signals to dampen the antenna response and to the intermediate drive motors, through contacts of deenergized azimuth and elevation MAN-AID relays K9 and K3 and the low-power servoamplifiers, as forward feed signals. Since the stators of the intermediate drive control transformers remain connected to the stators of the synchro control transmitters, error signals are induced on the intermediate shafts when the antenna rotates the synchro control transmitter rotors. These intermediate shaft error signals are

applied to the intermediate drive motors through the contacts of deenergized azimuth and elevation MAN-AID relays K10 and K4 and the low-power servoamplifiers. The forward feed and intermediate shaft signals cause the intermediate-drive motors to rotate the intermediate shafts to follow the rotation of the rotors of the remote control transformers in the antenna control unit and the rotation of the rotors of the azimuth and elevation synchro control transmitters. Velocity feedback signals are generated by the intermediate-drive tachometers and are applied to the low-power servoamplifiers to dampen the response of the intermediate shafts.

(3) The manual azimuth and elevation slew switches on the antenna control unit can replace the output error signals of the rotors of the remote control transformers with error signals of 6.3 volts a-c either 90° or 270° out of phase with the motor excitation voltage, depending on the switch position. The switches can make contact between the antenna control unit output and the rotors of the remote control transformers or either end of the center-grounded transformers the ends of which have potentials of 6.3 volts of opposite phase. During manual slewing, the remainder of the antenna positioning systems circuits operate as described in paragraph 68.

f. Servo test (figs 16-2 and 16-5 and sheet 48). The SERVO TEST switch on the missile radar control drawer, when in either INCREASE or DECREASE position, applies a constant +13.3-volt or -13.3-volt d-c error signal to the input of the angle modulators instead of the d-c error voltage from the error pulse rectifiers. Since the magnitudes of the d-c error voltages (the displacements of the antenna from the "on-missile" position) are known, the servo operation can be checked with the systems in automatic.

g. Antenna position indication. Dual-speed synchro systems link the azimuth and elevation data units with dials on the missile indicator panel. The rotors of the 1-speed coarse data synchro transmitters and of the 16-speed fine date synchro transmitters are geared to the main shafts of the data units. The stators of these synchro transmitters are connected to the stators of corresponding dial synchro-receivers B2 and B4, coarse data, and B1 and B3, fine data, in the indicator panel, the rotors of which are fastened to the azimuth (and elevation) dials. In addition, another set of coarse and fine dials are on the data units and are geared to the main shafts of the data units.

h. Missile position coordinate data supply for the computer. The azimuth and elevation data units furnish missile position data to the computer. This data begins as shaft positions mechanically set into the data units by the movement of the radar in tracking the missile. These shaft movements position pickoff arms on data potentiometers, the circuitry of which is shown in the computer prelaunch section of the schematics. The function of these potentiometers is discussed in TM 9-5000-13 and TM 9-5000-14.

69. ANTENNA POSITIONING SYSTEM DETAIL

NOTE: Second number or groups of numbers refer to the elevation antenna positioning system.

a. Automatic mode (Shs 20, 41, 42, 44, 47 and 48).

(1) For automatic operation, TEST-OPERATE switch S1 is in the OPERATE position and the azimuth and elevation MAN-AID-AUTO switches S9 and S8 may be in any position. (Note that regardless of the position of S1, placing S9 and S8 in AUTO will also prepare the systems for automatic operation.) COAST relays in the angle modulators must be energized for normal operation of the modulators. Therefore, either ATC relay K3 must be energized or DISABLE switch S2 must be in DISABLE. In automatic operation, deenergized azimuth and elevation MAN-AID relays K10 and K4 and deenergized azimuth and elevation ACQUIRE relays K8 and K2, through their contacts 1 and 9, couple the angle modulators control voltages to the azimuth and elevation coupling unit potentiometers R17 and R22 and load resistors R18 and R20. These potentiometers are used to adjust the amplitude of the signals applied from the angle modulators to the servopreamplifiers; thereby, adjusting the rate of azimuth and elevation rotation. The output of potentiometers R17 and R22 are applied to the respective servopreamplifiers through coupling resistors. At the outputs of the coupling units are balance switches which ground these outputs, permitting balancing of the servopreamplifiers. The outputs of the respective servopreamplifiers are applied to the 4 high-power azimuth antenna drive motors, B2A, B4A, B6A, and B8A, and to the 2 high-power elevation antenna drive motors, B2A and B3A, through the 4 azimuth high-power servoamplifiers, numbers 1, 2, 3, and 4, and the 2 elevation high-power servoamplifiers, numbers 5 and 6, respectively. These signals can be shorted together for balancing the high-power servoamplifiers by either of the azimuth high-power servoamplifiers and by the ELEVATION TEST switch (S7), located at the input to the elevation high-power servoamplifiers. These drive motors rotate the antenna in azimuth and elevation. They rotate the rotors of the 25-speed azimuth and elevation synchro control transmitters at a stepup speed ratio of 1:25. They rotate the rotors of the 1-speed missile acquisition control transmitters in the azimuth and elevation data units, the rotors of azimuth antenna drive tachometers B3, B5, B7, and B9, and elevation antenna drive tachometers B4 and B5. Phase potentiometers R2 and R1 in series with

the azimuth and elevation antenna drive tachometer excitation windings correct the phase of the tachometer output signals in the same manner as the range servo drive tachometer phase potentiometer R1, described in paragraph 65. Note, however, that only 1 potentiometer, R2, corrects the phase of the output of all 4 azimuth tachometers and only 1 potentiometer, R1, corrects the phase of the output of both elevation tachometers. The outputs of these azimuth or elevation tachometers are combined and applied across load resistors in the azimuth or elevation coupling units. The 400-cycle signals developed across these resistors are applied as velocity feedback voltages, through coupling unit resistors to the servopreamplifiers to dampen the response of the antenna and of the associated synchro rotors. The signals are also applied as forward feed voltages, through contacts 1 and 9 of deenergized azimuth and elevation MAN-AID relays K9 and K3 and coupling resistors R8 and R10 to the low-power servoamplifiers, numbers 2 and 1.

(2) Rotation of the rotors of the 25-speed azimuth and elevation synchro control transmitters when the antenna rotates, induces error signals in the rotor windings of the 25-speed control transformers B1 in the azimuth and elevation intermediate drives, since the stator windings of the azimuth and elevation synchro control transmitters are connected to the stators of the azimuth and elevation intermediate-drive control transformers. The signals on these respective intermediate shafts are applied across azimuth and elevation coupling unit load resistors R10 and R12 through contacts 8 and 12 of deenergized azimuth and elevation MAN-AID relays K10 and K4. The signals developed across these load resistors are applied through resistors R9 and R11 to the inputs of low-power servoamplifiers numbers 2 and 1.

(3) The amplified combined forward feed and intermediate shaft position error signals are then fed to the azimuth and elevation intermediate-drive motors, B6 and B2, which move the intermediate shafts in the directions and amounts necessary to cancel the error signals on the shafts. The rotors of intermediate-drive tachometers B6 and B2 rotate with the motor and generate velocity feedback signals which are applied across azimuth and elevation coupling unit load resistors R12 and R14. The signals developed across these load resistors are applied to the low-power servoamplifiers, numbers 2 and 1, through coupling unit resistors R11 and R13 to dampen the response of the intermediate shafts. PHASE potentiometers R3 and R1 are in series with the intermediate-drive tachometer excitation windings. These potentiometers adjust the phase of the speed feedback signals in the

same manner as the antenna drive tachometer PHASE potentiometers described above. Deenergized azimuth and elevation MAN-AID relays K9 and K3 prevent handwheel drive tachometer or RATE potentiometer arm error signals from entering the antenna positioning system.

(4) Four-tenths second after burst ordered or 3 seconds after a lost missile, the missile track slew control causes azimuth and elevation ACQUIRE relays K8 and K2 to energize through the action of acquired relay K6. These energize azimuth and elevation relays K2 and K1 in the launcher position unit, for the next designated launcher or the test responder. The stator windings of the data unit azimuth and elevation 1-speed missile acquisition control transmitters are connected to the stator windings of the launcher position unit 1-speed control transformers B1 and B2 through contacts 10 and 4, 11 and 5, and 12 and 7 of the now energized launcher position unit azimuth and elevation relays. The turning of the rotors of the missile acquisition control transmitters, when the antenna rotates, induces error signals on the manually positioned rotors of the launcher position unit control transformers. These error signals are applied across coupling unit load resistors R19 and R9 through contacts 1 and 9 of deenergized azimuth and elevation STAR GAZE relays K7 and K1 and contacts 10 and 4 of energized azimuth and elevation ACQUIRE relays K8 and K2. The signals developed across these resistors are applied to the antenna drive motors, through coupling unit resistors R2 and R8, the servopreamplifiers, and the high-power servoamplifiers, rotating the antenna in the direction and amounts necessary to zero the error signals on the launcher position unit control transformer rotors. The remainder of the antenna positioning system will operate just as in the automatic mode, except that energized azimuth and elevation ACQUIRE relays K8 and K2 will prevent any signals from the angle modulators from entering the systems.

b. Manual mode.

In manual operation, the TEST-OPERATE switch is in the TEST position and azimuth and elevation MAN-AID-AUTO switches S9 and S8 must be in MAN position, energizing magnetic clutch coils, angle modulator DISABLE relays and azimuth and elevation MAN-AID relays K9 and K10 and K3 and K4. With the angle modulator DISABLE relays energized, no signal should be sent from the angle modulators. In addition, energized azimuth and elevation MAN-AID relays K10 and K4 open the circuits for such signals to the antenna positioning systems. With magnetic clutch coils energized, the clutches will be disengaged,

the RATE potentiometer arms centered, and no signals should be sent from the RATE potentiometers. In addition, the circuits for such signals to the antenna positioning systems are opened by placing the azimuth and elevation MAN-AID-AUTO switches S9C and S8C in MAN. Mechanically turning the azimuth and elevation handwheels causes the rotors of the azimuth and elevation handwheel drive motors and tachometers to turn. These tachometers generate 400-cycle error signals. PHASE potentiometers R2 and BALANCE potentiometers R4 serve the same purpose as in the range handwheel drive. The tachometer outputs are permitted to pass through contacts 4 and 10 of azimuth and elevation MAN-AID relays K9 and K3, and across azimuth and elevation coupling unit load resistors R16 and R18. The signals developed across these resistors are applied to intermediate-drive motors B6 and B2 through coupling unit resistors R15 and R17 and the low-power servoamplifiers, numbers 2 and 1. These drive motors turn the associated tachometer rotors and the intermediate shafts. The error signals induced on the intermediate shafts are applied across coupling unit load resistors R5 and R4 through contacts 5 and 11 of energized azimuth and elevation MAN-AID relays K10 and K4 and coupling unit resistors R20 and R21. The signals developed across these load resistors are applied to the servopreamplifiers through coupling unit resistors R4 and R3. The signals generated by the intermediate drive tachometers are applied as velocity feedback signals across coupling unit load resistors R12 and R14. The signals developed across these load resistors are applied through coupling unit resistors R11 and R13 to the inputs of the low-power servoamplifiers to dampen the response of the intermediate shafts. The intermediate-drive tachometer signals are also applied as forward feed signals to the inputs of the servopreamplifiers through contacts 4 and 10 of energized azimuth and elevation MAN-AID relays K10 and K4 and coupling unit resistors R3 and R5. The combined amplified forward feed signals and intermediate shaft error signals are applied through the high-power servoamplifiers to the antenna drive motors. These motors rotate the rotors of the associated tachometers; the antenna in azimuth and elevation; the rotors of the 25-speed azimuth and elevation synchro control transmitters at a stepup speed ratio of 1:25; and the rotors of the data unit 1-speed missile acquisition control transmitters. Velocity feedback signals are applied from the antenna drive tachometers to the servopreamplifiers as in the automatic mode. They are not, however, applied to the inputs of the low-power servoamplifiers, since energization of MAN-AID relays K9 and K3 opened these circuits.

Tachometer phase potentiometers R2 and R1 operate as in the automatic mode. Rotation of the rotors of the 25-speed azimuth and elevation synchro control transmitters reduces the error signals induced on the intermediate shafts, since the stator windings of the synchro control transmitters are connected to the stator windings of the intermediate-drive control transformers.

c. Manual-aided mode. In manual-aided operation, TEST-OPERATE switch S1 is in TEST position and azimuth and elevation MAN-AID-AUTO switches S9 and S8 must be in the AID positions, energizing angle modulator DISABLE relays K2 and the azimuth and elevation MAN-AID relays K9 and K10 and K3 and K4 and deenergizing the azimuth and elevation magnetic clutch coils. Therefore, the circuitry described in paragraph 69 for the manual mode remains connected except for the magnetic clutch which is engaged. The outputs of the handwheel drive tachometers are called second derivative voltages when the systems are in the manual-aided mode of operation and will be present only while the handwheels are being rotated. The deenergization of the magnetic clutch coils causes the clutches to engage, mechanically coupling the RATE potentiometer arms to the handwheels. Rotation of the handwheels will now position these potentiometer arms, in the same manner as described in paragraphs 66 and 67. The 400-cycle error signals from the potentiometer arms are coupled through contacts 2 and 6 of MAN-AID-AUTO switches S9 and S8 and contacts 5 and 11 of energized azimuth and elevation MAN-AID relays K9 and K3 to coupling unit potentiometers R14 and R19 and load resistors R21 and R16. These potentiometers are used to adjust the amplitude of the signals applied from the rate potentiometers; thereby, adjusting the rate of azimuth and elevation rotation to a maximum of about 750 angular mils per second. The outputs of potentiometers R14 and R19 are applied to the inputs of low-power servoamplifiers 2 and 1 through coupling unit resistors R13 and R15. Here, they are mixed with the 400-cycle second derivative signals, if any. The effects of the rate potentiometer error signals from there on are identical with the handwheel tachometer error signals described in paragraph 69.

d. Remote antenna positioning.

(1) Plugging antenna control unit plug P1 in jack J7 in the equipment enclosure of the missile-tracking antenna mount assembly energizes the azimuth and elevation STAR GAZE relays K7 and K1 and thereby, deenergizes missile slew control launcher position relay K3 and energizes ACQUIRE relay K6, which energizes azimuth and elevation ACQUIRE relays K8 and K2 and deenergizes azimuth and elevation MAN-AID relays K9 and K10 and K3 and K4. Contacts 5 and 11 of relays K8 and K2 energize the range and angle modulator DISABLE relays as shown on sheet 48. The

circuits carrying the angle modulators, the handwheel-drive tachometers, the rate potentiometer arms, the launcher position unit control transformer rotors, and the intermediate systems are all opened and the range and angle modulators are disabled. Plugging in the antenna unit also connects the stator windings of its 25-speed azimuth and elevation remote control transmitters. Manually turning the rotor positioning knobs of the antenna control unit causes 400-cycle error signals to be induced on the rotors of the remote control transformers. These error signals are applied across coupling unit load resistors R5 and R4 through contacts 4 and 10 of energized azimuth and elevation MAN-AID relays K10 and K4 and coupling unit resistors R20 and R21. The signals developed across these load resistors are applied to the antenna drive motors through coupling unit resistors R4 and R3, the servopreamplifiers, and the high-power servoamplifiers. These drive motors rotate the antenna and its associated synchro rotors to reduce the error on the remote control transformer rotors and the antenna drive tachometer rotors just as in the normal mode of operation. The signals generated by the antenna drive tachometers are applied across coupling unit load resistors. The signals developed across these resistors are applied as velocity feedback signals to the servopreamplifiers through coupling resistor R6. The antenna drive tachometer signals are also applied, as forward feed signals, to the intermediate drive motors, through contacts 1 and 9 of deenergized azimuth and elevation MAN-AID relays K9 and K3, coupling unit resistors R8, and low-power servoamplifiers numbers 2 and 1. The stators of the intermediate drive control transformers continue to be connected to the stators of the synchro control transmitters. As the antenna rotates the rotors of the synchro control transmitters, error signals are induced on the intermediate shafts. These signals are applied across load resistors R10 and R12, through contacts 8 and 12 of deenergized azimuth and elevation MAN-AID relays K10 and K4. The signals developed across these load resistors are applied to the intermediate drive motors through coupling unit resistors R9 and R11 and the low-power servoamplifiers, numbers 2 and 1. The intermediate drive motors position the intermediate shafts to reduce the intermediate shaft errors and to follow the rotors of the synchro control transmitters and rotate the rotors of the associated intermediate drive tachometers. These tachometers generate velocity feedback signals which are applied across coupling unit load resistors, R12 and R14. The signals developed across these load resistors will be applied to the inputs of the low-power servoamplifiers, through coupling unit resistors R11 and R13 to dampen the responses or the intermediate shafts. If the antenna control unit is disconnected,

the antenna will not jump to its original position because there are no error signals on the intermediate shafts, since they were rotated by the antenna. Notice that the position of the TEST-OPERATE switch S1 has no effect on the operation of the antenna control unit. Therefore, the antenna control unit must be disconnected before the antenna can be positioned by either automatic or manual controls in the radar control van. That is, it must be disconnected to permit tracking of a missile.

