# Training Note

## COSSOR 787A

## CAT 3 DATA FLOW

This training note is issued for the guidance of students during training at RAF Locking. No amendments will be issued in respect of modifications introduced to the equipment referred to in this note.

This note is not intended as a substitute for the relevant Air Publication and must not be regarded as authority for modifications, servicing procedures, etc.

# CHAPTER 1

## INTRODUCTION AND GENERAL DESCRIPTION

1.1. The aids available at an airfield are numerous and vary from airfield to airfield. This chapter is intended to survey them generally and is not a description of any particular system.

1.2. The aids can be grouped into three systems:

a. Navigational Aids (Eureka, Tacan, CRDF, CADF).

b. Control and Surveillance Radars (AR1, CR787A, ACR7D).

c. Precision approach or Guided Control Approach Radars and Instrument Landing Systems (PAR, ILS).

### Navigational Aids

1.3. These can be either radar systems usually operating on the secondary radar principle (eg TACAN) or wireless directional finding systems (eg CRDF and CADF). These systems are used to assist the aircraft to navigate a correct course to its destination or to guide it to the airfield.

### Control and Surveillance Radars

1.4 These are usually operated by two controllers, a senior controller who is responsible for checking all aircraft in the area. An Aircraft landing at the airfield is guided in by CRDF/CADF or by using TACAN and the controller orders the pilot to orbit at a given height in the 'stack' while awaiting landing clearance. At the appropriate time the aircraft is released from the stack and handed over to the 'let down' controller who controls and guides the aircraft into the correct position for the GCA controller to take over.

### GCA Radars

1.5. The precision approach controller takes over control when he can see the aircraft on his displays. The aircraft is controlled in speed, let down rate and distance to left or right of the runway centre line. It is guided to a point near touchdown (typical figures, 500 ft. ½ mile) when the pilot should make visual contact. At this point it is the pilot's responsibility to decide whether visibility is suitable to make a landing.

General description

1.6. Cossor 787 is a medium range (100 Mile) surveillance radar operating in the "S" band (10 cm wavelength). The installation is divided into two sections:

a. The Radar Head includes the Aerial, two Transmitter/receivers, a Monitor Display system, and a Signal Booster for processing the signals for the other section, which can be up to 4,000 yd away.

b. Air Traffic Control contains two Display consoles with their waveform generators and power supplies.

Definitions

1.7. NR Normal radar: this includes all returns, from aircraft, hills, buildings, rain etc.

MTI Moving Target Indication: MTI video contains the returns only from moving targets.

PP Prepulse: A trigger pulse occurring 100 µsec before the transmitter fires; used to synchronise the Displays with the transmitter.

$T_o$ Transmitter firing time; all other triggers are related to this, eg. prepulse is at $T_o$ - 100.

NM North Mark: pulse occurring each time the aerial passes through north.

RR Range rings.

TB Timebase waveform.

Trigger production

1.8. The trigger source is the transmitter/receiver connected to the Aerial.

Transmitter

1.9. The two transmitters fire together; they are conventional magnetron transmitters fired by a modulator using a pulse-forming network. The output power from each transmitter passes to the waveguide switch, and the power from the spare transmitter is dissipated in a Dummy Load.

Turning information

1.10. Three systems are used in the Aerial Cabin to provide turning information for the Display which use the fixed-coil principle.

a. A sin/cos potentiometer provides sine and cosine data for the Monitor Display at the Radar Head.

b. A transmitter servo, consisting of a pair of magslips, provides turning information for Air Traffic Control.

c. The north mark microswitch provides an earth as the Aerial passes through due north; this switch is connected to the Display systems at the Radar Head and Air Traffic Control.

## Receivers

1.11 Received signals from the Aerial are passed through the waveguide switch to the master Transmitter/receiver. The receivers are conventional superhets, with RF amplification by a travelling-wave tube, and a very stable local oscillator (Stalo). The output of the receiver is Normal Radar at the IF of 30 MHz. The Normal Radar is also taken into the MTI system, where returns from fixed targets are suppressed. The outputs from the master transmitter/receiver are selected by the channel selection relays.

## Monitor Display (at the foot of the diagram)

1.12 This consists of a Display unit mounted on a Lower Base Unit. It receives direct all the inputs needed to produce a PPI display.

## Signal Booster

1.13 This unit processes the NR, MTI and PP to pass them down the landlines to Air Traffic Control. It does not handle turning information. The NR, still at 30 MHz, is merely amplified. The PP and MTI are mixed (with opposite polarity) and used to modulate a 20 MHz carrier.

## Air Traffic Control

1.14 In ATC there is a further Lower Base Unit supplying inputs to two operational Displays. This Lower Base Unit is the same as that used for the Radar Head Monitor; but examination of the diagram will show that some of the signals passing down the landlines are not the same as those supplied to the Monitor. These signals require further processing, which is done in the Upper Base Unit.

## Upper Base Unit

1.15 This unit accepts those landline signals that cannot be applied direct to the Lower Base Unit.

a. The servo system includes a pair of receiver magslips, and changes the turning information into sin/cos data.

b. The RF amplifier amplifies and detects the 20 MHz carrier, giving an output of combined MTI video (positive) and prepulse (negative). This combined output passes to the Lower Base Unit, and also to the Lock Pulse Separator, which passes only the prepulse.

1.16 Thus the inputs to the Lower Base Unit in ATC are now the same as those to the Radar Head Monitor, except that the MTI video line is also carrying prepulse. This is removed in the Lower Base Unit.

Lower Base Unit

1.17 Here are produced all the waveforms needed for two Displays.

Delayed pulse generator

1.18 The prepulse is at $T_o$ - 100, and must be delayed to $T_o$.

Range gate generator

1.19 A gate is produced by the delayed trigger; it is long enough to allow the display of 100 miles, ie from $T_o$ to $T_o$ + 1240 approx.

Timebase generator

1.20 Two identical sawtooth generators produce sweep waveforms; their timing is decided by the range gate, and their amplitude and polarity by the sine or cosine input.

NM generator

1.21 This circuit is normally biassed off; when the Aerial microswitch closes at due north, the bias is removed and the next range gate is allowed to pass.

Bright-up generator

1.22 This circuit passes the range gate for use as bright-up on the Display.

Range ring generator

1.23 Range marks are produced, starting at $T_o$, at intervals of 1, 5, 10 and 20 miles.

MTI range switching generator

1.24 On the Display, the inner part of the MTI picture is MTI alone, and the outer part is NR; the change-over point is adjustable. To produce this, MTI video is required for the first part of each scan, followed by NR for the remainder of the scan. The MTI range switching generator produces a waveform to control the change from MTI video to NR during each scan.

MTI video amplifier

1.25 At the input to this amplifier the negative prepulse is removed; MTI video is then amplified.

NR IF amplifier

1.26 NR, still at 30 MHz, is amplified and detected to produce NR video. This is passed straight to the Displays for the NR picture, and also to the electronic switch to be gated with MTI video.

Electronic switch

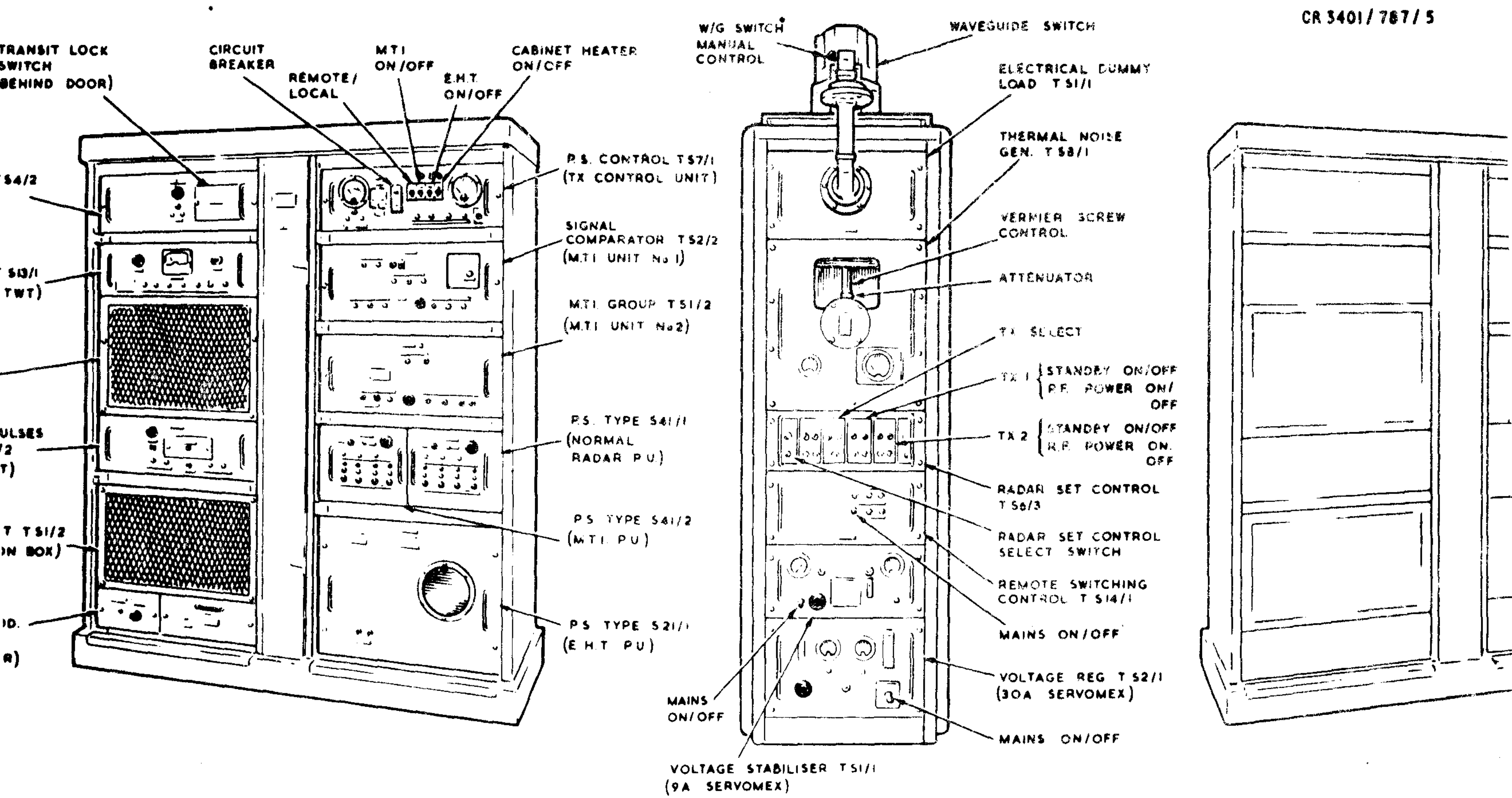
1.27 The electronic switch is controlled by the switching waveform from the MTI range switching generator; it passes MTI video for the first part of each scan, then is switched to pass NR for the rest of the scan. The gated output is called MTI/NR video.

Displays

1.28 All three Displays are identical. The Deflection Amplifiers provide the sawtooth current waveforms for the deflection coils. The bright-up mixer passes the bright-up waveform to the CRT grid; when the north mark occurs, it is added to the bright-up to intensify one complete sweep. The video mixer mixes the video picture with the range marks. All inputs to the mixers have separate gain controls.

Concise details

| | | |
|---|---|---|
| 1.29 | Transmitter frequency | 2940 - 2980 MHz |
| | Peak Power | 450 kW. |
| | Pulse width | 1 μsec. |
| | PRF | about 700 pps. |
| | Receiver noise figure | not worse than 8.5 dB. |
| | Ranges | 10, 25, 50 and 100 nautical miles. |
| | Aerial beam | Azimuth: 1.4°. |
| | | Vertical, cosecant-squared with 45° top angle. |
| | Aerial reflector | Metal reflector is 16 ft long by 6 ft 9 in high, built to withstand steady winds up to 70 knots and gusts up to 110 knots. |
| | Aerial polarisation | Normally horizontal; circular when anti-rain plate is in use. |
| | Aerial rotation | 12 rpm fixed. |
| | Special facilities | Moving Target Indication permits cancellation of echoes from fixed targets.<br>Quarter-wave plate removes rain returns.<br>RF amplification of received signals by low noise travelling-wave tube. |

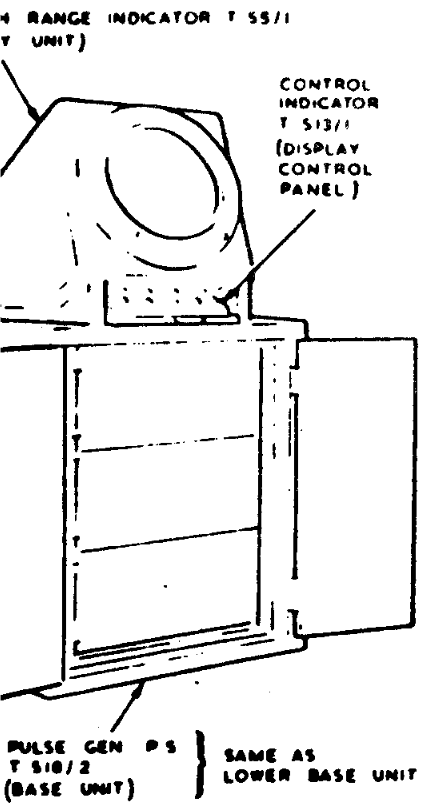



RADAR T/R ASSEMBLY No.1 TS1/2

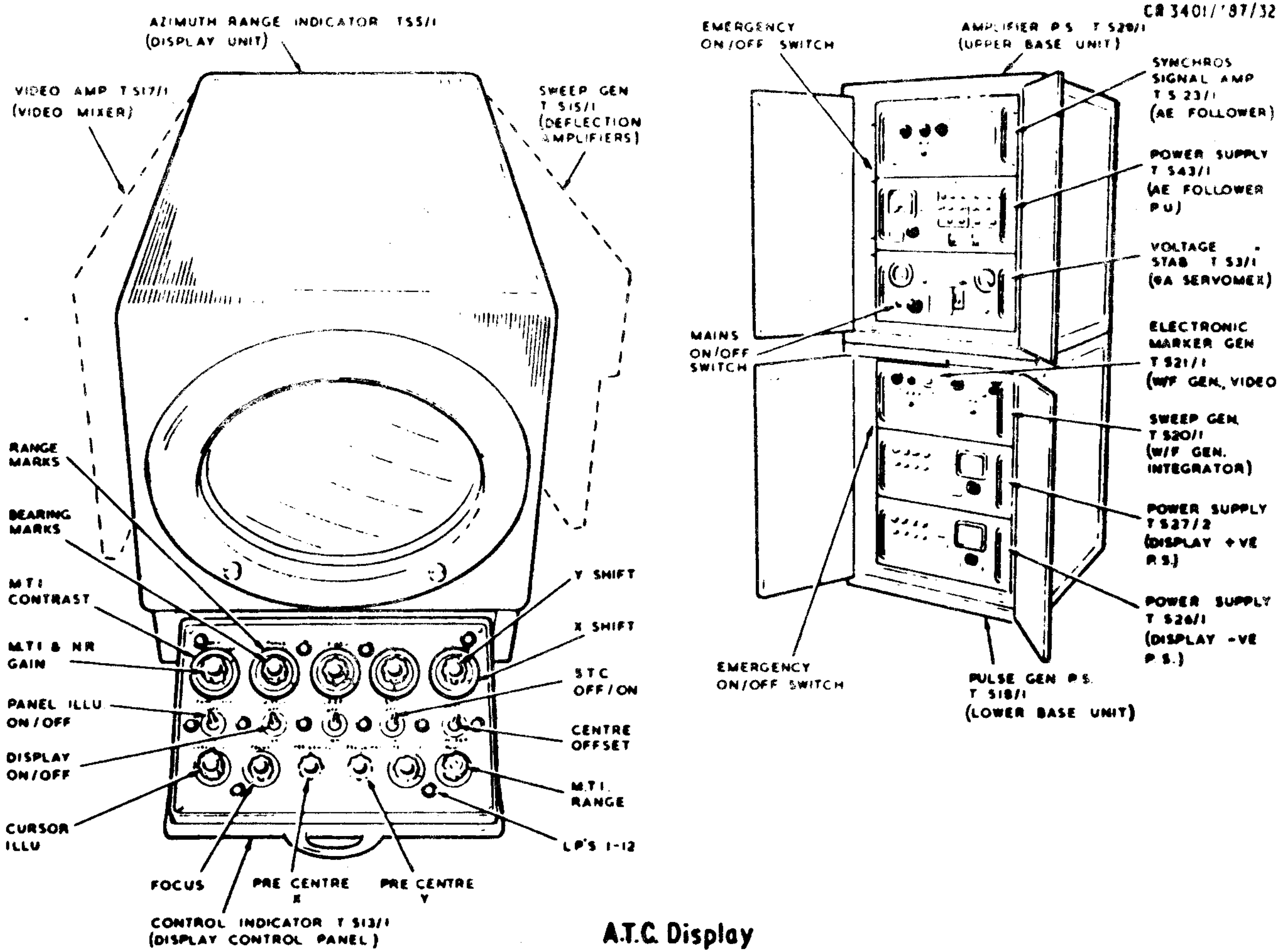
RADAR SET GROUP (CONTROL RACK) TS1/1

RADAR T/R ASSEMBLY No.2 TS1/2

CR787 EQUIPMENT (Sheet 1 of 2)




**Monitor Equipment**




**A.T.C. Display Equipment**

CR787 EQUIPMENT (Sheet 2 of 2)

# CHAPTER 2

## CONTROL SEQUENCE AND SIMPLIFIED POWER SUPPLIES

### Introduction

2.1 The major assemblies comprising the radar head equipment are:

a. Radar T/R Assembly S1/2 (No 1)

b. Radar T/R Assembly S1/2 (No 2)

c. Radar Set Group S1/1 (Radar Control Rack).

2.2 A Radar T/R Assembly consists of:

a. Power supplies.

b. Transmitter.

c. Receiver.

d. MTI circuits.

e. Control circuits

2.3 The Radar Set group S1/1 contains:

a. Voltage regulators providing 230 V a.c.

b. Control circuits for the various facilities provided by the equipment.

c. Noise generator device.

2.4 Either T/R assembly can be selected as the operational transmitter and is connected to the aerial via a waveguide switch mounted on top of the radar control rack. The standby transmitter can be run up provided the dummy load is connected. Alternatively, the noise generator can be fed to the standby receiver to facilitate a noise figure check.

2.5 Both T/R assemblies can be controlled and run-up at the transmitter if the Local/Remote switch on the T/R assembly is set to the local position. Normally these switches are set to the Remote position and control of both T/R assemblies is from the Master Radar Set Control Type S 6/3 mounted on the Radar Control Rack or from one of the two Auxiliary Radar Set Control Units Type S6/4 which are mounted adjacent to the displays in the ATC building.

AC Supply, +60 V d.c. supply, T/R Selection and Control

2.6 When the wall switch is made, the 230 V supply is completed to the Voltage Regulator S2/1 and the Voltage Stabiliser Type S1/1. The voltage regulator, provides 230 V regulated a.c. for the two T/R assemblies. The voltage stabiliser supplies 230 V regulated a.c. via the Remote Switching Control Type S14/1 to:

a. +60 V power supply circuit.

b. The noise generator.

c. The waveguide switch drive motor.

The a.c. supplies for the Monitor Display and the Signal Booster Unit are also drawn from the voltage stabiliser.

2.7 The +60 V d.c. supply is used to operate the relays used for:

a. Controller selection.

b. T/R assembly selection.

c. T/R Assembly power supply switching circuits.

d. Dummy load interlock circuits.

e. PRF check circuits.

2.8 SW5 (MASTER/AUX.1/AUX2 switch) on the Radar Set Control Unit Type S6/3 is used to select the controller in use, +60 V is connected to the selected controller via the contacts of relays K and J. Control of both T/R assemblies is similar on all controllers, the relevant switches being:

a. SW7 TX SELECT. This switch, in association with relays Q and R selects the operational transmitter and contact R3 connects 230 V a.c. to the waveguide switch drive motor so that the selected transmitter is connected to the aerial. Microswitches SC, SD and SF, mounted in the waveguide switch unit, in conjunction with relays P, M and N, operate interlock circuits to protect the equipment and to connect signals from the selected operational transmitter to the displays.
Note: When the equipment is switched on, T/R assembly No 1 will always remain connected to the aerial until T/R assembly No 2 is selected.

b. SW1 TX1 STANDBY ON/OFF. This switch with relays A and B controls relay H on the Power Supply Control Unit Type S7/1. Contact H1 completes 230 V a.c. to contactor 1 (circuit breaker switch closed), and initiates the transmitter run-up sequence.

c. SW2, TX1 EHT ON/OFF. This switch and relays C and D control relay F on unit S7/1. Contact F1 completes the e.h.t. interlock circuit and relay B energises starting the e.h.t. variac run-up sequence.

d. SW3. TX2. STANDBY ON/OFF. and relays E and F; SWH, TX2, EHT. ON/OFF and relays G and H control the T/R Assembly No 2.

T/R Assembly Control Circuits

2.9 The run-up control circuits are contained mainly in the Power Control Unit Type S7/1 and are operated either at the T/R assembly when the Local/Remote switch is at Local or from one of the radar control units when the switch is set to Remote.

2.10 When the 230 V a.c. supply from voltage regulator S2/1 is completed to the unit (para 2.6) the cabinet heaters, service sockets, variac illumination and 'mains on' indicator lamps are operative. If the main circuit breaker is made, 230 V a.c. is completed to contactor 1 and relay J via the 'Local' or 'Remote' paths. Contact J1 breaks the a.c. supply to the cabinet heaters. Contactor 1 contact completes a.c. to:

a. Equipment fan.

b. The preset section of the e.h.t. variac transformer providing a manually preset 230 V a.c.

c. The variable e.h.t. section of the variac.

d. The magnetron heater via a control circuit.

e. Relay contacts which are operated during subsequent stages of run-up.

2.11 The preset 230 V a.c. from the variac is connected to:

a. Power Supply Type S17/1 (Pre-Amp PS)

b. Power Supply Type S41/2 (MTI PS) and MTI major units.

c. Valve heater transformers as shown on diagram.

d. Power Supply Type S41/1. (Normal Radar PS).

2.12 The d.c. supplies from PS Type S41/1 are distributed as shown on the diagram. The d.c. supplies fed to the Power Supply Control Unit Type S7/1 initiate the 5½ minute delay period. This delay is necessary to allow the thyratron valve, used in the modulator, to warm up to operating temperature. After ½ minute DLS1 contacts close and relay A is energised. Contact A1 opens removing the -150 V bias from the delay circuits and the 5 minute period commences. Contact A2 completes the standby indicator lamp circuits. If the e.h.t. interlock line is complete, relay B will energise at the end of the 5 minute period.

a. Contact B1 makes to the 'raise' condition and the drive motor is operative.

b. Contact B2 closes connecting 230 V a.c. to contactor 2.

c. Contact B3 connects 200 V d.c. to the Head Amplifier Type S9/1.

d. Contact B4 forms part of the protection circuits.

2.13 When contactor 2 is energised, contact 1 completes the magnetron fan circuit and contact 2 completes the e.h.t. variac output to the EHT Power Unit Type S21/1.

2.14 As the variac output rises, the magnetron output power increases. The variac will run up to a predetermined level and the upper limit switch then breaks the motor circuit.

2.15 At the magnetron half power point relay C will energise:

a. Contact C1 opens, breaking the magnetron heater supply.

b. Contact C2 completes r.f. power on indicator lamp circuit.

c. Contact C3 forms part of the protection circuits.

d. Contact C4 opens and C5 closes, standby indicator lamps are extinguished and r.f. on indicator lamps are lit.

2.16 The equipment is now fully run up. Normally on switching on all switches are made, and if STANDBY and EHT switches are made simultaneously, the equipment will automatically run up to the full power state after the 5 minute delay period described above.

2.17 The standby transmitter can be run up to the full power condition when the dummy load waveguide is in position. In this condition a microswitch completes +60 V to relay S the contacts of which override the e.h.t. interlock relay M contacts. If the noise generator source is connected to the standby transmitter the equipment can only be run up to the 'standby' state.

2.18 Relays G, D and E with contacts of relays B and C form protection circuits which will operate if:

a. The magnetron flashes over.

b. EHT volts are excessive.

c. EHT current is excessive.

<u>'PRF' Check</u>

2.19 Relay W forms part of the p.r.f. check circuit in conjunction with relay T. When 'PRF check' is selected, both W and T relays are energised, the contacts of which operate as follows:

a. W1 'p.r.f. check' indicator lamp.

b. W2 operates 15 second delay.

c. W3 hold contact.

d. W4 breaks interlock in spare transmitter control circuit and transmitter runs down.

e. T1 de-energises A1 relay in T/R assembly No 1 lock unit.

f. T2 de-energises A1 relay in T/R assembly No 2 lock unit.

g. T3T4 break all synchronisation between the two lock units.

2.20 The operational transmitter lock unit reverts to its natural (lower) p.r.f. and suspect "second time round" echoes will move towards the origin of the trace. Correct returns will however be unaffected. After 15 seconds the equipment returns to normal conditions and No 2 T/R assembly will run up again if operating into the dummy load originally. During "p.r.f. check" selection, MTI facilities are, of course, eliminated.

# CHAPTER 3

## T/R ASSEMBLY S1/2 AC DISTRIBUTION

3.1 The unregulated 230 V a.c. supply from the wall switch is connected to the Voltage Regulator Type S2/1 (Servomex 30 Amp). When the MAINS ON/OFF, SW1 on this unit is made, a 230 V regulated a.c. supply is produced which is distributed to both T/R assemblies.

3.2 Within the T/R assembly S1/2 the primary distribution is:

a. Via FS1 and FS2 to two service sockets and to the variac illumination lamp.

b. Via FS1, FS2, relay contact J1 and SW4, CABINET HTRS ON/OFF to the two cabinet heaters and the CAB HTR ON indicator lamp. Relay J is energised during the run-up period and contact J1 opens switching off the cabinet heaters.

c. To the MAIN CIRCUIT BREAKER and to LP1. MAINS ON indicator lamp. The circuit breaker is manually operated but will automatically break if excessive current is drawn by the equipment.

3.3 MAIN CIRCUIT BREAKER made; 230 V reg a.c. is connected:

a. Via the Local/Remote switching circuit in LOCAL to the solenoid of CONTACTOR 1 and to relay J.

b. To the e.h.t. variac drive motor. (Note the neutral connection to the motor is via relay B contact B1 and the motor limit switches).

3.4 CONTACTOR 1 energised, 230 V reg a.c. is connected:

a. Directly to equipment cooling fan.

b. To magnetron heater control circuit DLS2 and to the magnetron heater transformer which is mounted in the Modulator Unit. (Note: After 30 seconds DLS2 contacts close and magnetron heaters are switched on. See para 3.12).

c. To e.h.t. variac. The variac has two output windings:

(1) One producing a PRESET 230 V a.c. reg supply.

(2) A variable output winding which supplies the a.c. to the e.h.t. power unit and is controlled by the variac drive motor.

3.5 The PRESET 230 V variac output is connected:

a. To Power Supply Type S41/1 (Normal Radar Power Unit). The d.c. supplies are available almost immediately and the 5 minute delay circuit in the Power Supply Control Unit S7/1 is energised and the delay period commences.

b. To Trigger Pulse Generator Type S6/2 (Lock Unit) heater supply transformer.

c. To Modulator Unit Type S1/1 heater transformers.

d. To Power Supply Type S21/1 (EHT PU) heater transformer.

e. To RF Oscillator Type S4/2 (STALO) heater transformer.

f. Via MTI MAINS ON/OFF, SW1 mounted on PSCU Type S7/1 to:

(1) Power Unit S41/2 (MTI PU).

(2) MTI Group S1/2 (MTI Unit No. 2).

(3) Signal Comparator S2/2 (MTI Unit No 1).

g. Via TR Line Assembly Plug Panel to Power Supply Type S17/1 (Pre-amp TWT) heater transformer T2.

h. To heater transformer mounted on TR Line Assembly Plug Panel which supplies units as below.

(1) RF Amp Type S13/1; swept gain circuit valve heaters.

(2) Power Supply Type S17/1; protection circuits.

(3) Head Amplifiers Type S9/1 (Signal and Coho Amps).

(4) Power Supply Control Type S7/1 (5 minute delay circuit valve heaters).

3.6 When the 5 minute delay period is completed relay B in the Tx Control Unit is energiswd, Contact B2 connects 230 V reg a.c. to CONTACTOR 2 solenoid; contact B1 connects neutral line to the 'raise' terminal of the variac drive motor and the output from the variac begins to rise.

3.7. CONTACTOR 2 energised:

a. Contact A connects 230 V a.c. reg to the magnetron cooling fan.

b. Contact B connects output from variac to the EHT Power Unit.

3.8 When the e.h.t. volts have risen to the half power level relay C in the Tx Control Unit is energised and:

a. Contact C1 opens, DLS de-energises and the magnetron heater supply is switched off (See para 3.12).

b Contact C2 closes completing RF POWER ON indicator lamp (LP3) circuit.

Voltage Regulator Type S2/1 (Servomex 30 amp)

3.9 This unit is mounted in the base of the Radar Set Group S1/1 (Control Rack). It will regulate the output a.c. voltage at any value between 200 V and 250 V and will accept frequencies between 45 Hz and 65 Hz.

3.10 The regulator is rated as follows:

a. 30 amps at ambient temperature of 25°C.

b. 24 amps at ambient temperature of 40°C.

3.11. The output voltage is maintained within the limit $\pm$ 0.25% for mains input variation within the limits of -20% and +10%.

Magnetron Heater Switching Circuit

3.12 When 230 V a.c. is completed to the magnetron heater transformer the 30 second delay DLS2 circuit is completed. After 30 seconds DLS2 contact closes and the magnetron heater transformer circuit is complete. This delay has no significance during run up. When the half power point is reached relay C energises and contact C1 opens de-energising DLS2 and DLS2 contact breaks the magnetron heater supply. Magnetron cathode emission is maintained by unfavourable electron bombardment. The function of the circuit DLS2 and contact C1 is to prevent the magnetron heaters being switched on and off when the run up sequence is broken momentarily by one of the protection circuits, ie overload, overvolts or magnetron flashover conditions.

Thyratron Interlock

3.13 The 230 V a.c. supplies to the modulator unit are connected via PL16. Pin 9 of this plug is used to provide an earth for the 5 minute delay system in the Tx Control Unit (S7/1). If the input socket to PL16 is disconnected the equipment cannot be fully run-up.

## CHAPTER 4

## T/R ASSEMBLY S1/2 DC DISTRIBUTION

4.1. There are four major d.c. power supply units. They are:

a. Power Supply Type S41/1 (Normal Radar PU).

b. Power Supply Type S41/2 (MTI PU).

c. Power Supply Type S17/1 (Pre-amp Power Unit).

d. Power Supply Type S21/1 (EHT Power Unit).

The power units S41/1 and S41/2 are similar.

### Power Supply S41/1 (NR PU)

4.2. This unit has four rectifier and smoothing circuits.

a. A halfwave rectifier MR9, 10, 11 is used to produce -800 V which is fed via the T/R line plug assembly and the RF Amp Type S13/1 (Pre-amp TWT) to the TR switch in the duplexer.

b. A fullwave rectifer MR12 to MR15 provides a d.c. voltage which is regulated by valves V7 to V9 to produce the -150 V supply which is fed to:

(1) Power Supply Control Type S7/1 (Tx Control Unit).

(2) Trigger Pulse Gen Type S6/2 (Lock Unit).

(3) T/R Assembly Plug Panel.

(4) RF Amp Type S13/1.

When -150 V is available RLA is energised and the d.c. supplies are connected to the other regulators.

c. A fullwave rectifier MR5 to MR8 feeds regulator circuit V1 to V4 producing +200 V which is fed to:

(1) Power Supply Control type S7/1 direct.

(2) Via e.h.t. interlocks to Power Supply Control Type S7/1. (See Tx Select and e.h.t. i/L Chain).

(3) Trigger Pulse Gen Type S6/2 and sub unit IF Amp Type S10/1 (Test Amp).

(4) T/R Line Assembly Plug Panel.

(5) R/F Osc Type S4/2 (STALO).

(6) Head Amp Type S9/1 (Signal Head Amp).

(7) R/F Amp Type S13/1 (Pre-Amp).

(8) Via a switching contact in PS Control Type 7/1 to Head Amp Type S9/1 (Coho Head Amp).

d. A fullwave rectifier MR1 to MR4 provides +470 V d.c. which is fed to the Trigger Gen Type S6/2 (Lock Unit). The +470 V is also used within the power unit to supply a regulator circuit V5 V6 which produces +330 V which is fed to:

(1) Power Supply Control Type S7/1.

(2) Trigger Pulse Gen Type S6/2.

(3) T/R Line Assembly Plug Panel.

(4) RF Osc Type S4/1 (STALO).

Power Supply Type S41/2 (MTI PU)

4.3 The circuits in this unit are identical to those in the Power Supply Type S41/1. The d.c. voltages produced are used as follows:

a. -800 V. Not used.

b. -150 V. Fed to:

(1) MTI Group Type S1/2 (MTI Unit 2) and sub-unit Amplifier Modulator Type S4/1 (Cable Drive Mod.).

(2) Signal Comparator Type S2/2 (MTI Unit 1) and sub-unit IF Amp Type S6/1 (Locking Amp).

c. +200 V. Fed to:

(1) MTI Group Type S1/2 and sub-units, Amp Mod Type S4/2 (Line Drive Mod), RF Osc Type S3/1 (20 MHz Osc), RF Amp Type S12/2 (Post Line Amp), RF Amp Type S5/1 (Comparison Amp).

(2) Signal Comparator Type S2/2 and sub-units, Signal Comparator Type S3/1 (Phase Sensitive Detector), IF Amp Type S6/1 (Locking amp), RF Osc Type S5/1 (COHO), IF Amp Type S7/1 (Limiting Amp).

d. +470 V is fed to both MTI Group Type S1/2 and Sig Comp Type S2/2 chassis, but is not used.

e. +330 V. Fed to:

(1) MTI Group Type S1/2.

(2) Signal Comparator Typs S2/2 and sub-unit Sig Comp S3/1 (Phase Sensitive Detector).

## Power Supply Type S17/1 (Pre-amp PU)

4.4 This power unit has two major circuits:

a. A fullwave rectifying circuit V1V2 which with neon stabilisers V3 to V5 produces the d.c. voltages to operate the travelling wave tube, when used.

b. A bridge rectifier MR1 produces -18 V which is used as the supply to the e.h.t. test overload relay.

All d.c. supplies are fed to the RF Amp Type S13/1 (Pre-amp TWT).

## Power Supply Type S21/1 (EHT Power Unit)

4.5. In this unit a voltage doubler and smoothing circuits produce a d.c. voltage of 6 kV which is fed to the modulator. Protection circuits are provided to switch off power supplies in the event of a current overload or an over-volts condition or if the unit is withdrawn from the main frame.

## RF Osc Unit Type S4/2 (STALO)

4.6. This unit has its own stabilised power supplies for the oscillator stage:

a. The +330 V d.c. supply is regulated by a series regulator V1 to V4 which produces +200 V for the anode of the oscillator valve. SW2 is used to disconnect the h.t. supply when the oscillator is locked in the 'transit' state.

b. The oscillator heater supply is 6.3 V d.c. and this is provided by a bridge rectifier circuit. Ripple frequency effects are reduced to a minimum by a saturable reactor and control circuit V6 to V8.

## Run-up Control Circuits

4.7 During the run-up process 230 V a.c. is applied to the Power Units S41/1 and S41/2. The +200 V, +330 V and -150 V d.c. supplies from PU S41/1 are fed to Control Unit S7/1 and used in the delay and protection circuits.

4.8. +200 V is available at PL1 Pin 8 and also via interlocks (see Tx select and EHT I/L chain) at PL3 pin 6. Providing the thyratron interlock on the modulator unit is made the delay circuit DLS1 is completed and after 30 seconds contact DLS1 makes energising relay A. Contact A1 breaks the -150 V supply to the 5 minute delay circuit and contact A2 completes standby indicator lamp circuit. After 5 minutes relay B is energised.

Contact B1 completes the e.h.t. variac drive motor circuit. Contact B2 completes contactor 2 circuit and LP4 EHT ON lamp circuit. Contact B3 completes switched +200 V d.c. supply to the Coho Head Amp.Contact B4 prepares magnetron flashover signal path to V1 grid.

4.9. When the EHT STOP/NORMAL switch is set to NORMAL the e.h.t. a.c. supply is run-up and an increasing d.c. voltage is applied to the modulator. When the half power point is reached a feedback voltage from the modulator actuates relay C. Contact C1 breaks DLS2 circuit and magnetron heaters are switched off by contact DLS2. Contact C2 completes RF Power On lamp, LP3, circuit (see T/R AC Distribution Chain). Contacts C4 and C5 control the remote indicator lamps (see Standby and EHT Rem Switching Chain). Contact C3 completes the magnetron flashover protection circuits.

Protection Circuits

4.10. Three conditions can cause the protection circuits to operate, they are:

a. Over-volts: if there is no load on the EHT PU (eg magnetron not firing) the sample voltage fed from the power unit to V2 in the Tx control unit rises causing V2 to operate and RLG is energised. Contact G1 closes, short circuiting RLA which de-energises and contact A1 closes applying -150 V to the 5-minute delay. This causes RLB to de-energise and the a.c. supply to contactor 2 is broken when contact B2 opens. Contactor 2 contact breaks the a.c. supply to the EHT power unit. Contact B1 causes the variac to run-down.

b. Overload: if excessive load current is drawn from the EHT power unit the voltage developed across R18 becomes sufficient to energise RLD in the Tx Control Unit. Contact D1 closes short circuiting RLA and switching off EHT as described in sub-para a above.

c. Magnetron flashover: if the magnetron arcs or flashes, a circuit in the modulator unit causes RLZ to operate. Contact Z1 completes relay E circuit. Contact E1 completes -150 V bias supply to the 5 minute delay circuit, and relay B de-energises. EHT is switched off as described in sub-para a. above. Because the magnetron will arc during the early stages of EHT run-up, this protection circuit will not operate until the half-power point is reached and relay C operates, then contact C3 prepares RLE circuit.

4.11 When the EHT is switched off by protection circuit action the cause is removed and the system will revert to the run-up condition and return to the fully operational state providing that the fault was a transient one.

4.12. An EHT overload test system has been introduced to ensure that relays 'D' and 'C' are operating satisfactorily. Negative 18 volts is fed via PL3 from the microwave power unit to switch 7, TEST EHT OVERLOAD, mounted on the front of the transmitter control unit Type S7/1. On pressing SW7, relays 'D' and 'C' will energise and the overload test button and the r.f. power light will glow. This will indicate that both relays are in a serviceable condition.

# CHAPTER 5

## TRANSMITTER SELECT AND EHT INTERLOCK CHAIN

### Transmitter Selection

5.1. This chain controls the changeover system which connects the operational transmitter to the aerial. When a changeover takes place, power supplies must be switch ed off and certain functions transferred from one transmitter to another. These switching functions are relay controlled during the changeover period. Tx1 or Tx2 can be selected as the operational transmitter by operating SW7, TX SELECT, on the appropriate Radar Control Unit.

5.2. The diagram shows the system with Tx1 selected as the operational Tx. If the TX SELECT, SW7 is operated to the Tx2 position +60 V is completed to relay R.

a. Contact R1 closes, Relay R hold.

b. Contact R2 not used,

c. Contact R3 changes position and completes 230 V a.c. to the waveguide switch drive motor.

5.3. The motor drives the switch from Tx1 to Tx2 condition,at the same time six microswitches SA to SE are operated. At the commencement of the changeover:

a. SA closes preparing the motor supply circuit for a change back to Tx1 condition.

b. SC opens breaking the +60 V to relay B in the Tx1 and Tx2 Lock Units (see Trigger Select Chain) and the +60 V supply to relay P in the Remote Switching Control Unit. When relay P de-energises contacts P1 and P2 open breaking the EHT interlock circuits of the two transmitters and the transmitters revert to the standby condition.

c. SE opens breaking +60 V supply to telay A in the Tx1 Lock Unit (see Trigger Select Chain).

5.4. When the changeover is complete:

a. SB opens breaking the a.c. supply to the drive motor.

b. SD closes completing +60 V to relay B in the Tx1 and Tx2 Lock Units (see Trugger Select Chain) and to relay P. Transmitters will revert to operational state providing the other interlocks are made.

c. SF closes completing +60 V to relays M, N, U in the Remote Switching Control Unit and to relay A in the Tx2 Lock Unit (see Trigger Select Chain).

d. Relay P energised:

(1) Contact P1 closes completing e.h.t. interlock system and Tx1 can be run-up to full operating condition.

(2) Contact P2 closes completing Tx2 e.h.t. interlock system and Tx2 can be run-up to full operating conditions.

(3) Contact P3 closes completing the earth return for the Tx to Aerial Indicator Lamps on the control units.

e. Relay M energised:

(1) Contact M1 connects secondary radar trigger from Tx2 to IFF equipment when in use.

(2) Contact M2 opens breaking Tx1 e.h.t. interlock circuit. Tx1 can only be run-up fully if dummy load is in position.

(3) Contact M3 closes completing Tx2 e.h.t. interlock circuit.

(4) Contact M4 connects pre-pulse from Tx2 to the displays.

f. Relay N energised:

(1) Contact N1 connects +200 V from Tx1 to the noise generator (see Noise Figure Chain).

(2) Contact N2 connects MTI from Tx2 to the displays (see MTI Production Chain).

(3) Contact N3 connects a load resistor to Tx1 pre-pulse output which is not used.

(4) Contact N4 completes Tx2 to AE indicator lamps circuits on the control units.

g. Relay U energised:

(1) Contact U1 connects normal radar signals from Tx2 to displays (see Normal Radar Signal Chain).

5.5. Relay S is energised provided the Electrical Dummy Load is connected, by the removable sections of guide, to Tx1 and contact W4 is closed.

5.6. Relays W and X and the $\frac{1}{4}$ minute delay are used when the PRF check switch is operated. Contact W4 opens breaking relay S circuit, contacts S1 and S2 open and the standby transmitter e.h.t.interlock circuit is broken. (See Trigger Select Chain).

5.7. If the TX SELECT switch, SW7, is set to the Tx1 position relay Q is energised, Contact Q1 breaks relay R hold circuit, de-energising the relay and contact R3 changes over.

# CHAPTER 6

## STANDBY AND EHT REMOTE SWITCHING CONTROL

6.1. When the LOCAL/REMOTE SWITCH SW2 mounted on the Power Supply Control S7/1 is set to the REMOTE position the T/R Assemblies S1/1 (Nos 1 and 2) can be controlled from one of three positions:

a. Radar Set Control Type S6/3 (Main) mounted in the Radar Set Group Type S1/1 (Control Rack).

b. Radar Sets Control Type S6/4 (Aux 1 and Aux 2) situated in the ATC building adjacent to the displays.

6.2. Selection of the controlling unit is by a three position switch marked MAIN/ AUX1/AUX 2 (SW5) which is mounted on the Main Control Unit.

6.3. The three control units are identical except for SW5 on the main controller. Switches 1 to 4 control the power supplies for the transmitters. Switches 6 to 9 control the other functions which are dealt with on their appropriate chain diagrams as follows:

a. SW6. PRF CHECK; Trigger Select Chain.

b. SW7. TX SELECT; Tx Select and EHT I/L Chain.

c. SW8. RAIN SUPPR; Anti-rain Plate Chain.

d. SW9. AE STOP/START; Aerial Turning Chain.

6.4. SW5 in the Main Controller and relays K and J in the Remote Switching Control Type S14/1 select the controller in use:

a. SW5 in MAIN position. Relays K and J de-energised and +60 V is completed to LP3, Control Available Indicator and via relay contacts K1 and J1 to the Main Controller.

b. SW5 in AUX1 position. Relay J energised, +60 V connected via contact J1 to the Aux1 controller.

c. SW5 in AUX2 position. Relay J de-energised, relay K energised, +60 V connected via contacts K1 and J1 to the Aux2 controller.

6.5. The control switches are three position switches which function as follows:

a. SW1. Tx1 ST/BY ON position. +60 V is completed to relay A in the Remote Switching Control Unit:

(1) Contact A1 - relay A hold contact closes.

(2) Contact A2 closes completing +60 V to relay H in the Power Supply Control S7/1 and contact H1 completes 230 V a.c. to contactor 1 starting the run-up procedure.

(3) Contact A3 closes completing the earth circuit of the Tx1 ST/BY ON Indicator Lamp LP8 on all three controllers.

b. SW1. Tx1 ST/BY OFF position. +60 V connected to relay B.

(1) Contact B1 opens breaking +60 V supply to RLA. Relay A is de-energised. All contacts open and all power supplies are switched off.

c. SW2. Tx1 EHT ON. +60 V connected to relay C in Remote Switching Control Unit.

(1) Contact C1, relay C hold contact closes.

(2) Contact C2 closes completing +60 V to relay F in the Power Supply Control S7/1 and contact F1 completes the EHT interlock circuit thus enabling the transmitter to be fully run-up.

(3) Contact C3 closes preparing the circuit of the Tx1 EHT ON Indicator Lamp LP7 on all three controllers.

d. SW2. Tx1 EHT OFF position. +60 V connected to relay D.

(1) Contact D1 opens breaking +60 V supply to RLC. All C contacts open and all power supplies are switched off.

6.6. Switch 3, Tx2 ST/BY ON and Switch 4, Tx2 EHT ON in conjunction with relays E, F, H and G, LP5 and LP6, function in the same way as Tx1 control circuits.

CHAPTER 7

# T/R ASSEMBLY AC DISTRIBUTION CHAIN CIRCUIT ANALYSIS

## Voltage Regulator Type S2/1 (Servomex 30 amp)

7.1. Two regulator or stabiliser units are mounted at the base of the Radar Control Rack (Radar Set Group S1/1). The lower unit regulates the a.c. mains supply to both T/R Assemblies Type S1/1 (Tx/Rx racks).

7.2. The output voltage can be regulated at any value between 200 V and 250 V and input frequency can vary between 45 Hz and 65 Hz. Output voltage is maintained within $\pm$ 0.25% and +10%.. For mains input variations between -20% and 10%.

7.3. Stabilisation is effected by the buck or boost transformer T1 the secondary of which is in series with the line head. The primary of T1 receives a variable voltage from the auto transformer T2, the supply for this transformer is taken from the stabilised output. The brush X can be moved over a range on either side of the fixed tapping Y and is driven by a motor which is controlled by the servo amplifier V1, V2.

7.4. The input to the servo amplifier is the out of balance voltage from the bridge consisting of the lamp LP1, P2 P1 etc. The a.c. input for this bridge is from a winding on T3. The primary of T3 is fed from the stabilised output via voltage selector taps so that the bridge is approximately balanced at the normal voltage selected. Exact judgement of the output voltage is by the set volts control P1 on the unit front.

7.5. Any variation in output voltage from the value at which the bridge is balanced causes a change in the resistance of the lamp LP1 and unbalances the bridge. The unbalanced voltage is stepped up approximately twenty times by T4 and applied to the grid of V1A via a third harmonic rejector circuit. This is fitted to remove an unwanted 150 Hz output which appears across the bridge.

7.6. A phase shift of approximately 90° occurs within the servo amplifier, the output of which is taken across T5 and applied to one winding of the motor. Since two voltages in quadrature are required to produce maximum torque from the motor a supply in phase with the input to the servo amplifier is taken from a winding on T3 for application to the other winding of the motor. A third winding on the motor has a voltage induced into it, proportional to the velocity of the motor. This voltage is fed back into the amplifier and serves to stabilise the servo system.

7.7. The motor is geared to the brush X on auto transformer T2 and dependent on the out of balance state of the bridge, governs the input to the primary of T1, the buck/boost transformer.

7.8. A moving iron voltmeter is fitted for measuring both input and output voltages, and an ammeter indicates the load current. The bridge lamp LP1 is mounted on the front panel and serves also as a pilot light.

7.9. The only component requiring regular attention is the variable transformer T2. After every 1000 hours of operation the winding and brush should be examined. Black patches on the track indicate a tendency to spark, possibly due to a worn brush.

The track should be cleaned with soft rag and, if the track is very pitted, with the finest grade of glass paper. The brush should be renewed when only 1 mm of carbon remains, this will be after approximately 5000 running hours.

# CHAPTER 8

## T/R ASSEMBLY DC DISTRIBUTION CHAIN CIRCUIT ANALYSIS

Power Supply Type S41/1 (Normal Radar PU), Power Supply Type S41/2 (MTI PU).

8.1. Two power units with identical circuitry but dissimilar face panels are mounted side by side in the right hand half of the transmitter/receiver rack. The a.c. input is from contactor No 1 and in the case of the MTI power unit is switched at the transmitter control unit. The outputs produced are:

a. -150 V stabilised - reference and bias voltage.

b. +200 V stabilised.

c. +330 V stabilised.

d. +470 V unstabilised.

e. -800 V unstabilised, - not used.

8.2. Transformer T2 supplies the bridge metal rectifier MR12 - MR15 to produce the -150 V output. A series regulator valve V7 is fitted in the positive (earth) side of the -150 V output. The grid of this series valve is controlled by the two halves of V8, a double triode, connected as a two stage d.c. amplifier, the cascade connection producing a high loop gain around the circuit. The cathode of V8A is held stable by the neon V9 and the grids of V8A and V8B are taken to a potential divider across the output. Any variations in output are offset by an amplified inverted change at the grid of the series valve V7. For example, should the load current rise causing a fall in output voltage, this fall appears at the grids of V8A and V8B. Amplified positive changes appear at the anode V8A and cathode V8B, the positive rise at the cathode of V8B assisting the fall at its grid. The current in V8B is reduced, resulting in a much larger positive rise at the anode of V8B and the grid of the series valve V7. The impedance of V7 is reduced, enabling it to pass the extra load current without dropping the output voltage. The high loop gain of this system results in only very small changes of output.

8.3. Ripple is reduced in the output by connecting the grid of V8A direct to one side of the output via capacitor C19, thus the whole of the ripple is applied to V7 grid in an inverted form. The -150 V output is used as a reference voltage in the positive power supply circuits and as bias in other units of the transmitter/receiver rack. The -150 V output is also used to operate relay RLA, the contacts of which are used to switch the positive supplies. Other windings of T2 supply the heater voltages to the regulator valves in the power units.

8.4. Transformer T1 has three secondary windings each feeding metal rectifier circuits. A bridge metal rectifier MR1 - MR4, produces +470 V. The unrgulated +470 V output is taken via contact A1 of RLA which ensures that the positive output is not fed to other units unless the -150 V bias voltage is present. A second output from the +470 V line is used to produce the stabilised +330 V output. A series regulator valve V5 is controlled by the high gain amplifier V6A, V6B. This circuit is similar to that of the negative output, no neon is used, the cathode of V6A being earthed.

8.5. The second winding on T1 feeds the bridge metal rectifier MR5 - MR8 whose output is switched by contact A2 to supply a regulator circuit which produces the +200 V stabilised output. The series regulator valves V1, V2 and V3 are connected in parallel, this method permitting greater current drain. The control circuit is similar to the +330 V and -150 V supplies and uses the two halves of V4.

8.6. The third winding on T1 produces the -800 V keep alive voltage for the T/R cell. Three silicon diodes are connected in series to act as a half wave rectifier, this output being smoothed by R2, C8 and C9.

8.7. The input, and all outputs other than the -800 V are fused. Lamps on the unit front panels indicate that the -150 V, +470 V, +330 V and +200 V outputs are available.

Power Supply Type S17/1 (Pre-amp TWT Power Unit)

8.8. This power unit is mounted in the transmitter/receiver centre rack below the signal splitter unit. Transformer T2 feeds a bridge metal rectifier to produce -18 V. A further metal rectifier diode MR2 protects the bridge rectifier from back surges when the equipment is switched off. The -18 V is used to supply the test e.h.t. overload system in the transmitter control unit.

Power Supply Type S21/1 (EHT Power Unit)

8.9. This unit provides the e.h.t. power supply to the modulator unit. The a.c. input to the step up transformer T1 is via a motor driven variac mounted in the centre of the main transmitter/receiver rack. Valves V1 and V2 form a full wave rectifier followed by a choke input filter. The smoothing capacitors C1 and C2 are rated at 7.5 kV. Withdrawing the unit from the rack releases a mechanical shorting bar to discharge these capacitors. To prevent excessive voltage being developed across R1 and R2 by the capacitor discharge current, contact 'b' of the shorting bar short circuits the resistors to earth before contacts 'a' and 'c' short circuit the capacitors. A microswitch mounted beside the mechanical shorting bar is also operated by it. This microswitch is in series with the e.h.t. interlock line and is closed only when the unit is pushed fully home into the rack, thus preventing e.h.t. being run up with the unit withdrawn.

8.10. If the e.h.t. was run up with the load disconnected, ie the modulator unit, high e.h.t. voltage would be produced. So that smoothing capacitors of a reasonable voltage rating can be used, over-voltage protection is necessary. For this purpose RV1, R16 and R19 at the earthy end of a bleeder chain provide a voltage output which is taken to a relay circuit in the transmitter control unit. If a rise in e.h.t. occurs this circuit removes the supply from the e.h.t. transformer. The "SET '0' VOLT TRIP" control, RV1, determines the voltage at which the circuit operates and is adjusted so that the trip will operate at 8 kV.

8.11. The parallel connected resistors R1 and R2 in the e.h.t. earth return lead produce a voltage that is proportional to the load current and hence the mean magnetron current. This voltage is taken to the transmitter control unit where it is used for magnetron heater switching and for overload protection.

RF Oscillator Type S4/2 (STALO) Power Supply Circuits

8.12. The +330 V input to the STALO unit is stabilised in the transmitter power unit, it is further regulated and reduced to +200 V in the circuit V1, V2, V3 and V4.

8.13. Valve V4 is the series regulation valve and V1 and V2 are connected as a long tailed pair, their action being to compensate for any changes in output and also for any fluctuating of emission due to, say, variations in their l.t. supply. Changes in output are fed to V1 grid via RV2 and the anti-phase signal at V1 anode is applied to V4 grid as in a normal series hard valve regulator circuit. V1 and V2 share a common cathode load R7 which is not by-passed. Should the heater supply voltage vary, the change in emission in V1 will provide a false error signal at V4 grid. With V2 connected to the top of R7 and obtaining its heater supply from the same source as V1, its valve current will also vary if the heater voltage varies. R7 will have flowing through it the current of both valves and will produce a negative feedback voltage double that which would be produced were V1 alone drawing current through it. V2 has its grid stabilised at +85 V by the neon V3 and plays no part in the normal regulator circuit. The extra feedback voltage is produced therefore only when heater variations occur.

8.14. The STALO l.t. supply of 6.3 V d.c. is produced by the circuit V6, V7, V8 together with a bridge metal rectifier (MR1) and the saturable reactor (TD1). The 230 V 50 Hz a.c. mains supply is stepped down to 22.5 V a.c. by transformer T1. This a.c. voltage is fed via a winding of the saturable reactor TD1 to the bridge metal rectifier MR1 where it is rectified to produce 6.3 V d.c. The actual a.c. voltage applied to MR1 depends upon the impedance of the winding of TD1, this in turn depends upon the current flowing in the bias winding of the transductor. This bias winding forms the anode load of V5, hence by setting the grid bias on V5 the 6.3 V d.c. output from MR1 can be controlled. The 6.3 V d.c. is taken direct to the heater of the STALO valve V9. This heater (shunted by R29, R20) forms the cathode load of the ripple suppression valves V6 and V8. Any ripple on the heater voltage is applied to the cathode of V8 via C11. This valve has its grid virtually grounded by C8. The in-phase ripple signal at V8 anode is amplified and inverted in V7 before being applied to the grid of the cathode follower V6. The cathode of V6 is on the STALO valve heater supply line and the anti-phase ripple at V6 cathode ensures a net resultant d.c. with negligible ripple being fed to V9.

## CHAPTER 9

## CONTROL RACK AND SIGNAL BOOSTER AC AND DC DISTRIBUTION

Voltage Stabiliser Type S1/2 (Servomex 9 Amp)

9.1. The 230 V unregulated a.c. supply from the wall switch is stabilised by Voltage Stabiliser Type S1/2 (Servomex 9 amp) to 230 V $\pm$ 0.25%.

9.2. The 230 V stab. supply is fed to:

a. Monitor units (see Monitor AC and DC Distribution Chain).

b. Amplifier Power Supply S25/1 (Signal Booster).

c. Remote Switching Control Unit Type S14/1.

d. Illumination lamp on Thermal Noise Generator Type S8/1.

9.3. The 230 V stab. supply to the Remote Switching Control Unit Type S14/1 is fed via SW1 mains ON/OFF to:

a. +60 V rectifier circuit.

b. Tx changeover switch (see Tx Select and EHT Interlock Chain).

c. Via SW3, NOISE SOURCE RUN/START, to the Thermal Noise Generator S8/1.

9.4. The +60 V d.c. supply is produced by a bridge rectifier using metal rectifier elements; the +60 V produced is used for controlling relays and switches used for trigger selection, anti-rainplate control, transmitter selection and e.h.t. interlock, aerial turning system.

9.5. 230 V stab. supply to the Signal Booster unit is controlled by SW3 OFF/CABINET HTRS/UNITS ON. When switch is in "CABINET HTRS" position, only anti-condensation heaters are on. In "UNITS ON" position line volts are connected to:

a. Rectifiers which produce -150 V, +330 V, +200 V d.c. supplies for the signal circuits.

b. Heater transformer TR1 which produces heater volts for valves in signal circuits.

Power Supply Type S46/1. ( Signal Booster Power Unit)

9.6. The power unit provides stabilised voltage for use in the signal booster amplifier and its sub-assemblies. The voltages produced are:

a. +330 Volts stabilised.

b. +200 Volts stabilised.

c. -150 Volts stabilised.

9.7. Full wave valve rectifiers are used to produce both the positive and negative outputs. The output levels of all outputs are adjusted by controls on the front panel, together with monitor sockets and lamps.

9.8. The mains input to the power unit is fed to a three position switch. When this switch is in the "CAB HEATERS ON" position the mains supply is fed from the power unit to two heaters in the base of the rack; in this position the supply to T2 and the equipment is switched off. The centre position of the switch is an OFF position. In the third position of the switch the equipment is ON and the cab. heaters are OFF.

NOTE: The regulating action of the series regulators in this unit is similar to those in the Normal Radar and MTI Power Units. (Refer to Chapter 8).

# CHAPTER 10

## MONITOR EQUIPMENT AC AND DC DISTRIBUTION

10.1. The monitor display equipment is situated in the radar head building. It consists of:

a. Azimuth Range Indicator Type S5/1 (Display Unit).

b. Pulse Generator Power Supply S18/2 (Base Unit).

The former is mounted on the latter to form a display console for monitoring purposes.

10.2. The necessary d.c. supplies are produced by sub-units of the pulse generator except for the CRT EHT which is produced by an r.f. oscillator and rectifier mounted in the azimuth range indicator.

10.3. When the appropriate wall switches are made the 230 V a.c. unstabilised supply is completed to:

a. The Display Unit supplying:

(1) Two service sockets, DSKAA and DSKAB.

(2) Two 30 W anti-condensation heaters via the closed contacts A3, A4 of relay A.

b. The Base Unit supplying:

(1) Two service sockets, ESKE and ESKD.

(2) LP2 UNSTAB MAINS ON indicator lamp and via SWB to the servicing lamp LP1.

(3) Via contact B1 of RLB to the 30 W anti-condensation heater.

c. Via interlock switches, SW.C (operated by Power Supply S26/1 chassis) SW.D (operated by Power Supply S27/2), SW.E (operated by Pulse Generator S14/1) to relay A.

10.4. The 230 V a.c. stabilised supply is fed to SWA, Emergency ON/OFF switch. If the interlocks referred to in para 10.3(c) are made RL.A is energised and the 230 V stabilised supply is completed via SWA and contacts A1, A2 to:

a. RLB, contact B1 breaks the 230 V a.c. unstabilised supply to the anti-condensation heater and completes it to the cooling fan.

b. LP1, 230 V AC STAB. MAINS ON indicator lamp.

c. Power supply sub-assembly S56/1 (Display Positive PU).

d. Voltage Stabiliser S5/1 (Positive Stab. PS) to transformer T1 which provides valve heater voltages.

e. Power supply sub-assembly S55/1 (Display Negative PU).

f. Voltage Stabiliser S4/1 (Negative Stab. PS) to transformer T1 which provides valve heater voltages and supplies a 28 V d.c. rectifier circuit.

g. Switch assembly S5/1 (Switch Unit X1) thence via safety interlock contacts A2, A4 or C1, C2 to the heater transformers in Sweep Generator Unit S20/1 (WF Gen. Integrator) and Electronic Marker Gen S21/1 (WF Gen. Video).

h. Switch assembly S5/1 (Switch Unit X2) thence via safety interlock contacts A2, A4 or C1, C2 to the heater transformer in the Azimuth Range Indicator S5/1 (Display Unit).

10.5. The d.c. voltages produced by the power units are:

a. Power Supply Type 27/2 (Display Positive PU).

(1) +500 V.

(2) +330 V.

b. Power Supply Type 26/1 (Display Negative PU).

(1) -500 V.

(2) -330 V.

10.6. These voltages are fed to the three switch units Type S5/1 (X1, X2 and X3; X3 is not used in the monitor) and thence to the circuits controlled by the appropriate switch unit. X1 controls the heater and d.c. supplies to the W/F Gen. Integrator and the W/F Gen. Video. X2 controls the heater and d.c. supplies to the units contained in the Display Unit.

10.7. The 28 V d.c. produced in the Negative Stab. PS is used to actuate the relays in the switch units. It is fed directly yo switch unit X1 and via the Display Unit to the switch unit X2. In the latter case the 28 V is fed via the DISPLAY ON/OFF switch SWD and two interlock switches actuated by the side doors of the unit to the switch unit X2. When the supply is complete RLA in the display unit is energised causing contacts A3, A4 to break the a.c. supply to the heater while A1 A2 make it to the cooling fan.

Switch Unit Control Action

10.8. If the +330 V d.c. supply from Power Supply S55/1 and the +28 V d,c. supply are present the switch unit will function as follows:

a. The +330 V fed via dropper resistor R1 energises RL.B.

b. Contact B1 closes completing RL.A circuit.

c. Contact A1 closes completing 6.3 V a.c. to 30 sec delay TD1.

d. Contacts A2 and A4 close completing 230 V a.c. stab. to the heater transformers in the appropriate units.

e. Contact A3 closes preparing RL.C and RL.D circuits.

f. After 30 seconds TD1 contact closes placing an earth at the junction of R1 and MP1.

g. Relays D and C energise.

h. Contacts D1, D2 close completing -330 V d.c. to the units.

j. Contacts D3, D4 close completing -500 V d.c. to the units.

k. Contact D5 closes RL5 hold contact.

l. Contact D6 closes to maintain the earth at R1, MR1 junction.

m. Contacts C1, C2 close bypassing contacts A2, A4.

n. Contacts C3, C4 close completing +330 V d,c. to the units.

o. Contact C5 closes completing RLE circuit.

p. RL.B de-energises.

q. Contact B1 opens breaking RL.A circuit.

r. Contacts A4, A2 open.

s. Contact A3 opens.

t. Contact A1 opens and TD1 reverts to 'cold' state.

u. Contacts E1, E2 close completing +500 V d.c. to the units.

10.9. If the +28 V d.c. supply is broken, all d.c. supplies to the units are broken and the full switching sequence must be repeated to restore them.

# CHAPTER 11

## MONITOR AC AND DC DISTRIBUTION CHAIN CIRCUIT ANALYSIS

### The Display Positive Power Unit (Power Supply Type S27/2)

11.1. The positive power unit chassis is sub-divided into a stabilised and an unstabilised power unit, the function of the unstabiliser power unit being to produce d.c. outputs from a regulated a.c. input. These outputs are fed to the stabilised power unit half of the chassis. The a.c. input to the unstabilised power unit is fed to a transformer with three secondary windings, each of these windings feeding a bridge rectifier circuit; the outputs produced are +650 V, +470 V and -160 V. Silicon rectifiers are used with associated surge resistors and capacitors. The initial current surge is limited by the choke L1 in the +470 V line. In the case of the other two outputs the resistors R19 and R20 limit initial current surges and are then shorted out when relay A is operated by a supply from the +330 V output of the stabilised half of the power unit.

11.2. The positive stabilised power unit produces the +500 V and +330 V rails for the waveform generator and viewing units, also a -85 V supply for internal testing of the power unit.

11.3. The +650 V input from the unstabilised chassis is used to produce the stabilised +500 V output. The parallel connected series regulator valves V5 and V10 are controlled by the shunt valve V4. The bias for this circuit is normally obtained from the -500 V output of the negative stabilised power unit.

11.4. The +470 V input is regulated to produce +330 V output by four parallel connected series regulator valves V6, V7, V8 and V9. The load current of these valves is equalised by making the grids of V7, V8 and V9 adjustable. Shunt control of the series valves is by the high gain amplifier V1, V2A and V2B. A portion of the output is fed to V1 grid and the inverted signal applied to the grid of V2A. Since V2A and V2B share a common cathode load the signal from V2B anode that is applied to the grids of the series valves is in anti-phase to the input to V1. The bias for this circuit is also normally obtained from the -500 V rail of the negative stabilised power unit.

11.5. To permit testing of the positive power unit alone, a bias line is produced within the power unit and switched into use by switch SB. The -160 V input from the positive unstabilised chassis is stabilised by the neon V3 at -85 volts. With SB at 'TEST' alternative resistor networks are brought into the grid circuits of V1, V2 and V4 to simulate normal working conditions with the lower bias voltage.

11.6. A small sub-chassis mounted on the positive stabilised power unit has inputs from the +330 V rail and from the -330 V rail of the negative stabilised power units. Two neons are fitted to stabilise the outputs of this sub-vhassis at $\pm$ 50 V d.c. which is fed to the sine/cosine potentiometer.

11.7. The regulated 230 V a.c. mains is supplied to the positive stabilised power unit and connected to transformer T1 to produce the valve heater voltages.

## The Display Negative Power Unit. (Power Supply S26/1)

11.8. The layout of the negative power unit is similar to that of the positive unit. Two sub chassis are bolted together to form the unit and are the unstabilised and the stabilised power units respectively. The circuitry of the unstabilised unit is identical with that of the positive unstabilised power unit, two negative outputs and one positive output are fed to the stabilised power unit chassis. The voltages produced by the negative stabilised power units are:

a. -500 V, stabilised.

b. -330 V, stabilised.

c. +170 V, internal reference voltage.

d. +28 V, for relay operation throughout the base and viewing units.