(2) The azimuth and elevation slew switch S1 and S2 on the antenna control unit, enables the operator to substitute either of two 6.3 a-c voltages, 180° apart in phase,for the normal remote control transformer rotor outputs of the unit. These voltages are acquired from the opposite ends of centergrounded transformer T1. The remainder of the remote antenna positioning system operates as described in paragraph 69d(1).

70. SERVO TEST CIRCUITS (sh 48)

Placing SERVO TEST-NORMAL switch S11 in either the INCREASE or the DECREASE position and TEST-OPERATE switch S1 in the TEST position energizes SERVO TEST relay K2 through contacts 2 and 1 or 2 and 3 of S11 and 2 and 3 of S1. Either +13.3 or -13.3 d-c voltages, depending on the position of S11 are applied to the inputs of the angle modulators, simulating azimuth and elevation "off-missile" conditions. Provision is made to apply similar signals to the range modulator, but it is not used. Placing DISABLE switch S2 in the DISABLE position energizes the COAST relays in the angle modulators, allowing these d-c voltages to charge the angle modulators COAST capacitors C1 and C2, and to pass on to the antenna positioning systems, if MAN-AID-AUTO switches S8 and S9 are in the AUTO positions. These signals drive the antenna in azimuth and elevation and allow azimuth coupling unit potentiometer R22 to be adjusted. The adjustments are made so that in azimuth, one revolution of the antenna is made in 10.7 ± 0.3 seconds and in elevation, the antenna moves from 1,000 to 3,000 mils in 3.3 ± 0.1 seconds.

71. MISSILE ANTENNA PLUNGE AND ELEVATION LIMIT CIRCUITS (sh 48)

a. General. During normal operation, the missile-tracking radar antenna must be able to elevate from -200 to +1,590 mils. However, during alinement procedures, it is necessary to plunge the antenna, that is, move the antenna in elevation from -200 to + 3,380 mils. When the antenna is plunged, provision must be made to reverse the azimuth positioning signals sense with respect to their sense before the time the antenna crossed the zenith. The antenna elevation stop and the plunge circuits perform these functions.

b. Normal elevation limit circuits. During normal operation, transformer T2 applies servo excitation voltage to the normally open contacts of the ELEVATION LIMIT switches S2, S3, and S4. When the antenna is lowered to -200 mils, the arm of 0° elevation limit switch S2 is mechanically disconnected from its grounded contacts and connected to its contact carrying the signal from terminal 3 of transformer T2. The signal is now applied to the elevation antenna drive motors through switch S2, the normally closed contacts of S4, OPERATE contacts 4 and 5 of TEST-OPERATE switch S1, elevation coupling unit resistor R2, and the elevation servopreamplifier and high-power servoamplifiers. The signal is exactly opposite in phase to the signal that drives the antenna downward; therefore, at -200 mils, it is applied as a braking voltage and drives the antenna upward if it goes below -200 mils. The 0° designation of the switch S2 is an arbitrary designation. A mechanical stop, at a slightly lower limit, prevents damage to the antenna if the braking voltage is not enough to stop the antenna's downward travel before the lens strikes the trailer. When the antenna is elevated past 1,590 mils, the arm of the 90° elevation limit switch mechanically moves from its normal position to connect with the contact carrying the signal from terminal 1 of transformer T2. This signal is opposite in phase to that on terminal 3. It is then applied to the elevation antenna drive motors through OPERATE contacts 4 and 5 of TEST-OPERATE switch S1, elevation coupling unit resistor R2, the elevation servopreamplifier, and the elevation high-power servoamplifiers. Since it is a downward driving signal, it brakes the motors and drives the antenna downward if above 1,590 mils. No mechanical stop is provided near this elevation limit. In normal operation, the 180° ELEVATION switch and the 90° PLUNGE switches have no function.

c. Plunge circuits. Placing TEST-OPERATE switch S1 in the TEST position opens the circuit carrying the normal braking signals from the 0° and the 90° elevation limit switches to the elevation coupling unit. If the antenna is lowered below -200 mils, closing 0° ELEVATION LIMIT switch S2, the upward driving signal from terminal 3 of transformer T2 is applied to the elevation antenna drive motors through the now closed contacts of S2, the normally closed contacts of 180° elevation limit switch S3, TEST contacts 5 and 6 of TEST-OPERATE switch S1, elevation coupling unit resistor R2, the elevation servopreamplifier and the elevation high-power servoamplifiers. If the antenna is elevated to 1,590 mils, the downward driving signal from terminal 1 of transformer T2 passes through the now closed contacts of the 90° ELEVATION LIMIT switch S4, but cannot pass beyond open contact 4 of TEST-OPERATE switch S1, so it has no effect. When the antenna is elevated beyond 3,380 mils, 180° ELEVATION LIMIT switch S3, is mechanically closed. The downward driving signal at terminal 1 of transformer T2 is now applied to the elevation antenna drive motors through the now closed contacts of S3, TEST contacts 6 and 5 of TEST-OPERATE switch

S1, elevation coupling unit resistor R2, the elevation servopreamplifier, and the high-power servoamplifiers. A mechanical stop is located at slightly greater than 3,380 mils to prevent the lens striking the trailer if the downward driving signal, applied at 3,380 mils, is not enough to stop antenna travel. Placing TEST-OPERATE switch S1 in the TEST position applies ground to one side of PLUNGE RELAY K1, through contacts 2 and 3 of S1. When the antenna is elevated beyond 1,590 mils, the 90° ELEVATION PLUNGE switch, S5 is mechanically closed, applying -26 volts to the other side of the PLUNGE relay K1, energizing it. When K1 is energized, the servo excitation to the azimuth angle modulator is reversed, thereby reversing the azimuth positioning sense. (In normal operation, servo excitation is applied to pin 9 of P2 of the azimuth angle modulator, through contacts 1 and 9 of deenergized PLUNGE relay K1 and neutral, to pin 11 of azimuth angle modulator P2, through contacts 3 and 10 of deenergized PLUNGE relay K1.) When PLUNGE relay K1 is energized, servo excitation is applied to pin 11 of azimuth angle modulator plug 2, through contacts 4 and 10 of energized PLUNGE relay K1 and neutral, to pin 9 of angle modulator plug 2, through contacts 2 and 9 of energized K1.

CHAPTER 5

CONTROL CIRCUITS

Section I. MISSILE SLEW CONTROL UNIT AND AGC MONITOR

72. INTRODUCTION

The target-tracking radar is capable of slewing to the range and azimuth of a designated target. Slew circuity is necessary to shorten the interval between the destruction of one target and the engagement of the next. In the missile-tracking radar, a corresponding interval exists between the burst of one missile and the acceptance of the beacon from the next selected missile. The rate of fire and, consequently, the effectiveness of the Nike battery are directly influenced by this delay period. If the burst order is sent, or if the missile beacon is lost, automatic circuits slew the missile-tracking radar to the range, azimuth, and elevation of the missile to be fired next. The time elements involved in this action make it probable that the missile radar will be locked on the next selected missile before the target radar is locked on the next designated target.

73. OVER-ALL PURPOSE (fig 17-1)

a. Launcher position units. These units, when properly adjusted, provide output voltages which may be used to slew the missile radar to any one of 16 launchers or to the test responder on the launcher control trailer.

b. Timer channel of missile slew control unit. This channel controls the instant at which the slew operation will begin. It also maintains slew control long enough to allow the radar to lock on the new missile beacon.

c. Coarse slew channel. This channel applies 400-cycle power to the range slew motor to slew the range gearing to a setting not more than 2,090 yards greater than the range to the selected launcher. Manually operated control circuitry associated with this channel permits manual slewing in either direction. This later feature is for test purposes only.

d. Fine slew channel. When the slew motor has driven the range setting within 2,090 yards of the range of the selected launcher, the fine slew channel operates through the range modulator, servoamplifier, and servomotor to position the range components precisely at the range of the selected launcher.

e. AGC monitor. This unit interrupts the normal operating sequence of the battery if the new missile generates an inadequate beacon signal or none at all. The unit automatically accepts a missile whose beacon signal is satisfactory, but rejection (or acceptance) of a missile which has an unsatisfactory beacon signal must be done manually by the missile-tracking radar operator.

74. SLEW CONTROL OF SERVO SYSTEMS (fig 17-2)

a. Launcher position unit. There are 17 launcher position units. Each of these units provides 3 output voltages, 1 for azimuth, 1 for elevation, and 1 for range. One of these units is adjusted to provide output voltages which, when applied to the missile-tracking radar servo section, will position the missile-tracking radar on the test responder in the launcher area. The remaining units may be adjusted to position the radar on a total of 16 individual launchers but normally, only 12 are used. The timer channel of the missile slew control unit normally controls the beginning of slew operation. The timer channel energizes acquisition control (KQC) relay K6 at an instant 0.4 second after the burst order is sent to the missile or 3 seconds after the beacon signal is lost (ATC relay deenergized). When K6 energizes, a -28-volt enabling voltage is applied through the launcher selection circuits to one of the 17 launcher position units. The enabling voltage, when applied to the selected launcher position unit, energizes three relays in the unit. This action makes the output voltages of the selected unit available to the three servo systems of the missile radar.

b. Azimuth servo system. The azimuth output voltage of the launcher position unit is obtained from the rotor winding of synchro transformer B2. The stator windings of this synchro transformer are connected to the stator windings of a 1-speed synchro transmitter which is driven by the azimuth gearing. When the launcher position unit is enabled, the rotor voltage of synchro B2 is applied through contacts of the deenergized STAR GAZE relay, K7, and through contacts of the energized ACQUIRE relay, K8, to the azimuth coupling unit. This voltage, after amplification, drives the azimuth servomotors. The antenna is driven in azimuth until the 1-speed synchro transmitter is positioned to the point where zero voltage appears across the rotor of B2 in the launcher position unit. This point is determined by preadjustment of synchro transformer B2.

c. Elevation servo system. The elevation output voltage of the launcher position unit is obtained from the rotor winding of synchro transformer B1. This voltage is applied through contacts of the deenergized STAR GAZE relay, K1, and through contacts of the energized ACQUIRE relay, K2, to the elevation coupling unit. Relay K2 is energized when KQC relay K6 becomes energized.

d. Range servo system. The range voltage from the launcher position unit is obtained from potentiometer R1. This potentiometer is adjusted so that the voltage present at the brush arm is proportional to the slant range to the individual launcher (or the test responder). When the launcher position unit is enabled, this d-c voltage is applied to both the coarse slew channel and the fine slew channel of the missile slew control unit. At the same time, these two channels receive a voltage, $+D_M$, which is proportional to the range setting of the missile-tracking radar. When the difference between these two voltages is considerable, as will initially be the case, the coarse slew channel will apply 400-cycle power to the range slew motor, causing the range setting to be driven at a rapid rate. As the range setting of the missile-tracking radar approaches the range of the selected launcher, the difference between the two compared voltages decreases. When this voltage difference becomes small, the coarse slew channel removes the 400-cycle power from the slew motor and applies a d-c braking voltage in its place. As the speed of the slew motor decreases, the clutch disengages the slew motor from the range gearing and connects the range servomotor to the gearing. A comparison of the two applied d-c voltages is also made in the fine slew channel. Any difference between the two compared voltages is amplified and appears at the output of the fine slew channel as a push-pull d-c voltage. During slew operation, this push-pull voltage is applied across the coast capacitors of the range modulator. This input to the modulator is converted to a 400-cycle signal which, after amplification, is applied to the range servomotor. When the slew motor is uncoupled, the servomotor drives the range gearing. The $+D_M$ voltage changes (decreases) in value. When the range gearing has been driven to the point where comparison of the two applied d-c voltages produces zero voltage at the output of the fine slew channel, the range gearing comes to a halt. The position at which the range gearing halts is predetermined by adjustment of potentiometer R1 in the launcher position unit.

75. LAUNCHER POSITION UNIT (fig 17-4)

a. General. There are 17 launcher position units. These units are located in the range and receiver cabinet.

b. Relays K1, K2, and K3. These three relays, connected in parallel, are normally deenergized. When KQC relay K6 energizes at the beginning of slew operation, the three relays in the selected launcher position unit become energized. If no launcher has been designated, the relays of the seventeenth launcher position unit, which is associated with the test responder, energize. The energizing voltage -28 volts, appears at terminal 14 of P1. When KQC relay K6 energizes, the -28-volt potential is applied through contacts 2 and 10 of K6 to pin A of J2 in the missile indicating panel. (This component is located in the missile console.) If no launcher has been designated, the enabling voltage is applied

through contacts 2 and 9 of LCHR NOT DESIG relay K13 to pin D of J3. From that point, the voltage is conveyed to the seventeenth launcher position unit. If a launcher has been designated, relay K13 (LCHR NOT DESIG) will deenergize. Assume that launcher 3 of section C has been designated. In that case, LCHR 3 relay K3 and SECT C relay K11 will be energized. The -28-volt potential will then be applied through contacts 2 and 9 of K3 and through contacts 5 and 11 of K11 to pin M of J3. From that point, the enabling voltage is carried to launcher position unit C3, associated with the selected launcher. When the enabling voltage is applied, the three relays of the launcher position unit energize.

c. Synchro transformer B1 and B2. When the launcher position unit is enabled, the stator windings of the elevation and azimuth synchro transformers are connected to the stator windings of the appropriate 1-speed synchro transmitters in the antenna trailer. At the same time, the output voltages of these two synchros are made available at pins 2 and 6 of P1. As previously described, these voltages are applied through contacts of two relays (STAR GAZE and ACQUIRE) to the coupling units. These voltages cause the servo systems to be driven to the azimuth and elevation to which synchro transformers B1 and B2 have been preset.

d. Potentiometer R1. When the launcher position unit is enabled a -100-volt potential appears across the 20,000-ohm range potentiometer, R1. The negative voltage at the brush arm of R1 is delivered through pin 10 of P1 to the missile slew control unit. The scale factor of this voltage is 10 millivolts per yard. The maximum output voltage of -100 volts is equivalent to 10,000 yards. (The maximum separation between the missile radar and any launcher is approximately 6,000 yards.) Terminal 2 of R1 is connected through pin 12 of P1 to ground. The negative d-c voltage which appears across R1 when the launcher position unit is enabled is derived from the -250-volt regulated source in the computer power cabinet. The circuit appears in TM 9-5000-26, page 159 at coordinates C14 on terminal 935 at the computer power cabinet. The voltage is applied through two 15,000-ohm resistors, R23 and R24, to terminal 15 of P1 in the launcher position unit. When a launcher position unit is enabled, a voltage divider exists from ground through potentiometer R1 in the launcher position unit, and through resistors R23 and R24 in the computer power cabinet, to the -250-volt source. The construction of the voltage divider is such that a 100-volt potential then appears across R1 in the selected launcher position unit and at pin 15 of P1 in the remaining 16 units.

76. TIMER CHANNEL, SLEW CONTROL UNIT (fig 17-2)

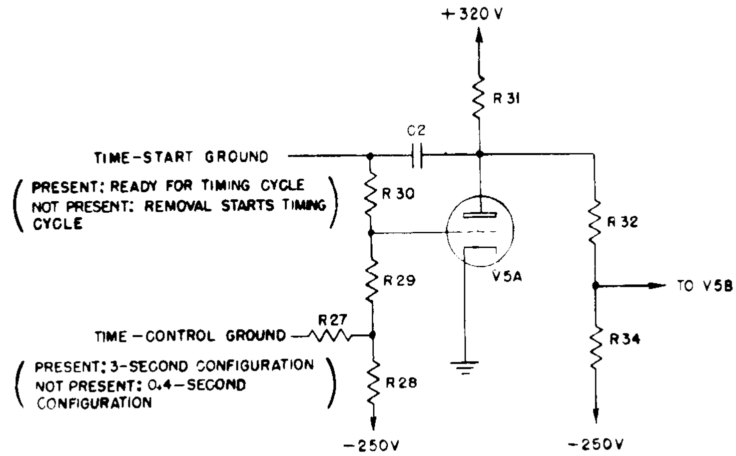
a. General. The missile slew control unit is located in the equipment drawer of the missile console, as shown on fig 1-13. The schematic diagram is

fig 17-2 . The operation of the timer channel is affected by relay control circuitry external to the unit.

b. Function. The timer channel energizes and deenergizes acquisition control (KQC) relay K6 during automatic missile acquisition. This is the only function of the timer channel.

c. Operating fundamentals. The timer channel consists of triodes V5A and V5B, TIME CONTROL relay K4, SLEW CONTROL relay K5, TIME OVER relay K6, and associated circuit components. TIME CONTROL relay K4 is controlled by the ATC ground at pin 11 of P2. SLEW CONTROL RELAY K5 is controlled by TIME OVER relay K6. TIME OVER relay K6 is controlled by tubes V5A and V5B. When V5A conducts, V5B is cut off by the negative potential that appears at grid 7. With V5B cut off, TIME OVER relay K6 is not energized. However, when V5A cuts off, V5B conducts heavily and energizes K6. The grid voltage of V5A controls the TIME OVER relay. The voltage at the grid of V5A is influenced by the application and removal of two ground connections. These grounds are the time-start ground, which may be applied at the junction of C2 and R30, and the time-control ground, which may be applied at the left end of resistor R27. Figure 26 tabulates the four possible conditions that may exist in the circuit. The time-control ground determines whether the circuit shall operate in a 3-second cycle (time-control ground present) or in a 0.4-second cycle (time-control ground not present). The time-start ground determines whether the circuit is ready for the timing cycle (time-start ground present) or if the timing cycle has begun (removal of the time-start ground starts the timing cycle).

d. The 3-second cycle. When the time-start ground is present at the junction of C2 and R30, tube V5A conducts. The amount of conduction is determined by the presence or absence of the time-control ground at the left end of R27. When the time-control ground is present, as it is for the 3-second cycle, the voltage-divider net consisting of R27, R28, R29, and R30 develops a -2.2-volt potential at the grid of V5A. With this bias, V5A conducts heavily and the voltage at the plate is low. Capacitor C2, connected from the plate of V5A to ground in this configuration, rapidly charges to the voltage at the plate. When the time-start ground is removed, the change in circuit configuration places C2 in series with R30 between the plate and grid of V5A. Capacitor C2 then charges, with the plate voltage increasing exponentially in a positive direction and the grid voltage increasing exponentially in a negative direction. The circuit constants are such that, 3 seconds after the time-start ground is removed, the plate voltage of V5A will have reached a level which will permit V5B to conduct and energize TIME OVER relay K6.



TIME-CONTROL GROUND	TIME-START GROUND	VOLTAGE AT GRID OF V5A	CONDUCTION OF V5A	CONDITION OF TIMER CHANNEL
PRESENT	PRESENT	-2.2 V(IMMEDIATE)	CONDUCTING	READY FOR 3-SEC CYCLE
	REMOVED	-68 V(EVENTUAL)	CUT OFF IN 3 SEC	3-SEC CYCLE STARTS WHEN TIME-START GROUND REMOVED
NOT PRESENT	PRESENT	-7.5 V(IMMEDIATE)	CONDUCTING	READY FOR 0.4-SEC CYCLE
	REMOVED	-250V(EVENTUAL)	CUT OFF IN 0.4 SEC	0.4-SEC CYCLE STARTS WHEN TIME-START GROUND REMOVED

Figure 26. Timing control, circuit configurations.

e. The 0.4-second cycle. In this configuration, time-control ground is not present at the left end of resistor R27. With the time-start ground present at the C2-R30 junction, tube V5A conducts. The grid voltage, now developed by voltage divider R28, R29, and R30, is -7.5 volts. Because this bias voltage is greater than that which existed in the 3-second configuration the conduction of V5A is now less. As a result, the plate of V5A is at a higher potential and the charge across C2 is greater. When the time-start ground is removed, C2 is placed in series with R30 between the plate and grid of V5A. As C2 charges, the plate voltage of V5A rises exponentially and the grid voltage becomes more negative. When the charge across C2 is such that the grid voltage reaches cutoff, tube V5A ceases to conduct. At this instant, the charge across C2 (approximately 300 volts) is very nearly the same as that which is present at the corresponding (terminating) instant of the 3-second cycle. However, in this case, the starting charge across C2 is greater and hence the required change of charge is smaller. It follows that the smaller change of charge will

require less time. As C2 charges, the rising voltage at the plate of V5A acts to raise the grid potential of V5B. The circuit constants are such that V5B conducts and also causes TIME OVER relay K6 to be energized 0.4 second after the removal of the time-start ground.

f. Missile in launcher. In the following discussion of the operating sequence of the timer channel, it is assumed initially that the missile-tracking radar is locked on a missile in a launcher and is receiving the beacon signal from the missile. It is also assumed that NORMAL-DISABLE switch S2 is in the NORMAL position. In this condition, the time-start ground is applied through contacts 1 and 2 of switch S2 to pin 1 of P2. The ATC ground is applied to pin 11 of P2 through contacts 6-11 of the deenergized BURST relay, K2, in the signal panel of the target console, and through contacts 2-3 of the energized ATC relay, K3, in the missile ATC unit. (The ATC relay is energized when the missile radar is locked on the beacon signal.) Although contacts 8 and 12 of BURST relay K2 apply time-control ground to contact 11 of FIRE relay K17 (in the missile indicating panel), this ground is not applied to terminal 3 of P2. This is because FIRE relay K17 is not energized. The presence of ATC ground causes TIME CONTROL relay K4 to be energized. SLEW CONTROL relay K5 is not energized, and the time-start ground is applied through contacts 4 and 10 of K4 and contacts 6 and 11 of K5 to the junction of C2 and R30. Ground is not present at the left end of R27. In this condition, the grid voltage of V5A is -7.5 volts, and that tube conducts. Because of the conduction of V5A, the grid of V5B is held below cutoff. Tube V5B does not conduct, and TIME OVER relay K6 is not energized.

g. Missile in normal flight. When the missile is launched, FIRE relay K17 is energized and the time-control ground is applied through contacts 8-12 of deenergized BURST relay K2, contacts 5 and 11 of FIRE relay K17, and pin 3 of P2 to the left end of resistor R27. The first of the conditions tabulated in figure 28 now exists. The grid voltage of V5A is -2.2 volts, V5A conducts, V5B is cut off, and the circuit is ready for the 3-second cycle.

h. Loss of beacon signal. If the beacon signal is lost during flight, ATC relay K3 deenergizes and its contacts open. As a result, TIME CONTROL relay K4 deenergizes. As contacts 4-10 of K4 open, time-start ground is removed from the junction of C2 and R30. This is the second condition tabulated in figure 28. As previously described, C2 now goes through a charging cycle which drives V5A to cutoff, allows V5B to conduct, and (after a time interval of 3 seconds) causes TIME OVER relay K6 to energize. SLEW CONTROL relay K5 is energized by time-start ground. This ground is applied through contacts 3 and 10

of K4 and contacts 4 and 5 of K6. A holding circuit for K5 is provided through contacts 4 and 10 of K5 and 1 and 9 of K4. Contacts 2 and 9 of K5 apply ground through terminal 7 of P2 to the acquisition control (KQC) relay, K6, as shown in figure 30. (When the KQC relay is energized, the servo systems of the missile radar slew to the next designated launcher.) Time start ground is reapplied to the junction of C2 and R30 through contacts 3 and 10 of K4 and contacts 5 and 11 of K5. Contacts 7 and 12 of K5 place a ground connection at the left end of R27. (This is necessary because FIRE relay K17 deenergizes when the KQC relay energizes.) The first condition tabulated in figure 26 again exists, and the circuit is immediately made ready for another 3-second cycle. TIME OVER relay K6 has become deenergized (because of the conduction of V5A and the resulting nonconduction of V5B). A second holding circuit for K5 is now provided through contacts 4 and 6 of K6 and 4 and 10 of K5. When the missile-tracking radar has slewed to the next designated launcher, the beacon signal from the new missile will be received. As a result, ATC relay K3 will energize again, and ground will appear at terminal 11 of P2. This ground energizes TIME CONTROL relay K4. As contacts 1 and 9 of K4 open, one of two holding circuits of K5 is broken. As contacts 3 and 10 of K4 open, time-start ground is removed from the junction of C2 and R30. This is, again, the second condition tabulated in figure 26. After 3 seconds, TIME OVER relay K6 energizes again. As contacts 4 and 6 of K6 open, the second holding circuit of SLEW CONTROL relay K5 is broken and K5 deenergizes. As contacts 2 and 9 of K5 open, the KQC relay deenergizes and slew control of the missile radar terminates. Time-start ground is now applied to the junction of C2 and R30 through contacts 4 and 10 of K4 and contacts 6 and 11 of K5. With ground at this junction, V5A immediately conducts, V5B becomes cut off, and TIME OVER relay K6 deenergizes.

i. Burst order. With the missile in normal flight, the first of the conditions tabulated in figure 26 exists. Tube V5A conducts with -2.2 volts at its grid, V5B is cut off, TIME OVER relay K6 is deenergized, SLEW CONTROL relay K5 is deenergized, TIME CONTROL relay K4 is energized, and the circuit is ready for the 3-second cycle. When the burst order is given, BURST relay K2 energizes. As shown in figure 17-2 , this removes both the ATC ground and the time-control ground. Removal of the time-control ground places the timer channel in the 0.4-second configuration, as tabulated in figure 26. Loss of the ATC ground causes TIME CONTROL relay K4 to deenergize, just as loss of the beacon signal caused it to deenergize. The sequence of operation that follows is identical to that caused by loss of the beacon signal, with one exception. Because time-control ground is removed by the burst order, slew operation is initiated (KQC relay energized) after an interval of only 0.4 second. The second time interval, which begins when the beacon signal from the new missile causes ATC relay K3 to energize, is again 3 seconds. This is because ground is furnished through contacts 7 and 12 of K5 to the left end of resistor R27.

j. Manual slew. In automatic slew control, the KQC relay is operated by the timer channel. Manual operation of the KQC relay is also possible. For manual control, switch S2 must be in the DISABLE position. As shown in figure 17-2, time-start ground is then no longer applied to terminal 1 of P2. Because the time-start ground is used to energize SLEW CONTROL relay K5, it follows that K5 must remain deenergized without this ground. Therefore, with S2 in the DISABLE position, the timer channel can have no effect upon the KQC relay. With S2 in the DISABLE position, however, operation of LAUNCHER ACQUIRE switch S4 will provide an energizing circuit for the KQC relay. ATC control of slew operation may be restored by returning switch S2 to the NORMAL position. This manual-control feature allows selection of a new missile (or the test responder) after the missile-tracking radar is already tracking a missile in a launcher.

77. COARSE SLEW CHANNEL (fig 17-2)

a. General. Manual slewing of the range components is done by application of appropriate voltages to the range slew motor. These voltages are applied through contacts of SLEW IN relay K1 and SLEW OUT relay K2. These two relays are components of the coarse slew channel of the missile slew control unit. With the TEST-OPERATE switch in TEST, either K1 or K2 may be energized by operation of the range SLEW switch, S3. In this TEST condition, the SLEW switch places a ground at either pin 5 or pin 7 of P1. Although either relay may be energized under manual control, only SLEW IN relay K1 may be energized automatically by operation of the coarse slew channel. The coarse slew channel controls the operation of SLEW IN relay K1. The channel is almost identical to the relay amplifiers in the computer, which also control the operation of relays.

b. Input voltages. The selected launcher position unit is enabled only when acquisition control (KQC) relay K6 is energized. While the KQC relay remains energized, the range voltage from the selected launcher position unit appears at pin 9 of P1. This launcher position range (LPR) voltage is negative. The scale factor is 10 millivolts per yard. Another d-c voltage is applied to the slew control unit. This is the missile range position (MRP) voltage, which appears at pin 11 of P1. This voltage (called $+D_M$ in the computer) is obtained from the driven shield of the output cable of the missile range data potentiometer in the range unit assembly. The MRP voltage leaves the range unit assembly through pin K of J3, which connects with pin K of P40. It then goes to terminal 410 in the radar range and receiver cabinet, and from there to terminal 76 in the missile console. The voltage is then brought to the slew control unit through pin 11 of J37, which connects with pin 11 of P1 in the unit. This voltage is positive. The scale factor is 1 millivolt per yard.

c. Mixing circuit. The two d-c voltages are applied to the mixing circuit consisting of resistors R1 and R2. The negative LPR voltage, at a scale factor of 10 millivolts per yard, is applied through a 10-megohm resistor. The positive MRP voltage, at a scale factor of 1 millivolt per yard, is applied through a 1-megohm resistor. The voltage at the junction of the two resistors is applied to both the coarse slew channel and the fine slew channel. This voltage may be considered as being composed of two increments. One of these is equivalent to one-eleventh of the negative LPR voltage. The other is equivalent to ten-elevenths of the positive MRP voltage. Thus, if the range setting of the missile radar were 33,000 yards and the range position of the selected launcher were 4,400 yards, potentials of +33 volts and -44 volts would appear at pins 11 and 9 of P1. A positive 26-volt potential would then appear at the junction of the two mixing resistors. It will later be explained how a positive potential in excess of 1.9 volts, at the junction of R1 and R2, causes the range components to be slewed in. When the range setting of the missile-tracking radar decreases to 6,490 yards (2,090 yards greater than the range of the selected launcher) the voltage at the junction of R1 and R2 will be +1.9 volts. At this point, control of the range setting will switch from the coarse slew channel to the fine slew channel. When slew operation is not in progress, the junction of resistors R1 and R2 is grounded through contacts 1 and 9 of LAUNCHER POSITION relay K3. When the KQC relay is energized for slew operation, relay K3 energizes and this ground connection through contacts 1 and 9 is broken.

d. Circuit operation, initial phase. Automatic slew operation begins 3 seconds after the beacon signal is lost or 0.4 second after the burst order is sent. In either case, the range setting will normally be considerably greater than the range position of the next selected launcher. Therefore, when slewing begins, a comparatively large positive voltage will suddenly appear at the junction of the mixing resistors, R1 and R2. This voltage is applied through resistor R11 and across capacitor C1 (which together make up a simple R-C filter) to the grid of V1B. The appearance of this positive voltage causes the conduction of V1B to increase. A negative-going change occurs in the voltage at the plate of V1B. This change is directly coupled through R10 to the grid of V2A. The conduction of V2A decreases, causing a positive-going change in the voltage at the plate. This positive-going change is coupled through R14 to the grid of V2B, and causes V2B to conduct heavily. The plate current of V2B flows through the coil of SLEW IN relay K1 (part of the plate load of V2B). When the current through K1 exceeds 8 milliamperes, the relay energizes. When K1 energizes, 400-cycle power is applied to the range slew motor. The 400-cycle power (motor excitation) is applied through contacts of lower-limit switch S2, contacts 2 and 3 of the energized SLEW IN relay, and the contacts of SLEW DISABLE switch S1 to terminal 5 of the motor windings.