11.9. The unstabilised inputs which produce the negative stabilised outputs are floating with respect to earth. The 470 V input is between +140 V and -330 V and the 650 volts input is between +150 V and -500 V.

11.10. The -500 volt stabilising circuit employs V8 as a series regulator in the earthy side of the output. V8 cathode being grounded through the current monitoring resistor R46, and its screen stabilised at +75 by the neon V10. The anode of V8 is returned to the +105 V output from the unstabilised chassis. The control valve acting on V8 grid is V4; it obtains its h.t. supply from the +330 V rail of the positive stabilised power unit. The neon V12 stabilises V4 cathode at 85 V above the -500 V line from the unstabilised unit. The grid of V4 is returned to a fixed point on a potential divider between the -500 V rail and earth. Any change in the input is fed via V4 to the series valve V8 maintaining the -500 V rail at a constant potential with respect to earth.

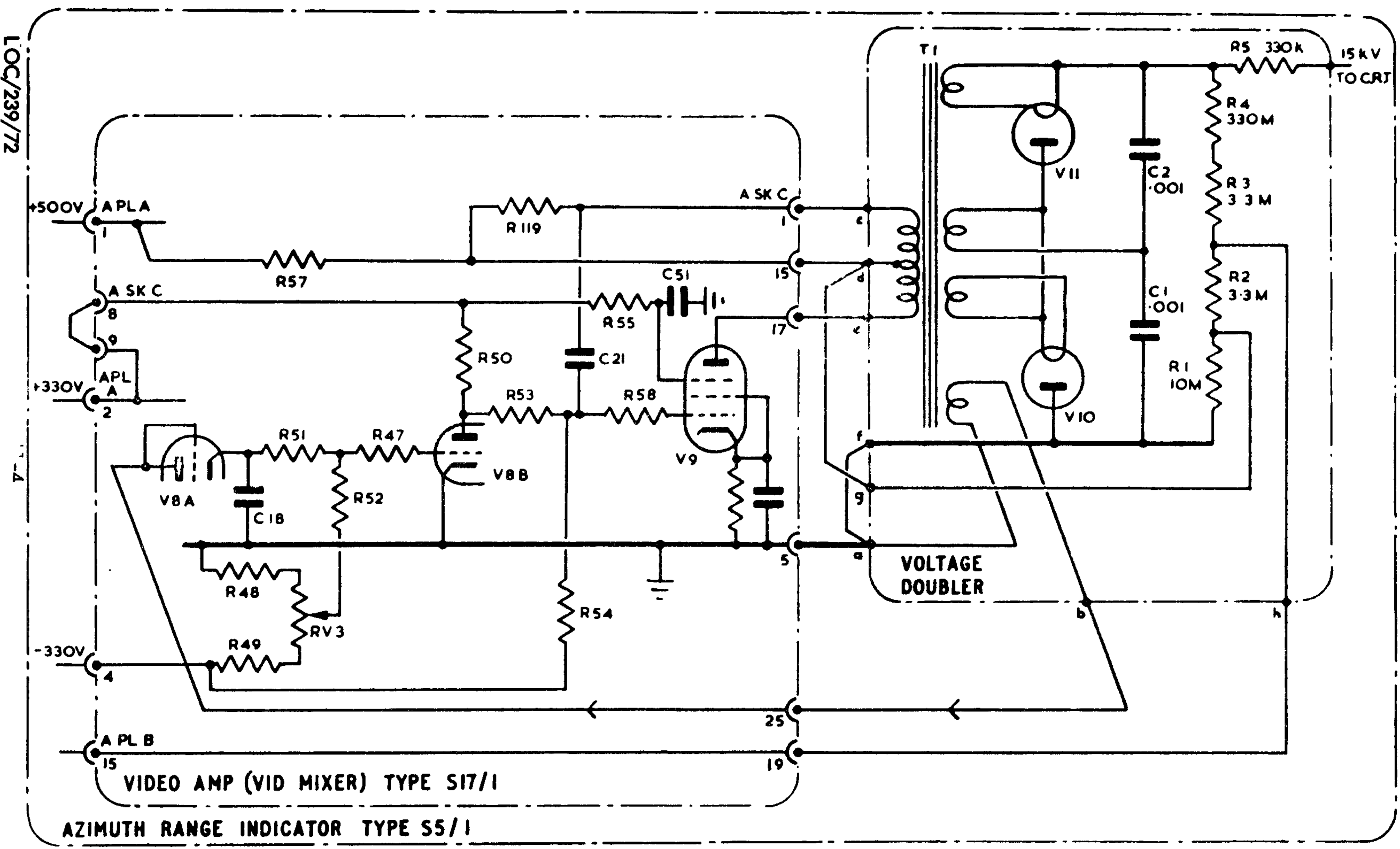
11.11. The -330 volt stabilising circuit employs four parallel connected series regulator valves V3, V5, V6 and V7. Current through these valves is equalised by including controls in the grid circuits of V3, V6 and V7. These series regulators are controlled by the high gain amplifier circuit V1, V2A and V2B. The action of this circuit is identical to that already described for the +330 V circuit of the positive stabilised power unit. The series valves are connected between earth and the +140 V line from the unstabilised power unit and the -330 V stabilised output is taken from the cathode of V1.

11.12. Normally the +330 V rail from the positive stabilised power unit is used to provide the h.t. supplies for the amplifier circuit V1 and V2. To permit internal testing of the negative power unit alone an internal h.t. supply is developed from the +330 V line from the negative unstabilised chassis by the circuit of V9 and V11. Under normal conditions the h.t. for V1 and V2 is +300 V and this supply is also regulated by V9 and V11 to feed +170 V to the screens of V3, V5, V6 and V7. When switch SB1 is set to 'TEST' the -330 V from the negative unstabilised chassis is stabilised at +170 V by V9 and V11 and is used for h.t. on V1 and V2 and also for the screens of V3, V5, V6 and V7. To allow for the lower h.t. on V1 and V2, switch SB1 introduces R15 into the cathode circuit of V2.

11.13. The 230 volts regulated a.c. supply is brought into the negative stabilised power unit to feed the valve heater transformer T1. One winding on this transformer supplies a bridge silicon rectifier circuit producing +28 volts. This output is used to control the three switching units which are sub-assemblies mounted on the negative stabilised power unit.

Display EHT Supply

11.14. The c.r.t. final anode potential of +15 kV, d.c., is produced by a circuit, some of the components of which are mounted on the video mixer unit. V9 is connected as a Hartley oscillator, the tank circuit being formed by the primary winding of the e.h.t. transformer. The oscillator frequency is 33 kHz and the +500 V h.t. reaches the valve via the transformer. The secondary of the e.h.t. transformer generates the e.h.t. and feeds a voltage doubler circuit V10 and V11 with C22 and C24 as the doubling capacitors. The transformer is hermetically sealed in an oil filled can which also contains V10, V11, C22 and C23. This can is suspended from the top frame of the viewing unit. The oscillator valve V9 and the e.h.t. control V8B and V8A are mounted on the video mixer unit chassis.


LOC/239/72
+500V
APL A
1
A SK C
8
9
+330V
APL A
2
-330V
4
APL B
15
R119
R57
R55
C51
R50
C21
R53
R58
R51
R47
V8A
V8B
V9
C18
R52
R48
RV3
R49
R54
A SK C
1
15
17
5
25
19
c
d
e
f
g
a
b
h
T1
R5 330K
15KV
TO CRT
R4
330M
R3
3·3M
R2
3·3M
R1
10M
C2
·001
C1
·001
V11
V10
VOLTAGE
DOUBLER
VIDEO AMP (VID MIXER) TYPE 517/1
AZIMUTH RANGE INDICATOR TYPE 55/1

# CHAPTER 12

## ATC EQUIPMENT AC DISTRIBUTION

12.1. The equipment in the air traffic control centre is identical to the monitor equipment. Some additional units are necessary to:

a. Provide a stabilised 230 V a.c. power supply.

b. Relate aerial and trace rotation.

12.2. These units are contained in the Amplifier Power Supply Cabinet Type 29/1 and comprise:

a. Voltage Stabiliser 9 Amp S3/1 (Servomex 9 Amp).

b. Synchro Signal Amp. Type S23/1 (Aerial Follower).

c. Power Supply S43/1 (Aerial Follower PS).

12.3. The a.c. distribution for the a.c. chain is similar to that of the monitor a.c. supplies with the following additions:

a. The cooling fan is controlled from either the Amp PS S29/1 (Upper Base Unit) or the Pulse Gen PS S18/2 (Lower Base Unit).

b. The unstabilised a.c. supply is fed to the lower base unit and distributed to:

(1) Two service sockets.

(2) The a.c. voltage stabiliser.

(3) A control and interlock system similar to that discussed in the monitor chain.

12.4. The a.c. stabilised power supply is distributed to:

a. The Aerial Follower Power Supply.

b. The Heater Transformer in the Aerial Follower.

c. The remainder of the distribution is as for the monitor a.c. supply.

12.5. The Pulse Gen Power Supply Units S18/1 and S18/2 are electrically identical but their air cooling duct connections differ. The S18/1 is used in the ATC displays and the S18/2 at the radar head monitor displays.

12.6. The equipment in the air traffic control centre is similar to the monitor display equipment. Some additional units are necessary (see paras 12.1. and 12.2).

12.7. At the ATC centre two displays are provided and thus all three switch units S5/1 are used.

Power Supply Type S43/1 (Aerial Follower PS)

12.8. The aerial follower power and control unit is mounted immediately below the follower and is fed with 230 V a.c. stabilised mains from the third unit of the upper base unit, a voltage stabiliser.

12.9. It produces the stabilised voltages for use within the aerial follower; outputs are:

a. +470 volts, unstabilised.

b. +330 volts, stabilised.

c. +200 volts, stabilised.

d. -330 volts, stabilised and reference voltage.

12.10. An ON/OFF switch on the front of the unit completes mains to transformer T2. Secondary windings on this transformer supply valve heaters and also a thermal delay switch V10. This delay is provided to ensure that all valve heaters have been on for at least one minute before positive h.t. can be applied to them.

12.11. A further winding on T2 feeds a bridge metal rectifier producing -330 V, which is stabilised by the series hard valve regulator circuit V7, V8 and V9. The negative output of the unit is not connected until the standby ON/OFF switch, SD, is closed. This switch earths both relays A and B via the thermal delay V10. The relays energise and contact B1 completes the negative output line. Contact A1 opens and breaks the heater supply to V10 and simultaneously latches relays A and B via switch SD. Contact A2 energises relay C. The contact C1 is in series with the "POSITIVE HT ON" switch, SE, and when both contact and switch are closed the 230 V a.c. supply is fed to the primary of transformer T1. Twin secondary windings feed bridge metal rectifiers producing the positive h.t. outputs. Stabilisation of the positive outputs is provided in this unit. However, the heavy current drain is from the +330 volt line and it is this circuit which has parallel connected series regulator valves, not the +200 V line.

12.12. Internal metering of the power unit is provided by the meter on its front panel with the INT/EXT switch set to 'INT'. When this switch is set to 'EXT' the meter is connected to the aerial follower unit and the meter switch on that unit selects the junction to be metered.

# CHAPTER 13

# TRIGGER SELECT CHAIN

## Trigger Production

13.1. The time related triggers for use throughout the equipment are produced in the Trigger Pulse Generator Type S6/2 (Lock Unit). Triggers are produced at a free-running frequency of 666 p.p.s. (1500 microsecond spacing) or the trigger source is synchronised by a lock pulse from the MTI circuits to a frequency of 714 p.p.s. approximately (1400 μsec spacing). Normally trigger frequency is controlled by the MTI circuits of the operational transmitter and the standby transmitter system is synchronised by a pre-pulse from the operation transmitter to prevent interference on the displays. A check facility is provided to identify 'second time round echoes'.

13.2. The triggers and their uses are as follows:

a. Modulator trigger, positive going, time of occurrence defined as $T_o$; used to initiate the transmitted pulse.

b. Secondary radar trigger, positive going, occurs at $T_o$ - 30 μS: used to trigger the IFF equipment when fitted.

c. Pre-pulse trigger, positive going, occurs at $T_o$ - 100 μS: used to trigger the swept gain circuits.

d. Display pre-pulse trigger, positive going, occurs at $T_o$ - 100 μS: used to trigger the display circuits and to synchronise the standby transmitter.

## Trigger Distribution

13.3. a. Modulator Trigger. Is fed directly to the modulator unit which is part of the Transmitter Chain.

b. Secondary Radar Trigger. The secondary radar trigger from the Lock Unit of the operational transmitter is fed via Tx selection relay contact M1 to the IFF equipment when used.

c. Pre-pulse Trigger. Is fed to the swept gain circuits, which are mounted on the Pre-amp Unit, and initiates the swept gain waveform.

d. Display Pre-pulse. Is fed from the lock unit of the selected operational transmitter via Tx selection contact M4 to amplifier circuits in the Signal Booster Rack thence via landline to the ATC displays. (See Time Base Chain). The output ofthe standby lock unit is terminated by R9 via the Tx select relay contact N3. The pre-pulse is also fed from the lock unit of the operational transmitter to the lock unit of the standby transmitter to synchronise it.

## Synchronising Trigger Selection

13.4. When TX1 is selected as the operational transmitter SWE on the waveguide switch unit completes +60 V via contact T1 to Relay A in the lock unit. Contact A1 makes to the MTI lock position and the multivibrator V1, V2a is synchronised by the MTI lock pulse. SWF on the waveguide switch unit is open and relay A in TX2 lock unit is de-energised, thus contact A1 is in the pre-pulse position and the display prepulse from TX1 lock unit synchronises TX2. When TX2 is selected the relays conditions are reversed. Relay B in the lock units is de-energised when a transmitter select operation takes place and both relays are energised by:

a. SWC in the waveguide switch unit when TX1 is operational.

b. SWD in the waveguide switch unit when TX2 is operational.

13.5. a. In the TX1 operational condition of the waveguide,switch relays N and M are de-energised. Contact M4 connects the display prepulse to the displays while contact N3 terminates the unused output from TX2 lock unit.

b. In the TX2 operational condition of the waveguide, switch SWE connects +60 V to relays N and M. Contact M4 connects the prepulse from TX2 lock unit to the displays and contact N3 terminates the unused output from TX1 lock unit.

## PRF Check Facility

13.6. a. If SW6 CHECK PRF switch on the selected control unit is depressed +60 V is completed to relays W and T.

b. Relay T energised:

(1) Contacts T3 and T4 open breaking the pre-pulse connections to the lock units.

(2) Contacts T1 and T2 open breaking +60 V supply to relays A in the lock units.

c. Relay W energised:

(1) Contact W1 closes completing PRF CHECK indicator lamp circuit.

(2) Contact W2 opens and 1/4 minute delay commences.

(3) Contact W3 closes completing +60 V hold voltage to relays W and T.

(4) Contact W4 opens. The e.h.t. interlock circuit of the standby TX is broken. (See TX Select and EHT Interlock Chain).

13.7. During the $\frac{1}{4}$ minute delay period the operational transmitter operates at 'free run' frequency, 666 p.p.s., and 'second time round echoes' can be recognised on the display.

13.8. a. After $\frac{1}{4}$ minute approximately, relay X is energised, contact X1 opens breaking the 60 V holding voltage to relays T and W.

b. Relay T contact closes restoring the synchronising pulses and relay A in the operational transmitter is energised. The transmitters revert to normal operation.

c. (1) Relay Contact W1 opens - PRF CHECK lamp circuit broken.

(2) Relay contact W2 moves to the re-set position terminating the delay period and relay X de-energises.

(3) Relay contact W3 opens.

(4) Relay contact W4 closes completing standby transmitter e.h.t. interlock circuits.

# CHAPTER 14

## TRIGGER SELECT CHAIN
## CIRCUIT ANALYSIS

Trigger Pulse Generator Type S6/2. (Lock Unit).

14.1. This unit is primarily a trigger-pulse generator and is usually triggered, the trigger pulses originating in the MTI circuits of the transmitter which is connected to the aerial. In this way both operational and standby transmitters fire at the same instant and no interference occurs at the waveguide switch which could appear on the final display. The outputs from the lock unit are as follows:

a. Modulator trigger pulse, positive going, the time of occurrence of which is defined as $T_0$.

b. A secondary radar trigger pulse, one microsecond wide and 20-30 volts in amplitude which may be made to occur at any time between $T_0$ minus 30 µS and $T_0$.

c. The pre-pulse, a positive going pulse starting at $T_0$ minus 100µS, used to trigger the swept gain circuits.

d. The display pre-pulse, a positive going pulse 3µS wide and 12 volts in amplitude occurring at $T_0$ minus 100µS is used to trigger the display units, and the lock unit of the standby transmitter.

14.2. When the transmitter is connected to the aerial, relay RLA is energised and the incoming synchronising pulse from the MTI units is applied to the grid of the buffer amplifier (V1A). When the transmitter is at standby, ie not connected to the aerial, RLA is de-energised and the synchronising pulse from the lock unit of the other transmitter is fed, via the switching rack (mounted between the two transmitters) to the unit.

14.3. Valves V1B and V2A form an asymmetric multi-vibrator which produces a positive going pulse at the anode of V2A the width of which is set to 100µS by means of the pre-pulse width control RV2. This sets the potential to which V2A grid aims. The amplitude of the negative going pulse applied to V2A grid is stabilised by V6A thus preventing changes of pulse width due to changes in the gain of V1.

14.4. RV1 enables the p.r.f. of the multivibrator to be adjusted between the limits 525-850 p.p.s. The control is set with the synchronising input to V1A disconnected, to give an interpulse period of about 1500µS. When the synchronising pulse is connected the repetition of the multi-vibrator is raised to that of the MTI system and the interpulse period reduces to about 1425µS. The input synchronising pulse is positive going but is inverted in V1A and used to cut off V2A.

14.5. The negative going waveform at V2A grid is applied to the grid of the buffer amplifier V2B, producing at the anode of V2B a positive going rectangular pulse of about 80 volts amplitude. This arrangement frees the anode circuit of V2A from the loading of the input circuit of V3 and ensures that the leading and trailing edges of the pulse are steep. The function of relay RLB in the anode of V2B is to stop the operation of the lock unit during the changeover period of the waveguide switch when selecting the other transmitter to the aerial.

14.6. The relay is normally energised but during the changeover, the supply to the relay coil is interrupted and contact B1 opens breaking the h.t. supply to V2B. At the same time the e.h.t. is switched off, the e.h.t. contactor however acts more slowly than RLB, so when the trigger output from the lock unit is removed the e.h.t. voltage is liable to rise and operate the over voltage trip. This would result in a delay of five minutes before the e.h.t. could be restored. To prevent this C5 and C15 are fitted to delay the collapse of h.t. to V2B.

14.7. The positive pulse from V2B anode is applied to the grid of the phase splitter V3. This valve has a differentiating transformer in its anode circuit; the pulse of anode current in V3 heavily saturates the core of T1 so that an e.m.f. is only induced in the secondary during the rise and fall.

14.8. Valve V4 is normally held cut-off from the potential divider R29, R30 but the positive pulse produced in T1 secondary at the trailing edge of the multivibrator squarewave causes V4 to conduct and a negative pulse of 400 volts amplitude is produced at its anode. Transformer T3 inverts the pulse and a positive going pulse of 3.5 $\mu$S duration and 400 volts amplitude is fed out to the modulator.

14.9. A step down transformer T2 in the cathode of V3 has a ratio of 4 : 1 and produces a 23 volt positive going pre-pulse output. This pre-pulse is used to trigger the swept gain circuit mounted on the r.f. amplifier unit.

14.10. A second output is taken from the anode of the buffer amplifier V2B and applied to the grid of the cathode follower V7. This pulse is differentiated by C16 and R54 in the grid circuit of V7. Only the positive pip produced at $T_0$ minus 100 $\mu$S has any effect on V7. The output across R57 is taken to the waveform generator unit (video) in the display system and second lock unit via the radar control rack.

14.11. A secondary radar trigger pulse is also produced in the lock unit although at present no secondary radar equipment is fitted. Because of transponder delay, secondary radar must be triggered before $T_0$ to produce a correct display on primary radar.

14.12. The negative going pulse at V1 anode is fed via C13 to cut-off V5B. This valve recovers towards cut-on, on a time constant C13, R46 and the potential towards which it is recovering is determined by RV3, (the SR trigger delay). Therefore, at V5B anode the fall due to the valve cutting on again can be varied between $T_0$ minus 30 $\mu$S and $T_0$. This fall is applied via C12 to the anode of the blocking oscillator V5A.

14.13. Valve V5A is normally held cut-off from the potential divider R41, R42, the fall at V5B anode fed via C12 is inverted in transformer T4 and appears as a rise at the grid of V5A cutting the valve on. Normal blocking oscillator action takes place producing a large negative pulse at V5A anode. The winding on T4 inverts this and steps it down producing a positive going pulse of 1 $\mu$S duration and 20-30 volts amplitude.

14.14. Multivibrator jitter due to hum is minimised by injecting a small a.c. voltage at V2A grid, amplitude and polarity of this voltage being set by RV4.

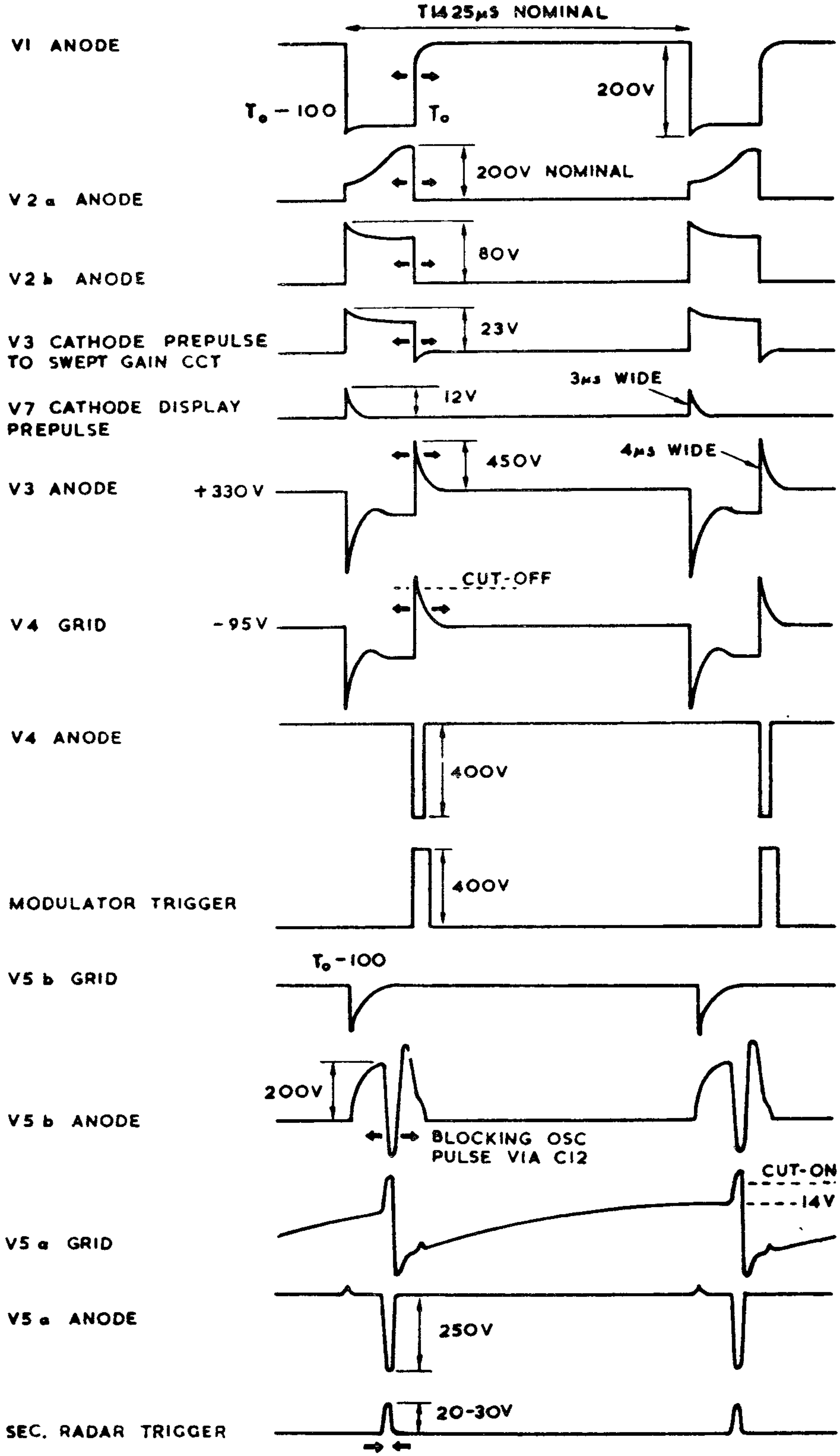



Fig 14.1. Lock Unit Waveforms

# CHAPTER 15

## TRANSMITTER CHAIN

15.1. The radar transmitters are duplicated (TR1, TR2) and normally while one is operational the other is on standby. The operational transmitter is connected to the aerial while the standby one can be run up and operated into a dummy load.

15.2. The trigger circuits (Trigger Selection Chain) of the operational transmitter are normally synchronised by the MTI lock pulse and the output to the transmitter is a trigger at time $t_o$ The standby transmitter trigger circuits are synchronised by a prepulse trigger at $t_o$ - 100 μS from the operational transmitter. The trigger circuits produce a transmitter trigger at $t_o$ thus both transmitters fire at the same instant minimising interference on the displays.

15.3. The EHT d.c. voltage of 6 kV approximately is fed into the Radar Modulator S1/1 at PL2. The modulator is a basic type, an artificial line and hydrogen thyratron discharge valve triggered by the transmitter trigger at $t_o$ produce a current pulse in the primary of a pulse transformer, the output of the secondary fed to the magnetron cathode is a 27 kV 1 μS negative going pulse.

15.4. The magnetron is mounted in a box, a blower cools both the magnetron and the local oscillator ensuring that both are kept at the same temperature. The burst of r.f. oscillation produced by the magnetron is probe coupled into the waveguide exciting an HO 1 mode in it. The amplitude of the magnetron pulse is set at 35 amperes peak and the e.h.t. power unit output is adjusted to produce this figure. The depth of the probe in the guide can be adjusted and an adjustable plunger is used to match the waveguide and the magnetron in conjunction with a phase shift control.

15.5. The phase shift device consists of a distrene plate placed longitudinally in the waveguide. It can be moved laterally across the waveguide and alters the load reactance presented to the magnetron.

15.6. The transmitted energy is fed via a transmit/receive assembly to the aerial via the transmitter select switch. An attenuated sample of the magnetron pulse is fed via the coho cavity to the MTI system to phase lock the reference oscillator in the MTI circuits.

15.7. A neon standing wave indicator is fitted in the transmitter to facilitate the magnetron setting up.

15.8. A thermo couple in the waveguide run to the aerial feeds a power indication meter mounted on the Thermal Noise Generator Type S8/1 (Noise Source).

15.9. The waveguide switch, controlled by the transmitter select system, connects the operational transmitter to the aerial and the standby transmitter to the dummy load. A mechanical interlock is operated by the dummy load so that the standby transmitter can only be fully run up when the dummy load is connected.

15.10. An anti-rain (circular polarisation) facility is available on the aerial assembly.

## CHAPTER 16

## TRANSMITTER CHAIN, CIRCUIT ANALYSIS

### Radar Modulator Type S1/1 (Modulator Unit)

16.1. Basically the modulator unit consists of an artificial line which is discharged by a hydrogen thyratron to produce a 27 kV pulse of 1 µS duration across the magnetron.

16.2. The artificial line DL1 is charged via the resonant choke from the e.h.t. line. The choke together with the sum of the line capacitances form a series resonant circuit. When the +6 kV is applied to the line the charging process excites an oscillation in the resonant circuit and at the end of half a cycle of this oscillation the line is charged to twice the e.h.t. voltage.

16.3. The trigger pulse from the lock unit arrives at the grid of the thyratron at the instant when the line is charged to 12 kV. The time of discharge is the double transit time of the delay line, ie 1 µS.

16.4. The discharge path is via the primary of T3, the impedance of this transformer being matched to that of the p.f.n. so that a 6 kV pulse is dropped across each, the discharge current being 180 amperes. The twin secondary windings of T3 step up the pulse to 27 kV for application to the magnetron.

16.5. The magnetron heater transformer T2 is also mounted in this unit and has one secondary winding of T3 in each leg of its secondary winding. Capacitor C3 across T2 secondary equalises the pulse potential across the filament transformer secondary and C5 reduces any natural inductance in C3.

16.6. Capacitors C1 and C2 together with R6 form an anti-droop circuit. These capacitors are charged by the initial heavy discharge current and when this current starts to fall off the capacitors boost the current thus maintaining the pulse shape.

16.7. For maximum efficiency the thyratron must always fire when the line is fully charged, ie at 12 kV. The value of L1 and the line capacitance are chosen therefore to resonate at half the p.r.f. of the system. If the p.r.f. of the trigger is too low the voltage across the line would begin to decrease before the trigger pulse arrived. Conversely if the p.r.f. is too high the voltage will not have reached its maximum when the pulse arrives.

16.8. If the voltage pulse applied to the magnetron rises too sharply the magnetron may fail to oscillate in the desired mode. For this reason the choke L2 is inserted in the anode circuit of the thyratron to limit the initial current surge when the thyratron fires. Similarly a metrosil mounted in the lock unit limits the rise of voltage at the thyratron grid from being fed back into the lock unit.

16.9. Faulty operation of the magnetron can cause a series of momentary short circuits which result in high negative voltages building up at the thyratron anode. Should sparking occur in the magnetron a sudden drop in the impedance of the load is presented to the delay network; because the thyratron in a uni-directional switch a negative charge is left on the line after each pulse. This charge builds up after a number of pulses and to safeguard the delay line, thyratron and resonant choke, the over swing diode V2 is fitted. This diode discharges the negative potential and in doing so operates relay RLZ which in turn breaks the e.h.t. control circuit.

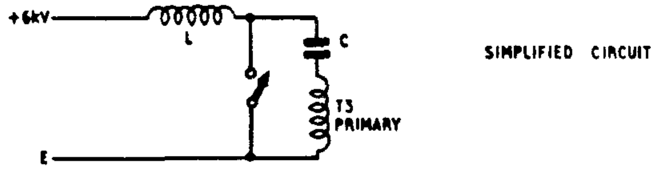



Fig 16.1 SIMPLIFIED CIRCUIT OF THE MODULATOR

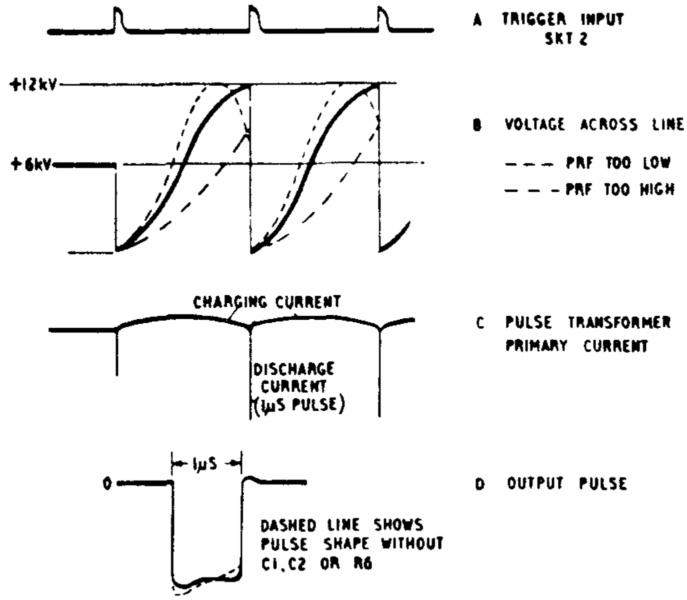



Fig 16 MODULATOR WAVEFORMS

<u>TR Line Assembly</u>

16.10. The coho cavity, a tuneable high Q resonant cavity, loosely coupled to the waveguide, supplies a sample of the transmitted pulse to the mixer. The 30 MHz IF signal is used to phase lock the reference oscillator in the MTI System. Above the coho cavity is an ATR cell which is in the form of a glass nail fitted with Brazilian crystal which ionises in a similar way to the normal gas filled cell. The ATR cell is coupled to the waveguide by a window and is backed by a waveguide stub $\frac{\lambda g}{4}$ from the waveguide wall. At $\frac{\lambda g}{2}$ away from the ATR cell is situated the main non-tunable wide band TR cell.

16.11. During transmission the cells ionise. The ATR cell is designed so that a short circuit, caused by the ionisation of the glass nail, presents a high impedance at the waveguide wall and the power will pass towards the scanner. The discharge of the TR cell reflects energy back to the main waveguide in phase with the transmitted energy reducing considerably the amount of energy break through to the receiver.

16.12. Incoming signals do not cause the TR cells to ionise. The TR cell offers low impedance to the signals, which pass to the RF amplifier. The ATR cell is located $\frac{\lambda g}{4}$ from the TR branch and the ATR itself has a stub mounted $\frac{\lambda g}{4}$ from the waveguide wall. These two distances constitute a $\frac{\lambda g}{2}$ open line interposed between the magnetron and the TR branch, minimising signal leakage towards the magnetron.