The capacitive winding of the motor is grounded at this time through contacts 1 and 9 of the deenergized SLEW OUT relay, K2. In this configuration, slew motor B5 turns in the direction of decreasing range. The speed of rotation of the slew motor causes the centrifugal clutch to engage, and the range gearing is driven in at a rate of 12,000 yards per second. At the same time, the slip clutch disengages the range servomotor from the gearing.

e. Circuit operation, final phase. As the range setting decreases, the magnitude of the positive missile range position (MRP) voltage decreases. Therefore, the positive potential applied to the control grid of V1B also decreases. When the range components have been slewed to a setting 2,090 yards greater than the range to the selected launcher, a potential of +1.9 volts will be present at the junction of mixing resistors R1 and R2. As the grid voltage of V1B decreases to +1.9 volts, the current through V1B decreases to approximately 0.14 ma, and the plate voltage of V1B rises to 116 volts. The grid of V2A is connected to the junction of R10 and R12, which form a voltage divider between the plate of V1B and the negative 250-volt supply. As the plate of V1B rises to 116 volts, the grid of V2A changes in a positive direction to -4 volts. The current through V2A increases, and the voltage at the plate of V2A decreases to approximately 100 volts. The grid of V2B is connected to the junction of R14 and R37, which form a voltage divider between the plate of V2A and the -250-volt supply. As the plate voltage of V2A falls to 100 volts, the grid voltage of V2B changes in a negative direction to -11 volts. The current which then flows through V2B and the coil of the SLEW IN relay (approximately 2 milliamperes) is not enough to hold the relay energized. Relay K1 deenergizes when the voltage at the junction of the mixing resistors, R1 and R2, no longer exceeds +1.9 volts. When the SLEW IN relay deenergizes, contacts 2 and 3 open, removing 400-cycle power from the slew motor. As shown in figure 29, a -28-volt braking voltage is then applied to the slew motor through contacts of the braking centrifugal switch S4 (closed by rotation of the slew motor), contacts 3 and 10 of deenergized SLEW OUT relay K2, contacts 1 and 3 of deenergized SLEW IN relay K1, and contacts of SLEW DISABLE switch S1. This d-c potential produces a strong, motionless field which rapidly stops the slew motor. As the slew motor slows to a stop, the centrifugal clutch disengages the slew motor from the gearing. As the same time, the range servomotor is connected through the slip clutch to the range gearing.

f. Other considerations. To assure that the SLEW IN relay will deenergize when the grid voltage of V1B falls to +1.9 volts, accurate control of the operating point of V1B is necessary. This is done by V1A. The two sections of V1 have a common cathode connection, returned to the -250-volt supply through a large (0.825-megohm) resistor, R7. The grid of V1A is connected to a fixed

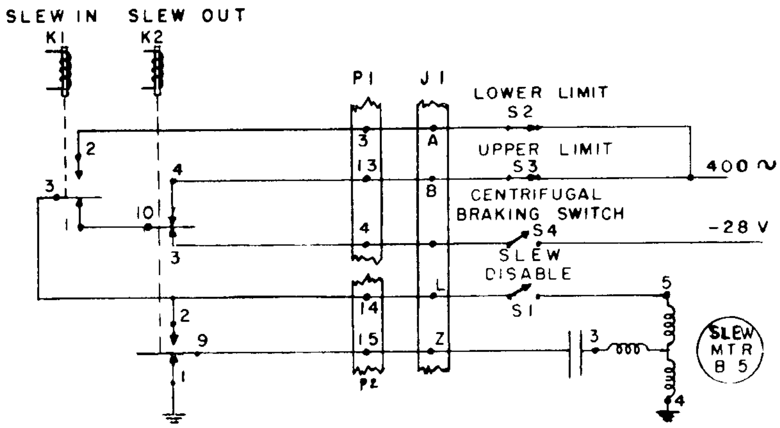


Figure 27. Missile range slew motor, control circuitry.

1.9-volt positive source at the junction of voltage divider R3-R4. As the grid voltage applied to V1B changes, the conduction of V1A changes to keep the operating point of V1B approximately constant. Resistor R36, in series with V2B, limits the maximum amount of current which can flow through the coil of relay K1. Resistor R9 has a similar function during manual slew operation (fig 27).

g. Manual slew. As shown in figure 28, when TEST-OPERATE switch S1 is placed in the TEST position, a ground appears at terminal 2 of SLEW switch S3. Operating the SLEW switch to the IN position completes a circuit for the coil of SLEW IN relay K1, and it will energize. The operation of the slew motor with K1 energized has already been described. However, in manual control, the slew motor will continue to operate until the SLEW switch is released or until the lower limit of the servo gearing is approached. In the first case, relay K1 deenergizes and the d-c braking voltage is applied across the motor windings. In the second case, lower limit switch S2 is opened and 400-cycle power is no longer applied to the motor. Operation of the SLEW switch to the OUT position completes the circuit for SLEW OUT relay K2. When K2 energizes, as shown in figure 29, 400-cycle power is applied through upper limit switch S3, contacts 4 and 10 of K2, contacts 1 and 3 of K1, and contacts of SLEW DISABLE switch S1 to terminal 5 of slew motor B5. At the same time, 400-cycle power is applied to the capacitive winding of the motor, through contacts 2 and 9 of K2. In this configuration, the slew motor rotates in the direction of increasing range. Movement will continue until the SLEW switch is released (at which time, 400-cycle power will be replaced by the d-c braking voltage) or

until the upper limit switch is operated (at which time, power is removed from the motor).

h. Slew motor B5. Slew motor B5 is a capacitor-start, induction-run motor, similar to those used in the range servo system of the target-tracking radar and in the magnetron tuning circuit of all three radars of the Nike system. The motor is easily reversible because only 1 of its 3 leads need be switched. When the range servo is driven by the slew motor, the range setting changes at a rate of 12,000 yards per second.

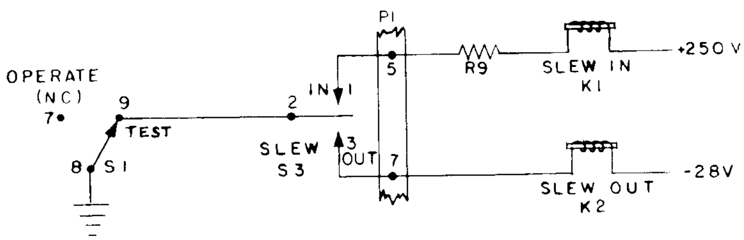


Figure 28. Manual slew, control circuitry.

78. FINE SLEW CHANNEL

a. General. Figure 29 shows the functional operation of the fine slew channel. When the KQC relay energizes for slew operation, contacts 1 and 9 of the KQC relay provide a ground through contacts 6 and 11 of the normally deenergized REMOTE CONTROL (or STAR GAZE) relay, K1, to pin 5 of P2 in the slew control unit. This ground energizes LAUNCHER POSITION relay K3, at the output of the fine slew channel. As a result, the output of the fine slew channel is applied through terminals 4 and 6 of P2 to the range modulator. Contacts 1 and 9 of the KQC relay also provide a ground for ACQUIRE relay K5, causing K5 to energize. Contacts 7 and 12 of the energized ACQUIRE relay provide a ground which energizes DISABLE relay K2 in the range modulator. With K3 in the slew control unit and K2 in the range modulator both energized, a direct connection exists between the fine slew channel of the slew control unit and the coast capacitors of the range modulator.

b. Operation under no-signal conditions. When the KQC relay is deenergized, contacts 1 and 9 of LAUNCHER POSITION relay K3 provide a ground at the junction of R1 and R2. This junction is connected directly to the grid of DC amplifier V3A. The grid of V3B is also grounded. Because of the balanced circuitry, the static currents of the two tubes are equal. This static current is approximately 0.115 milliamperes. With twice this value of current flowing through

the large cathode load, a small positive biasing potential is present at the cathodes. The plate current of V3A, added to the current through R19 and R22, develops a drop across R15, which produces a potential of +134 volts at the plate. This same voltage is present at the plate of V3B. By voltage divider action, -8.45-volt potentials appear at both grids of V4. With this grid voltage, each section of V4 draws 10 milliamperes. Hence, the voltage at the cathode of each section, with respect to ground, is zero. Because the LAUNCHER POSITION relay is not energized in this configuration, the cathode voltages of V4A and V4B are not applied to the range modulator.

c. Operation during slew, initial phase. Automatic slew operation begins when the timer channel causes KQC relay K6 to energize. At that instant, the LPR voltage appears at pin 9 of P1 and, because K3 energizes, ground is removed from the junction of mixing resistors R1 and R2. Normally, slew operation under control of the coarse slew channel will take place. However, even before the voltage at the junction of R1 and R2 falls below +1.9 volts, the fine slew channel operates. The positive voltage that appears at the grid of V3A increases the conduction through that tube. As a result, the plate voltage of V3A falls and the cathode voltage rises. Because the grid of V3B is grounded, the rising cathode voltage reduces the current through V3B, and the plate voltage rises. The voltage changes at the plates of V3A and V3B appear, in part, at the grids of V4A and V4B. The direction of these voltage changes is such as to decrease the conduction of V4A and increase the conduction of V4B. The voltage at the cathode of V4A becomes negative, and the voltage at the cathode of V4B becomes positive. Because K3 in the slew control unit and K2 in the range modulator are both energized, these push-pull cathode voltages are applied across the coast capacitors of the range modulator. The resulting 400-cycle output of the range modulator is applied through the coupling unit and low-power servoamplifier to the range servomotor, causing the servomotor to move in the direction of decreasing range. However, because the rotation of the slew motor has caused the servomotor to become disengaged from the range gearing, the servomotor does not control the setting of the range components at this time.

d. Operation during slew, final phase. As previously explained, the slew motor stops when the voltage at the junction of mixing resistors R1 and R2 goes less positive than +1.9 volts. At this time, the servomotor resumes control of the range gearing (through the slip clutch). The servomotor then operates under control of the fine slew channel to drive the range setting in. As the range setting approaches that of the selected launcher, the voltage at the junction of R1 and R2 (and at the grid of V3A) approaches zero. When the desired range setting is attained, this voltage is zero. At that time, the voltages present at the cathodes of V4A and V4B are both zero. With zero voltage applied across the coast capacitors of the range modulator, the servomotor halts. The circuit

will remain in this condition until 3 seconds after the beacon signal from the missile has caused the ATC relays to operate. At the end of the 3-second interval, the KQC relay is deenergized by action of the timer channel. When the KQC relay deenergizes, LAUNCHER POSITION relay K3 deenergizes. This grounds the junction of R1 and R2 and opens the output circuit from the cathodes of V4A and V4B. At the same time, relay K2 in the range modulator deenergizes, and the coast capacitors resume their normal function in that unit.

e. Other considerations. Resistors R17 amd R18, in the cathode circuit of V3, are the BAL 1 and BAL 2 controls, respectively. Resistor R17 balances the operation of the two sections of this channel so that, with ground present at the grid of V3A, the cathodes of V4A and V4B will be at the same potential. Resistor R18 adjusts the bias of V3A and V3B so that, with ground present at the grid of V3A, the cathodes of V4A and V4B will be at zero potential with respect to ground. Resistor R26, connected between contacts 3 and 6 of LAUNCHER POSITION relays K3, serves no purpose during normal operation. This resistor will shunt the coast capacitors of the range modulator only when K3 of the slew control unit is deenergized and K2 of the range modulator is energized. This condition can exist only in manual or aided-manual operation, when the RANGE switch is in either the MAN or the AID position and the TEST-OPERATE switch is in the TEST position. In such a case, manual operation of the missile LAUNCHER ACQUIRE switch will cause the fine slew channel to place a charge across the coast capacitors. Releasing the LAUNCHER ACQUIRE switch places resistor R26 across the coast capacitors. If the switch were released prematurely, a charge would remain across the capacitors. Resistor R26 provides a fast discharge path to dissipate this undesired charge.

79. AGC MONITOR

a. General (fig 17-5). The slew control unit causes the missile range servo system to be driven to the setting corresponding to the range position of the selected launcher and holds the servo system in this position until 3 seconds after the beacon signal from the new missile has caused the ATC relays to operate. At the end of this period, the MISSILE TRACKED signal lamps at the missile console and at the battery control console (in the battery control trailer) normally light. This indicates that the operating sequency may be continued through the ready-to-fire, fire, and launch phases. However, it is not wise to attempt to fire a missile whose beacon signal is weak, erratic, or otherwise inadequate. For this reason, the normal operating sequence may be interrrupted at this point if the beacon signal from the missile is unsatisfactory. This is done by the AGC monitor. The AGC monitor is located in the equipment drawer of the missile console.

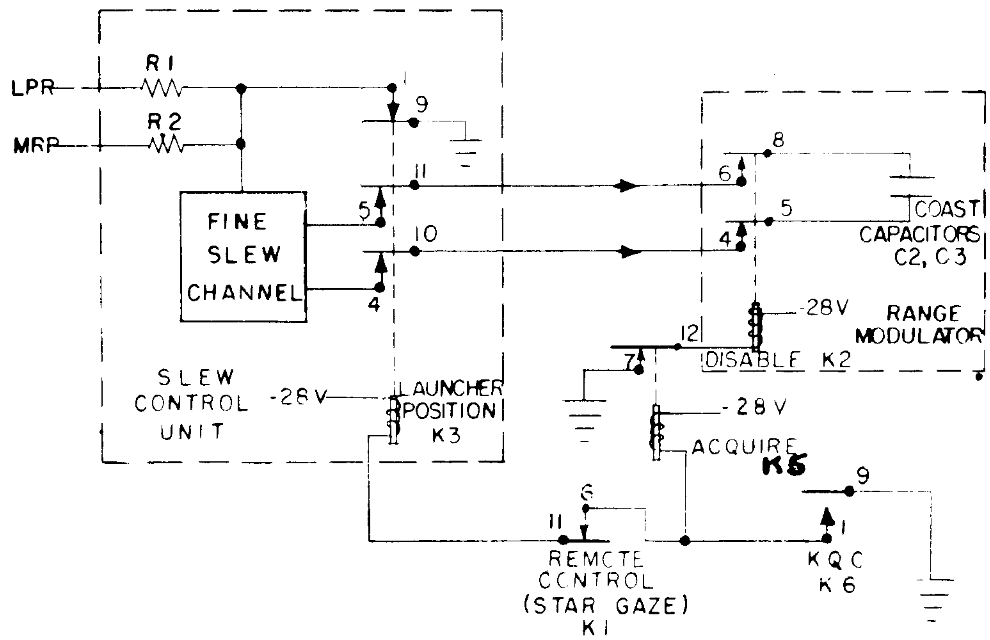


Figure 29. Functional operation of fine slew channel.

b. Input circuit. The input voltage of the AGC monitor is at pin 3 of P1. This voltage is obtained from the AGC unit. The voltage is applied through limiting resistor R1 to pin 7 of P1, from which point it is applied to RECEIVED SIGNAL meter M2 on the equipment drawer. Normally, this is the sum AGC voltage. The meter reading indicates the relative strength of the signal received from the missile (because the magnitude of the AGC voltage is a function of this signal strength).

c. Operation (fig 17-6). The AGC monitor controls the operation of relay K1. Except for the input circuit, the unit is almost identical to the coarse slew channel of the slew control unit and to the relay amplifiers in the computer. These circuits cause the controlled relay to energize when the grid voltage of the B-section of the first stage is positive with respect to the grid voltage of the A-section. In the coarse slew channel, this is done by applying a positive voltage to the B-section grid. In the AGC monitor, however, the same result is obtained by applying a negative voltage to the A-section grid. When no AGC voltage is applied at pin 3 of P1 (zero voltage present at that point), the voltage at the grid

of DC amplifier V1A is determined only by the setting of LEVEL SET control R4, connected in a voltage divider between the +250-volt supply and ground. With R4 in the maximum setting, a potential of about +56 volts is present at the brush arm of the potentiometer and a +5-volt potential appears at the grid of V1A. The conduction of V1A in this condition raises the cathode voltage to a value which prevents conduction in V1B. (The grid of V1B is grounded.) With V1B cut off, the voltage at its plate is maximum. As a result of this large positive voltage, V2A conducts heavily, with its grid drawing current. The low voltage at the plate of V2A produces a cutoff potential at the grid of V2B. Hence, no current flows through the coil of AGC relay K1, and that relay is not energized. The AGC voltage at pin 3 of P1 has a normal maximum value of -6 volts. With the LEVEL SET control still adjusted to the maximum position, an AGC voltage of -6 volts will cause the grid voltage of V1A to be approximately -0.9 volt. (An AGC voltage of -5.6 volts will produce zero potential at the grid of V1A when R4 is in the maximum position.) With a negative voltage at its grid, the conduction of V1A will be reduced so that the lower cathode voltage will permit V1B to conduct. In this case, the B-section conduction is greater than the A-section conduction. The lower plate voltage of V1B will reduce the conduction of V2A. The greater voltage which will then be present at the plate of V2A will raise the grid voltage of V2B. The plate current of V2B will then energize relay K1. Adjustment of the LEVEL SET control to a less positive value will permit a smaller AGC voltage to energize K1.

d. Action of AGC relay K1. When K1 is energized, contacts 4 and 5 complete the circuit for lamp I1 on the AGC monitor chassis. The lighting of this lamp indicates that the relay is energized. The AGC relay affects the operating sequence of the battery through contacts 2 and 3. This circuitry is shown in figure 30. Contacts 7 and 12 of MISSILE READY relay K14 are normally closed before the missile-tracking radar slews to a new missile. When the slew operation is completed, and the ATC relays have been operated for a 3-second period, KQC relay K6 deenergizes. At this instant, contacts 5 and 9 of the KQC relay close. If the signal received from the new missile is strong enough to cause AGC relay K1 to energize, then MISSILE TRACK relay K16 will energize. The energizing circuit of K16 is normally completed through contacts 5 and 9 of the deenergized KQC relay, pin 11 of P1 in the AGC monitor, contacts 2 and 3 of the AGC relay, pin 9 of P1 in the AGC monitor, contacts 7 and 12 of the energized MISSILE-READY relay, and contacts 8 and 12 of the deenergized MISSILE REJECT relay. If the AGC relay fails to operate because of an inadequate beacon signal, the missile must be accepted or rejected manually. The missile is accepted manually by operation of the TRACKED switch. As shown in figure 30, the contacts of this switch parallel the contacts of the AGC relay. When MISSILE TRACK relay K16 is energized, contact 7 and 12 of K16 provide a holding circuit around both the TRACKED switch and the AGC relay. Once K16 has become energized,

it cannot be deenergized merely by opening the contacts of the AGC relay, but will be deenergized by opening the contacts of the KQC relay. This prevents K16 from deenergizing until 3 seconds after loss of the beacon signal (or 0.4 second after the burst order is transmitted).

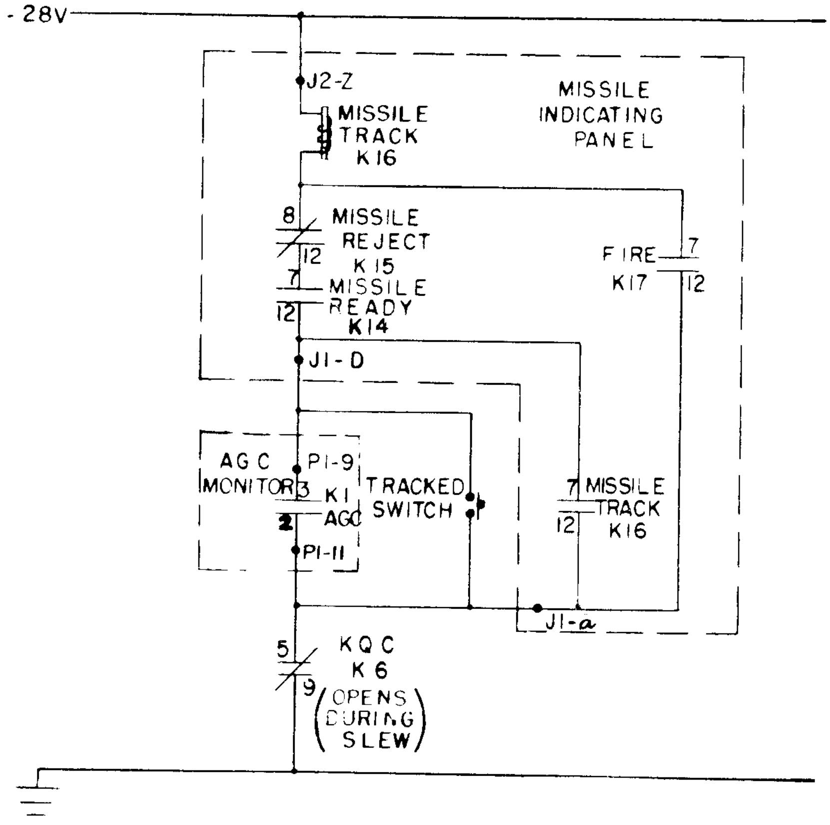


Figure 30. Control circuitry affected by AGC relay K1.

Section II. MISSILE-TRACKING RADAR CONTROL CIRCUITRY

80. INTRODUCTION

To the radar operator and radar repairman, the dials, scopes, switches, and lights which are before him on the console are his helpers in controlling the radar. It is essential that the operator or repairman know the function of each console control. The indications on the console are usually the first sign of trouble in the radar, and the repairman must be able to read and interpret these signs. Without exception, the successful repairman uses the information available to him on the control panel as the first link in his troubleshooting procedure. Tied in with each knob and switch on the console is a relay or series of relays. It is essential to understand the relay sequence so that troubleshooting can be done intelligently.

81. OVER-ALL PURPOSE.

The missile-tracking radar control circuits switch components of the radar in and out of action at the proper time. Each switch, button, knob, light, meter, and relay on the missile console has a function in the switching operations and all will be discussed in turn.

82. MISSILE-TRACK CONTROL PANEL (fig 11-2)

a. General. The missile control panel is located on the right-hand side of the missile console and has the indicators and controls which are concerned with the high-voltage power supply, indicator high-voltage power supply, frequency of the transmitter, and receiver gain control.

b. Magnetron meter. This meter (M1) operates in conjunction with spring-loaded toggle switch S5, which is located immediately below it. In the center position of the switch, the meter registers magnetron current in milliamperes. Normal reading for this position is 12 ma. When the toggle switch is pushed to the left, the meter has a scale factor of 20 kilovolts for full-scale reading and registers the kilovolt output from the high-voltage power supply. Normal reading is approximately 6.5 kv. When the toggle switch is pushed to the right the meter has a scale factor of 200 milliamperes for full scale reading and registers the current output of the high-voltage power supply. Normal reading in this position is approximately 140 ma. Toggle switch S5 is spring-loaded so that it remains in its center position.

c. Frequency meter. This meter (M2) operates in conjunction with spring-loaded toggle switch S6, which is located immediately below it. The meter is calibrated to read the approximate operating frequency of the magnetron. When the toggle switch is placed in the DECREASE position, it causes the magnetron tuning drive motor to turn and tune the magnetron to a lower frequency. At the same time, a potentiometer arm in the magnetron tuning drive unit is caused to move so as to pick off less voltage and the meter reading consequently decreases. Opposite action takes place if the switch is placed in the INCREASE position. Midscale reading of M2 should approximate 9,000 megacycles and the upper and lower ends of the meter should approximate 9,600 and 8,500 megacycles respectively.

d. START-MAX control. This knob controls the variac which feeds the primary of the plate transformer in the high-voltage power supply. It must be turned counterclockwise to the START position each time the high voltage is turned on. This position of the knob closes the turn-down interlock, S3, which in turn permits voltage to be applied to the primary of the high-voltage plate transformer. If S3 were not in the circuit, the position of the variac might cause a damaging surge of current to flow through the power supply.

e. READY light. Green light I2 is a duplicate of the HIGH VOLTS READY light on the radar power control panel. This light comes on when the high-voltage power supply is warm and ready to operate. It goes out when the high voltage is turned on.

f. ON light. Red light I3 is a duplicate of the HIGH VOLTS ON light on the radar power control panel. Light I3 is controlled by pushbutton switches S1 and S2. When ON button S1 is pushed, it causes the ON light to light and the READY light to go out. The ON light remains lit until OFF button S2 is pressed. Then the READY light is lit. After the OFF button is pressed, it is necessary to rotate the START-MAX control all the way counterclockwise before the ON button will have any effect.

g. IND HV light and OFF switch. White light I1 is controlled by toggle switch S1. The indicator high-voltage switch has only one labeled position, which is OFF. This is the down position of the switch and in this position the indicator high-voltage power supply is not energized. In the up position of S1, the IND HV light is lit and high voltage is applied to the range indicator on the missile console.

h. GAIN control and AGC-MANUAL switch. The GAIN control, R7, furnishes manual receiver gain control for the missile-tracking radar when the AGC-MANUAL

switch, S7, is in the MANUAL position and the TEST-OPERATE switch, S1, in the missile control drawer is in the TEST position.

83. MISSILE-TRACK RANGE INDICATOR (figs 7-12 and 7-13)

a. General. The missile range indicator presents an A-type display of range on the indicator scope. It also has a dial which indicates range. All controls on the face of this unit are used to vary the length, intensity, image spacing, and focus of the scope display. The track-range indicator in the missile console is identical to the track-range indicator in the target console.

b. FOCUS and INTENSITY controls. The FOCUS control knob, R6, is used to focus the trace on the scope. The INTENSITY control knob, R4, controls the intensity or brightness of the trace on the scope.

c. IMAGE SPACING switch. The IMAGE SPACING switch, S1, serves no image spacing function in range indication, therefore, it should always be in the OFF position.

d. SWEEP LENGTH control. The SWEEP LENGTH control knob, R3, is used to change the length of range display on the scope. The counterclockwise position produces maximum range display from zero and the clockwise position produces minimum range display from zero.

e. Range dial. The dial has coarse and fine indications which are controlled by the coarse and fine synchros, B1 and B2, respectively, located behind the face of the panel.

84. MISSILE-TRACKING EQUIPMENT DRAWER (fig 5-6)

a. General. The equipment drawer in the missile console has controls and indicators which are concerned primarily with the status of the missile being tracked by the radar. Many of the indicating lights can be changed by the missile radar operator who has the necessary switches available to him on the missile indicating panel. This action is resorted to when the 3-mile cable is broken and operations have to be carried out by telephone or radio.

b. DESIGNATED lights. The amber DESIGNATED light indicates that no action has been taken to designate a missile. This amber light goes out and the green DESIGNATED light just above it goes on when a missile is designated. The green light is normally lit by signals from the launching control area, but can be done in an emergency by the missile radar operator who presses switches on the missile indicating panel. These lights are duplicated on the tactical signal panel.

c. READY lights. The amber READY light indicates that the designated missile is not ready to be fired. The green READY light indicates that the sequence or events required to prepare a missile in the launching area has been completed and that the designated missile is ready to be fired. It is possible, in emergency, for the missile radar operator to complete this sequence. This pair of lights is duplicated on the tactical signal panel.

d. TRACKED lights. The amber TRACKED light indicates that the AGC monitor has not accepted the beacon signal of the designated missile. This amber light goes out and the green TRACKED light is lit when the beacon signal is accepted. The green TRACKED light indicates that the designated missile is being tracked and the beacon is strong enough for radar tracking. The missile radar operator can accept the beacon manually if the need arises. This pair of lights is duplicated on the tactical signal panel.

e. FIRE lights. The amber FIRE light indicates that the fire order has not been given. This amber light goes out and the green FIRE light comes on when the fire switch has been operated. The battery control officer operates the switch that completes this sequence, or in an emergency, the firing can be done in the launching area and then the pressing of the fire key in the battery control trailer switches the lights and cause certain computer operations to take place. This light is duplicated on the tactical signal panel.

f. LAUNCH lights. The amber LAUNCH light indicates that the computer has not detected missile away. This amber light goes out and the green LAUNCH light is lit when the computer has detected missile away. (There are MISSILE AWAY signal lights in the launcher control trailer which are lighted by microswitch action at the instant the missile leaves the launcher rails. This action is not duplicated anywhere in the battery control area.) The computer, using tracking data from the missile-tracking radar, causes the green LAUNCH light on the missile equipment drawer to light when the missile has reached a fixed altitude above the launcher. This action occurs approximately 1 second after launch. The LAUNCH lights are duplicated on the tactical signal panel and the target radar signal panel.

g. BURST lights. The amber BURST light indicates that the computer has not given the burst signal. This amber light goes out and the green BURST light is lighted when the computer gives the burst signal. This light is duplicated on the tactical signal panel.

h. TRANSMITTER ERROR meter. The TRANSMITTER ERROR meter, M1, indicates the percentage of missing transmitter pulses from the missile-tracking

radar. There is a duplicate meter on the transmitter pulse monitor, which is located in the missile-tracking r-f unit. A switch on the transmitter pulse monitor will change the meter calibration so that full-scale deflection will indicate either 10 percent missing pulses or 100 percent missing pulses.

i. RECEIVED SIGNAL meter. The RECEIVED SIGNAL meter, M2, gives a reading which is proportional to the strength of the beacon signal from the missile. Deflection of the meter needle is caused by the amount of AGC bias applied to the sum i-f amplifiers, this amount of bias is proportional to the strength of the received signal. The signal used to produce meter deflection is taken from the missile AGC monitor, which receives its signal from V3B in the AGC unit.

j. TARGET-STANDBY-MISSILE switch. This switch, S1, is used in conjunction with the r-f test set and is left in the STANDBY position during normal operation. The MISSILE position of the switch permits the use of the r-f test set with the missile-tracking radar and also causes the RECEIVER TEST LIGHT to light. In the TARGET position of S1, the target radar is set up to be used with the r-f test set and the RECEIVER TEST light on the target console is lit. The TEST-OPERATE switch, S1, on the control drawer must be in the TEST position before the TARGET-STANDBY-MISSILE switch has any effect.

k. RECEIVER TEST light. This red light is lighted when the TARGET-STANDBY-MISSILE switch is in the MISSILE position. The light indicates that the missile-tracking radar receiver can be tested.

l. SIGNAL LEVEL adjustment. This knob adjustment is used when the TARGET STANDBY-MISSILE switch is in the MISSILE position. The knob is connected to synchro B1, which controls an attenuator in the r-f test set during testing of the missile radar. A dial located just above the knob indicates the amount of attenuation.

m. RANGE SLEW switch. The RANGE SLEW switch, S2, is used in conjunction with the r-f test set to change the apparent range of the r-f test set.

n. RANGE TRIM control. This control knob is a fine adjustment for the RANGE SLEW switch.

85. MISSILE INDICATING PANEL (fig 17-3)

a. ELEVATION ERROR meter and AZIMUTH ERROR meter. These meters, M2, and M1, indicate the angular tracking errors in the missile-tracking radar.

A portion of the error signals being sent to the angle modulators is used to cause deflection of the meter needles.

b. SECTION indicating lights. These green lights indicate which launcher section is to fire the missile.

c. SECTION pushbuttons. These buttons are used when it is necessary for the missile-tracking radar operator to manually acquire the new missile. If the launcher control officer cannot acquire the proper launcher section, then the missile operator, acting upon verbal instructions, presses the correct SECTION button and thus begins to manually acquire the missile. Other steps are also necessary and will be discussed later.

d. LAUNCHER indicating lights. These lights indicate which launcher is being used to fire the missile.

e. LAUNCHER pushbuttons. These buttons are used when it is necessary for the missile-tracking radar operator to manually acquire the new missile. If the remote designation signals cannot be received from the launcher control area, then the missile operator, acting upon verbal instructions, presses the correct LAUNCHER button and thus continues the process of manually acquiring the missile. Other steps are also necessary and will be discussed later.

f. TEST RESPONDER indicating light and pushbutton. The missile-tracking radar operator can use this pushbutton switch S9, to manually acquire the test responder, and the amber light, I9, indicates that the launcher position unit for the test responder is energized.

g. MISSILE READY switch. This switch, S11, is used to manually indicate that the missile is ready. It is used by the missile-tracking radar operator only when he is using local acquisition.

h. LOCAL DESIGNATE switch. This switch, S10, permits manual missile designation by the missile-tracking radar operator. In the unlabeled position, the switch is off and permits remote designation. The operator must put the switch in the LOCAL DESIGNATE position before he can produce any results by pushing the SECTION and LAUNCHER buttons.

i. SIGNAL LIGHTS control knob. This knob is connected to R1, which controls the brightness of all signal lights on the missile console.

j. DIAL LIGHTS control knob. This knob is connected to R3, which controls the brightness of all dial lights on the missile console.

k. ELEVATION and AZIMUTH dials. These dials are controlled by synchros in back of the panel and indicate the azimuth and elevation of the missile-tracking radar antenna.