## CHAPTER 17

## NORMAL RADAR SIGNAL CHAIN

17.1. The normal radar signal chain shows the signal path from the reception of the r.f. pulses at the aerial to the final processed video signals appearing on the display.

17.2. RF signals received at the aerial are fed via the transmitter select switch to the operational transmitter. Signals fed via the duplexer system are amplified in the r.f. Amplifier S13/1 (Pre-amp). This device provides good amplification with low noise factor of the r.f. signals. Becauseitis a wideband device an image rejection cavity is used to reject unwanted frequencies. Signals from the Pre-amp are fed via a 'despike' diode and mixed with a local oscillator signal from the RF Oscillator S4/1 (Stalo) to produce i.f. signals which are amplified in a five stage amplifier, Head Amplifier S9/1 (Signal Head Amp). The gain of the signal head amp is controlled by a potentiometer on the Power Supply Control Panel S7/1 and a swept gain facility is available. The gain control voltage is a composite of the level set by the manual gain control and the swept gain waveforms. Signals are fed to a Variable Attenuator (S3/1) (Signal Splitter Attenuator) and two outputs are fed to:

a. MTI circuits (MTI production chain):

b. the 'Normal Radar' select relay contact U1 in the Remote Switching Control S14/1.

17.3. Normal radar signals from the operational transmitter are fed via the Radar Set Group S1/1 (Control Rack) and an impedance matching network TS3/1 to the local (radar head) and remote (air traffic control) displays. The signal paths are similar but an additional unit is required in the remote display signal path because the signals have to be transmitted along a landline of maximum length 4000 yards.

17.4. Signals from the impedance matching network are fed to the IF Amplifier Unit T S26/1 (30 MHz IF Amp). This is a two stage amplifier whose output is fed via Attenuator B and the landline to the remote display. Attenuator B is used to maintain the signal amplitude at the display input constant and independent of the length of landline.

17.5. The signals are fed to the Pulse Generator Power Supply S18/1 (Lower Base Unit) thence to the IF Amp S11/1 (Normal Radar Amp) which is mounted in it. The normal radar amp provides four stages of r.f. amplification followed by a detector and the resultant video signals are fed to:

a. a switching circuit which provides a composite MTI and normal radar video signal. (Refer to Chapter 21, " MTI System Description').

b. the two display units.

17.6. In the Display Unit the signals are fed directly, or via the STC (anti-clutter) circuit to a mixer stage, V3. At this point the MTI/Normal radar signal and the normal radar signal waveforms are combined and fed with range marks, video map and secondary radar signals (refer to Timebase Chain), to the output amplifier stages V4 V5, thence to the c.r.t. cathode.

## CHAPTER 18

## NORMAL RADAR SIGNAL CHAIN, CIRCUIT ANALYSIS

18.1. The returning echoes from radar targets are picked up by the radar aerial and fed via the waveguide to the duplexer system mounted on the TR line assembly. (Note: the duplexer action is described in Chapter 16).

### Klystron Power Unit Type WE40

18.2. The power unit provides stabilised voltages for use in the Parametric Amplifier. The voltages produced are as follows:

a. +300 volt, stabilised.

b. -100 volt to -200 volt, stabilised.

c. 6.3 volt, 50 Hz.

18.3. The power unit is mounted in a separate chassis on top of each transmitter. It is a conventional series stabiliser consisting of V1 (series valve), V2A and V2B (constant current control valves). A meter (M201) in conjunction with SW202C, mounted on the front of the main chassis, is used to monitor the output voltages.

### RF Amplifier (Parametric)

18.4. Mounted in the microwave pre-amp chassis is the Parametric Amp which has replaced the original Travelling Wave Tube.

18.5. Parametric Amplifiers are a comparitively recent innovation and a brief introduction to the basic principles follows:-

18.6. a. Consider a simple parallel resonant circuit consisting of a resistor, inductor and capacitor. If, at the instant the applied a.c. voltage is a maximum the separation between the capacitor plates is increased, and thus the capacitance is reduced, the voltage is increased since, for a fixed change , voltage is inversely proportional to capacitance. If, at a time a quarter period later, the plates are returned to their original position no change of voltage or charge can take place since they are both, at this instant, at zero. This process may be repeated; at each voltage maximum the voltage may be increased by reduction in capacitance with a corresponding increase of capacitance at the voltage zeros.

18.7. The energy used to separate the capacitor plates is effectively transferred to the circuit via a variable reactance.

18.8. The action of varying the reactance is termed 'pumping' and is achieved electrically by the use of a varactor diode (derived from VARIABLE REACTOR). If a semi-conductor p - n junction is reverse-biassed a depletian layer is formed in which there are relatively few holes and electrons. The net fixed charge is not neutralised by mobile carriers as it is in the region outside the layer and the junction behaves as a parallel plate capacitor with plates oppositely charged. If the voltage it is required to amplify is impressed across the varactor diode and the capacitance is varied by the application of the pump frequency then amplification results.

18.9. The practical amplifier consists of three tuned circuits, colloquially, the signal, pump and idler. Each is tuned to a harmonically related frequency. The 'pump' frequency is three times the 'signal' frequency and the 'idler' frequency is the difference frequency resulting from the pump and signal frequencies mixing in the varactor diodes. Further mixing between idler and pump frequencies produces power at the signal frequency. This mixing action, if done with the usual resistive crystal mixer, would give very little output, but by using reactive mixing, amplification is obtained.

18.10. Pump frequency power is fed through waveguide to two varactor diodes mounted side by side across the waveguide. One diode is mounted in reverse direction to the other, so forming a series resonant circuit at the idler frequency.

18.11. Signal frequency power is fed into and out of the diodes through a short length of coaxial line. Idler energy is unable to couple to signal or pump arms due to mode of configuration of the circuit. Pump power is prevented from coupling into the signal arm by a choke resonant at the pump frequency, and signal energy cannot propagate down the pump waveguide as it is beyond cut-off at the signal frequency. Separation of the three circuits is complete and in order to separate the input from the amplified output, a circulator is utilised. (See fig 18.1).

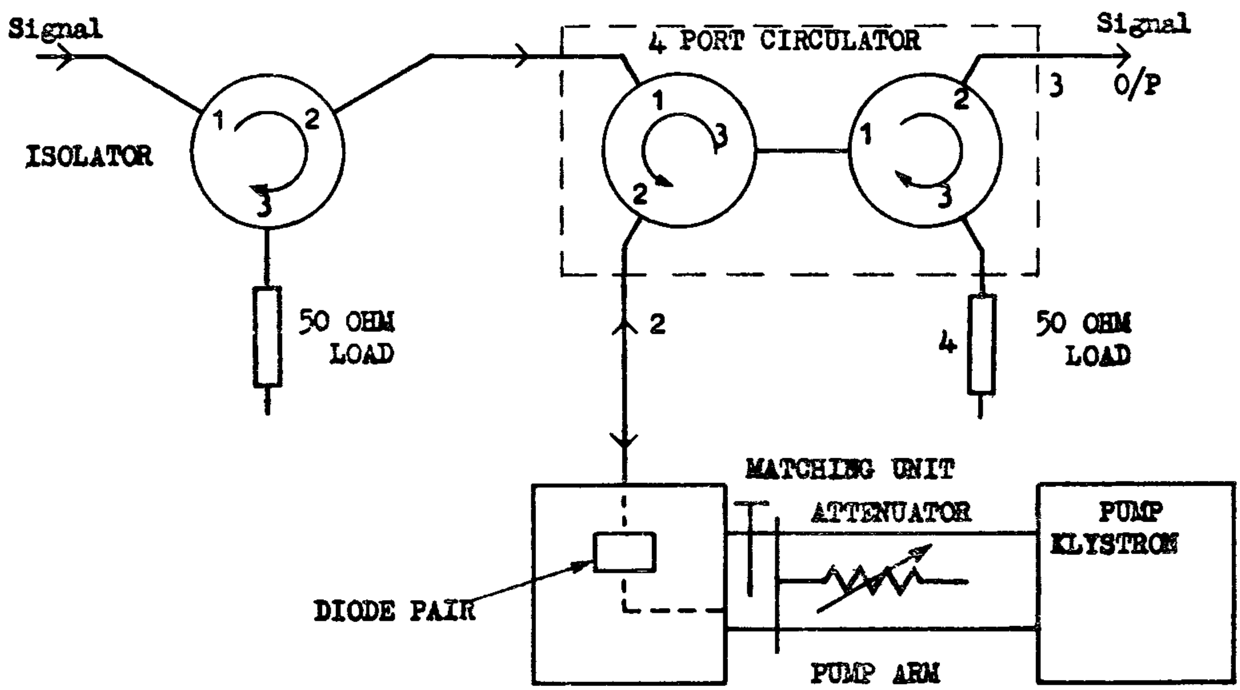



Fig 18.1. Flow Diagram of Parametric Amplifier

18.12. The circulator is a ferrite device which, basically, has three ports or terminals. Power entering at the first terminal emerges at the second, power entering at the second emerges at the third and power entering at the third emerges at the first. The device effectively guides a signal round in one direction only and, as fitted to the parametric amplifier, follows the input signal on terminal 1 to reach the amplifier on terminal 2. The amplified signal on terminal 2 is guided to terminal 3 from whence it passes to the second stage via the output isolator.

18.13. If the matched load is connected to, say, terminal 3 of the three terminal circulators the device acts as an isolator whereby power entering at terminal 1 will reach the output at terminal 2, but power entering terminal 2 from, say, a mismatch, will be guided to the match load on terminal 3 and absorbed. Thus power can only be fed from terminal 1 to terminal 2. Such a device is fitted to the input line of the amplifier. A similar device is fitted to the output and ensures isolation and constant impedance at the output.

18.14. The gain of the amplifier is adjusted by means of a waveguide attenuator, normally preset, inserted between the klystron pump and the diode block and determines the pump power incident on the diodes.

18.15. The amplifier is non-degenerate and with the circulator ensures that in the event of klystron failure, or power supply, the system will 'fail' safe.

18.16. <u>Concise details:</u>

At 25°C.

| | |
|---|---|
| Frequency Range | 2960 ± 50 MHz. |
| Bandwidth | 60 MHz ± 20 MHz. |
| Gain | 20 dB ± 2 dB |
| Noise Figure | less than 3.5 dB. |
| Pump Frequency | 9.0 to 9.6 GHz. |

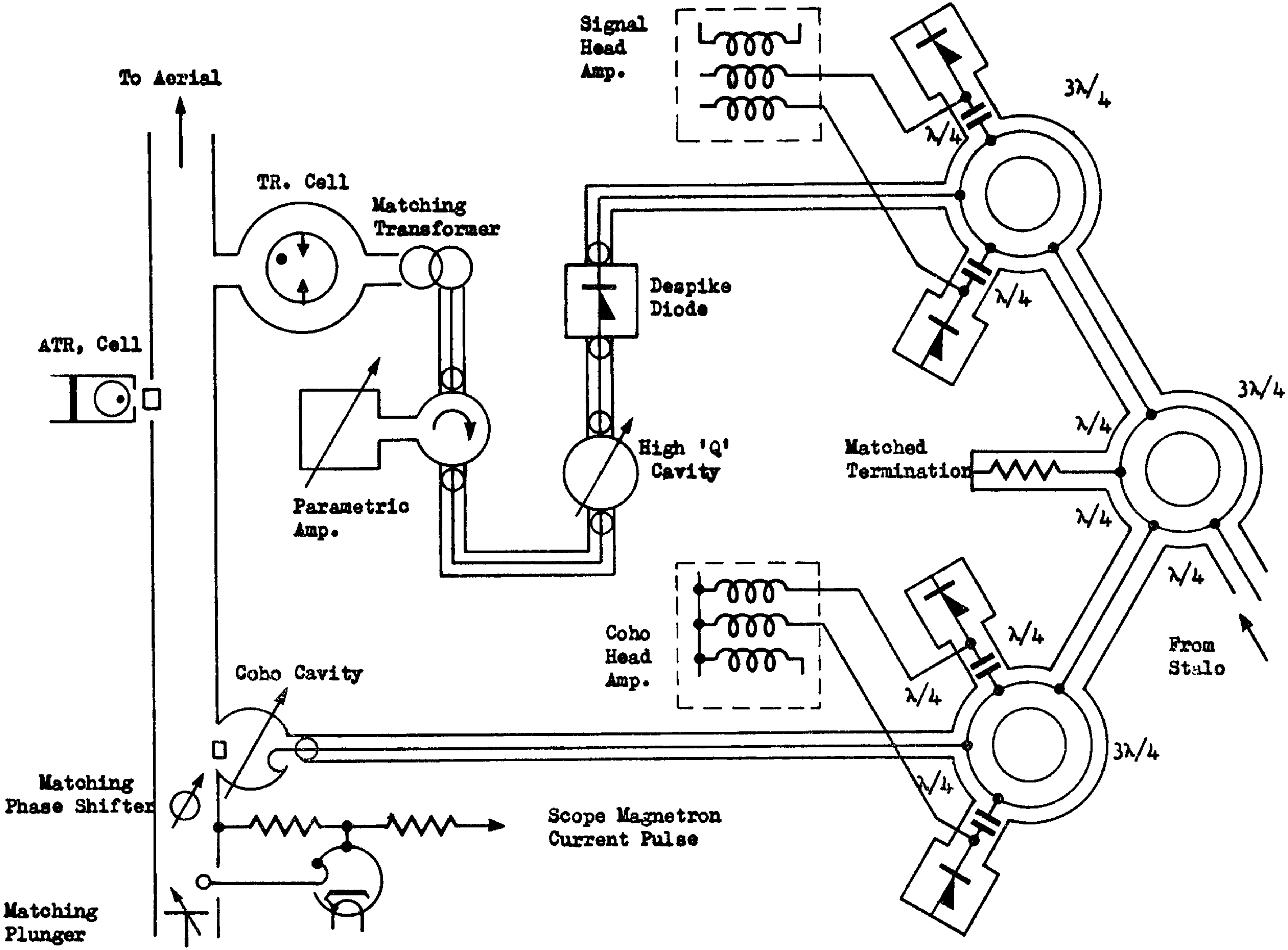



Fig 18.2. T/R Assembly

## RF Oscillator Type S4/2 (STALO)

18.17. The local oscillator unit is known as the STALO, a corruption of STABLE LOCAL OSCILLATOR. The circuit employs a disk-seal triode valve connected as a tuned anode, tuned grid oscillator and mounted in a block of brass. The assembly is of massive construction to give good thermal conduction and to ensure electrical and mechanical stability. The oscillator, which has an anti-vibration mounting, may be tuned 30 MHz above or below the transmitter frequency, in practice it is generally found to function better when tuned below the transmitter frequency.

18.18. Tuning of the oscillator is by probes screwed into the grid/cathode cavity (coarse tuning) and the grid/anode cavity (fine tuning). A slug introduced into the end of the grid/cathode cavity is adjusted for maximum amplitude of oscillation. The output of the oscillator is taken from the grid/anode cavity by a probe similar to the fine tuning probe Depth of insertion of this probe controls the amplitude of output that is fed to the mixer circuits, and it is adjusted to give the correct amount of signal crystal current. It should be noted that this output probe has a similar effect to the fine tuning probe and a change of coupling will alter the oscillator frequency slightly. If too deep an insertion of the probe is made the tight coupling introduced is liable to stop the valve from oscillating. Similarly over coupling of the cathode tuning slug can prevent oscillation.

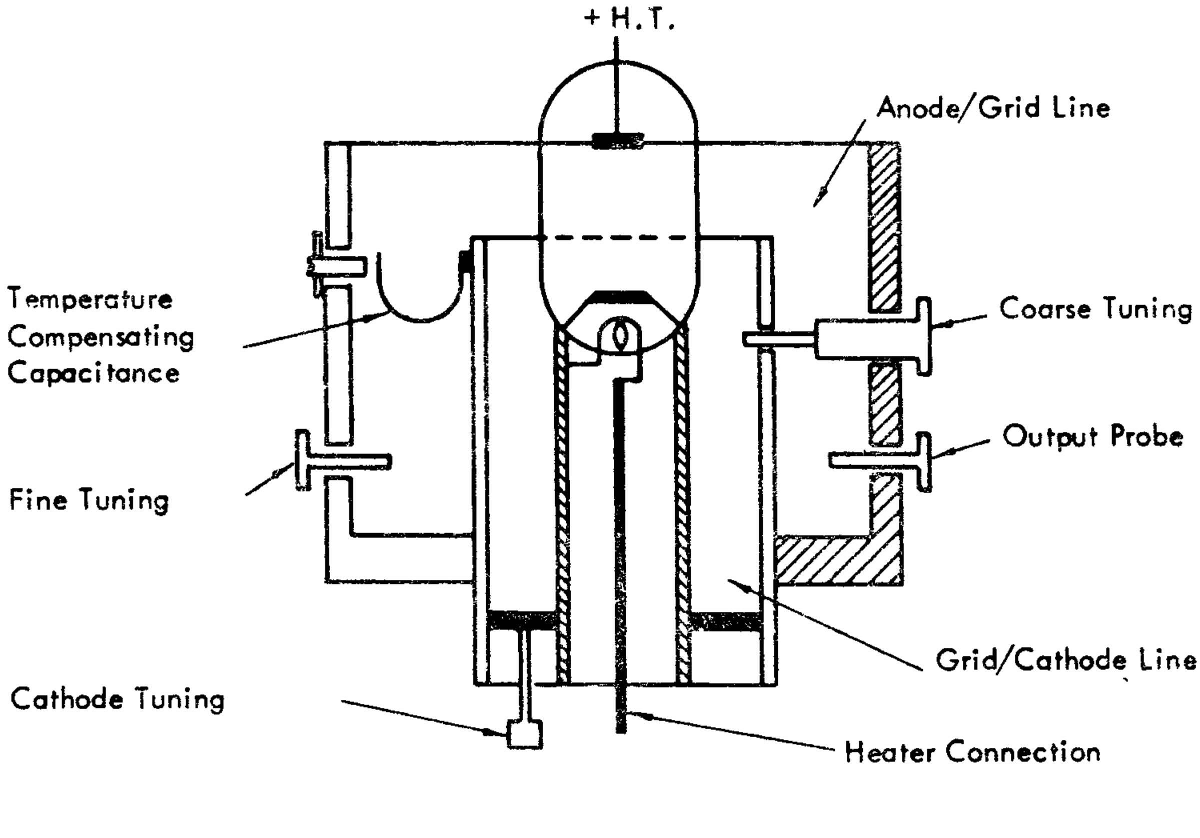



Fig 18.3. Stalo Schematic Diagram

18.19. Compensation for changes in operating temperature which are liable to cause changes in output frequency is effected by a bi-metal strip fitted in the anode/grid to form a shunt capacitance. The temperature co-efficient of the oscillator frequency is about 60 kHz per degree C, which is almost the same as the magnetron. Since the same airstream cools both the oscillator and the magnetron, any change in ambient temperature has an equal effect on both and the difference frequency remains constant.

18.20. The output of the STALO is fed into a coaxial line hybrid ring, whence it divides into two further hybrid rings in which are mounted balanced crystal mixers. The use of the centre isolating hybrid ring ensures no interference between the coho and signal channels.

18.21. The upper hybrid ring (signal mixer) has antiphase connected crystals, these crystals are the silicon type. The STALO input from the isolating ring is arranged to feed the signal crystals in anti-phase. The r.f. signal input to the mixer ring is from the r.f. pre-amplifier and is fed in phase to the two crystals. This system of connections results in a reduction of noise in the input to the head amplifier since the noise which is generated mainly in the STALO cancels in the windings of the head amplifier input transformer. The path lengths from the signal input to the STALO arm differ by half a wavelength and hence there is no signal fed back to the isolating ring. The output signals from the signal mixer hybrid ring are fed to the signal head amplifier.

Head Amplifier Type S9/1. (Signal Head Amplifier)

18.22. The unit is a high gain amplifier for use at 30 MHz and is mounted so that the input socket fits directly into the crystal holder of the hybrid ring mixer. The gain is adjustable by a potentiometer on the Tx control unit. Gain is 60 dB max, with a bandwidth of 4 MHz.

18.23. Five stages of amplification consist of two staggered triplers T1 to T3 and T4 to T6. A low noise triode is used for the first stage and is neut alised by Vc1. The bias on V2, V3 and V4 is variable by the gain control and has the swept gain waveform superimposed on it.

18.24. Relays RLA and RLB permit the crystal current to be monitored when the amplifier is fitted to the signal channel only. The crystal current can be read at positions 6 and 7 of the meter switch on the T/R assembly plug panel. The meter must not be left switched to either of these positions during normal operation or the receiver noise figure will be greatly increased.

18.25. The output of the signal head amplifier is fed to the signal splitter mounted in the centre panel of the transmitter rack. From here outputs are taken to the centre control rack and also to the MTI circuits within the transmitter/receiver rack.

18.26. The swept gain waveform is superimposed on the gain control voltage fed to the head amplifier.

RF Amplifier Type S13/1 Parametric Amp. Swept Gain Circuits

18.27. The swept gain circuit components are mounted on the chassis of the r.f. pre-amplifier. The positive going 100 µS prepulse from the lock unit is fed into the unit and a negative going output of variable amplitude and recovery time is produced.

18.28. The positive prepulse is fed to the grid of V1 and the fall produced at the anode of that valve is passed through the diode V2 and causes capacitor C5 to be charged negatively. The amplitude of the charge on C5 is determined by the bias applied to V1 suppressor, the 'SWEPT GAIN AMPLITUDE' control being mounted on the transmitter control unit. At the end of the prepulse, ie at $T_0$, the diode V2 is again cut off and the capacitor can only discharge via the resistor selected by the 'SWEPT GAIN LAW' switch. This switch determines the recovery time and hence the range over which swept gain is operative. In the first position of the switch the pulse from V1 anode is passed to earth via C4 giving an 'OFF' position.

18.29. The swept gain waveform is superimposed on the manual signal gain level. This level is set by the bias on V3A, the cathode load of which is supplied by V3B. The voltage rise at the anode of V3A is fed to the grid of V3B reducing the impedance of this valve and assisting the fall at the cathode of V3A.

18.30. Signals from the Sig. Head Amp are fed via the Impedance Matching Network Type S3/1 mounted on the wall to:

a. Pulse Gen Power Supply Type S18/2 (Base Unit); the monitor display at the radar head.

b. Via amplifying circuits in the Amp Power Supply Type S30/1 (Booster Rack), and landline to the Pulse Gen Power Supply Type S18/1 (Lower Base Unit); the ATC displays. The radar head and ATC display systems are similar and the ATC display system is described.

IF Amp Type S26/1 (30 MHz IF Amp)

18.31. The normal radar signals at the system IF frequency of 30 MHz are fed from the remote switching unit in the radar control rack to the 30 MHz i.f. amplifier sub-assembly in the signal booster.

18.32. This amplifier is a two stage, transformer coupled amplifier with an overall gain of approximately 20 dB. The gain of the amplifier is not adjustable. The diode V3 detects the signals and provides a positive going output at Skt K for monitoring purposes.

IF Amplifier Type S11/1 (NR IF Amp)

18.33. The normal radar amplifier is a sub-chassis mounted on the waveform generator (video). The input is at the i.f. frequency of 30 MHz and in the case of the operational displays has been fed via the signal booster rack, in the radar head monitor the input is from the radar control rack. Four stages of amplification give a gain of 85 dB maximum, the gain control operating on the grids of V1, V2 and V3. A germanium crystal diode detector X1 feeds positive going normal radar signals to the parallel connected cathode followers V5A, V5B.

18.34. This amplifier is a standard unit fitted in several equipments and some of the facilities provided are not used. Relay A is permanently de-energised and the junctions between R14 and R24, also R17 and R20 are earthed. No use is made of the diodes X2 and X3 on this installation.

MTI/Normal Radar Switching Circuits

18.35. Output video signals from the amplifier are fed:

a. Via cathode followers V46A and V46B to the Azimuth Range Indicator/s Type S5/1.

b. To the MTI/Normal Radar gating circuits V39 to V41.

18.36. The gating circuits are controlled by a switch timing circuit V34 V35 which is synchronised with the time base production. The gating circuits accept signals from the normal radar and the MTI systems and produce a composite display giving the maximum advantage of both signals. During the initial part of the trace MTI signals are displayed to avoid clutter from nearby permanent echoes. At a pre-determined point on the time base,normal radar video signals are presented. The changeover is controlled by RV28, MTI DURATION. The MTI/NR composite signal is fed via cathode followers V45A and V45B to the Azimuth Range Indicator/s Type S5/1.

18.37. The normal radar and the MTI/Normal radar signals are fed to the Video Amp. Type S17/1 (video mixer). Normally both signals are fed directly to mixer stages V3A V3B. The composite output is then combined with range rings, further amplified by V4, V5, V6 and V12 and fed to the c.r.t. cathode for display. The amplitudes of the normal radar and MTI/normal radar signals are controlled by RV7 NORMAL RADAR (CONTRAST) and RV6, MTI/NR GAIN respectively.

18.38. A short time constant circuit can be switched into circuit, using SW.B STC ON/OFF if the target clutter on the display is excessive.

CHAPTER 19

# NOISE FIGURE CHAIN

## The Receiver Noise Figure Principle

19.1. It may appear that by providing a receiver with sufficient gain it would be possible to detect any signal, no matter how weak. However, noise generated within the receiver must be kept to a minimum since its final effect on the radar display may be such that if the noise level is high, the desired signal echo may be obscured.

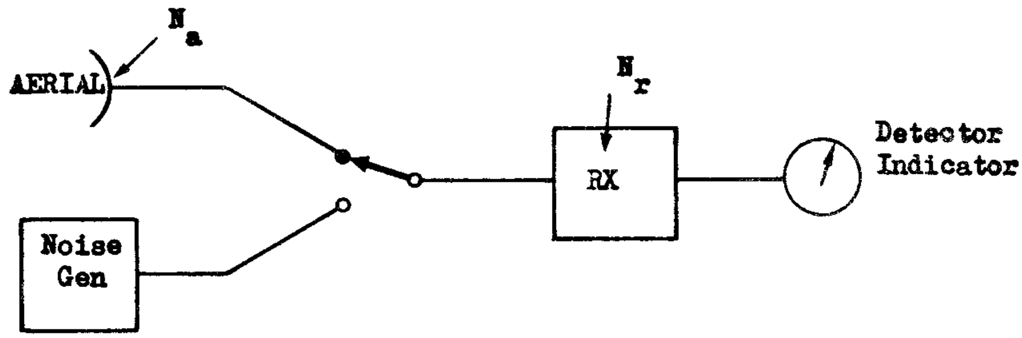
19.2. A measure of this requirement is known as the noise factor (or noise figure). This is expressed as the ratio of signal to noise of the input to the signal to noise of the output (expressed in decibels). It is a measure of the noise introduced by the receiver itself.

$$\text{Noise Factor N} = 10\,\text{Log}_{10}\,\frac{\text{sig/noise i/p}}{\text{sig/noise o/p}} = \text{N dB} \qquad (1)$$

where N = Noise factor.

## The relation between the noise factor and the noise factor check

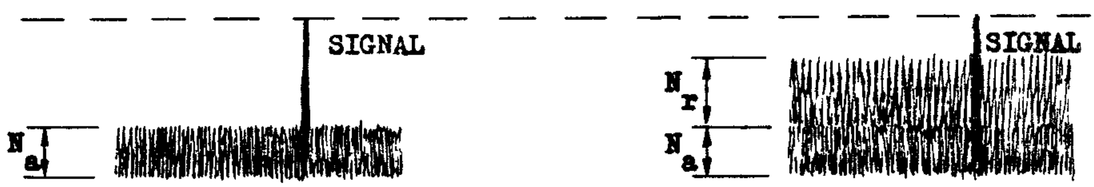
19.3. Receiver system to be checked.




Where $N_a$ = Aerial thermal noise (ie i/p noise)

$N_r$ = Noise generated in Receiver.

19.4. A representation of signal to noise ratios.




Receiver I/P Ratio

Receiver O/P Ratio

19.5. It will be seen from these two ratios and equation (1) that:

$$10 \text{ Log}_{10} \frac{\text{o/p noise}}{\text{i/p noise}} = \text{N dB}$$

ie

$$10 \text{ Log}_{10} \frac{N_r + N_a}{N_a} = \text{N dB}$$

19.6. $N_a$ is known by the manufacturer, $N_r$ is not. Therefore $N_r + N_a$, ie o/p noise, has to be found by the noise generator test set.

19.7. If the noise generator is switched in and noise is injected into the receiver so that the detector indicator indicates twice the original reading, the noise output from the generator will be a measure of the original output noise. If the manufacturer then divides this noise by $N_a$ and expresses it in decibels then the result is the noise factor in dB.

19.8. The maximum noise output power from a noise generator is known and is calibrated as a ratio of the thermal aerial noise power of the aerial expressed in decibels.

ie $$10 \text{ Log}_{10} \frac{\text{Noise Generators max o/p}}{\text{Aerial thermal noise}} = N_{(max)} \text{ dB} \quad \text{(say 15.8 dB).}$$

19.9. If the max output from that generator will just double the original noise from the output of the receiver system then the noise factor of that system is 15.8 dB.

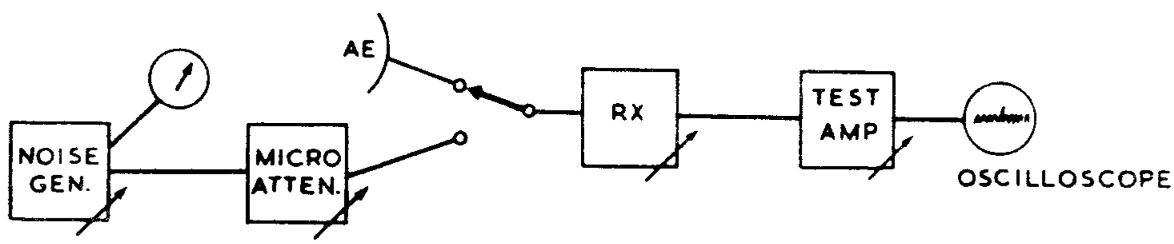
19.10. If the noise from the generator has to be attenuated to produce an output noise of twice the original value from the amplifier system, then the noise factor of that receiver is the difference between the generator's maximum value in dB and the attenuation in dB used.

ie Noise factor = 15.8 dB - attenuation in dB (say 9.6) = 6.2 dB.

19.11. Note that the smaller the numerical value of the noise factor for a given receiver, the better the receiver will be able to detect weaker signals.

Method used to tune the receiver and check noise figure

19.12. Tune Receiver.




**Simplified Noise Figure Chain**

Tune receiver for max signal on oscilloscope, ie stalo fine tune, TR cell, filter cavity, parametric pump oscillator and reflector volts.

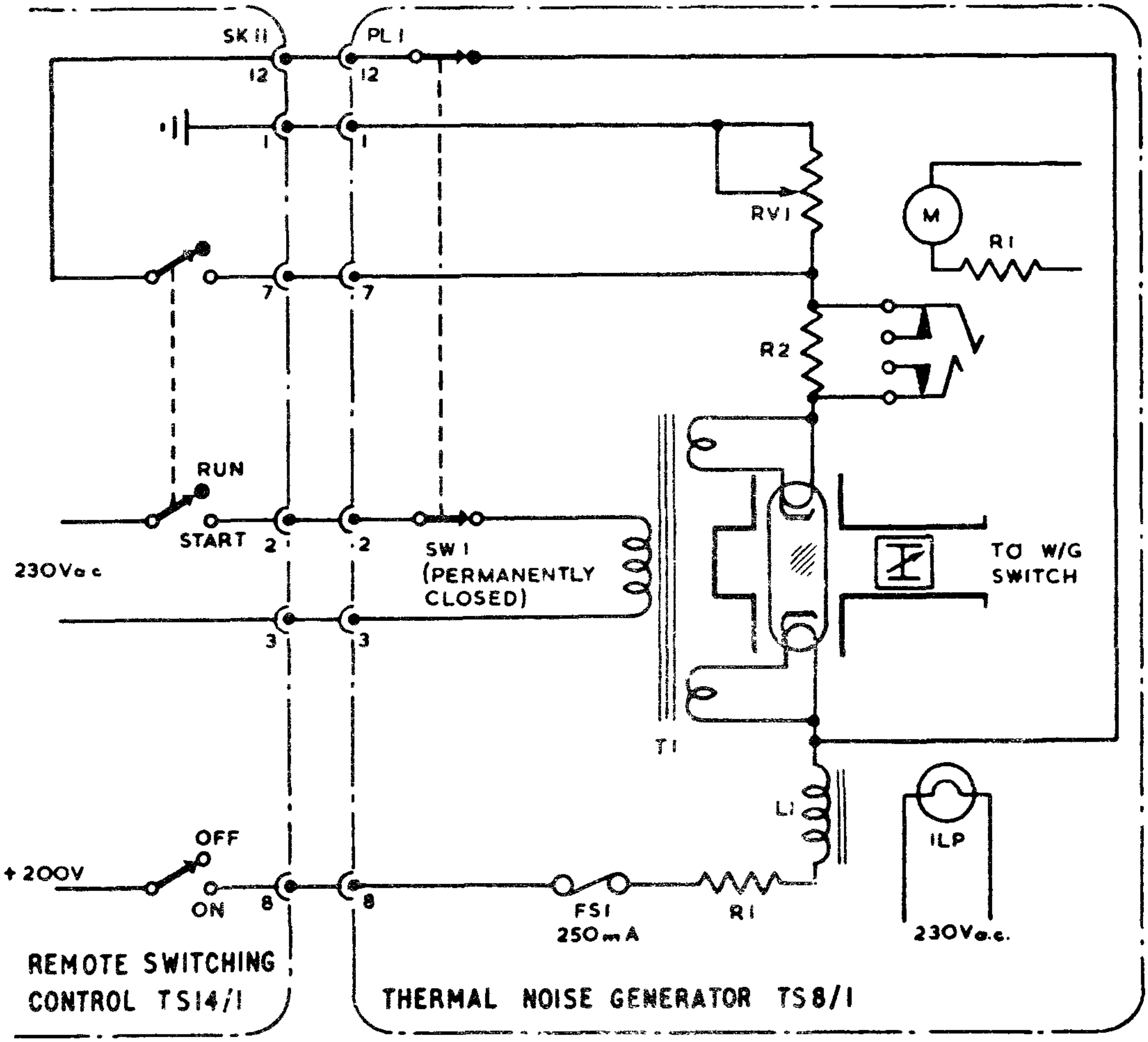



Fig 19.1. Noise Source Generator Circuit

# CHAPTER 20

## MTI PRINCIPLES

### 20.1. What changes as the target moves?

Consider the waveforms shown in Fig 20.1 The transmitter pulse has been fed to a circuit which continues the oscillation for about 1300 μsec, while received signals arrive.