86. MISSILE CONTROL DRAWER (sheet 44)

a. MAN-AID-AUTO switches. There are 3 of these switches on the missile control drawer, 1 for azimuth, elevation, and range servos respectively. The switches are effective only when the TEST-OPERATE switch is in TEST, otherwise the set is in the automatic mode.

b. TEST-OPERATE switch. This switch, S1, permits the operator to put the missile-tracking radar in any mode of operation. If this switch is in OPERATE, the radar will be in automatic regardless of the position of the MAN-AID-AUTO switches. In the TEST position of S1, it is possible to perform many tests on the missile-tracking radar.

c. SERVOS switch. If the TEST-OPERATE switch is in the TEST position, the TEST position of S11 will energize SERVOS TEST relay K2 in the missile track console assembly. A voltage will be sent to the angle modulators. This voltage may be used to check the respective servo for its maximum rate, either increasing or decreasing. Each servo may be checked individually, even though the SERVOS switch makes voltages available to all of the servos.

d. Handwheels. Three handwheels allow manual tracking with the missile-tracking radar when the TEST-OPERATE switch is in TEST.

e. COAST indicating light. This red light, controlled by the ATC unit, lights when the radar goes out of automatic tracking.

f. DISABLE switch. When this switch, S2, is in the DISABLE position, the ATC unit no longer has control over the TIME CONTROL relay, K4, in the missile slew control unit, and COAST relay K1 in the range and angle modulators. This switch is used primarily to disable ATC and permit the servo test voltage to be sent into the modulator for testing rates and balancing the servo.

g. REJECT pushbutton. If the missile beacon is not acceptable, the missile-tracking radar operator presses the REJECT button, S7, and this removes all

indications of missile tracked and lets the section panel operator know it is necessary to designate a new missile. It is not possible to reject after a missile is fired.

h. LAUNCHER ACQUIRE switch. This is a spring-loaded switch, S4, used when manually acquiring a missile.

i. TRACKED pushbutton. This button, S6, is used only in manual acquisition and lights the TRACKED signal lamp on the missile radar console and lights the MISSILE TRACKED signal light on the tactical signal panel.

j. RANGE CALIBRATE switch. This switch, S5, has three positions; NORMAL, ZERO, and RANGE CALIBRATE. In the NORMAL position, the range circuits are set up for normal operation. In the ZERO position, with the TEST-OPERATE switch in TEST, 2,000-yard calibration marks appear on the track range indicator to be used in the ZERO CALIBRATION of the missile radar range servo. In the RANGE CALIBRATE position, with the TEST-OPERATE switch in TEST, it is possible to proceed with the range calibration procedure for the missile-tracking radar.

k. SLEW switch. This switch, S3, is spring-loaded in its center position. It has two other positions labeled IN and OUT. This switch slews the range of the missile radar. It is possible in slew range only when the TEST-OPERATE switch is in TEST.

87 AUTOMATIC MISSILE RANGE TRACKING AND MISSILE ACQUISITION (Shs 43 and 44)

a. General. All components in the following discussion are located in the missile control drawer unless otherwise specified. For automatic range tracking, the TEST-OPERATE switch must be in the OPERATE position. The MAN-AID-AUTO switch for the range servo can be in any position, but assume it is in AUTO. It is necessary for the ATC unit to furnish a ground for the COAST relay, K1, in the range modulator, because if K1 is not energized, the automatic error signal will not enter the modulator. The RANGE MAN-AID relay, K12, will be deenergized. The handwheel assembly will be disconnected from the system and the signal from the modulator will now go to pin 4 of the range coupling unit, through R1, and out pin 8 of the coupling unit to the low-power servo-amplifier. The output of this amplifier drives the range servomotor in the range unit assembly. A negative feedback voltage, from the tachometer on the range servomotor, is fed back to the range coupling unit through terminal 3 to R3.

b. Coast. Assume now that the missile-tracking radar loses the missile for 1 or 2 seconds and then picks it up again and resumes automatic tracking. The ground from the ATC unit is lost and the COAST relay, K1, in the range modulator is deenergized. This removes the error signal input to the modulator, but since K12 still couples the output of the modulator to the servo, the charge on C2 and C3 in the modulator will hold the system in a coast condition. The COAST light will now come on because when K3 in the ATC unit is deenergized, it furnishes a ground for the COAST light through terminals 4 and 6 of K3. When the missile is picked up again in less than 3 seconds, ATC ground is returned to COAST relay K1 and automatic tracking is resumed.

c. Lost missile. Suppose now that the missile is lost and is not picked up again in 3 seconds. The radar is in the coast condition described above and the deenergizing of K3 in the ATC unit caused the TIME CONTROL relay, K4, in the missile slew control to be deenergized. Relay K4 is normally energized through contacts 2 and 3 of K3 in the ATC unit and contacts 6 and 11 of the BURST relay, K2, in the target radar signal panel. When K4 is deenergized, 3-second timing begins in the missile slew control. During this 3-seconds, the coast condition is maintained by the charge on C2 and C3 in the range modulator. If ATC ground is not returned by the end of the 3 seconds of coast, the TIME OVER relay, K6, in the missile slew control furnishes a ground through pins 4 and 5 of K6 to the SLEW CONTROL relay, K5, in the missile slew control unit. Relay K5, in turn, furnishes a ground through its terminals 2 and 9 for the ACQUIRE (KQC) relay, K6. Contacts 2 and 10 of K6 energize K3 in the designated launcher position unit through contacts 9 and 2 of LAUNCHER relay K4 and contacts 12 and 7 of SECTION relay K12, both in the missile indicating panel. It is possible for pins 9 and 2 of one of the other LAUNCHER relays to be substituted for K4 and contacts 12 and 7 of one of the other LAUNCHER relays to be substituted for K12. This substitution depends upon which section and which launcher has been designated at the launching control area. Contacts 1 and 9 of the energized ACQUIRE relay, K6, energize ACQUIRE relay K8 and K5 and also LAUNCHER POSITION relay K3 in the missile slew control. Contacts 7 and 12 of ACQUIRE relay K5 furnish a ground to the DISABLE relay, K2, in the range modulator. This action connects C2 and C3 in the modulator to K3 in the missile slew control, which is also energized, and connects C2 and C3 to the output of the fine slew channel in the missile slew control. Now that all the necessary relays are energized, the system begins to move. When the missile-tracking radar last tracked the missile, it was in flight, so the range of the radar in almost every instance of acquiring a new missile will be greater than that of the new missile. The error voltage that causes movement originates in the range potentiometer of the launcher position unit. This signal is sent through contacts 12 and 7 of energized K3 in that unit to the missile slew control where it causes the SLEW IN

circuit to energize SLEW IN relay K1 in the missile slew control. Relay K1 removes the -28-volt braking voltage from the slew motor and applies power to make the servo to slew in. The high rate of slew causes the centrifugal clutch to disengage the range servo motor until the slew motor is deenergized by the slew control. Then the fine slew channel, being connected to C2 and C3 in the range modulator, drives the range servo to the correct range, as established by the launcher position unit. Now that the radar range servo is at the correct range, it only remains for automatic tracking to be resumed. To make sure that the system is locked on the new missile, the missile slew control and the ATC are arranged so as to give a 3-second delay after the ATC signal is received. At the end of the 3 seconds, the SLEW CONTROL relay, K5, in the missile slew control unit deenergizes. This removes the ground through 2 and 9 of K5 for ACQUIRE relay K6, which deenergizes. Since none of the relays energized by K6 have holding contacts, all of those relays deenergize and automatic tracking is resumed.

d. Burst missile. Assume now that a BURST order was given to the missile. The operation of automatically slewing to a new missile is basically the same as that described for losing the missile, except for the time delay. In the case of a burst missile, the delay before slewing to a new missile begins is a 0.4 second. Until the burst order is given, the timer is set for 3 seconds by a ground to contact 12 of the SLEW CONTROL relay, K5, in the missile slew control unit. This ground goes through contacts 5 and 11 of the energized FIRE relay, K17, in the missile indicating panel and contacts 8 and 12 of the deenergized BURST relay, K2, in the target signal panel. When the BURST signal is given, the BURST relay, K2, is energized, thereby opening the timer ground circuit and setting up the timer for 0.4-second operation. After 0.4 second of coast, the missile-tracking radar will slew to a new missile. Then when ATC ground is received, the timing delay is 3 seconds before automatic tracking is renewed.

88. MANUAL MISSILE RANGE ACQUISITION (fig 17-3)

a. General. Assume a condition now where automatic radar tracking is possible, but the cable connections to the launching control trailer have been broken and it is necessary for the missile-tracking radar operator to manually designate and acquire a missile. The instructions for this type of operation are normally relayed to the operator by telephone. Since no missile has been designated locally or otherwise, the missile-tracking radar will automatically slew to the test responder 0.4 second after the missile is burst and remain there until the missile-tracking radar operator locally acquires another missile.

b. Manual designation. For purposes of illustration, assume that the first step in manually acquiring the missile is to operate the proper switches and buttons on the missile indicating panel. The LAUNCHER NOT DESIGNATED relay, K13, in the missile indicating panel is energized through contacts 10 and 3 of the SECTION relays, K5, K6, K7, and K8. Deenergized K13 furnishes a ground through contacts 11 and 5 for the test responder light, I9, indicating that the missile-tracking radar is positioned to the test responder. This action results because no missile could be designated from the launching control area and none has been designated by the missile-tracking radar operator. The missile-tracking radar operator switches S10 to the LOCAL DESIGNATE position. Switches S10B and S10D furnish RELAY GROUND from J2-B to the movable contacts of the SECTION and LAUNCHER buttons on the missile indicating panel. Next, the operator is told that A-section and launcher 4 are the proper designations, so he presses the A-SECTION button. He need not hold this button, because contacts 12 and 7 form a holding contact for the SECTION A relay, K5. The LAUNCHER switch, S4, is the next button he must press and it energizes K4, which has a holding circuit through contacts 11 and 5. The indicator lights are lit when energized K4 and K5 furnish ground circuits through contacts 10 and 4. These relays have provided all the visual indications necessary and now it is necessary to energize the correct launcher position unit. When the SECTION A button energizes SECTION A relay K5, it also energizes SECTION A relay K9 in the missile indicating panel. Contacts 12 and 7 of K9 furnish -28 volts (KQ) from 2 and 9 of K4 to the launcher position unit, if ACQUIRE relay K6 is energized.

c. Local acquisition. Since ACQUIRE relay K6 must be energized so that the -28 volts (KQ) are available to the launcher positioning unit, the action for energizing K6 and supplying the -28 volts will now be covered. The missile slew control does not have ATC ground or time-control ground, so TIME CONTROL relay K4 in the missile slew control is deenergized and TIME OVER relay K6 energizes long enough to furnish a ground to SLEW CONTROL relay K5. When SLEW CONTROL relay K5 energizes, its contacts 2 and 9 furnish a ground for ACQUIRE relay K6. Acquisition of the missile proceeds as in automatic. The ACQUIRE switch, S4, on the missile control drawer is necessary only when the system is in manual or aided operation. Pressing the ACQUIRE switch will energize the ACQUIRE relays and COAST relay K1 in the range modulator, and the launcher position signal will be switched into the servo to position it to the range of the designated missile.

89. MANUAL AND AIDED MISSILE RANGE TRACKING (sh 43)

a. Manual missile range tracking. Manual range operation of the missile-tracking radar is possible only when the TEST-OPERATE switch, S1, is in the

TEST position. The reason for this is that the high rate of speed attained by the missile makes it virtually impossible to track manually in range. The cost of the missile, the speed, and the importance of the Nike mission were all reasons why it was decided to use only automatic tracking for the missile-tracking radar during firing. The manual mode is used only in testing. In manual tracking, the primary control signals are generated in the range handwheel drive. The handwheel rotates a tachometer that generates a 400-cycle voltage whose amplitude depends upon the speed of rotation and whose phase depends upon the direction of rotation. The TEST-OPERATE switch furnishes a ground through contacts 11 and 7 of K6 and 1 and B of the MAN-AID-AUTO switch to the coil of K12. The TEST-OPERATE switch also furnishes a ground through 1 and A of the MAN-AID-AUTO switch to the coil of the magnetic clutch solenoid in the handwheel assembly. When K12 is energized, the DISABLE relay, K2 in the range modulator is energized by a ground furnished through contacts 8 and 12 of deenergized ACQUIRE relay K5. The energizing of the DISABLE relay, K2, places a 220-ohm resistor in the missile slew control across C2 and C3 in the range modulator, thereby discharging these capacitors. The manual control voltage generated by the tachometer is sent through contacts 5 and 11 of K12 and 1 and 9 of the CALIBRATE relay, K11, to the range coupling unit. In the range coupling unit the signal is developed across R8 and goes through R7 to the low-power servoamplifier, causing rotation of the range servomotor. The tachometer feedback is the same as in the automatic mode.

b. Aided missile range tracking. The aided mode of operation is possible only when the TEST-OPERATE switch is in the TEST position and the MAN-AID-AUTO switch is in the AID position. The primary control signal originates in the RATE potentiometer, R3, in the range handwheel drive. Since the magnetic clutch coil is deenergized in aided operation, the clutch is engaged and operation of the handwheel will move the arm of R3. The position of the arm from center determines the phase and amplitude of the control voltage. The voltage from R3 is sent through contacts 2 and C of the MAN-AID-AUTO switch, 4 and 10 of energized K12, and 3 and 10 of deenergized CALIBRATE relay K11. Then, the control voltage is sent through R2 of the range coupling unit and on to the low-power servoamplifier. Operation of the range servo from this point is the same as in automatic. Note that the tachometer in the handwheel assembly is still connected to the low-power servoamplifier through contacts 5 and 11 of K12, 1 and 9 of K11, and the range coupling unit. Five and one-half turns of the handwheel from the center position of the RATE potentiometer will give a maximum aid voltage, but the handwheel can still be turned because the magnetic clutch will slip after the potentiometer arm hits its mechanical limit stop. The voltage now obtained from the tachometer will add to the voltage from the potentiometer and causes added speed of the range servo. When the handwheel is no longer turned, this added voltage is no longer available, and the system settles out at the rate determined by the aid voltage.

90. MANUAL RANGE SLEW AND LIMIT SWITCHES (sh 43)

Slewing of the range servo depends upon the action of the missile slew control unit. This can be done automatically by the signal from the potentiometer in the launcher position unit. It may also be done manually by the SLEW switch on the missile control drawer. The circuit for manual range slewing requires that the TEST-OPERATE switch, S1, be in the TEST position. This furnishes a ground through contacts 8 and 9 of the TEST-OPERATE switch to contact 2 of the SLEW switch, S3. When S3 is held in the IN position, contacts 1 and 2 of S3 furnish a ground for the SLEW IN relay, K1, in the missile slew control unit. Contacts of the SLEW IN relay, K1, remove the -28-volt braking voltage and apply excitation to the range slew motor causing the range to slew in. If the SLEW switch is held long enough, the servo will drive to its lower limit and the LOWER LIMIT switch, S2, will open. This removes the motor excitation voltage and stops the motor. The limit switches are necessary because of the high slew rate. If the motor were permitted to drive into the mechanical limits at the slew rate, it is probable that damage would result, so the limit switches are provided to cut off power before the mechanical limit is reached. Slewing out is the same basic operation as slewing in, except for position of the SLEW switch and the removal of excitation by the UPPER LIMIT switch, S3.

91. RANGE CALIBRATION (fig 15-3 and sh 43)

The control circuitry for placing the missile-tracking radar into a mode of operation that permits range calibration begins with TEST-OPERATE switch, S1. This switch must be in the TEST position and the MAN-AID-AUTO switch must be in MAN or AID. The CALIBRATE relay, K1, will then energize if the RANGE CALIBRATE switch, S5, is placed in the RANGE CALIBRATE position. Ground is furnished through contacts 7 and 12 of K12, contacts 3 and 2 of S5, and contacts 2 and 3 of S1. Relays K1 in the range error detector and K1 in the range unit assembly energize at the same time as the CALIBRATE relay, K11, and through the same contacts. The CALIBRATE SYNCHRO, B3, in the range unit assembly is connected to the range coupling unit through 5 and 11 of K11. This synchro furnishes a null every 2,000 yards so that the servo can be stopped and checked at exact 2,000-yard intervals. Relay K1 in the range unit assembly substitutes a synchronizing pulse in place of the preknock and K1 in the range error detector substitutes pulses 500 yards apart in place of video. This calibration circuitry permits checking and adjusting of the servo.

92. AUTOMATIC AZIMUTH TRACKING ACQUISITION (fig 16-2 and 17-2 and Shs 42 and 44)

a. General. The conditions for automatic azimuth tracking require that the TEST-OPERATE switch, S1, be in the OPERATE position. The MAN-AID-AUTO switch, S9, may be in any position, but assume it is in the AUTO position. The primary control signal which is developed in the azimuth angle modulator is sent through contacts 1 and 9 of AZIMUTH MAN-AID relay K10 to contacts 1 and 9 of ACQUIRE relay K8. From here, the control signal goes through the azimuth coupling unit to the servopreamplifier and on out to the high-power servoamplifiers in the antenna trailer. The outputs from the high-power servoamplifiers drive the azimuth servomotors, which, in turn, drive the antenna. Negative feedback from the tachometers goes back to the azimuth coupling unit and is sent to the servopreamplifier for stability. Movement of the antenna drives the rotor of synchro B1 in the equipment enclosure. Synchro B1 acts as a synchro transmitter for synchro transformer B5 in the azimuth intermediate drive unit. The output from B5 goes through contacts 8 and 12 of K10 and then through R9 in the azimuth coupling unit to the low-power servoamplifier which drives the motor in the intermediate drive unit. This motor, B6, drives the rotor of the synchro, B5, to take out any error which might exist between the positions of B5 and B1.

b. Coast. A 3-second azimuth coast feature is used if the missile is lost and automatic tracking stops. In normal automatic tracking, the TIME CONTROL relay, K4, in the missile slew control unit is energized through contacts 2 and 3 of K3 in the ATC unit, and contacts 6 and 11 of the BURST relay, K2, in the target signal panel. While still in automatic tracking, a ground circuit holds the timer ready to begin its 3-second timing. This ground is furnished through contacts 1 and 2 of the DISABLE switch, S2, contacts 10 and 4 of the energized TIME CONTROL relay, K4, in the missile slew control unit, and contacts 6 and 11 of deenergized SLEW CONTROL relay K5 in the missile slew control. At the same time, the COAST relay, K1, in the angle modulator is energized through contacts 5 and 6 of either K1 or K2 in the ATC unit and contacts 4 and 5 of the DISABLE switch, S2. The COAST relay, K1, in the angle modulator is the relay that connects in the automatic error signal. When deenergized, it disconnects the error signal and permits the charge on the coast capacitors in the angle modulator to drive the servo. When automatic tracking fails and the ATC relays deenergize, the COAST relay, K1, loses its ground and the servo goes into a coast condition. The TIME CONTROL relay, K4, in the missile slew control unit is deenergized and the 3-second timer begins its timing action. If the missile is picked up again and tracked within 3 seconds, the system drops back into automatic tracking. However, if the missile is not reacquired within 3 seconds, the missile radar automatically slews to a new launcher, or to the test responder if no launcher is designated. When the missile is burst, the action is almost the same except for a 0.4 second coast instead of the 3-second

coast as established during tracking. The 0.4-second condition is set up when the BURST relay, K2, in the target signal panel is energized. Opening of contacts 11 and 6 of K2 deenergize the TIME CONTROL relay, K4, in the missile slew control, and opening of contacts 12 and 8 of K2 remove the ground at contact 12 of the SLEW CONTROL relay, K5, in the missile slew control unit. Removal of both ground circuits at the same time produces the 0.4-second coast. The 0.4-second coast after burst is used so that the event recorder may record many elements of data which exist in the Nike system at that instant and to insure that the missile receives the burst signal.

c. Burst. The SLEW CONTROL relay, K5, in the missile slew control unit is energized, thus furnishing a ground circuit through its contacts 2 and 9 to ACQUIRE relay K6, which then energizes. Contacts 2 and 10 of K6 furnish +28 volts (KQ)to K2 in the designated launcher position unit through contacts of the LAUNCHER and SECTION relays in the missile indicating panel. Contacts 1 and 9 of energized ACQUIRE relay K6 furnish a ground circuit for ACQUIRE relay K8. Contacts 5 and 11 of energized K8 furnish a ground circuit for the DISCHARGE relay, K2, in the angle modulator and a 220-ohm resistor in the angle modulator is placed across the coast capacitors so that they are discharged. The azimuth control signal originates in servo transformer B2 in the launcher position unit. The stator windings of B2 are connected through K2 in the launcher position unit to the stators of a servo transmitter, B1, in the azimuth data unit in the missile antenna trailer. Transmitter B1 has its rotor mechanically connected to the antenna gearing. The rotor of servo transformer B2 is connected through contacts 9 and 2 of K2 in the launcher position unit, contacts 1 and 9 of STAR GAZE relay K7, and contacts 10 and 4 of ACQUIRE relay K8, to the azimuth coupling unit. From the azimuth coupling unit, the signal drives the servo until the antenna position agrees with the position previously set into the synchro transformer in the launcher position unit. When the missile radar is pointed at the new missile, it will begin to automatically track the beacon. Relay K3 in the ATC will energize and through its contacts 2 and 3, and contacts 6 and 7 of the BURST relay, K2, in the target signal panel, will energize the TIME CONTROL relay, K4, in the missile slew control unit. Contacts 9 and 1 of energized K4 open one of the holding contacts for the SLEW CONTROL relay, K5, in the missile slew control unit. Three seconds later, the other holding circuit through 4 and 6 of K6 and 10 and 4 of K5, both in the missile slew control, is lost when K6 is energized. The missile-tracking radar is again in automatic and ready for another engagement.

93. MANUAL MISSILE AZIMUTH ACQUISITION AND TRACKING (shs 42 and 44)

a. Acquisition. Manual missile azimuth acquisition follows the same pattern as manual missile range acquisition. The positioning voltage originates in synchro transformer B2 in the launcher positioning unit.

b. Manual tracking. In manual tracking, the antenna is rotated by an amount proportional to the rotation of the azimuth handwheel on the control drawer of the missile console. This mode of operation is used only in testing and the TEST-OPERATE switch must be in the TEST position. The MAN-AID-AUTO switch must be in the MAN position. As a result, the magnetic clutch coil, L1, in the azimuth handwheel assembly, the DISABLE relay, K2, in the angle modulator, and azimuth MAN-AID relays K9 and K10 are all energized. The ground circuit that allows these relays to energize is furnished through contacts 2 and 3 of the TEST-OPERATE switch, S1, contacts 7 and 11 of deenergized ACQUIRE relay K6, and contacts 1 and B of MAN-AID-AUTO switch S9B. Rotation of the handwheel generates a voltage in the handwheel tachometer. This voltage is sent through contacts 10 and 4 of K9 and the azimuth coupling unit to the low-power servoamplifier which connects to the motor, B6 in the intermediate drive. Motor B6 rotates the rotor of synchro transformer B5 in the intermediate drive. The resulting voltage goes through contacts 11 and 5 of MAN-AID relay K10 to the azimuth coupling unit. From the azimuth coupling unit, the signal operates the servo as in the automatic mode.

c. Aided tracking. In aided tracking, the primary control signals are obtained from a rate potentiometer, R3, in the handwheel assembly. Since the magnetic clutch coil in the handwheel assembly is deenergized, the clutch is closed and rotation of the handwheel will move the arm of the potentiometer until the desired rate voltage is picked off. The TEST-OPERATE switch, S1, must be in the TEST position and the MAN-AID-AUTO switch, S9, in the AID position. The magnetic clutch coil, L1, in the handwheel assembly has no path to ground from contact 2 of S9, so it is deenergized. The control voltage from RATE potentiometer R3 is sent through contact 2 and the contact arm of S9C, contacts 5 and 11 of MAN-AID relay K9, R13 in the azimuth coupling unit, and then to the low-power servoamplifier that controls the intermediate drive motor. Operation from here on is the same as in manual. The handwheel tachometer is still in the circuit through contacts 10 and 4 of K9, so it is possible to supplement the aid voltage if necessary. This is the same action as described in aided range tracking.

d. Tracking limitations. On sites where the surrounding terrain will offer masks in the line of sight to the missile launcher positions, it will be found that there are limits to the ability of the missile-tracking radar to acquire and track

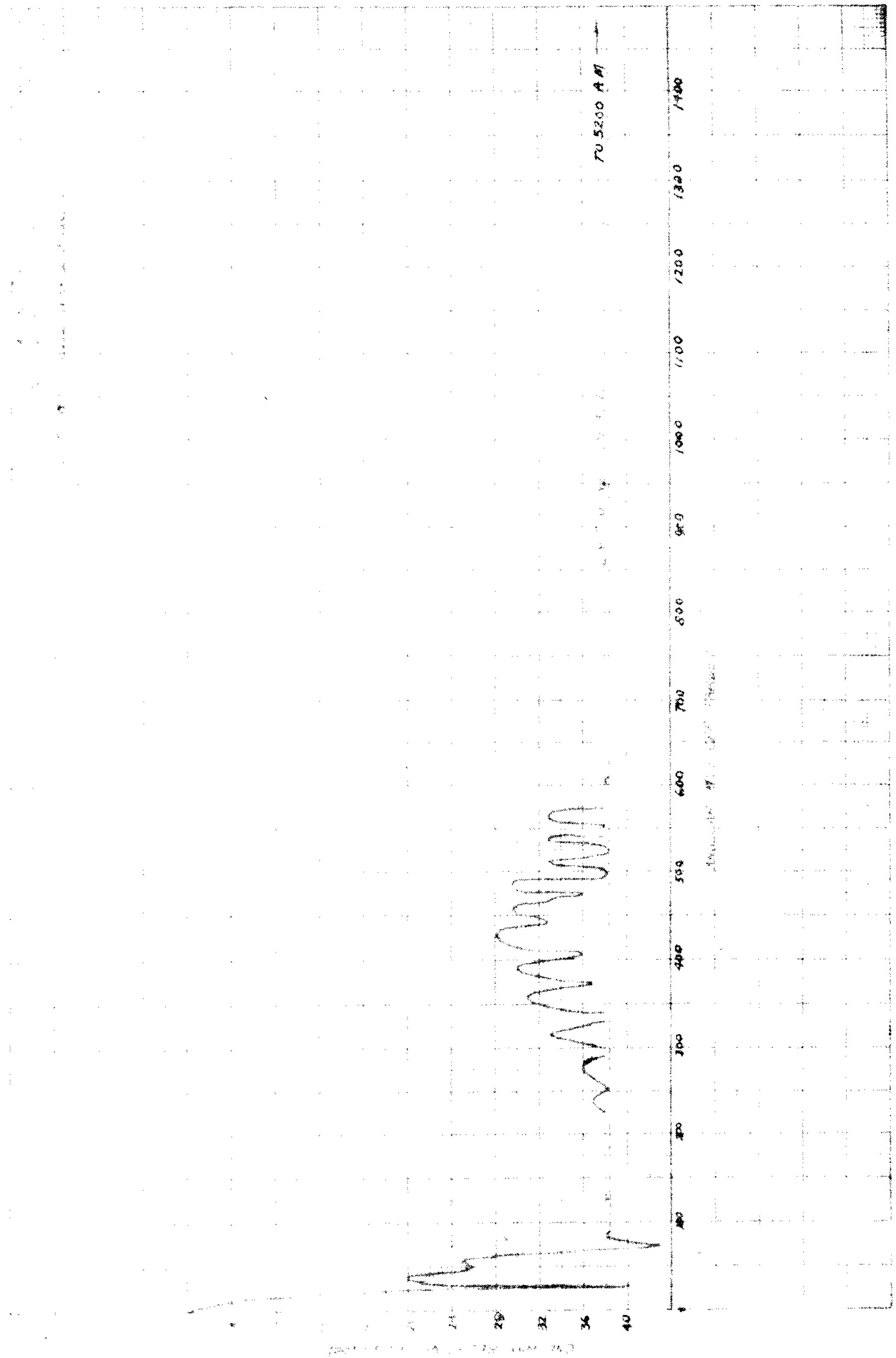


Figure 31. Typical missile-tracking radar antenna pattern, azimuth.

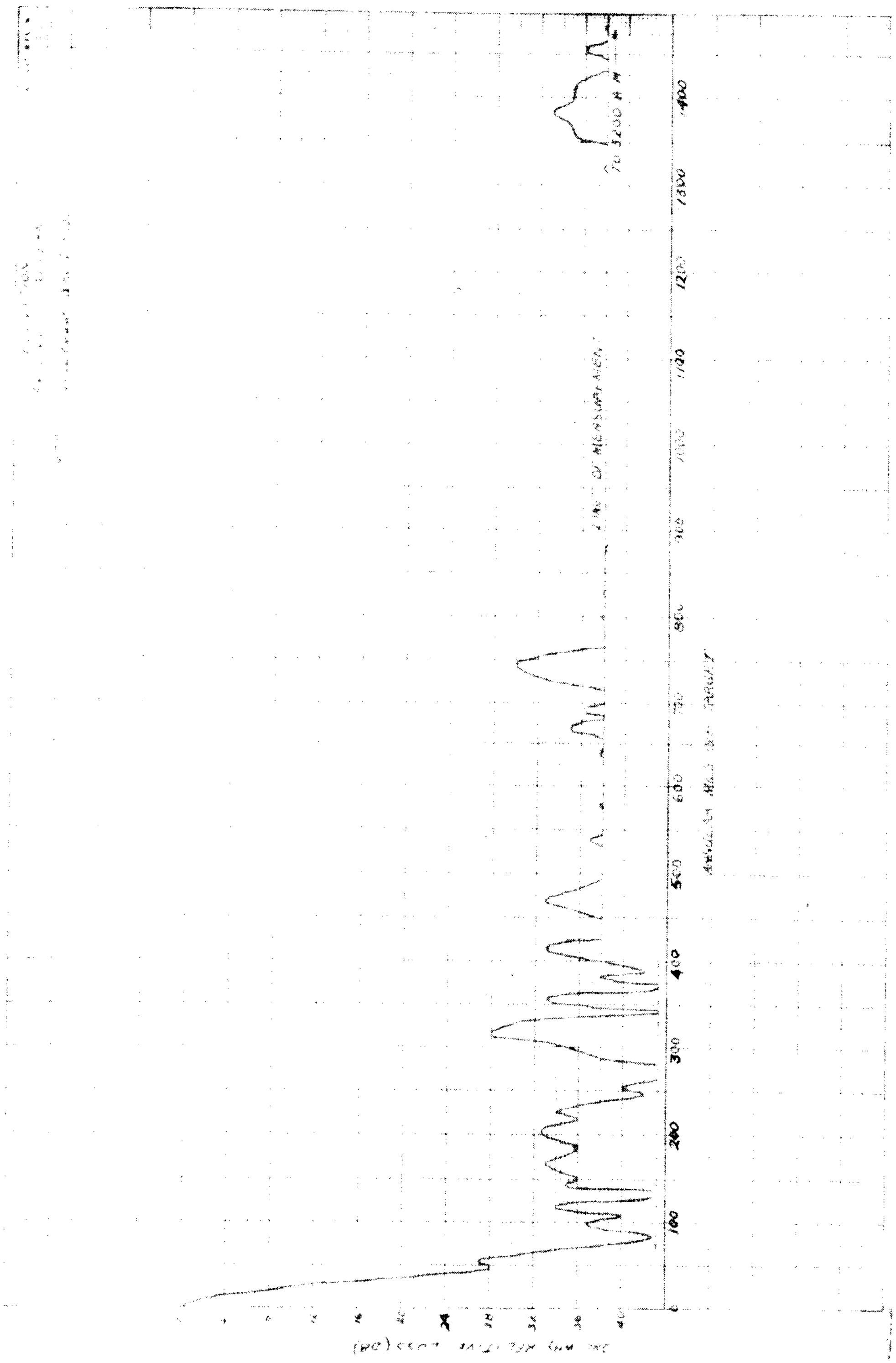


Figure 32. Typical missile-tracking radar antenna pattern, elevation.

the missile designated. The effects of this limitation may be seen in the accompanying charts of typical antenna patterns for azimuth (fig 31) and elevation (fig 32). It may be seen, from these typical antenna patterns, that distortion of minor lobes of radiation sometimes returns a greater signal strength to the receiver when there is a pointing error in the region of 300 to 400 mils than for a pointing error of 100 mils. Thus, it can be seen that consideration must be given to masking effects in assigning the site for the missile-tracking radar. In conjunction with the tracking limitations illustrted graphically in figures 31 and 32, certain ordnance requirements on siting of equipment have been specified. Two of these are:

(1) A 4-foot horizontal separation is required between center lines of adjacent erected missiles measured in a vertical plane passing through the missile closest to the battery control area and perpendicular to the line of sight from the missile-tracking radar to this missile.