The signal from target A comes in after a time dependent on its range, and in this instance has a phase angle of 45° to the transmitter oscillation. The signal from target B is at 270°, and that from target C at 180°.

This phase comparison is repeated 1425 μsec later, for the next transmitter pulse. Target A has moved slightly closer, and its phase angle has changed to 300°; target B has not moved, so its phase angle is still 270°; target C has moved farther away, and now has a phase angle of 90°.

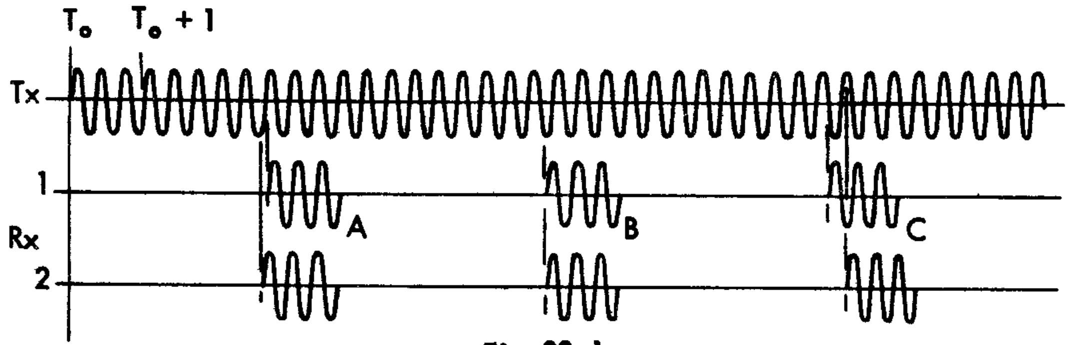


Fig 20.1.

If a target is stationary, the phase angle between received and transmitted signals remains constant; if the target is moving, the phase angle changes.

### 20.2. Inputs to MTI

MTI requires two inputs; received signals and transmitter sample. Received signals at IF are provided by the Signal Splitter. The transmitter sample comes from the waveguide through the Coho Cavity and an attenuator to the coho mixers; then through the Coho Head Amp and into MTI as a 1 μsec burst of IF.

### 20.3. Maintain the transmitter sample

The transmitter sample lasts for only 1 μsec. Fig 20.1 shows that the oscillation must continue throughout the reception period. The sample is fed to a tuned circuit, which will ring as shown in Fig 20.2

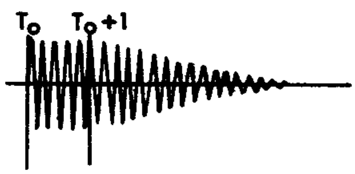


Fig 20.2

The oscillation in the tuned circuit is maintained, without change of phase, by positive feedback using a valve, producing the oscillation shown in Fig 20.1 This circuit, operating at 30 MHz, is the Coho Oscillator.

## 20.4. Measure the phase angle

The angle is measured by the Phase Sensitive Detector (PSD), which produces a video pulse for each received signal. This pulse may be positive or negative, large or small, according to the phase angle. A typical set of outputs, for six targets on two consecutive transmissions, is shown in Fig 20.3

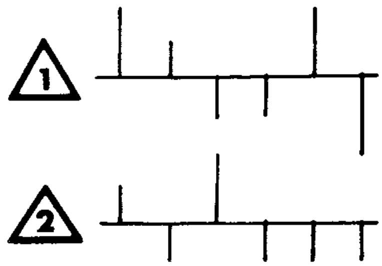


Fig 20.3.

## 20.5. Cancel fixed targets

Transmission 2 is 1425 μsec after transmission 1. The way to cancel is to delay 1 by 1425 μsec so that it coincides with 2, which has been inverted. Fig 20.4 shows this, and Fig 20.5 is a possible circuit.

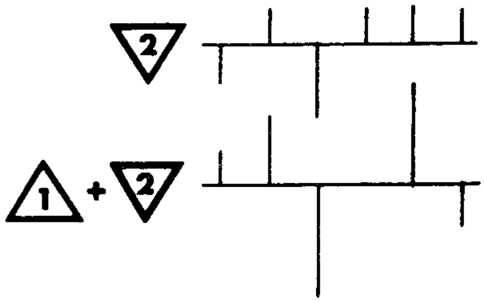


Fig 20.4.

A full-wave rectifier is used to produce a positive pulse for each signal left after cancelling fixed targets.

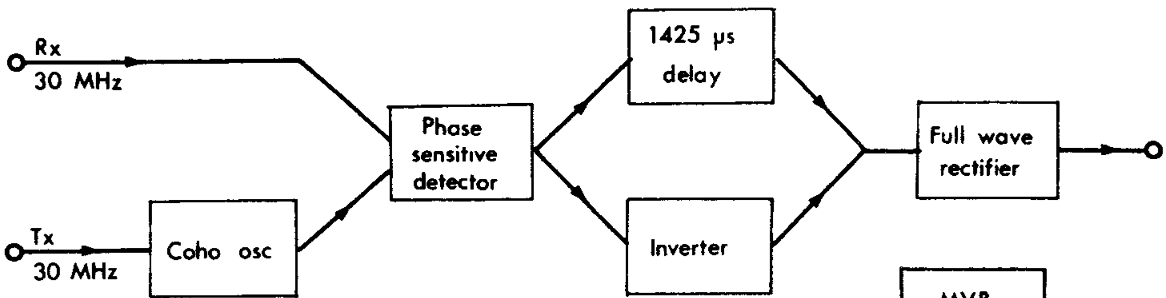


Fig 20.5.

## 20.6. Lock-round

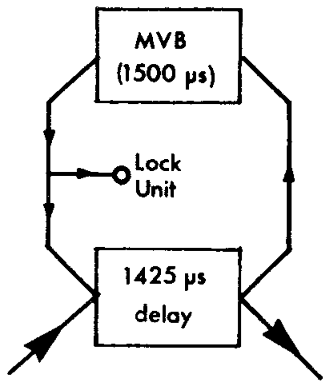


Fig 20.6.

For 1 and 2 to coincide, the interpulse period must exactly equal the delay. This is done by making the delay line fix the interpulse period.

The free-running time of the MVB in MTI 1 (Fig 20.6 is 1500 μsec. The output square wave is passed through a short CR to produce a pulse which passes down the delay line, and synchronises the MVB after 1425 μsec. A pulse is taken out to synchronise the Lock Unit.

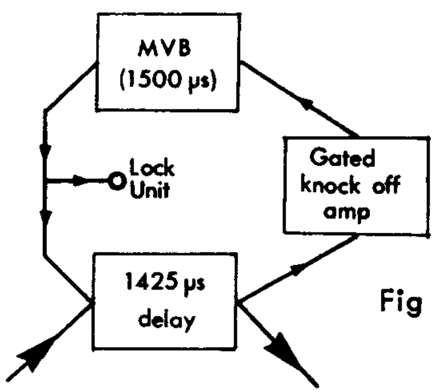


Fig 20.7.

## 20.7. Knock-off gate

In Fig 20.6 video goes down the delay line, and could trigger the MVB early, causing jitter. A gate is used to block these video pulses: Fig 20.7 The gate is opened only at trigger time ($T_o$ - 100). The gate duration is set by KNOCK-OFF GATE WIDTH.

## 20.8. Carrier wave

Video and the Knock-off pulse cannot pass down such a long delay line because of the high attenuation, they must be placed on a carrier: Fig 20.8.

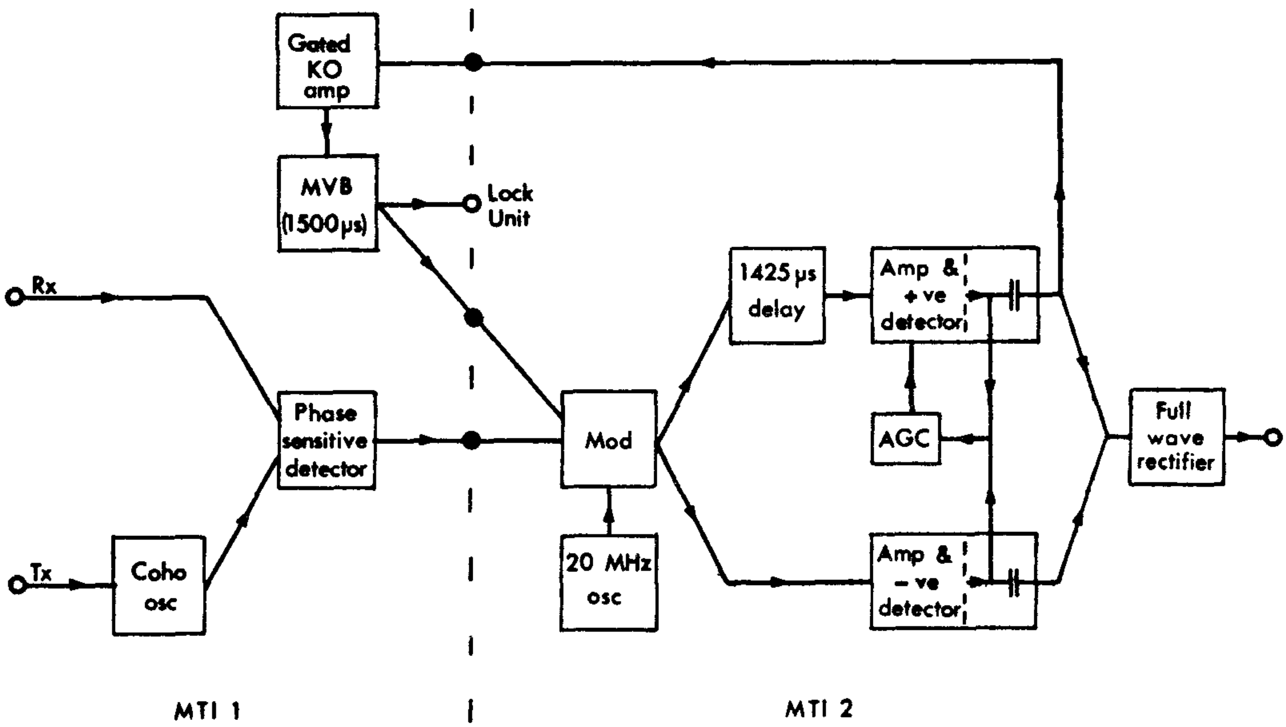



Fig 20.8.

Fig 20.9shows the carrier waveforms, and the results after detection. After removing the DC levels by capacitors, the output from the negative detector is an inverted form of the original signal. Thus the separate inverter stage of Fig20.5is no longer needed.

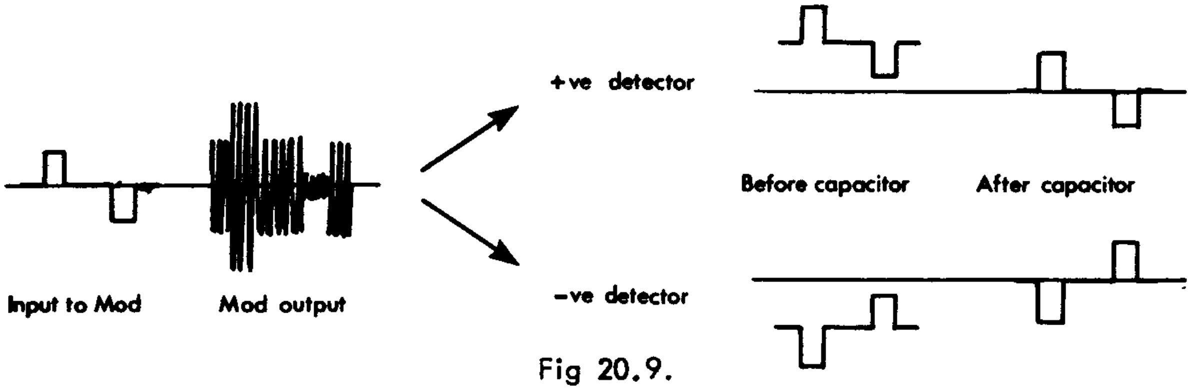



Fig 20.9.

The DC levels indicate the carrier strengths, which should be equal. If they are not, the remaining DC voltage is amplified by the AGC circuit for Automatic Gain Control of the delayed channel.

| | |
|---|---|
| Amplifier with positive detector : | Post Line Amplifier. |
| Amplifier with negative detector: | Comparison Amplifier. |

20.9. Blind speed

If an aircraft moves exactly one wavelength nearer or farther away in one interpulse period, the phase angle will not change, and MTI will cancel the return. Aircraft speeds at which this happens are called blind speeds.

MTI Descriptive Diagram

20.10. Fig 20.11.shows how the previous principles are applied to Cossor 787. The parts to be treated in detail, comprising the main chassis of MTI 1, are outlined more heavily.

20.11. Received signals come from the T/R switch and are mixed with stalo to produce a 30 MHz IF; this is amplified by the Head Amp and passed to the Limiting Amp. Here all signals are limited to the same amplitude. The Limiting Amp is cut off for 30 μsec by the Signal Gate (see Fig 20.10). This leaves the delayed channel clear for the lock-round pulse to circulate by itself.

20.12. The transmitter sample comes from a cavity on the waveguide; it is mixed with stalo and passes through the Head Amp and Locking Amp as a 1 μsec burst of 30 MHz. It is applied to the Coho Oscillator, which was gated off at $T_0$ - 100 by the Coho Gate. The sample makes the oscillator ring, and the rising edge of the Coho Gate (integrated at the input) allows the Coho Osc to continue in phase with the sample.

20.13. The Phase Sensitive Detector (PSD) produces a 1 μsec video pulse for every received signal; the amplitude and polarity depend solely on the phase angle between received signal and the Coho oscillation.

20.14. The lock-round system is shown as before, with the addition of the gate generator which produces the Knock-off Gate ana the Signal Gate. Normally the Signal Gate allows the Limiting Amp to pass signals, while the Knock-off Gate stops them passing through the Gated Knock-off Amp. For 30 μsec the Limiting Amp is cut off so that signals and receiver noise cannot pass; during this time the Gated Knock-off Amp is open to allow the lock-round pulse to pass. The Signal Gate ensures that no signals or receiver noise pass to the multivibrator with the lock-round pulse.

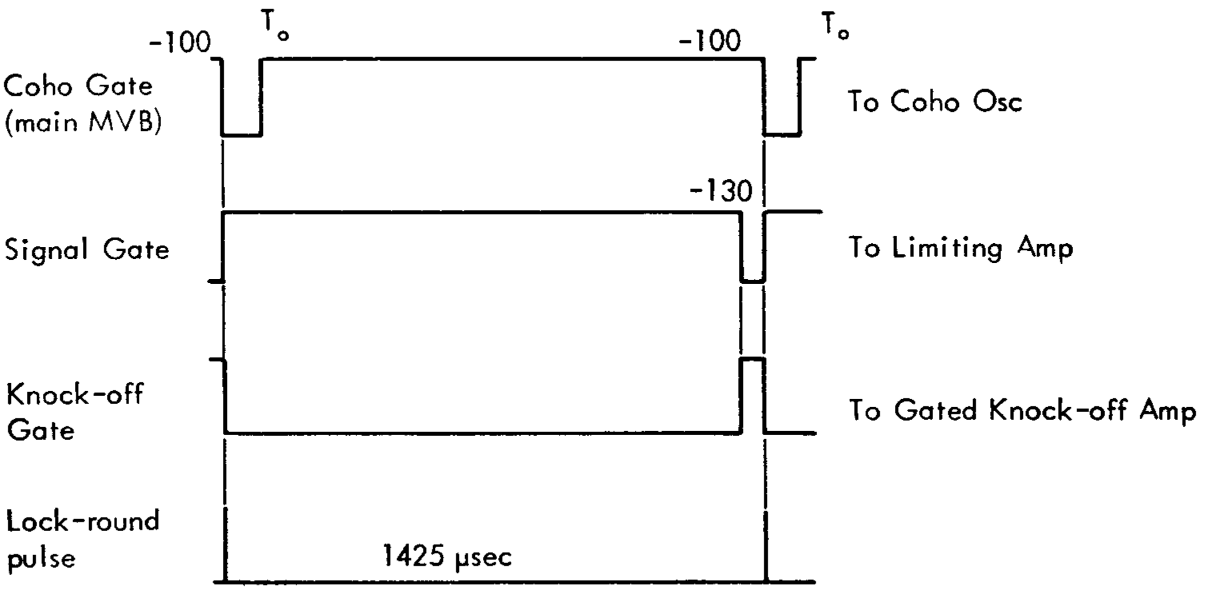



Fig 20.10MTI Gating Waveforms

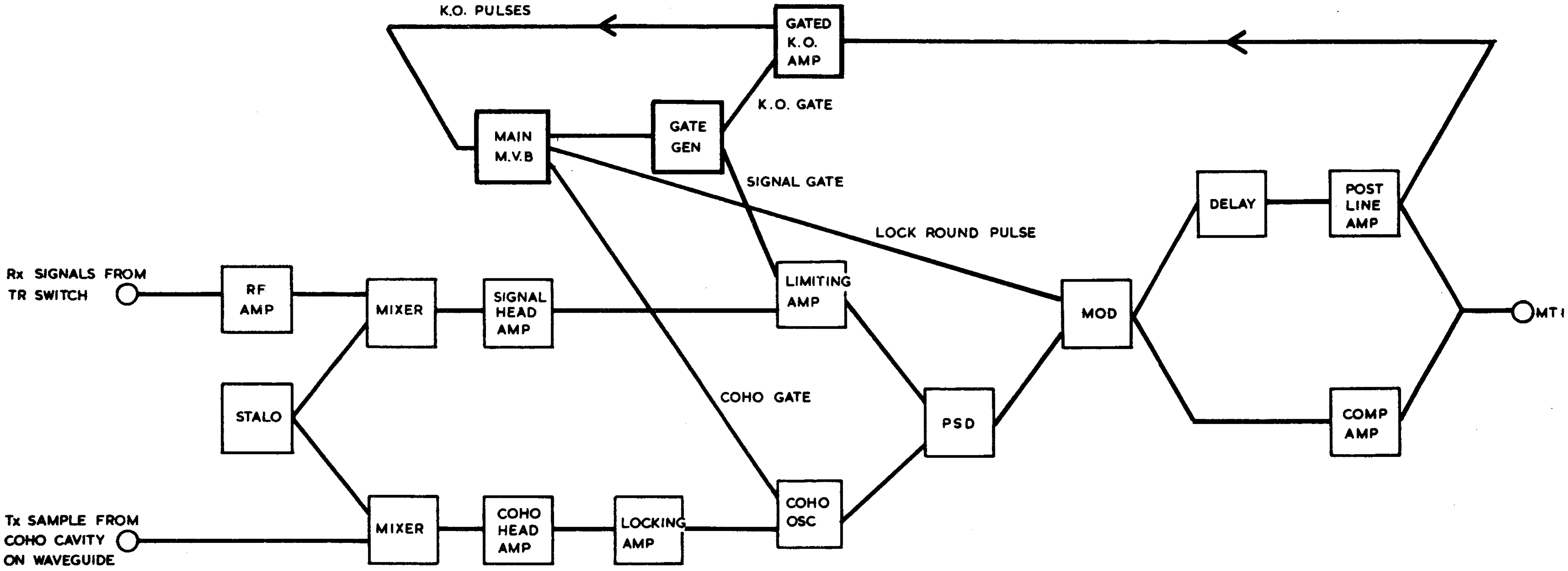



Fig 20.11 MTI DESCRIPTIVE

NOTE: SECTIONS OUTLINED HEAVILY COMPRISE THE MAIN CHASSIS OF MTI I.

# MTI SYSTEM DESCRIPTION

## Normal Radar Production

21.1. Normal radar signals, ie returns from all targets, are produced in a typical superhet radar receiver. Signals are fed via the waveguide switch and T/R cell to a travelling wave tube r.f. amplifier. The waveguide switch is set to the T/R assembly in use by the transmitter select switch. Under these conditions, transmitter No 2 can be fully run up, provided a waveguide connection to the dummy load is made. The T/R cell, which strikes when the magnetron fires, safeguards receive circuits on transmit. On receive, when de-ionised, the ATR cell stops received energy being absorbed by the magnetron.

21.2. Received signals are amplified, then mixed in a hybrid ring mixer with a stable local oscillator (STALO). The stalo gives best results if tuned 30 MHz below the incoming frequency.

21.3. From the mixer, the 30 MHz normal radar signals are fed:

a. To the limiting amplifier for the eventual production of MTI signals.

b. Via the transmitter selection relay contacts to the aerial head monitor, and air traffic control display systems.

## MTI Radar Production

21.4. Pulse returns from an aircraft will reach the receiver in time t. Since the aircraft is moving, time t will change for every successive pulse. A stable reference oscillator is started coincident with the transmitter firing, and phase coherent with the magnetron oscillator. A returning pulse is phase compared with the reference oscillator signal in a phase sensitive detector. The output from the phase sensitive detector is delayed one inter pulse period and compared with the corresponding output from the phase detector for the next transmitted pulse.

21.5. When the magnetron, which is a random phase oscillator, fires a sample of the pulse is fed via the coho cavity to a hybrid ring mixer. The resultant 30 MHz pulse is fed via the coho head amplifier and locking amplifier, to ensure that the COHO reference oscillator commences oscillation phase coherent with the magnetron. To make this possible, a coho gate stops the oscillator between scans and allows oscillations to recommence gradually at transmitter firing time.

21.6. If the test delay line is brought into operation by the TEST/NORMAL switch, the limiting amplifier stops passing normal signals and instead amplifies simulated fixed target returns produced in the test delay line.

## Bi-Polar Video Production

21.7. The 30 MHz COHO output and the 30 MHz normal signals from the limiting amplifier are fed to a phase sensitive detector. The phase sensitive detector output consists of bi-polar video, the amplitude and polarity of the video being entirely dependent upon the phase relationship between signal pulse and COHO oscillation.

## Delayed and Undelayed Channels

21.8. To reduce attenuation losses in the delay line, the bi-polar video is superimposed on to a 20 MHz carrier before application to the two channels.

a. Delayed Channel. A quartz delay line causes a delay exactly equal to one inter-pulse period. A post line amplifier then amplifies the signal and video is extracted by a positive detector circuit. The delayed video then passes via an auxiliary delay to the cancellation point.

b. Undelayed Channel. This consists only of a comparison amplifier which is designed to produce the same effects on a signal as the same signal would suffer in passing through the whole of the delayed channel.

## Trigger Waveform Generator

21.9. The central timing system of the operational transmitter is a free running multivibrator loacted in MTI Unit No 1. Outputs from this multivibrator are responsible for the following:

a. Coho Gate. A negative waveform applied to the COHO commencing at To-100 μS and ending at To. The lagging edge rises on an exponential to ensure the COHO is phase coherent with the magnetron lock pulse.

b. Signal Gate. A negative waveform fed to the limiting amplifier stopping the passage of normal signals from To-130 μS to To-100 μS.

c. Knock off Gate. A positive going waveform, To-130 μS to To-100 μS, which allows the knock off pulse to pass and synchronise the trigger waveform generator.

d. To-100 μS prepulse. This positive pulse is applied to two separate circuits as under:

(1) Lock Unit. The prepulse synchronises the multivibrator in the lock unit so that the transmitter trigger pulse produced in the lock unit is locked to the delay line delay time.

(2) Lock Round System. The prepulse, called the lock round pulse, is fed through the delayed channel and emerges as the knock-off pulse. This pulse triggers the multivibrator in the trigger waveform generator, ensuring that the multivibrator timing is in step with the delay line delay time.

21.10. Since the knock-off pulse initiates the next lock round pulse there will be a finite time delay before the new pulse reaches the cancellation point via the undelayed channel. To compensate for this delay the previous pulse and all video leaving the post line amplifier is held back in an auxiliary delay line thus ensuring good cancellation. Following cancellation, the moving target resultant of bi-polar video is converted to positive unipolar video and fed to the displays.

## PPI Display Production, Air Traffic Control

21.11. From the selected T/R assembly, the unipolar video, together with normal radar signals and the display prepulse, is fed via the transmitter selection relay contacts in the centre control rack to the signal booster. In the signal booster the unipolar video and display prepulse modulate a 20 MHz carrier to facilitate passing the signals along land lines. Normal radar signals still at 30 MHz, are amplified and passed down the land line.

NB. The maximum length of line between the aerial head and air traffic control is 4000 yards.

21.12. At air traffic control, the MTI video and display prepulse are amplified, detected and separated in the aerial follower unit, before being fed to the waveform generator unit. Normal radar signals are amplified in the waveform generator before being fed to the electronic switch and the displays.

21.13. In addition to initiating the timebase circuits the display prepulse is responsible for the production of an MTI/normal radar switching waveform. The purpose of this switching circuit is to produce an output from the electronic switch which can be any one of the following:

a. MTI video changing to normal radar video at a preset time during the scan.

b. MTI video for the whole of the scan.

c. Normal radar video for the whole of the scan.

21.14. This preset changeover is adjusted to give maximum reduction of clutter where most needed, ie at short range.

21.15. Amplitude controlled normal radar video is also available at the video mixer so that a 'contrast' background can be introduced if required during MTI.

21.16. One, or two, displays may be utilised at air traffic control.

## Aerial Head Monitor Display

21.17. From the centre control rack transmitter selection relay contacts, the display prepulse, MTI unipolar video, and normal radar signals from the selected T/R assembly are fed direct to the waveform generator, monitor equipment. From this point, the monitor display production is exactly the same as at air traffic control.

## CHAPTER 22

## MTI PRODUCTION CHAIN

### Introduction

22.1. The moving target indication system is a means whereby normal radar, consisting of returns from moving and fixed targets is converted to video pulses from which all returns due to fixed targets have been eliminated. Since permanent echoes due to buildings, hills, etc., are most troublesome at minimum range it will be advantageous if moving targets only can be displayed between zero miles and some predetermined range. In CR787A it is possible to show on all ranges of the displays, normal radar for the whole of the scan, MTI for the whole of the scan, or MTI for part of, and normal radar for the remainder of the scan. The range at which MTI changes over to normal radar is preset.

### Normal Radar Production

22.2. Incoming signals are fed via the waveguide switch, (position dependent upon which one of two T/R assemblies is selected), TR cells and a matching plunger to the r.f. amplifier, a travelling wave tube. From the t.w.t. the returns, still at 3000 MHz approx are fed via an image rejection cavity to a hybrid ring mixer system and mixed with a very stable local oscillator to produce the i.f. of 30 MHz. The 30 MHz signals are amplified in the Signal Head Amplifier Type S9/1 which is gain controlled by RV2 (SIGNAL GAIN). A swept gain waveform is superimposed on this controlling bias. From the signal head amplifier the 30 MHz normal radar is fed via a signal splitter attenuator to the normal radar circuits and also to the MTI circuits in MTI Unit No 1.

### MTI Production

### Coho Oscillator

22.3. This oscillator, phase coherent with the magnetron, provides a 30 MHz oscillation from transmitter firing time ($T_o$) to the end of every scan. This provides a reference oscillation with which normal radar signals can be phase compared, to produce bi-polar video for use in the later MTI circuits. Every time the transmitter fires, a magnetron sample is fed via the tuned coho cavity to a hybrid ring crystal mixer and mixed with the stalo. The 30 MHz signals produced are amplified in the coho head amplifier, gain controlled by RV1 (COHO GAIN) and fed to the MTI circuits in MTI Unit No 1.

### Signal Comparator Type S2/2 (MTI 1)

22.4. a. IF Amplifier S7/1 (Limit Amplifier). This amplifier is designed to produce a constant amplitude output for most of the returning signals ie within the MTI selected range. This ensures that the phase sensitive detector which follows the limit amplifier will not become sensitive to amplitude, as well as phase change.

b. IF Amplifier Type S6/1. (Locking Amplifier). Accepts and amplifies the 30 MHz coho lock pulse from the coho head amplifier before feeding same to the 30 MHz coho oscillator.

c. RF Oscillator Type S5/1 (Coho Oscillator). The oscillator is gated on gradually at $T_o$ so that oscillations start phase locked to the coho lock pulse. The oscillations will continue until stopped by the leading edge of the next coho gate at $T_o$-100 µS.

d. Normal/Test Switch. In the NORMAL position of the switch the limit amplifier is operational but V3 of the locking amplifier is rendered inoperative. In the 'TEST' position, the limit amplifier is inoperative and the locking amplifier, in addition to passing the coho lock pulse, produces an output which in the 60 µS test delay line, is converted to a series of artificial, stable permanent echoes. These test pulses are utilised during setting up.

e. Signal Comparator Type S3/1 (Phase Sensitive Detector). The coho and signal inputs to this circuit are balanced by the balance and gain controls. When no signal pulses are present the 30 MHz from the coho oscillator will be the only input and the phase sensitive detector output under these conditions is zero. With a 30 MHz signal pulse applied, the phase sensitive detector output will be a video pulse of amplitude and polarity dependent entirely upon signal phase with respect to coho phase. From the foregoing it can be seen that successive returned signals from a fixed target should bear the same phase relationship to the coho when compared in the phase sensitive detector and will therefore produce the same phase sensitive detector output. For any video train produced by the transmitter firing at $T_o$, the phase sensitive detector output will be bi-polar video, consisting of both fixed and moving target echo returns. If video trains are now delayed one inter pulse period and compared with the train immediately following, it is possible, by cancellation, to remove the video caused by fixed target returns.

## Timing Circuits

22.5. Synchronisation of the MTI delay line (one inter-pulse period), the lock unit (transmitter trigger $T_o$) and the MTI main multi-vibrator is essential. The necessary timing circuits are incorporated in MTI Unit No 1. The timing circuit outputs are:-

a. Signal Gate. $T_o$-130 to $T_o$-100 µS, negative going, fed to gate off the limit amplifier for 30 µS during which time the lock round pulse is fed back to the main multivibrator.

b. Knock-off Gate. $T_o$-130 to $T_o$-100 µS, positive going, gates on the knock-off gate amplifier so allowing the lock round pulse to trigger the main multivibrator.

c. $T_o$-100 Pulse. This pulse is fed from MTI No 1 and serves two purposes:

(1) From the operational transmitter, the trigger is fed to the standby transmitter lock unit to synchronise it and thus prevent interaction between transmitters.

(2) Known as the 'lock round pulse' the trigger is fed via the delay circuits in MTI Unit No 2 back to the main multivibrator in MTU Unit No 1. This ensures that the delay line delay time is synchronised with the main multivibrator PRF.

MTI Unit No 2

22.6. In this unit the video, together with the lock round pulse, is fed into delayed and undelayed channels. By this method, successive video trains can be compared and since fixed targets for successive returns will appear as equal amplitude but opposite polarity video pulses, they will be cancelled. The following circuits and sub-units are contained within MTI Unit No 2:

a. Line Drive Modulator. To facilitate propagation through the delay line, the bi-polar video from the phase sensitive detector and the lock round pulse are superimposed on to a 20 MHz carrier. The carrier, video and lock pulse are mixed and amplified in the Amplifier Modulator Type S4/2 (Line Drive Modulator) before application to the delay line.

b. Quartz Delay Line. The delay line converts electrical impulses to mechanical vibrations at the input and introduces a delay of one i.p.p. before converting the energy back to electrical impulses Thus, the signals applied to the delay line emerge one i.p.p. later.

c. RF Amplifier Type S12/2 (Post Line Amplifier). The output from the delay line which has suffered attenuation is amplified in the post line amplifier and positively detected, then passed via auxiliary delay DL1 to the cancellation point.

d. RF Amplifier Type S5/1 (Comparison Amplifier). This amplifier constitutes the undelayed channel and to produce good cancellation must be designed to produce the same attentuation and distortion as the delayed channel. The final stage is a negative detector which will provide antiphase signals for comparison with the delayed channel output.

e. AGC. Any inequality in gain between delayed and undelayed channels is detected in the AGC circuit to produce a correction voltage which is applied as a variable bias to stages in the post line amplifier For setting up purposes manual gain control can be selected by SW2.

f. Lock Round System. The lock pulse taken from the post line amplifier is fed via the knock off amplifiers; (gated on by the knock off gate $T_0$-130 to $T_0$-100), to trigger the main multivibrator in MTI Unit No 1.

g. Auxiliary Delay DL1. Since there is a finite delay in the timing circuits and the line drive modulator, the lock pulse from the post line amplifier to the cancellation point must be delayed until the next lock pulse produced by the main multivibrator arrives at the comparison amplifier output. This ensures that both pulses reach the cancellation point together.

h. Bridge Rectifier. At the cancellation point, fixed target returns are cancelled and moving target returns will result in bi-polar video. The bi-polar video is then converted into positive uni-polar video by the action of V2 and bridge rectifier MR1, 2, 3 and 4.