(2) There should be no reflecting structures 90 ± 30 yards behind any erected missile along the radar line of sight (although this is not expected to cause any unsuccessful round, it is expected to give trouble when designating a new missile after a rejected missile).

94. REMOTE ANTENNA POSITIONING (figs 16-2, 16-5 and shs 42 and 48)

a. Azimuth positioning. The missile-tracking radar antenna can be positioned in azimuth at the antenna trailer by the track antenna control unit. This unit is plugged in at the antenna assembly only when the function of positioning control at the antenna is needed for testing and alinement. When the track antenna control unit is plugged in, it completes a circuit that furnishes -28 volts to the STAR GAZE (plunge) relays, K7 and K1, in the missile track console. The control voltage from synchro transformer B1 in the track antenna control unit is sent from the missile-tracking radar antenna trailer through contacts 4 and 10 of STAR GAZE relay K7 in the missile console. From K7, the control voltage is sent through contacts 11 and 6 of MAN-AID relay K10 to the azimuth coupling unit, where it drives the servo as in any other mode of operation.

b. Elevation positioning. Remote positioning of the missile radar antenna can be done in the same way as the positioning in azimuth. Synchro B2 in the track antenna control unit furnishes the control voltage. This signal goes through contacts 10 and 4 of STAR GAZE relay K1 and contacts 11 and 6 of MAN-AID relay K4 to the elevation coupling unit.

95. AUTOMATIC ELEVATION TRACKING (sh 41)

The conditions for automatic elevation tracking require that the TEST-OPERATE switch, S1, be in OPERATE. The MAN-AID-AUTO switch, S9 may be in any position, but assume that it is in the AUTO position. The primary control signal developed in the elevation angle modulator is sent through contacts 1 and 9 of ELEVATION MAN-AID relay K4 to contacts 1 and 9 of ACQUIRE relay K2. Then the control signal goes through the elevation coupling unit and drives the elevation servo in the same manner as the azimuth servo was driven. The elevation intermediate drive serves the same purpose in the elevation servo as the corresponding unit in the azimuth servo. The output from servo transformer B1 in the elevation intermediate drive goes through contacts 8 and 12 of MAN-AID relay K4, R11 in the elevation coupling unit, and the low-power servoamplifier that drives the motor in the elevation intermediate drive. The 3-second coast feature during automatic tracking and the 0.4-second coast after burst operate in the same manner for elevation as they do for azimuth.

96. MANUAL MISSILE ELEVATION ACQUISITION AND TRACKING (shs 41 and 48)

a. Acquisition. Acquisition of the missile for elevation follows the same pattern as that used in azimuth. Elevation synchro transformer B1 in the launcher position unit furnishes the positioning voltage and K1 in the launcher positioning unit is the relay which, in its energized position, connects B1 into the elevation servo system.

b. Manual tracking. Manual operation of the antenna in elevation follows the same pattern as that for azimuth. The TEST-OPERATE switch must be in TEST and the MAN-AID-AUTO switch must be in MAN. The elevation MAN-AID relays, K3 and K4, are energized through a ground circuit consisting of contacts 2 and 3 of TEST-OPERATE switch S1, contacts 7 and 11 of deenergized ACQUIRE relay K6, and contacts 1 and B of MAN-AID-AUTO switch S8.

c. Aided tracking. Aided elevation tracking also follows the azimuth pattern. The TEST-OPERATE switch, S1, must be in the TEST position and the MAN-AID-AUTO switch, S8, must be in the AID position. The voltage from the rate potentiometer in the elevation handwheel assembly is sent through contacts 2 and C of MAN-AID-AUTO switch S8C, contacts 5 and 11 of energized MAN-AID relay K3, the elevation coupling unit and into the low-power servoamplifier. From here on the effect of the rate signal is the same as for manual tracking.

97. ANTENNA PLUNGE CIRCUIT (sh 48)

During alinement of the Nike I ground guidance system, it is necessary to plunge the antennas of the tracking radars. The action of plunging consists of moving the track antenna in elevation through its zenith. Figure 33 should be an aid in showing why it is necessary to make a change in the azimuth servo to correct for the change in sensing of the error signals. In figure 33(1), the target is located to the right of the electrical azis and the lens provides the left horns with the strongest signal. The servo will correct the error by moving the antenna clockwise. In figure 33(2), the antenna has been plunged. A better understanding of the effect of plunging can be seen in figure 33(3), where the plunged antenna is rotated 3,200 mils in azimuth so that it is again pointing in the same direction as in figure 33(1). Note that in figure 33(3), the left horns and right horns changed places. The right horn is now receiving the strongest signal. If no change were made in the circuit, the effect of receiving the stronger signal in the right horns would be to cause counterclockwise azimuth rotation of the antenna. To correct this difficulty it is only necessary to reverse the phase of the reference voltage in the angle modulator and now a counterclockwise sensing will produce a clockwise movement of the antenna in azimuth. It is now possible to automatically track the r-f test unit and continue with the alinement procedure. The plunge circuit is operated by the upper limit switch, S5, in the track antenna trunnion assembly. The TEST-OPERATE switch, S1, must be in the TEST position (fig 34). If the plunging is to be done by the radar operator from his position at the console, then the MAN-AID-AUTO switch must be in MAN or AID. The MAN-AID relays are grounded through MAN-AID-AUTO switch contacts 7 and 11 of ACQUIRE relay K6, and the TEST-OPERATE switch. The AID position will produce aided operation of the elevation servo. In the MAN position, normal manual operation is produced. When the antenna closes upper limit switch S5 at 1,600 mils, a -28 volts is furnished to the PLUNGE relay, K1, in the missile track console assembly. The ground circuit for K1 goes through contact 11 of ACQUIRE relay K6, and contacts 3 and 2 of the TEST-OPERATE switch to ground. The contacts of K1 reverse the phase of the reference voltage applied to T1 in the azimuth angle modulator and gives reversed sensing. If the plunging is to be done by using the track antenna control unit, the TEST-OPERATE switch must be in the TEST position. When the control unit is plugged in, the STAR GAZE relays are energized and contacts 5 and 11 of energized STAR GAZE relay K7 furnish a ground to ACQUIRE relay K6. When K6 is energized, it prevents any possibility of an operator at the console energizing the MAN-AID relays. The ground circuit for the PLUNGE relay, K1, is unchanged from that already described.

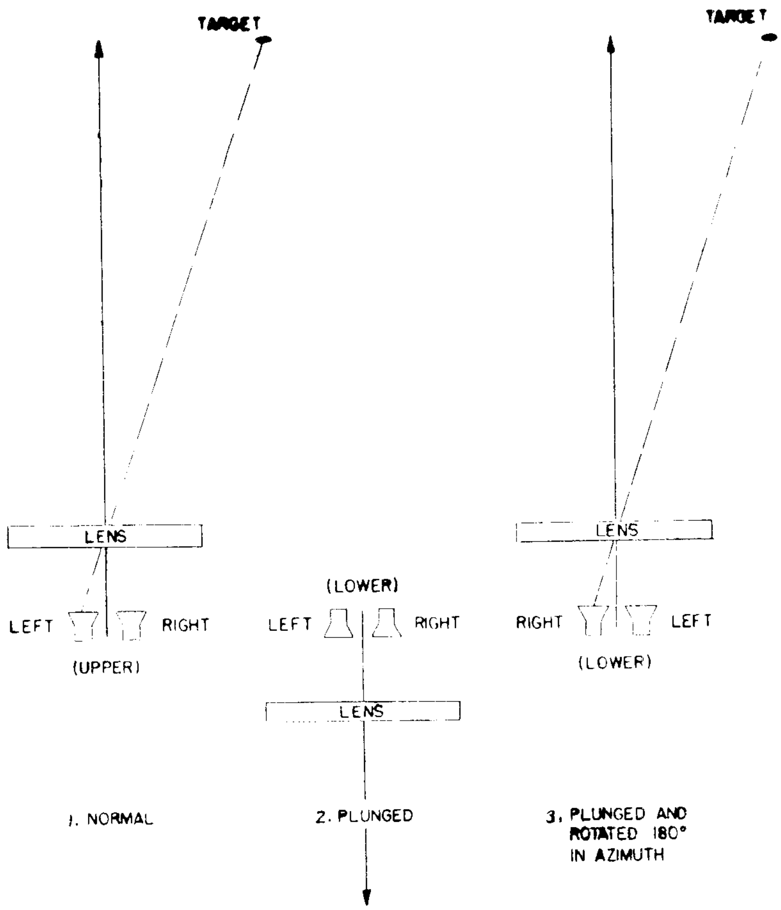


Figure 33. Effect of plunging on target sensing.

98. ELEVATION LIMIT SWITCHES

a. The elevation limit switches keep the antenna from being driven below -200 mils elevation or above 1,600 mils elevation during normal operation. In the test mode of operation, the upper limit switch has no function and limiting of antenna movement occurs only when the antenna attempts to go below -200 mils at either end of the plunging movement. Switch S5, which is ganged to upper limit switch S4, will close at 1,600 mils elevation and cause reverse sensing in azimuth.

b. In normal operation, when the antenna is driven below -200 mils in elevation, S2 closes and sends the signal from terminal 3 of T2 through S4 to contacts 5 and 4 of the TEST-OPERATE switch, S1. From S1, the signal goes through the elevation coupling unit and from there it goes to drive the antenna back to -200 mils.

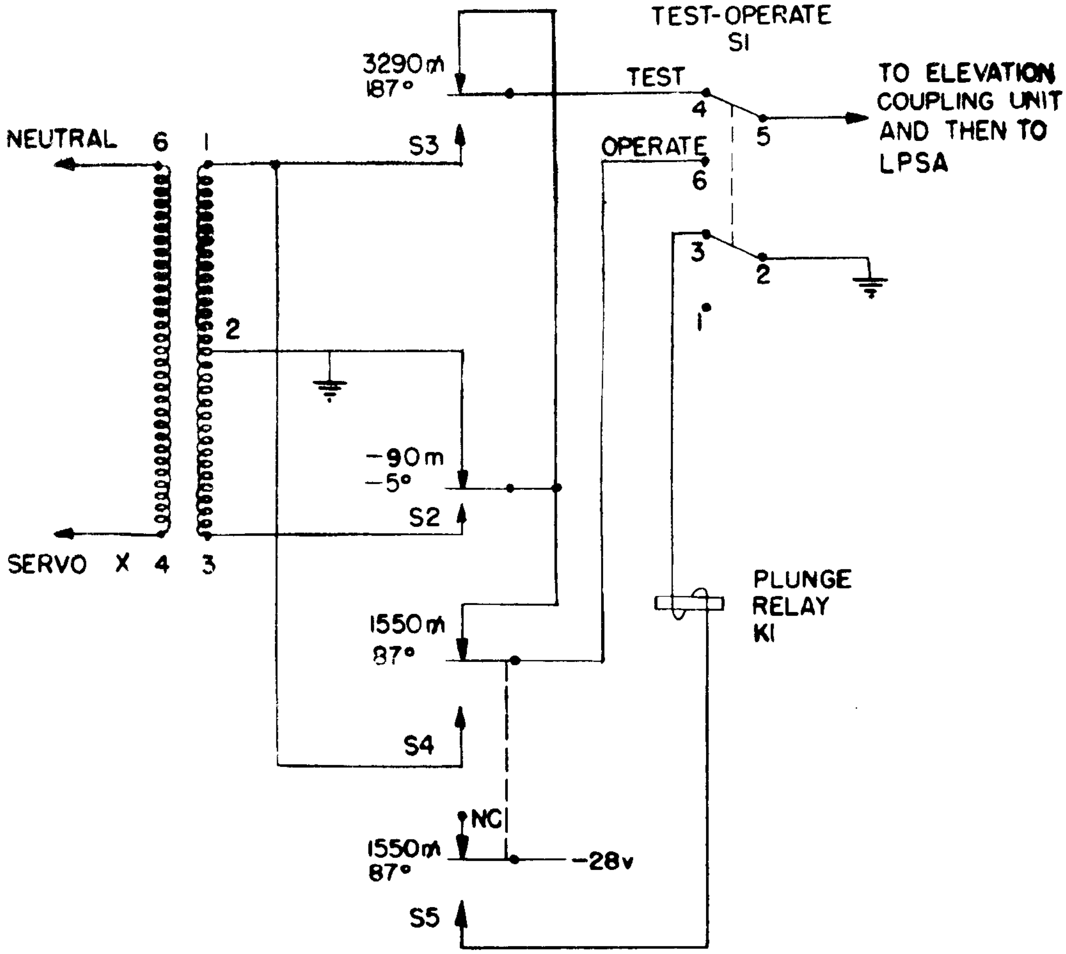


Figure 34. Elevation limit switches and plunged relay, simplified schematic.

Beyond 1,600 mils elevation, S4 closes and sends the signal from terminal 1 of T2 to drive the servo. Since this latter signal is of opposite phase from terminal 2, the antenna will be driven down to 1,600 mils. If the test mode is used, the limit switch action at -200 mils is the same as that described for normal operation. At 1,600 mils, the closing of S4 has no effect, since the current from terminal 1 of T2 cannot go through the open contacts of S1; however, S5 also closes and causes the PLUNGE relay to energize. As far as the elevation servo is concerned, the antenna is still going up in elevation as it moves beyond 1,600 mils. As it plunges beyond 3,300 mils it is necessary to apply a signal of the same phase as was used to drive the antenna down from the limit of 1,600 mils. When the antenna drives beyond 3,300 mils, switch S3 closes and applies the voltage from terminal 1 of T2 and the antenna is driven back to the 3,300 mil setting by a voltage the same phase as the signal used to drive away from 1,600 mils.

99. SERVO TEST

The servo testing procedure involves supplying the servo to be tested with a fixed d-c voltage which will produce maximum tracking rates. This d-c voltage is reversible in polarity, so that the rate in either direction may be checked. The TEST-OPERATE switch must be in TEST, the MAN-AID-AUTO switch must be in AUTO, the DISABLE switch in DISABLE, and the SERVOS switch must be in either INC or DEC.

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