MTI Routing.

22.7. The MTI uni-polar video from MTI Unit No 2 is fed to the Remote Switching Control Type S14/1 in theRadar Set Group Type S1/1 (Radar Control Rack). MTI uni-polar video from the selected transmitter is fed via the N2 contact of RLN/4 for distribution (see MTI Distribution Chain Diagram). If Transmitter No 2 is selected RLN/4 is energised and contact N2 accepts MTI uni-polar video from transmitter No 2.

Transmitter Selection

22.8. If transmitter No 2 is selected, (see Transmitter Select Chain Diagram) MTI production is exactly the same as in the foregoing information, and MTI distribution will be common to whichever transmitter is selected.

# CHAPTER 23

## MTI PRODUCTION CHAIN, CIRCUIT ANALYSIS

### Introduction

23.1. A sample of the transmitted pulse is coupled via the coho cavity to the hybrid ring mixer. The coupling is very loose so that only a few milliwatts of power are applied to the germanium crystals in the mixer. The sample pulse and the STALO signal are mixed and produce the 30 MHz i.f. frequency which is fed to the Head Amplifier S9/1 (COHO). This unit is identical to the Signal Head Amplifier described in the Normal Radar Signal Chain. The COHO GAIN control, RV1, is mounted on the Power Supply Control Unit Type S7/1. The output from the Coho Head Amplifier is fed to the IF amplifier S6/1 (Locking Amplifier) in the Signal Comparator S2/2 (MTI Unit No 1).

### Signal Comparator Type S2/2 (MTI 1)

### The Phase Comparator Circuits

23.2. The Phase Comparison circuits comprise - five sub units mounted on MTI Unit No 1. The sub units are:

a. Limiting amplifier (IF Amplifier S7/1).

b. Locking amplifier. (IF Amplifier S6/1).

c. Coho oscillator. (RF Oscillator S5/1).

d. Phase sensitive detector (Signal Comparator S3/1).

e. 60 μS test delay line.

23.3. Two inputs are received from the head amplifiers at the transmitter; one is a sample of the transmitted pulse and the other contains echo signals, both inputs are at the i.f. frequency of 30 MHz. The sample of transmitted pulse is used to phase lock the coho oscillator and so provide the reference oscillation for the Phase Sensitive Detector. Echoes are amplitide limited and also fed to the PSD.

### The Limiting Amplifier (S7/1)

23.4. In order that the output from the Phase Sensitive Detector shall vary only as a result of phase changes, it is essential that constant amplitude signals shall be applied to it. The Limiting Amplifier is used for this purpose. The signals at the i.f. frequency are fed via the signal splitter mounted in the centre of the transmitter/receiver rack and are applied to the grid of V1. The grid circuit of V1 is tuned by transformer T6 and the anode circuit comprising T1 couples the signal to V3 grid. Four further stages of amplification follow and the gain of the amplifier is controlled from a potential divider chain mounted on MTI Unit No 1 and applied to the grids of V3, V4, V5 and V6. This bias line has the signal gate superimposed on it, which cuts the amplifier off at the time when the knock off pulse is due to pass through the delay line. The screens of all valves are run at a higher potential than the anodes so that bottoming occurs shoul d the grid input exceed a certain level. This will ensure constant amplitudesignals from the Limiting Amplifier despite varying input amplitudes.

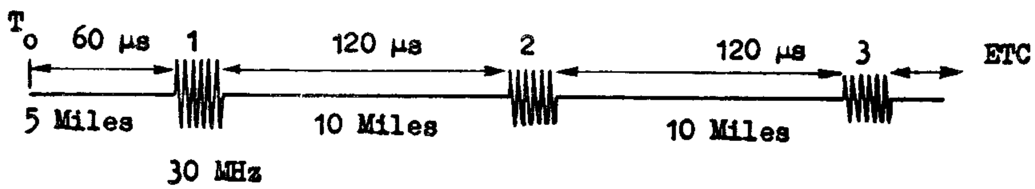
23.5. V2 enables an artificial signal derived from the coho locking pulse to be injected in place of normal echo signals, this is useful for setting up purposes as the phase comparison circuits can then be set up irrespective of the aerial position. The amplified locking pulse is fed from the Locking Amplifier via a 60 μS quartz delay line mounted on the chassis of MTI Unit No 1. A NORMAL/TEST switch on the front of MTI Unit No 1 is used to suppress amplification of echo signals when the test pulse is in use. The grid of V1 is connected to a divider network R12, R13 on the main chassis. In the NORMAL position of the switch, R12 is shorted out so that V1 grid is returned to earth. In the TEST position, the short across R13 is removed and a negative bias of 15 volts cuts V1 off.

## The Locking Amplifier

23.6. This sub unit receives the 30 MHz sample of the transmitted pulse from the coho head amplifier and provides an output to lock the phase of the coherent oscillator. The main amplifier comprises V1 and V2 which together have a 4 MHz bandwidth, these valves provide the locking pulse for application to the coho. Valves V1, V3 and V4 provide a similar pulse but of greater amplitude for application to the test delay line, the greater amplitude being necessary to compensate for the attenuation of this line. Bias to V2 is adjusted by RV1 the LOCK BIAS control. This sets the amplitude of output to the coho. The test output is of fixed amplitude.

23.7. With the TEST/NORMAL switch at NORMAL, V3 is cut off with -15 volts applied to its grid, this bias being removed on switching to TEST.

23.8. The 60 μS quartz delay line has crystal transducers at either end. Reflections within the quartz result in more than one pulse being fed to the Limiting Amplifier.




Falling Amplitude of Pulses due to Reflection within Quartz Line

Fig 23.1. Output of Test Delay Line
(NORMAL/TEST Switch on TEST)

## The Coherent Oscillator

23.9. This oscillator is phase locked by the 30 MHz sample of transmitted pulse and is used to maintain this phase reference during the remainder of the repetition period. A modified Colpitts oscillator is used and is designed to be non critical of valve capacitances.

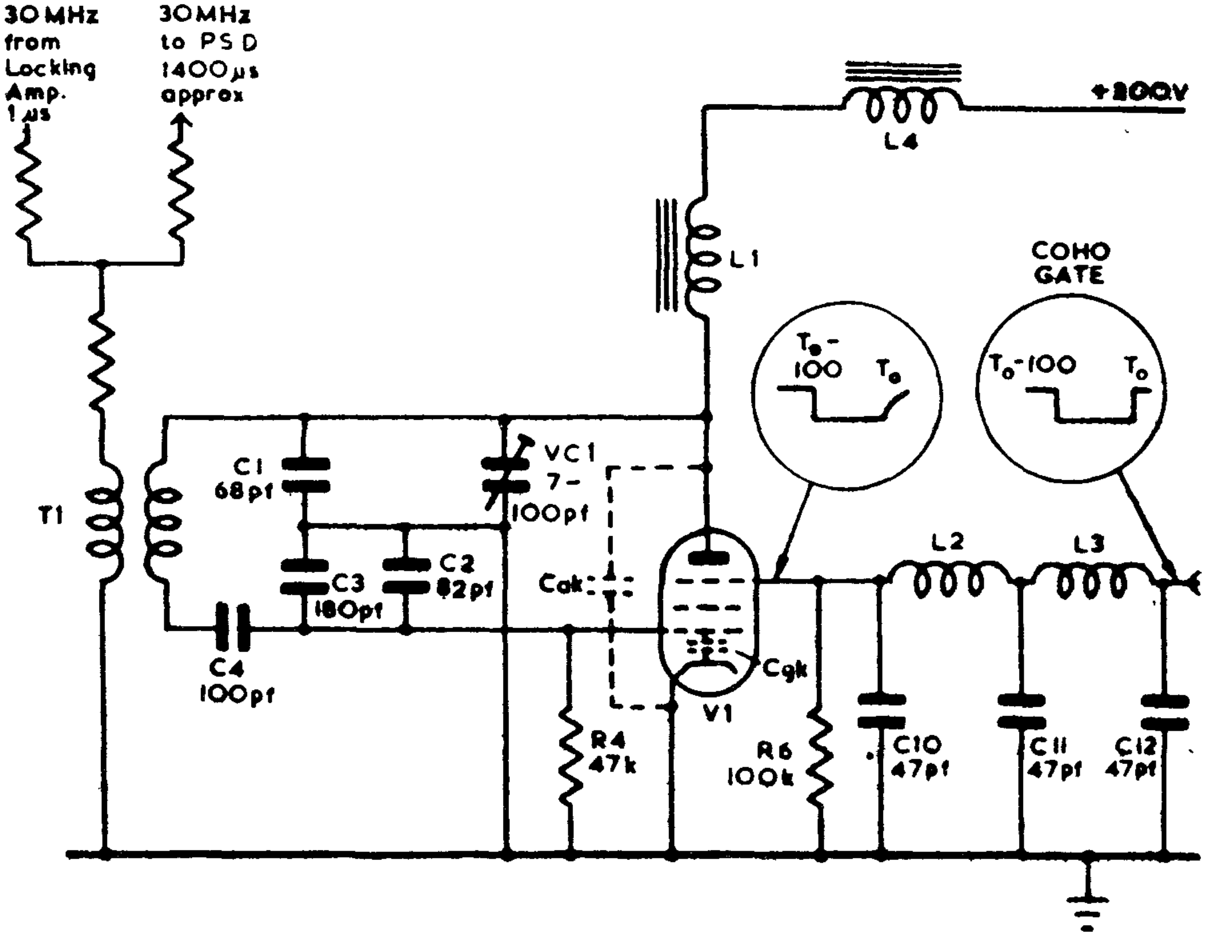



Fig 23.2. The COHO Oscillator

23.10. The oscillator tuned circuit comprises the secondary of T1 with a capacitance consisting of C1, C2, C3, C4 and VC1. Tuning is effected by VC1. The input capacitance $C_{gk}$ is across C2 + C3 and is small compared with the sum of these capacitances. Therefore any change in valve capacitance has negligible effect on the tuned circuit, similarly the anode-cathode capacitance shunts C1 and VC1 and is small compared to their sum. A low microphony pentode, CV358, is used; overall frequency stability is one part in 100,000 per degree centigrade.

23.11. The negative going coho gate waveform from the pulse generator is applied to the oscillator suppressor via the low pass filter, C12, L3, C11, L2 and C10. This input prevents the valve from oscillating between $T_0$-100 and $T_0$. The leading edge of the gate cuts off V1 rapidly but due to the cut off V1 and R6 the suppressor rises gradually to cut-on ensuring phase coherence with the lock pulse.

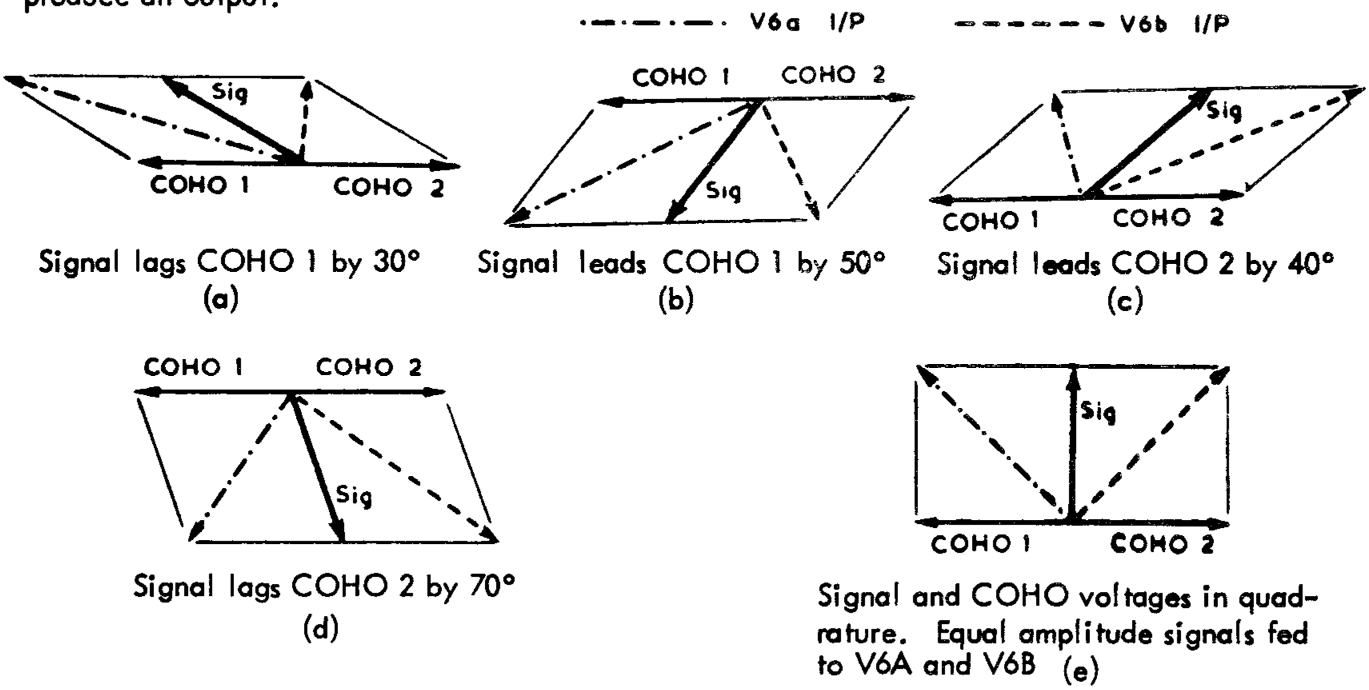
23.12. At $T_0$ the sample of transmitted pulse sets up a low level oscillation in the tuned circuit. For correct locking the coho gate width is adjusted (RV9) so that the gate terminates and the valve commences oscillation one µS after the locking pulse ends. The increasing amplification then builds up an oscillation which is maintained until the valve is again switched off at $T_0$-100 µS. If the coho tune and coho gate controls are correctly adjusted the sustained oscillation will be in phase with the incoming lock pulse. The coho output is taken to the Phase Sensitive Detector.

## The Phase Sensitive Detector

23.13. The Phase Sensitive Detector compares the phase of the 30 MHz received signals with the phase of the 30 MHz coho reference oscillator. It provides an output of bi-polar video, the amplitude and polarity of which is dependent upon this phase difference.

23.14. The reference oscillation is amplified in V1 and its output is used to drive the balanced amplifiers V2 and V4 in whose anode circuits are the primary windings of transformers T2 and T3. In the absence of signals the outputs from the secondaries of these transformers pass to the double diode V6A and V6B, the outputs of which cancel across the common load resistor R16 and no output passes to V7.

23.15. The signals from the limiting amplifier are fed in phase to V3 and V5. The anode of V3 is joined to that of V2 and the anode of V5 is joined to that of V4. Thus the primaries of T2 and T3 which receive the antiphase reference oscillations also receive in phase radar signals. The resultant voltages applied to V6A and V6B will depend upon the relative phases of the received and coho signals. Both signals are of constant amplitude and when the signal vector is in the COHO 1 sector V6A output will be the greater, thus positive video signals are produced. If the signal vector is in the COHO 2 sector V6B output is greater and negative going video signals are produced. The amplitude of the video signals will depend on the phase difference between radar and coho signals. When the radar signal is in quadrature with the coho signal there will be no output from the PSD. This will not prevent a moving target indication on the display as the radar signal from the next transmitted pulse will bear a different phase relationship from the coho and will thus produce an output.




Signal lags COHO 1 by 30° (a)

Signal leads COHO 1 by 50° (b)

Signal leads COHO 2 by 40° (c)

Signal lags COHO 2 by 70° (d)

Signal and COHO voltages in quadrature. Equal amplitude signals fed to V6A and V6B (e)

Fig 23.3. PSD Vector Diagrams

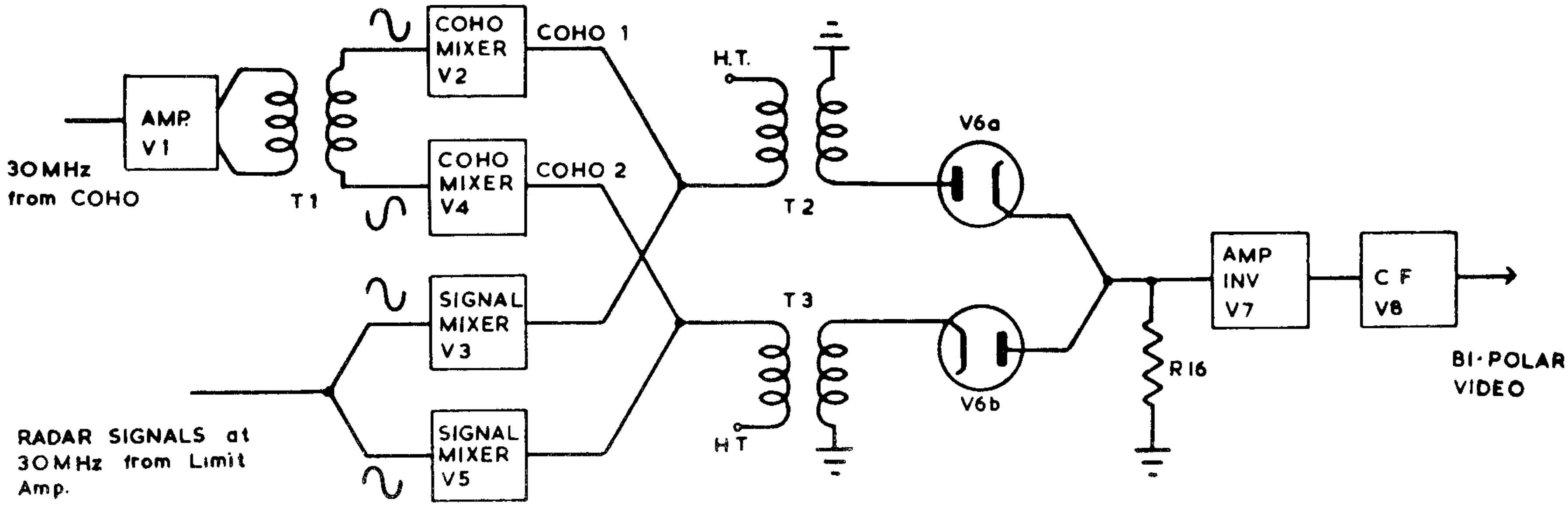



Fig 23.4. Descriptive Diagram of the Phase Sensitive Detector

23.16. MTI Unit No 2 is the cancellation unit. The unit receives the bi-polar video output from MTI Unit No 1 and compares successive video trains. After cancellation the resultant video signal is fed to the central control rack and hence to the indicators. It also receives the lock round pulse from the pulse generator (MTI No 1) at $T_0$ - 100 µS and after delay returns the knock off pulse to trigger the pulse generator. MTI Unit No 2 contains the following sub assemblies:

a. 20 MHz oscillator (RF oscillator S3/1).

b. Line drive modulator unit. (Amplifier Modulator S4/2).

c. Quartz delay line.

d. Post line amplifier (RF Amplifier S12/2).

e. Comparison amplifier (RF Amplifier S5/1).

f. Cancellation circuit and AGC amplifier.

## The 20 MHz Oscillator

23.17. The oscillator valve V1 operates in a modified Colpitts circuit which is arranged so that the valve capacitances have little effect on the constant of the resonant circuit. The h.t. supply is decoupled by C1 and the l.t. supply is decoupled by C3, L1 and C4. The 20 MHz output is taken via Skt 1 to the Line Drive Modulator Unit.

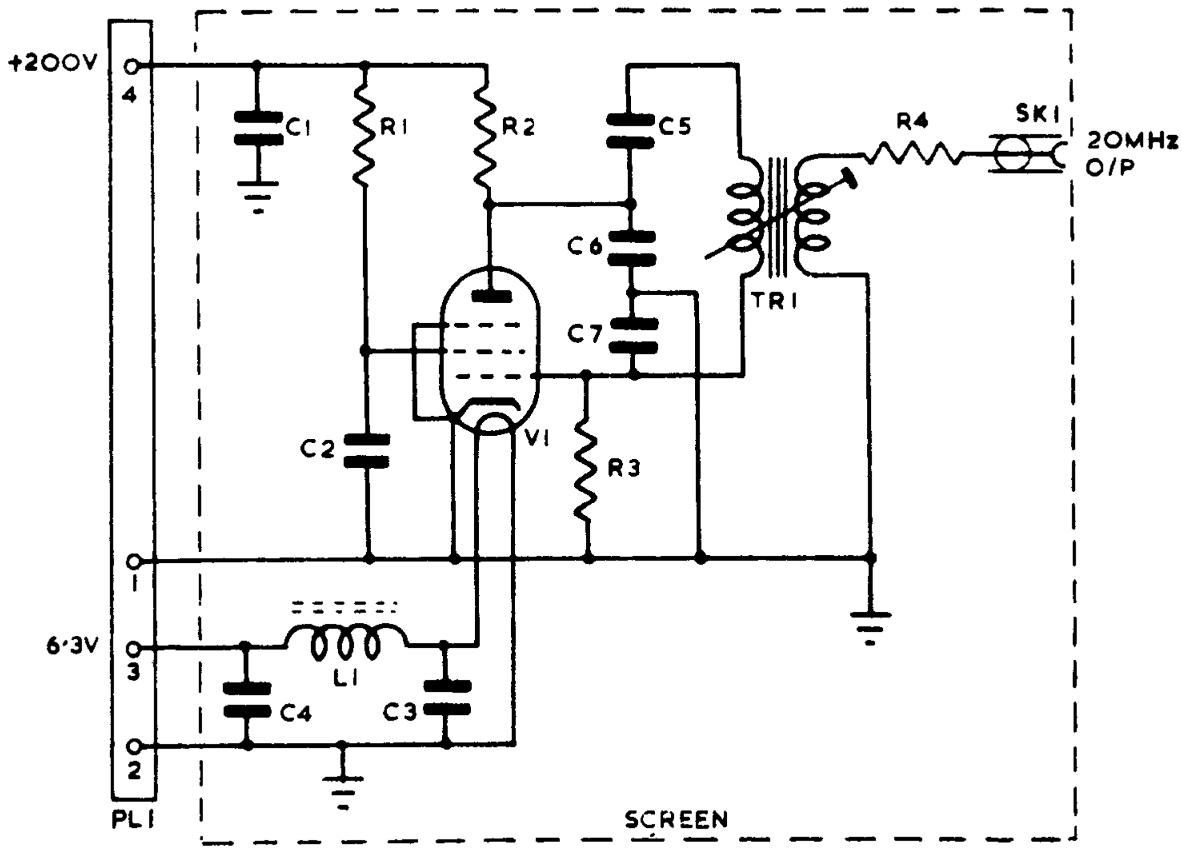



Fig 23.5. RF Oscillator Type S3/1 (20 MHz Osc)

23.18. The 20 MHz input from the 20 MHz oscillator is amplified by V1, this valve acts as a buffer and its bias is set by RV4 the Carrier Level control.

23.19. The 20 MHz carrier is fed from V1 anode via C5 to the third grid of the mixer valve V2. This valve has both bi-polar video and the knock off pulse applied to its first grid. These inputs modulate the 20 MHz carrier and this modulated carrier is fed from the secondary of T1 to the grid of V3. A coupling winding on T1 together with VC1 form a neutralising network for V2. The anode circuit of V3 contains a centre tapped transformer feeding the push-pull amplifiers V4 and V5. These valves have the output transformer T3 connected across their anodes. This transformer has twin secondary windings and provides outputs to both the delayed and undelayed channels. The tuning of T1 and T2 is staggered to increase the bandwidth of the amplifier.

23.20. Diode V6 is included with the filter circuit C24, L6, C25, L7, L8 and C27 to provide an oscilloscope monitoring point of the drive input to the quartz delay line. The output across R21 is used to measure the level of the 20 MHz carrier applied to the delay line when the meter selector switch is in position 11.

23.21. The Line Drive Modulator operates about the mean carrier level; positive signals increase the carrier amplitude, negative pulses decrease it. The form of the output is shown in fig 23.6.

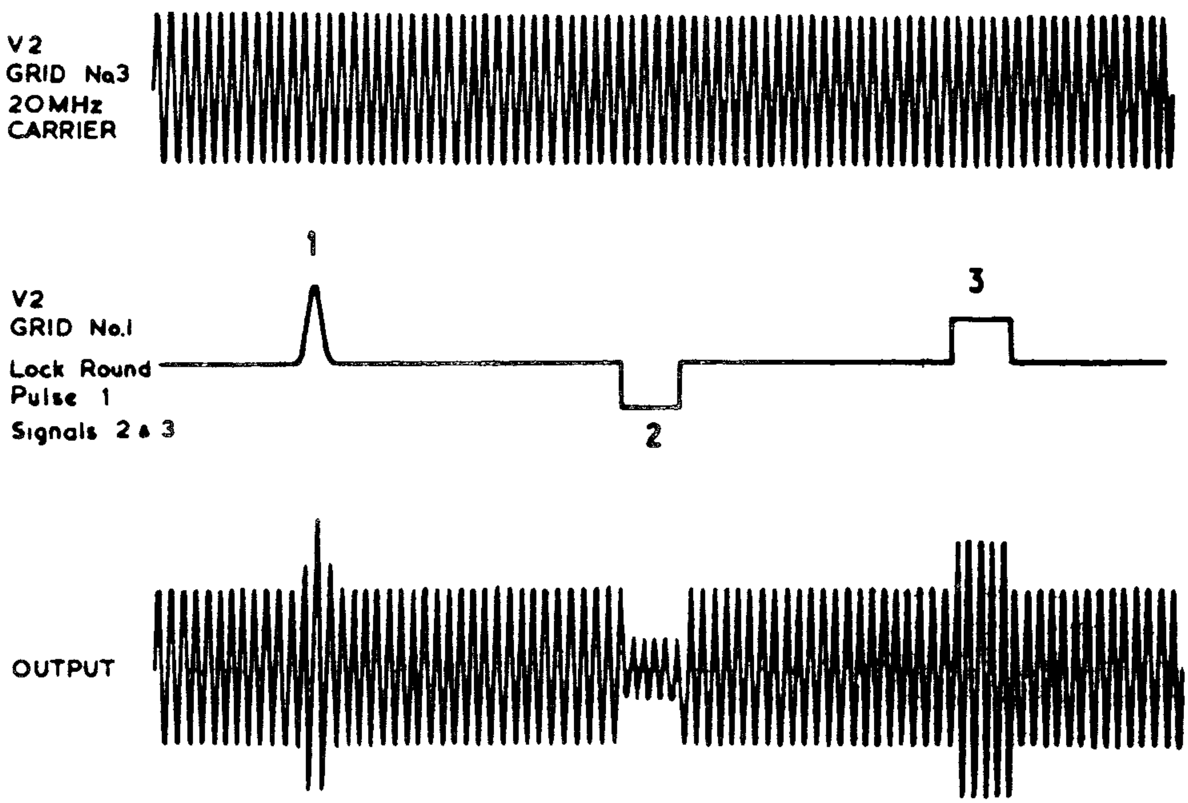



Fig 23.6. Waveforms in the Line Drive Modulator

## The Quartz Delay Line

23.22. The quartz delay line used in the operation of the MTI system is an irregularly shaped polygon of quartz hermetically sealed in manufacture and is anti-shock mounted. A fixed delay of 1425 µS is derived from the line. Input and output connections are by coaxial sockets.

## The Post Line Amplifier

23.23. To offset the attenuation of the quartz line a high gain amplifier follows it. The Post Line Amplifier employs six stages, staggered tuning being employed throughout. The response of individual tuned circuits is flattened by the use of damping resistors. Valves V1, V2, V3 and V4 are controlled by the AGC voltage and have undecoupled biasing resistors resulting in a measure of negative current feedback; this minimises impedance changes with AGC voltages. The signal output at the secondary of T6 is fed to the double diode detector V7 which has both halves parallel connected and provides a positive going output. From the diode load R24 the demodulated signal is fed to the double cathode follower V8. This valve produces at Skt 2 the knock off pulse for the main multivibrator in the pulse generator circuit. The delayed video output is taken at Skt 1 directly from the cathode of V7 and is fed to the cancellation circuit.

## The Comparison Amplifier

23.24. Undelayed signals are fed to the comparison amplifier from the Line Drive Modulator Unit and are connected to an attenuator network in the grid circuit of the amplifier V1. The amount of attenuation is determined when setting up the MTI cancellation circuit and is chosen to preset the level of the output at V2. The tuned circuit T1, damped by R10 is set to 20 MHz. From the secondary winding of T1 an output is fed to the cathode of the detector and the rectified negative going video output is taken to the cancellation circuit, the connection via the filter circuit L8, L9, C17-C19, is provided for measuring diode current when setting up the equipment.

## The Pulse Generator

23.25. The pulse generator is mounted on MTI Unit No 1 and produces trigger pulses and gating waveforms for the MTI system. It maintains a p.r.f. which is accurate and stable from pulse to pulse and provides an output to control the Lock Unit. The system p.r.f. is governed by a quartz delay line and a Lock Round circuit ensures that the p.r.f. is at all times locked to the delay line delay time.

23.26. Valves V2A and V4A form the main multivibrator, a 100 µS wide positive square wave being developed at the anode of V2A, the trailing edge of this pulse being coincident with $T_0$. Coupling from V2A anode to the grid of V4A is via the cathode follower V2B. This removes the high capacitive loading from the anode circuit of V2A and ensures a fast rise time at the start of the positive going pulse.

23.27. The rectangular pulses at V2B cathode have a positive going portion of width between 80 and 120 µS duration depending upon the setting of RV9, the coho gate width control, which sets the recovery time of V2A grid. This positive pulse is differentiated by C8, R35 and applied to the grid of V3. V4B removes the negative spike at the trailing edge of the positive pulse and a positive spike of approximately 20 volts amplitude appears at

V3 cathode; this spike occurs at $T_0$ - 100 µS. Two parallel outputs are taken from V3 cathode, one to Line Drive Unit on MTI Unit No 2, the other to the Lock Unit for synchronisation of the transmitter. In MTI Unit No 2 the positive spike from V3 cathode is subjected to a precise delay by means of a quartz delay line, the delayed output pulse being known as the knock off pulse. This pulse is used to initiate the succeeding trigger pulse. The free running time of the multivibrator V2A, V4A is slightly longer than the delay of the quartz line and after inversion in V1 the negative going knock off pulse is applied via the diode V6A to cut off V2A. For the major part of the repetition period V4A is cut off with its grid rising slowly towards cut on; when the knock off pulse arrives at V2A grid then V4A cuts on. RV2, the COARSE PRF control sets V4A grid aiming potential.

## The Lock Round System

23.28. The positive spike occurring at $T_0$ - 100 µS at the cathode of V3 in the pulse generator circuit is fed to the Line Drive Unit on MTI Unit No 2. It is modulated on to a 20 MHz carrier and passed through a quartz delay line of approximately 1425 µS delay. The pulse is demodulated in the Post Line Amplifier, also in MTI Unit No 2, and then fed back into MTI Unit No 1, to the grid of the gated knock off amplifier V1. This valve is suppressed between trigger pulses and only gated on a few µS before the knock off pulse is due to emerge from the quartz delay line. The gating waveforms to achieve this are produced by the gating flip flop V5. The diode V6B clamps V1 suppressor preventing the gating waveform from V5 raising it above earth potential; between gating waveforms V1 suppressor is at -150 V.

23.29. Due to the gating waveform at its suppressor V1 is in a state of low conduction from $T_0$ - 130 µS; when the positive knock off pulse is applied to V1 grid its anode potential falls by about 200 V in 0.25 µS and this fall is transmitted via V6A to the grid of V2A. Since the anode is biased by RV8 (the FINE REP. control), a delay of up to 0.1 µS can be introduced between the arrival of the knock off pulse and the re-triggering of the main multivibrator. A monitoring point across R65 in the screen of V1 permits monitoring of the relative positions of the knock off pulse and knock off gate.

23.30. The knock off gate is produced by the flip flop V5A and V5B. Initially V5A is cut off and V5B conducting. At $T_0$ - 100 µS, the negative going square wave at the anode of V2B is applied to the differentiating circuit C15, R51. Only the negative spike coincident with the $T_0$ - 100 µS is passed through the diode V7B to the grid of V5B cutting the valve off. The grid of V5B rises towards cut on at a rate determined by the time constant C13, R52 and the setting of RV10, the knock off gate width control. To improve stability the negative excursion of V5B grid is limited to -150,V by the diode V7A.

23.31. At V5A anode therefore, a negative going square wave is produced, beginning at $T_0$ - 100 µS and continuing until about 30 µS before the arrival of the next trigger from V3B anode. The 30 µS wide positive going portion is used to gate on the knock off amplifier V1 at its suppressor in readiness for the arrival of the knock off pulse from the delay line.

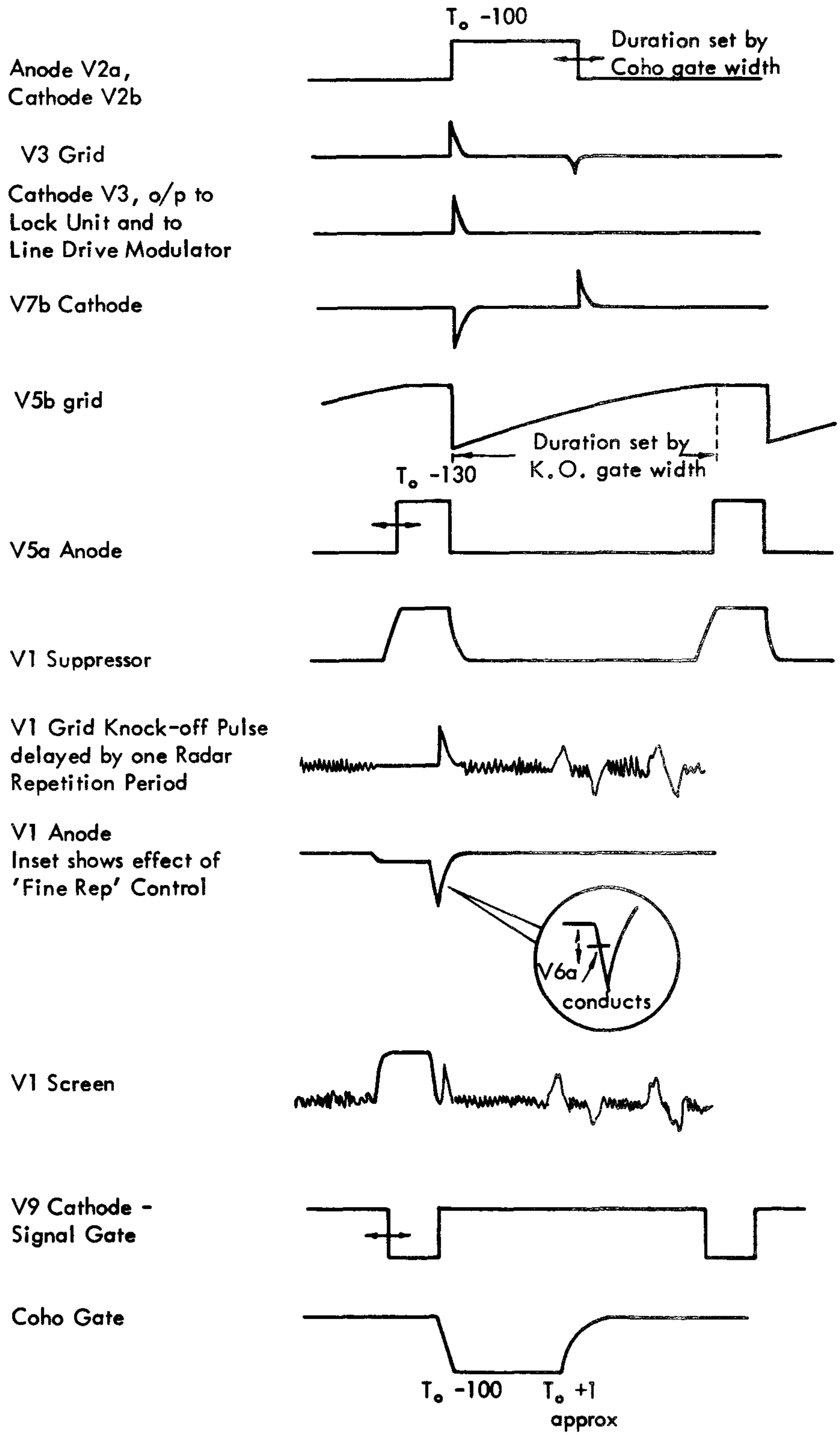



Fig 23.8. MTI Timing Waveforms

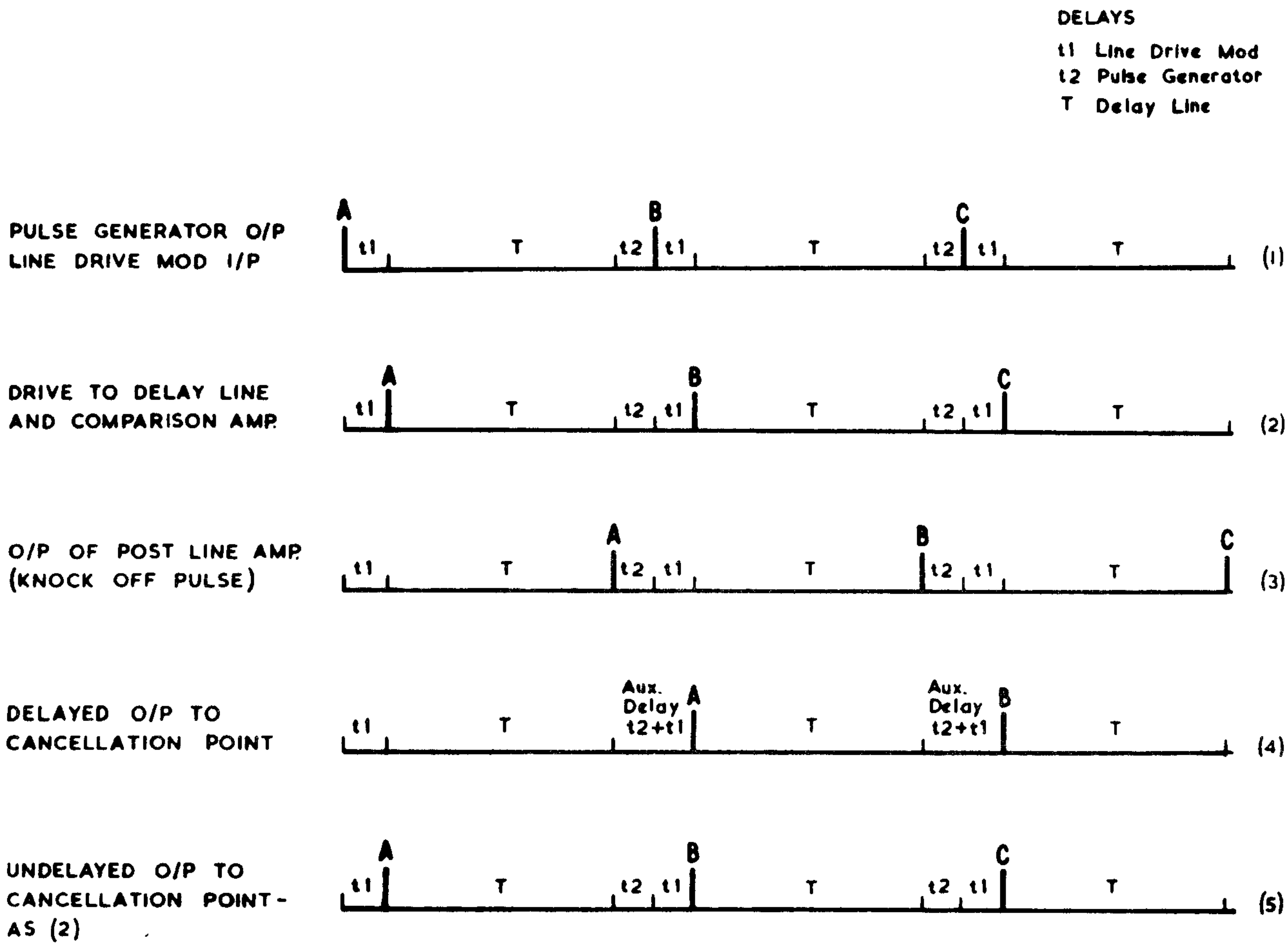



Fig 23.10. Delayed and Undelayed Pulse Timing

## The Cancellation Circuit

23.36. This section of MTI Unit No 2 is mounted on the main chassis of the unit and consists of a bridge comparison circuit, a simplified form of which is shown in fig 23.11.

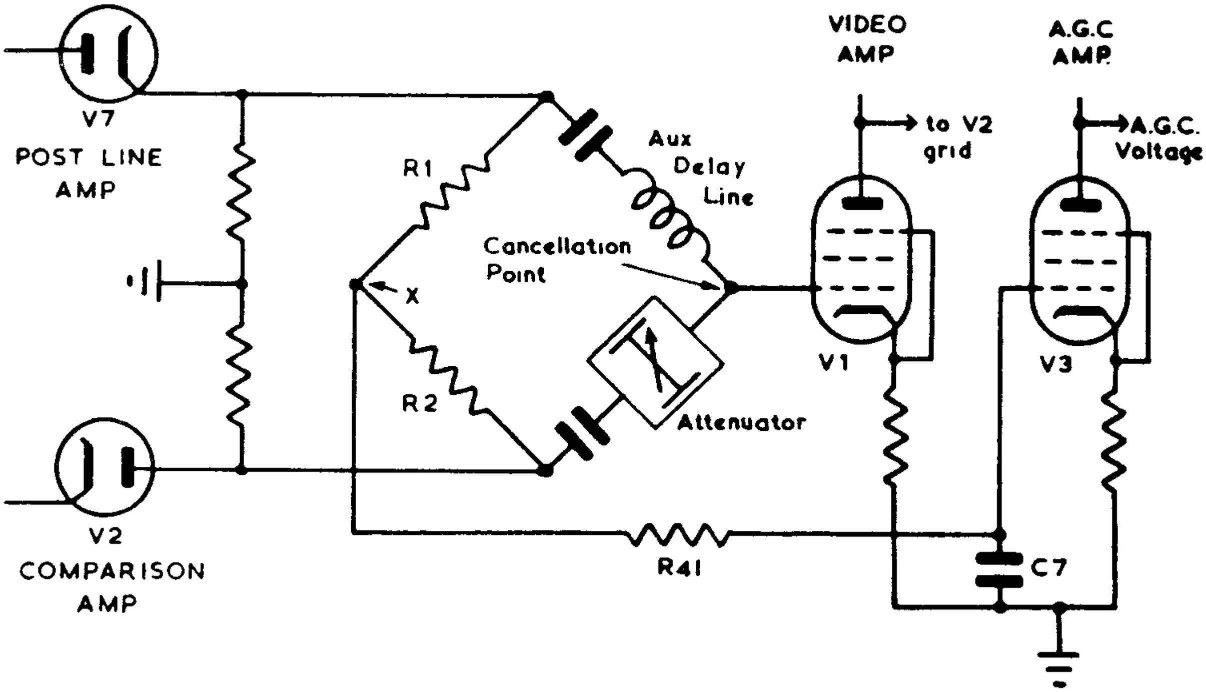



Fig 23.11. Simplified Cancellation Circuit

23.37. One arm of the bridge consists of the auxiliary delay line, this arm carrying the delay output from the post line amplifier. Another arm consists of a preset resistive attenuator, this arm carrying the undelayed output from the comparison amplifier. The other two arms of the bridge comprise R1 and R2 shunted by the equal diode loads in the post line and comparison amplifiers. The junction of the diode loads is earthed. Although junction R1, R2 is not earthed it is held at zero potential when the system has been balanced.

23.38. The grid and cathode of V1 are across the junction of the arms of the bridge and earth. Any difference in the two input levels results in a signal voltage at the grid of V1. Ideally the two inputs are of equal amplitude for permanent echoes and being of opposite polarity, cancellation takes place. However, for moving targets the bridge inputs are unequal and moving target indications are passed to the video amplifier. After amplification in V1 the moving target signals are fed to the phase splitter V2. The antiphase outputs of V2 are applied to the bridge rectifier circuit X1 - X4, which passes on only positive video pulses to the cathode follower V2B. The diode X5 d.c. restores the grid of V2B.

## The Automatic Gain Control Circuit

23.39. The AGC circuit develops the bias voltage for the Post Line Amplifier. If the output of either the delayed or undelayed channel changes for any reason then the mean potential at the junction of R1 and R2 will change. The polarity of this potential will depend upon the channel with the greater output. The AGC circuit is a d.c. amplifier which restores the balance of outputs for permanent echoes only. It does this by ensuring that the mean carrier levels in the outputs of the post line amplifier and comparison amplifier are the same.

Currents through R1 and R2 are the d.c. component of the mean c.w. input at 20 MHz to the detectors in post line and comparison amplifiers.

23.40. If the gain of the Post Line Amplifier rises, its mean output also rises and the junction of R1 and R2 becomes positive. This potential change is fed via R41 to the grid of V3. The resultant amplified change at V3 anode is passed to the grid of V5, a cathode follower. The output of V5 is used as the gain control voltage on the Post Line Amplifier.

23.41. A long time constant, C7/R41, is used in the input circuit to V3 and avoids instantaneous gain changes resulting from the pulse component of the input to R1 and R2. The diode clamp V4 ensures that the cathode of V5 cannot rise above -1 volt with respect to earth and take the control grids of the valves in the post line amplifier into the positive grid region.

23.42. The standing bias to the post line amplifier is preset by RV3, (the AGC LEVEL CONTROL) on the front panel of MTI Unit No 2.

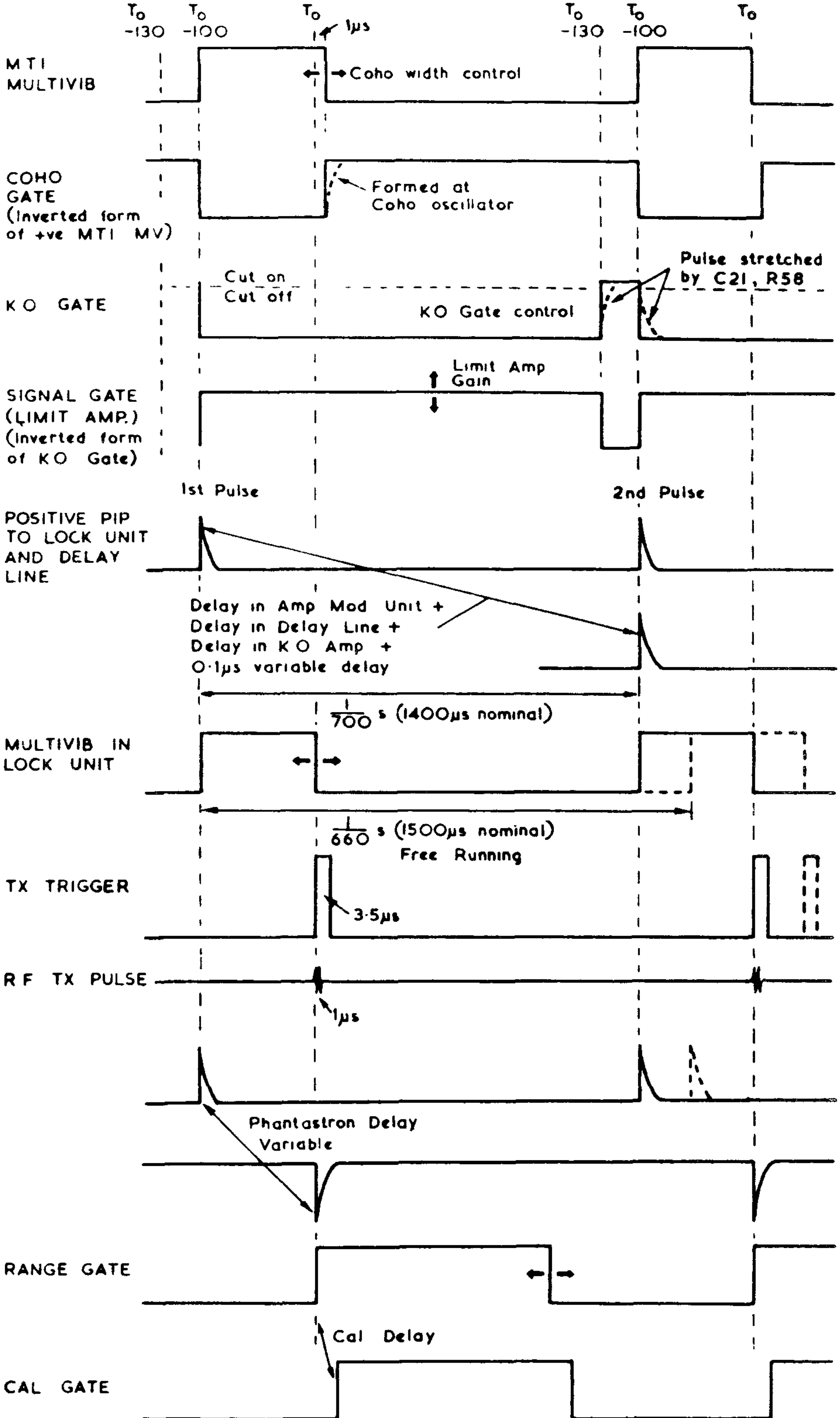

To -130
To -100
To
1µs
To -130
To -100
To
MTI MULTIVIB
Coho width control
COHO GATE (Inverted form of +ve MTI MV)
Formed at Coho oscillator
Pulse stretched by C21, R58
KO GATE
Cut on
Cut off
KO Gate control
Limit Amp Gain
SIGNAL GATE (LIMIT AMP.) (Inverted form of KO Gate)
1st Pulse
2nd Pulse
POSITIVE PIP TO LOCK UNIT AND DELAY LINE
Delay in Amp Mod Unit +
Delay in Delay Line +
Delay in KO Amp +
0·1µs variable delay
1/700 s (1400µs nominal)
MULTIVIB IN LOCK UNIT
1/660 s (1500µs nominal)
Free Running
TX TRIGGER
3·5µs
RF TX PULSE
1µs
Phantastron Delay Variable
RANGE GATE
Cal Delay
CAL GATE

Fig 23.12.

# MTI DISTRIBUTION CHAIN

## Introduction

24.1. The MTI uni-polar video from the centre control rack (see MTI production chain diagram), is fed via an impedance matching network Type S1/1 and split to supply:

a. One or two displays at air traffic control.

b. A local monitor display.

## Air Traffic Control Displays

### Amplifier PS Type S30/1 (Signal Booster)

24.2. The MTI video is amplified and mixed with the $T_o$ - 100 µS display prepulse from the lock unit of the selected transmitter in the Amplifier Converter Type S25/1 (MTI and Prepulse Amplifier). In order to minimise attenuation distortion of the video in passing down the land lines, both video and prepulse modulate a 20 MHz carrier in the Modulator Oscillator Type S3/1 (Cable Drive Modulator). From the cable drive modulator the 20 MHz signal is fed via a variable attenuator to the land line. Monitor and metering test points are included where necessary and the diagram shows their location. The land line can be a maximum of 4000 yards and at air traffic control the 20 MHz is fed to the Amplifier Power Supply Type S29/1 (Upper Base Unit), and thence to the RF Amplifier Type S24/1 (Post Cable Amplifier).

### Synchros Signal Amplifier Type S23/1 (Aerial Follower)

24.3. The post cable amplifier and lock pulse separator are both located in the aerial follower and the lock pulse separator passes the lock pulse on to the timebase circuits. In the post cable amplifier the MTI video is detected and fed to the Electronic Marker Generator Type S21/1 (Waveform Generator Video) which is located in the Pulse Generator Power Supply Type S18/1 (Lower Base Unit).

### Electronic Marker Generator Type S21/1 (Waveform Generator Video)

24.4. In the waveform generator video, both the MTI and normal radar video are fed to a switching circuit. The MTI/normal switch timing circuit, which is initiated by the 'range gate' in the timebase circuit, arranges for MTI video to be displayed from time $T_o$ until a time preset by RV28 (MTI DURATION control). At this time the MTI will be gated off and the normal radar passed to the display. At extreme settings of RV28 it is possible to display all normal or all MTI video. From the waveform generator video the MTI/normal video is fed to one or two Azimuth Range Indicators, Type S5/1 (Display Unit).

Video Amplifier Type S17/1 (Video Mixer)

24.5. The MTI/normal video is fed via an optional short time constant circuit controlled from the Control Indicator Type S13/1m to amplification and mixing circuits gain controlled by RV6 in the control indicator. Gain controlled normal radar signals are available, to provide a background of fixed targets during the MTI portion of the scan. Range rings are also mixed with the MTI/normal radar and normal (contrast) radar before application to the c.r.t. cathode.

Monitor Display

24.6. From the splitter impedance matching network Type S1/1 the MTI unti-polar video is fed direct to the waveform generator video in the Pulse Generator Power Supply Type S18/2 (Base Unit). The MTI video is then treated exactly the same as in paras 24.4. and 24.5., but only one monitor display c.r.t. is used.

## CHAPTER 25

## MTI DISTRIBUTION CHAIN, CIRCUIT ANALYSIS

### Introduction

25.1. The MTI video signals from the cathode follower final stage of the MTI 2 unit are fed via the Impedance Matching Network Type S1/1 to:

a. the Monitor Display circuits.

b. the Amplifier Converter Type S25/1 where they are processed for onward transmission along the land line to the remote displays.

### Amplifier Power Supply Type S30/1

25.2. This cabinet contains two major units:

a. Power Supply Type S46/1 providing all necessary d.c. supplies.

b. Amplifier/Converter Type S25/1, This amplifier has three purposes:

(1) amplification of the normal radar signals, which is carried out by the IF Amp Type S26/1 (30 MHz IF AMP). See Normal Radar Signal Chain, Chapter 17.

(2) amplification of the MTI video signals and of the display prepulse from the operational transmitter.

(3) production of a 20 MHz carrier which is modulated by the MTI video and display prepulse for transmission along the land line to the remote displays.

25.3. The amplifier unit accepts the display prepulse from the transmitter lock unit via the remote switching unit in the radar control rack and similarly the MTI video signals from the operational transmitter. These signals are amplified and caused to modulate a 20 MHz carrier generated in the cable drive modulator.

25.4. The positive going MTI video signals are fed to the grid of V1 via MTI/PP ratio control RV1. The positive going prepulse is fed to the grid of V2. V1 and V2 are connected as a long tailed pair and the positive MTI video at the common cathodes appears still positive going at V2 anode; the prepulse however is inverted in V2. This mixed MTI/PP is fed to the cathode follower V3A which has V3B as its cathode load. The amplified and inverted composite signal at V3A anode is fed to V3B grid. The output from the circuit is taken at the junction of V3B anode/V3A cathode. This circuit has the advantage of maintaining its output impedance reasonably constant for both positive and negative inputs. The composite output is passed to the cable drive modulator.

25.5. The cable drive modulator provides the carrier at a frequency of 20 MHz which is modulated by the composite MTI video/PP waveform. The information contained in the carrier is then passed over land lines to the remote site.

25.6. The double triode V1 is a crystal oscillator generating a 20 MHz sine wave. The output is taken across the secondary of T1 to the buffer amplifier stages V2 and V3. Two outputs are taken from the secondary of T3. One output is passed to the modulator valve V6, the other to the diode V4.

25.7. The negative going halves of the 20 MHz carrier are passed through V4, which is connected to the +200 V line via the 'SET 20 MHz DRIVE' control, RV2. The output of V4 taken at the junction of R19, R20, is smoothed by C42, R26, C44 etc and is fed via T1 secondary to the grid of V2. This provides AGC for the buffer amplifier and ensures a constant carrier amplitude at the level determined by RV2 irrespective of drift of oscillator amplitude or buffer amplifier gain. The diode V5 (connected between the AGC line and the -150 V bias line) ensures that the AGC voltage cannot go above -1 volt. The normal output level is set to 3 volts peak into a 75 ohm load.

25.8. The valve V6 is the modulator and is fed with the composite MTI video PP waveform and also with the 20 MHz carrier. An input at Skt P permits feeding of a test pulse into the unit for fault finding on the signal booster in the absence of signals from the receiver.

25.9. The output is taken across T4 and the depth to which the MTI video modulates the 20 MHz carrier is determined by RV1 on the main amplifier unit; it is adjustable between positive 30% and zero. The prepulse modulates the carrier to a depth of 100% and is not variable. The purpose of maintaining different levels of depth of modulation between the prepulse and the MTI video is to enable the prepulse separation circuits in the aerial follower unit to operate satisfactorily. The ratio is normally set at six to one, ie with the carrier level set to 3 volts and the display prepulse set to 3 volts (100%) the peak MTI video modulation is set to 0.5 volts.

25.10. The modulated carrier is further amplified in V7 and in the push-pull output stage V8 and V9, the output being taken across the secondary of T6. The two halves of V10, connected in parallel, detect the output of the cable drive modulator for monitoring purposes.

25.11. Signals from the Cable Drive Mod are fed via Attenuator A to the land line. The attenuator is used to maintain input signal amplitude to the display units constant and compensates for varying lengths of land line used under varying operational conditions.

25.12. The carrier-borne signals are fed via the land line to the RF Amp Type S24/1 (Post Cable Amp) which is a sub-unit of the Synchros Signal Amp Type S23/1 (Aerial Follower).

## Post Cable Amplifier

25.13. The Post Cable Amplifier is a sub-assembly mounted on the aerial follower unit. It provides amplification of the prepulse and MTI video signals to offset attenuation which results from transmission over the land line.

25.14. Five stages of amplification are followed by a positive detector and a cathode follower output stage. Gain of the amplifier is 75 dB maximum, and controlled by the MTI gain control on the front of the aerial follower. This varies the control grid bias on V2, V3 and V4. The bandwidth of the amplifier is 4 MHz centered on 20 MHz.

25.15. The output from the cathode follower V7 consists of positive going MTI video signals combined with a negative going prepulse. The waveform is fed to the lock pulse separator circuit on the main chassis of the aerial follower unit (Time Base Chain) and to the Electronic Marker Generator Type S21/1.

25.16. In the waveform generator (video) MTI signals are fed to a two valve amplifier V36, V42. The gain of this stage is controlled by RV27. The positive going MTI video is applied to the grid of V39B, similarly the normal radar video is applied to the grid of V39A. The grids of these two valves are d.c. restored by V38 and V25A respectively and are balanced by the mixed video balance control RV29. The gating action is controlled by V41.

25.17. At the start of the trace V41B is conducting and allowing V39B to act as a cathode follower, MTI video is therefore passed through the isolating diode V40B to the twin output cathode followers V45A and V45B. Current through R319 maintains a sufficiently positive voltage at V41A cathode to keep this valve cut off. The cathode of V39A is correspondingly high and this valve is prevented from cathode follower action. No normal radar signals are therefore passed to V45.

25.18. V34 is a monostable circuit which is controlled by a negative going sawtooth waveform from the range gate phantastron V1 shown on the Timebase Chain. The negative going waveform rundown starts at $T_0$ and ends approximately 1236 µS later (100 nautical miles). This voltage is applied to V34A grid. At the start of the trace V34A conducts heavily and the volts drop across R404 is sufficient to hold V34B cut-off despite the positive voltage to which its grid is returned. During the rundown of the range phantastron V34A grid falls until its valve current is not sufficient to maintain V34B cut off. A negative pulse is therefore produced at V34B anode, starting at the point where the circuit of V34 changes over from V34A conducting to V34B conducting. This point is adjustable by varying the MTI DURATION control RV28. At the end of the input waveform the circuit returns to its initial state.

25.19. The negative going pulse from the anode of V34B is applied to the bistable stage V35A, V35B. At the start of the trace V35B conducts heavily and its common cathode resistor R295 holds the cathode high enough to ensure V35A is cut off. The arrival of the negative going pulse from V34B at the grid of V35B reverses the state of V35 and V35A cuts on. The positive going square wave produced at V35B anode is fed to the grid of V41A.

25.20. As mentioned earlier V41A is cut-off at the start of the trace by the high cathode potential due to valve current in V41B. The positive going waveform from V35B anode reverses the state of V41 and also that of V39. V39A now acts as a cathode follower passing normal radar signals via the isolating diode V40A to the cathode followers V45A and V45B (fig 25.1).

25.21. Since V35 is a bi-stable circuit it has to be triggered in order that it will revert to the initial state of V35B conducting and V35A cut-off. This is achieved by feeding the end of scan pulse from the integrator chassis to the grid of V35A, cutting the valve off.

25.22. The mixed MTI/normal radar video output is fed to the video amplifier Type S17/1 (Video Mixer), which accepts inputs from the waveform generator circuits, mixes them and feeds them to the appropriate electrodes of the display c.r.t. The unit also contains part of the circuit which produces the e.h.t. supply for the tube and a focus control circuit. The components of the video mixer are mounted on a similar hinged chassis to those of the deflection amplifiers, the sub-assembly being on the left-hand side of the viewing unit, as viewed from the tube face.

25.23. Provision is made for several inputs to the unit; of these only five are used, these being:

a. Range rings. (Time Base Chain).

b. Normal radar. (Normal Radar Signals Chain).

c. MTI and normal radar mixed. (MTI Production Chain).

d. Brightener pulses. (Time Base Chain).

e. North marker. (Time Base Chain).

25.24. V3B grid is fed with MTI/normal radar video signals. The input to this grid can be switched through a short time constant circuit if it is desired to reduce clutter. Relays A and B are switched at the display control panel and are energised from the +330 V line. The input is then differentiated by C5, R7, the diode V7B removes the negative spikes after differentiation. Range markers are fed to the grid of V1B. The anodes of V3A, V3B and V1 share a common anode load, R23, with the frequency compensating choke L1 in series with it. The h.t. of these three valves is derived from the +330 V line and is lowered to +70 V by the series hard valve regulator circuit of V17A, V17B. More stable operation of these valves occurs when a lower h.t. value is used. The same +70 V supply is also used in the brightener mixing circuits V13 and V14.

25.25. The negative going mixed video and range rings are applied to the unbiased valve V4; this valve is conducting heavily, its grid/cathode therefore acts as a d.c. restorer, restoring the mixed signals negatively. The positive going output at V4 anode is frequency compensated by L2 and is applied to the grid of the output valve V5. This valve is held just above cut-off by the potential from the cathode of V6B; the input is positively d.c. restored by V6A. The negative going output across V5 anode load is frequency compensated by L3 and is applied to the cathode of the c.r.t. The diode MR1 operates as a limiter to restrict the output to a level within the grid base of the c.r.t. One side of MR1 is connected to a point on a divider chain across the +500 V and -330 V rails. This divider includes V12A and by adjusting the bias on this valve the limiting potential of the diode MR1 can be set. Any signals large enough to cause MR1 to conduct are fed back to the grid of V5 in antiphase with the input and so limit V5 current.

NOTE: For the remaining circuit analysis of the video mixer unit refer to the Timebase Chain Circuit Analysis, Chapter 32.

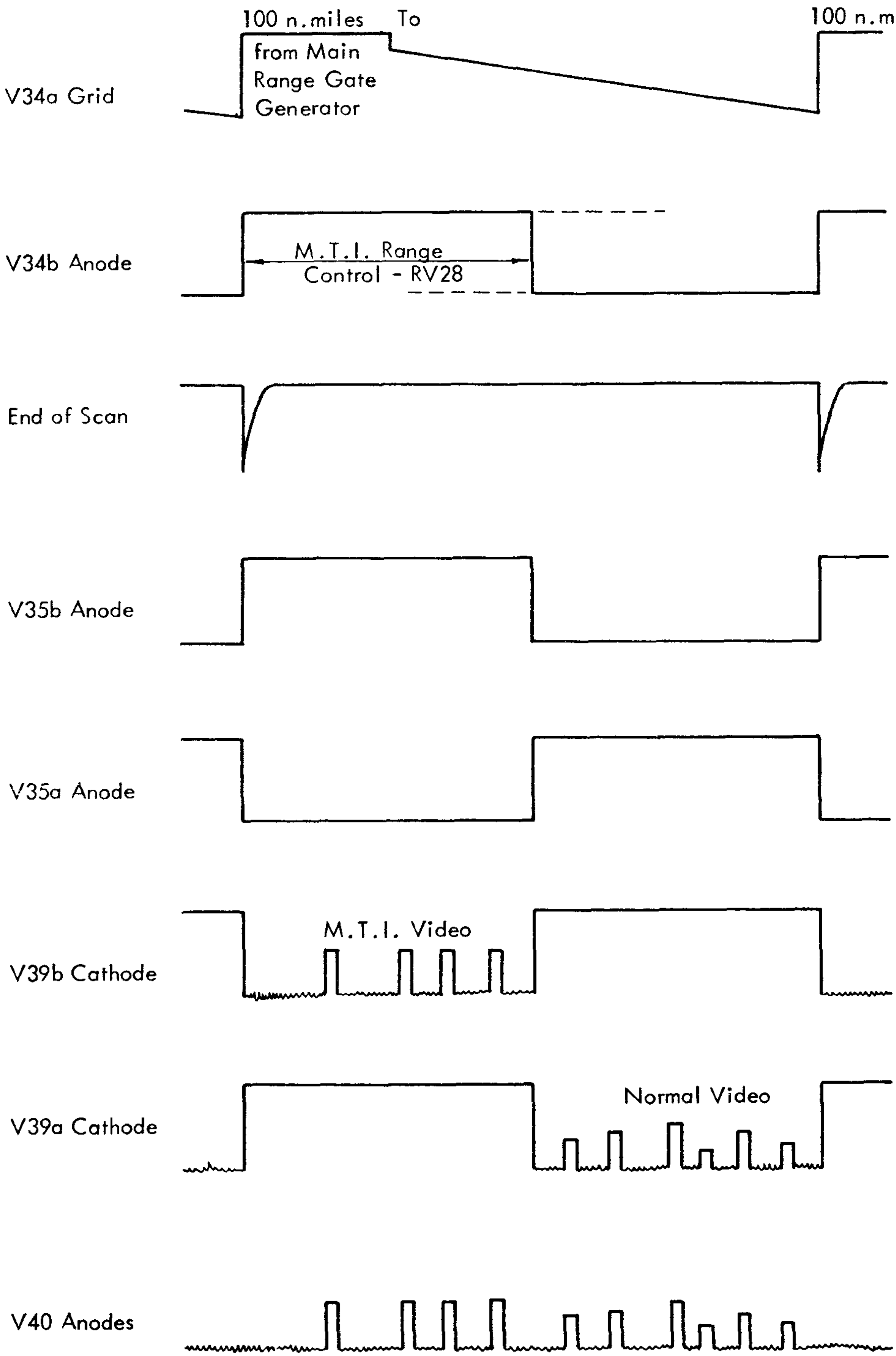



Fig 25.1. - MTI/NR Gating Waveforms

# AERIAL CABINET AC POWER DISTRIBUTION

26.1. 230 V a.c. supply from the radar head building is fed to the MAIN CIRCUIT BREAKER AND EARTH LEAKAGE SWITCH, CB2. Six outputs from CB2 supply the following circuits:

a. Scanner Motor Starter circuit. (See Aerial turning control Chain).

b. Rain plate actuator starter. (See Anti-rain plate chain) via circuit breaker, CB14.

c. Via circuit breaker CB13 and slip rings to the obstruction light.

d. Via circuit breaker CB12 and slip rings to the radar horn defrosting heater. A thermostatic control switches the heater on when the ambient temperature falls below 4° centigrade (39.2°F).

e. Via circuit breaker CB15 to the cabin light and two service sockets.

26.2. The circuit breakers are all rated at 5 amp except the main which has a 30 amp rating.

# AERIAL AND AERIAL TURNING CONTROL CHAIN

## Aerial Construction and Critical Measurements

27.1. The aerial is mounted on a tubular steel framework and consists of a double curvature steel reflector, fed by a horizontally polarised horn. The reflector apertures are 16 feet (horizontal) by 6 feet 9 inches (vertical). This produces a cosecant squared pattern with a 1.4° azimuth beam width. The whole of the aerial assembly can be tilted through a 4° arc (2° either side of horizontal) by adjustment of three bolts, each fitted with a locking nut. A scale and pointer show the angle of tilt. A 300 watt heater is fitted behind the flange of the aerial horn and prevents icing over of the horn window. This heater is switched in the aerial machine cab and is supplied with 230 V a.c. via the slip rings. A thermostat mounted in the machine cab roof plug box is set to switch the heater on at +4°C, ± 2° C. Twin obstruction lamps are mounted on a bar clamped to a corner of the aerial catwalk frame, the only switch for these lamps is mounted in the aerial machine cab.

## Aerial Turning Gear and Starter Circuits

27.2. The machine cab on which the aerial is mounted contains the aerial drive motor, a gear box, final drive torque tube with integral rotating joint, a magslip resolver unit, aerial starter mechanism and a switch panel.

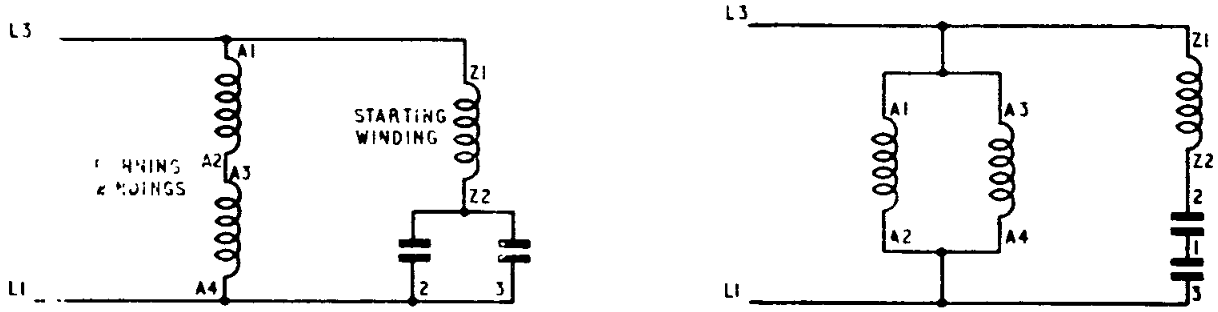
27.3. The turning motor is a single phase, capacitor start motor, running at a fixed speed of 1440 r.p.m. Power input to the motor is 200-250 V, 50 Hz 5 kVA and the motor can be controlled from push buttons on the starter unit or remotely via relays from either the Radar Set Control Type S6/3 (Master) or the Radar Sets Control Type S6/4 (Aux 1 and Aux 2). Selection of the Controller in use is carried out by SW5 on the Master control unit.

## Aerial Turning Control

27.4. The control system is designed to operate in two stages:

a. When the aerial motor is first energised the motor windings are connected in a 'START' configuration to limit excess current in the windings due to the low back e.m.f.

b. As the aerial begins to rotate back e.m.f. builds up and the motor windings are then switched to the 'RUN' configuration.




(a) Starting (b) Running

Fig 27.1. Connections to Scanner Motor Winding

## Action

27.5. With AC WALL SWITCH and ISOLATE SWITCH closed a.c. is available to the control system. A +60 V supply from the Radar Set Group Type S1/1 (Control Rack) is available when the main equipment is switched on and therefore relay G is energised and contact G1 closed.

27.6. When operating remotely, if SW9 AE STOP/START is depressed to the START position, +60 V is completed to RLA and contact A1 closes.

27.7. The START/RUN CONTACTOR SRC/7 circuit is now completed:

a. Contact SRC1 closes completing the MAIN CONTACTOR MC/4 circuit and contact MC1 bypasses the START contact.

b. Contacts SRC2 to 7 connect the motor windings in the START configuration.

27.8. MAIN CONTACTOR MC/4 contacts:

a. MC1a closes - hold contact for MC/4: SRC/7. MC1b opens and prevents energising of SRC/7 if START button is pressed during running.

b. MC2 completes line volts to motor.

c. MC3, MC4, complete neutral line to motor.

27.9. The current in the START/RUN contactor circuit heats the thermal switch and, after a preset period (dependent on chosen setting) the delay contact opens and SRC/7 is de-energised.

a. Contact SRC1 opens and thermal switch cools.

b. Contacts SRC2 to 7 changeover to the RUN configuration.

27.10. To stop the aerial turning SW9 is moved to the STOP position. This action energises RLB and B1 contact opens breaking the a.c. supply to the MAIN CONTACTOR. Contacts MC2 to MC4 open and the turning motor stops.

27.11. Thermal overload bi-metallic strips in the motor supply lines operate an overload contact in the MAIN CONTACTOR supply line if excessive drive motor current is drawn.

27.12. A SAFETY KEY SW1 in the Machine Cab, which makes aerial starting impossible, can be removed when work on the Aerial is being carried out.

CHAPTER 28

# ANTI-RAIN PLATE CONTROL CHAIN

## Purpose

28.1. The rain plate consists of a quarter wave plate system which when placed in the path of the energy radiated by the aerial converts the horizontally polarised transmission to circular polarisation. The rain plate normally lies along the aerial boom but can be raised to a position across the radiating elements. When in operation it has the effect of reducing the returns from spherical objects (ie rain) and therefore reducing the clutter caused by rain on the displays.

28.2. The anti-rain plate actuator motor can be controlled from either the Radar Set Control S6/4 (Aux 1 Aux 2) or from the Radar Set Control S6/3 (MASTER) at the radar head. The motor is held in position (either up or down) by a magnetic brake. A solenoid in series with the motor winding releases the brake only whilst the motor is turning.

28.3. Selecting anti-rain plate 'ON' completes relay RLC, contact C2 energises the contactor and mains are applied to the motor. The motor rotates and through suitable gearing raises the anti-rain plates. Contact C1 latches RLC via D1. When the rain plate is raised, a cam on the motor which has turned half a revolution operates the micro switch and energises relay RLF. Contact F2 changes over breaking the contactor supply and stopping the motor, F1 completes the circuit of the 'rain suppressor' on lamp. When anti-rain plate 'OFF' is selected relay RLD is energised, contact D1 unlatches RLC and contact C2 changes over reapplying mains to the contactor. The motor turns a further half revolution in the same direction, the micro switch opens breaking the supply to RLF. Contact F2 changes over and breaks the contactor supply and F1 opens breaking the lamp circuit.

## CHAPTER 29

## BEARING RESOLVER CHAIN

### Introduction

29.1. In the bearing resolver system, bearing information from the aerial head ensures that all PPI displays rotate in step with the aerial at 12 r.p.m. Up to three displays are normally situated as under:

a. Two operational displays at air traffic control.

b. A monitor display at the aerial head.

### Air Traffic Control Displays

### Servo System

29.2. When the aerial rotates, two servo control transmitter rotors, housed in the aerial machine cab, are driven, one at aerial speed 12 r.p.m. (low speed) and the other through suitable gearing at 36 times aerial speed (high speed). A suitable a.c. voltage fed to the transmitter rotors provides bearing information via the Cable Compensation Unit S3/1 and landline to the stators of the high and low speed servo control receivers in the Synchros Signal Amplifier S23/1 (Aerial follower). A servo motor in the aerial follower turns the rotors of the control receivers at similar speeds to the transmitter rotors . Control of this servo motor is effected by the difference in position between transmit and receive rotors.

29.3. In the 'FOLLOW' position of switch A the low speed error signal is amplified and fed to the control winding of the servo motor in such a manner as to reduce the discrepancy in position between low speed transmitter and receiver rotors.

### High Speed Takeover

29.4. When the difference between transmitter and receiver rotors, hence the error signal, has fallen to a low value, provided the error signal is non-ambiguous , the system will go over to high speed. Since the high speed rotor is turning at 36 times aerial speed the error signal is increased, servo motor control becomes more positive and the follow error can be reduced to an absolute minimum.

### Feedback System

29.5. Since the following system comprises a high gain closed loop system, there is danger of oscillation occurring, particularly when acceleration or decleration occurs. To offset this, direct (velocity), and delayed forms of negative feedback are incorporated.

a. Direct Feedback. A tacho-generator, rotated by the servomotor provides a negative feedback voltage which opposes the error signal input at the input to the servo amplifier. If the servo motor accelerates or decelerates, the direct feedback from the tacho-generator is such as to reduce overshoot.

b. Delayed Feedback. During normal FOLLOW conditions when no feedback is required, the delayed feedback cancels the direct feedback at the input to the servo amplifier. Since the delayed feedback cannot change immediately, if the servo motor slows suddenly, direct feedback will decrease and the delayed feedback will assist the servo motor.

c. Phase Sensitive Rectifier. Should the servo motor for any reason reverse its direction, both direct and delayed feedback voltages will change phase by 180°. The error signal input to the servo amplifier will, under such circumstances, be such as to cause the servo motor to reverse. The feedback system will therefore operate satisfactorily for either direction of rotation of the servo motor.

## Sine Cosine Resolver

29.6. The sin/cos resolver potentiometer is rotated by the servo motor and geared down to 12 r.p.m. The sin/cos potentiometer outputs are then employed to produce suitable timebase waveforms for the display.

## Switch A (Aerial Follower Front)

29.7. A four position switch which can select any one of four positions:

a. FOLLOW. Position 2. The normal operational position when the p.p.i. follows closely the rotating scanner at 12 r.p.m.

b. FREE RUN. Position 1. Under these conditions a voltage is fed to the servo amplifier so that, for test purposes, the servo motor will rotate independent of aerial rotation.

c. 0° and 270°. Positions 3 and 4. In these two positions fixed voltages are fed to the stators of the control receivers. The rotors turn in such a manner that the sin/cos potentiometer produces voltage outputs which place the trace in the position selected. Positions 1, 3 and 4 of switch A are used during setting up.

## North Marker Switch

29.8. As the aerial rotates, switch A in the Synchro assembly (S1/1) closes once per revolution. This data is fed to the north marker generator circuit in the waveform generator integrator. The circuit arranges for one trace to receive extra brightness and the cam position is usually adjusted so that switch A makes as the antenna passes through true north.

## Local Monitor Display

29.9. Since the monitor display is situated in close proximity to the aerial head a servo system, as used to convey data to air traffic control displays is unnecessary. The sin/cos resolver is therefore housed in the aerial cab and turned, through suitable gearing, at 12 r.p.m. by the aerial turning motor. The sin/cos output voltages, along with north marker data are fed to the local sweep generator integrator to produce a PPI display in the manner described above.

CHAPTER 30

# BEARING RESOLVER CHAIN, CIRCUIT ANALYSIS

## Introduction

30.1. In the bearing resolver system, bearing information from the aerial head ensures that all PPI displays rotate in step with the aerial at 12 r.p.m. Up to three displays are normally situated as under:

a. Two operational dusplays at air traffic control.

b. A monitor display at the aerial head.

## Air Traffic Control Display

### Synchro System

30.2. The aerial motor, housed in the aerial machine cab, turns two control transmitter synchro rotors, one at aerial speed (low speed), and the other through suitable gearing at 36 times aerial speed (high speed).

30.3. To prevent phase discrimination, the rotor a.c. supplies are fed from the Power Supply S43/1 (Aerial Follower PU) via land line, and the Impedance Matching Network S3/1 (Cable Compensation Unit), to the low and high speed transmitter rotors. Bearing information from the control transmitter synchro stators is fed via the cable compensation unit and landline to the stators of the low and high speed control transformer synchros in the Synchros Signal Amplifier S23/1 (Aerial Follower). The rotors of the control transformer synchros are turned by a servo motor in the aerial follower at aerial speed (low speed), and 36 times aerial speed (high speed), respectively. Control of the servo motor speed is effected by the difference in position between transmitter and control transformer rotors.

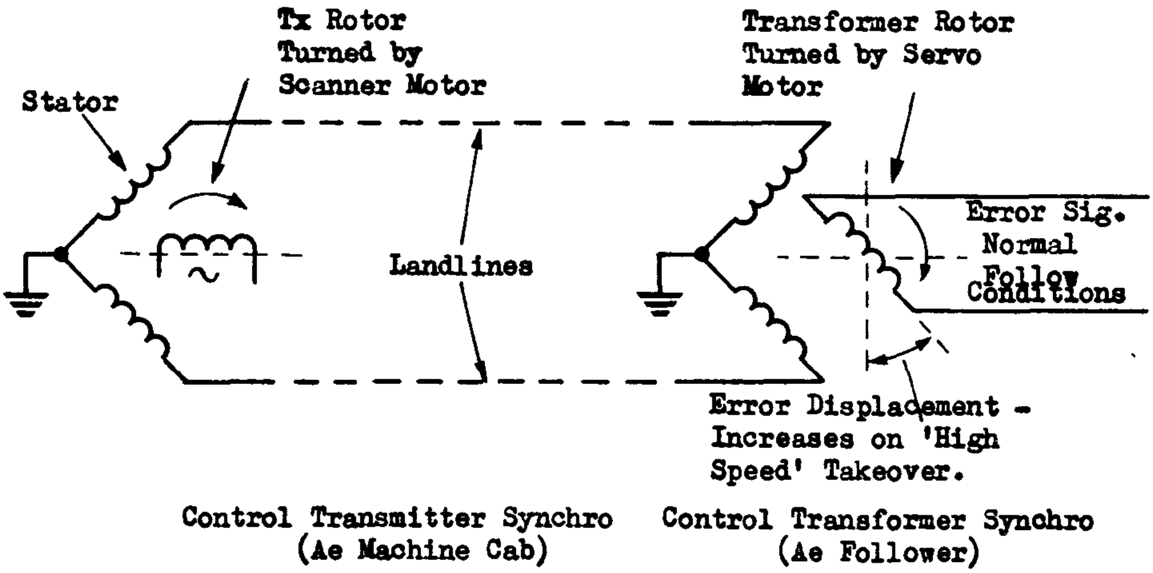



Diagram shows low speed system, transmitter rotor turning 12 r.p.m., high speed system (36 x aerial speed) is identical, but error displacement, hence error signal, is increased 36 times.

Fig 30.1.

30.4. On the normal FOLLOW position of switch A the error signal from the low speed control transformer rotor is fed via RL1 contact 2 and a phase correction circuit to the grid of V13A. V13A output passes via a servo amplifier V5, V6, V7 and V8 and T2 to provide the second phase for the two phase servo motor, one phase being fed from T1. Since the servo motor turns the control transformer rotors the error signal will gradually be reduced until the low speed system cannot reduce the discrepancy further.

High Speed Takeover

30.5. When the error signal has reached a minimum value on low speed, and provided the error signal is non-ambiguous, the system will go over to high speed. As the error signal falls, V1 anode signal falls and V3A, an anode bend detector passes less current and its anode volts rise. A non-ambiguous state exists when the input to V2 (3R winding in series with a 2.5V a.c. reference voltage) is also a minimum, ie in anti-phase. This will cause a further rise, due to V3B, at V3 anode and RL1/2 in the anode of V2 will energise. RL1 contact 2 changes over and the error signal from the high speed control transformer synchro rotor is now passed to the servo amplifier. Since the high speed rotor is 36 times removed physically from the low speed rotor the error signal is greatly increased. RL1 contact 1 reduces the servo amplifier input under high speed conditions and the system now reduces the follow error to an absolute minimum.

Feedback System (See Para 30.18).

30.6. Since a high gain, closed loop follow system is employed, there is a danger of oscillation occurring, particularly during acceleration or deceleration. To offset this, velocity and delayed velocity forms of negative feedback are incorporated.

30.7. The feedback voltage is derived from a tacho-generator which is rotated by the servo motor. The input tothe tacho-generator is 50V a.c. from T1 and the output has an amplitude dependent upon speed of rotation and a phase dependent upon direction of rotation.

30.8. Velocoty feedback (d) is fed direct from the tacho-generator via the PHASE ADJUST control (RV8) and the VELOCITY FEEDBACK control (RV4) to amplifier V13B. The output from V13B is fed via contacts 1 and 2 of relay 2 and V13A to V5B of the servo amplifier. Since the tacho-generator output is in anti-phase to the error signal volts any sudden change at the servo amplifier input will be opposed by the velocity feedback.

30.9. In the delayed velocity feedback system, the balanced modulator produces no output provided there is no tacho-generator output fed to the phase sensitive rectifier V10 V11. When the tacho-generator produces an output, the grids of V12 are unbalanced and there will be an output from V12 anode due to the 6.3V a.c. fed to V12 cathode from T1. If the servo motor changes direction V12 grids will be unbalanced in the reverse manner and the delayed velocity feedback signal from the anode of V12 will change phase by 180°. Any change in tacho-generator output does not immediately result in a change of signal at V12 anode because of the delaying CR networks between V10, V11 and V12.

30.10. Any change in the tacho generator output is therefore apparent at the balanced modulator grids after a short delay. Since the delayed velocity feedback (e) is always in anti-phase to the velocity feedback, during normal follow conditions, (no change in error signal amplitude or tacho-generator output), the two feedbacks will cancel at V13B.

a. Sudden scanner acceleration. Para 30.18, Case 1.

b. Sudden scanner decleration. Para 30.18, Case 2.

30.11. Should the error signal volts change phase by 180° (eg due to movement of scanner, after FREE RUN conditions etc.) the servo motor, hence tacho-generator, will reverse direction. Both feedback systems will reverse phase by 180° and circuit stability will be maintained until the servo system has corrected the direction of rotation of the servo motor. For the action of the phase sensitive rectifier see para 30.19.

Sin/Cos Resolver

30.12. The sin/cos resolver potentiometer, geared down to 12 r.p.m., is driven by the servo motor. The sine and cosine outputs are fed to the Sweep Generator Type S20/1 (Waveform Generator Integrator) and the timebase waveforms produced feed the Sweep Generator Type S15/1 (Deflection Amplifiers) in the two display cabinets.

Switch A (Aerial Follower Front)

30.13. A four position switch which selects the foregoing normal follow action or one of three test positions as under:

a. Position 1 - FREE RUN.

b. Position 2 - FOLLOW.

c. Position 3 - 0°.

d. Position 4 - 270°.

30.14. Free Run. In this position of switch A, the inputs to the low and high speed control transformer synchro stators are removed and relay RL2/2 is energised. Since the error signal input to V1 is zero, and the anode of V2 is at earth potential, the potential at V4 grid is such as to cause RL1/2 to be energised. The system will therefore operate in high speed conditions. 6.3V a.c. is fed from T1 via the FREE RUN speed control (RV3), SA5 and relay 1 contact 2 to V13A grid and the servo amplifier. Relay 1 contact 1 and relay 2 contact 2 reduce the input to the servo amplifier under free run conditions. As there is no error signal to reduce, the feedback system is earthed by relay 2 contact 1 and the servo motor speed can be controlled by RV3. On FREE RUN therefore, the servo motor and resolver potentiometer can rotate at 12 r.p.m. independent of aerial rotation, for test purposes.

30.15. 0° and 270°. In these two test positions of the switch A, the PPI trace is made to assume a fixed position at the bearing selected.

a. 0°. A 70 V a.c. supply from T1 is fed to the 1S winding of both the low and high speed synchro control transformer stators. The motor then turns the rotors until they are so aligned as to receive no error signal from the energised system after which the system stops. The low speed and high speed system is used to obtain the positioning accuracy as in the FOLLOW condition.

b. 270°. The 70 V a.c. supply from T1 is fed to the 4S low speed stator winding and the 1S high speed stator winding. This energising voltage will simulate the exact stator conditions as the aerial passes through 270°.
NB: 90° displacement of the low speed rotor is the equivalent of 9 complete revolutions of the high speed rotor. The low speed, high speed system is again used to obtain positioning accuracy.

North Marker Switch

30.16. A cam, driven by the aerial turning motor, closes switch A in the synchro assembly (S1/1) once per aerial revolution. This will occur normally as the aerial passes through true north. Switch A completes an earth line to the north marker generator in the waveform generator integrator. The north marker generator arranges for one trace to receive extra brightness on the bearing corresponding to the aerial position when switch A closes. (See Timebase Chain, Circuit Analysis, Chapter 32).

Local Monitor Display

30.17. Since the monitor display is situated in close proximity to the aerial head, a servo system as used to convey data to the air traffic control displays, is unnecessary. The sin/cos resolver is therefore housed in the aerial cab and turned directly at 12 r.p.m. by the aerial turning motor. The 50 volts positive and negative required for the resolver are fed from the positive display power unit (S27/1). The sin/cos output voltages, along with the north marker data are fed to the sweep generator integrator to produce a PPI, as previously described.

30.18.

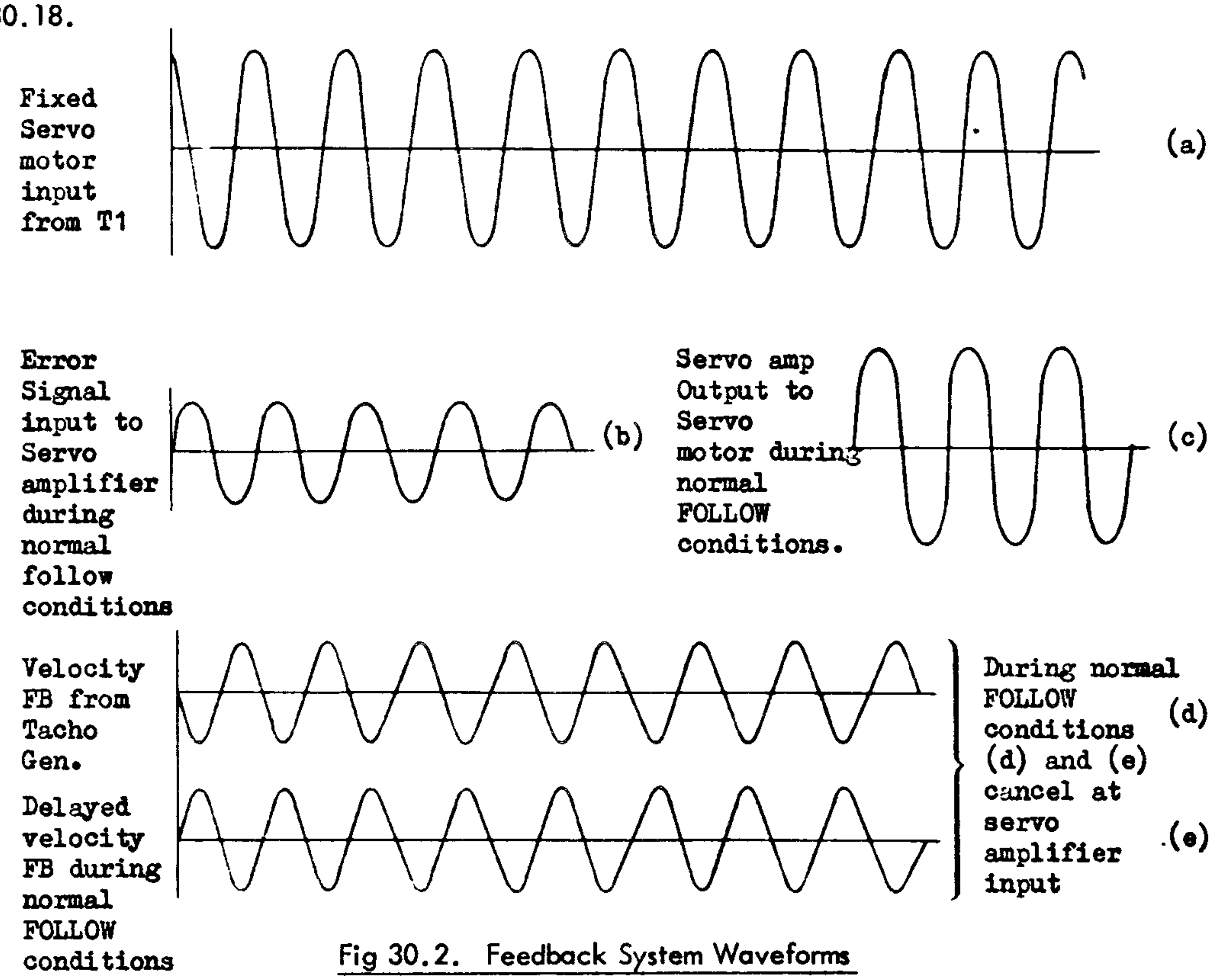



Fig 30.2. Feedback System Waveforms

Case 1. a. Scanner accelerates suddenly, control transformer synchro field leads more on rotor, error signal (b) increases. Servo amplifier output (c) increases and servo motor speeds up. Tacho-generator output increases and direct FB (d) increases to offset sudden rises at servoamplifier input.

b. Delayed FB (e), in antiphase to direct feedback cannot change immediately so a strong NFB voltage is applied to offset sudden increase at servo amplifier input.

c. Since this is a closed loop system the p.p.i. should rapidly make up on the scanner with minimum overshoot and hunting.

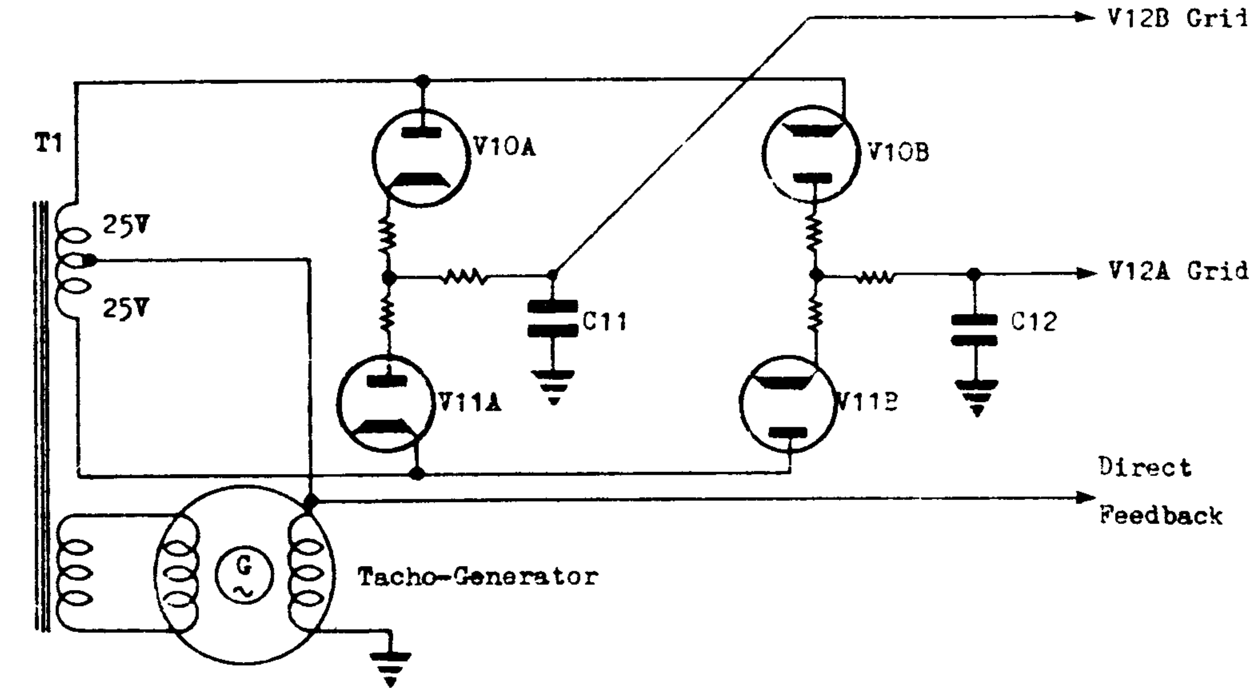
d. Servo amplifier output falls to original state,(d) again cancels (e), - normal FOLLOW conditions.

Case 2 a. Scanner decelerates suddenly, control transformer synchro field leads less on rotor, and error signal (b) decreases. Servo amplifier output (c) decreases and servo motor slows down. Tacho-generator output decreases and direct FB(d) decreases to offset sudden fall at servo amplifier input.

b. Under these conditions the delayed FB (e) boosts the falling input to the servo amplifier and stops too rapid a deceleration.

c. Servo amplifier output rises to original state, (d) again cancels (e) normal FOLLOW conditions.

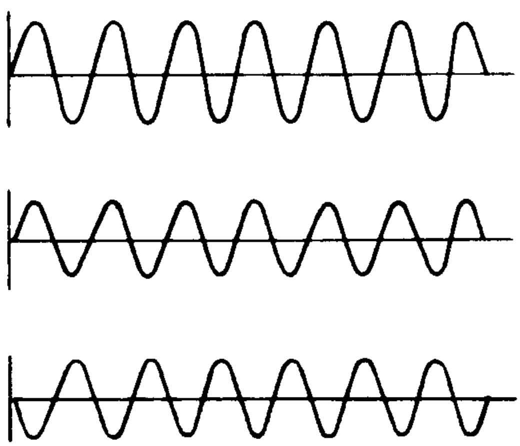
30.19. Phase Sensitive Rectifier




25V-0-25V Output
From T1

The Tacho-Geerator Output
Phase is dependent on
direction of rotation and
amplitude on speed of
rotation

Tacho-Generator Output
if rotation reversed.



(a)

(b)

(c)

Fig 30.3. Phase Sensitive Rectifier Circuit

a. With no output from the tacho-generator the 25 V - 0 - 25 V will cause V10A V11A and V10B V11B to conduct on alternate half-cycles. C11 and C12, under such conditions, will receive equal and opposite charges and remain at zero volts. There will therefore be no difference in potential between the grids of V12A and V12B.

b. With output (b) from the tacho-generator.

(1) On the first half-cycle V10A current increases (positive charge C11), and V11A current decreases (Negative charge C11) so C11 becomes positively charged.

(2) On the next half-cycle V10B current increases (Negative charge C12) and V11B current decreases (Positive charge C12) so C12 becomes negatively charged.

(3) A potential difference therefore exists between V12A and V12B grids, polarity dependent upon tacho-generator phase and magnitude upon tacho-generator output amplitude.

c. If tacho-generator output changes phase to (c) then V12A and V12B grid polarity will reverse.

CHAPTER 31

# TIMEBASE CHAIN

## Introduction

31.1. All timebases in the system are originated by the $T_o$ - 100 µS prepulse produced in the trigger select chain by the selected operational transmitter. The prepulse is split in the Impedance Matching Network Type S1/1 and used to initiate both monitor and air traffic control displays.

31.2. Monitor Display.

The prepulse, together with sine and cosine resolver, and north marker data from the aerial cabin, is fed to the Pulse Generator Power Supply Type S18/2 (Base Unit) which houses the Pulse Generator Typs S14/1 (Waveform Generator).

31.3. Air Traffic Control Displays.

The prepulse is fed via the Amplifier Converter Type S25/1 (MTI and prepulse amplifier) and the Modulator Oscillator Type S3/1 (Cable drive Modulator) both units being in the Amplifier Power Supply Type S30/1 (Signal Booster Rack) to the land line. At air traffic control the prepulse is fed to the Synchros Signal Amplifier Type S23/1 (Aerial Follower) contained in the Amplifier Power Supply Type S29/1 (Upper Base Unit). From the upper base unit the prepulse goes to the Electronic Marker Generator Type S21/1 (Waveform Generator, Video) contained within the Pulse Generator Power Supply Type S18/1 (Lower Base Unit). Sine, cosine and north marker data is also fed from the bearing resolver chain to the Sweep Generator Type S20/1 (Waveform Generator, Integrator).

31.4. Pulse Generator Type S14/1 (Waveform Generator).

In both monitor, and air traffic control displays, the waveform generator, (video and integrator) produces the timebase waveforms which are fed to the respective deflector amplifier units in the display cabinet, Azimuth Range Indicator Type S5/1 (Viewing Unit).

## Air Traffic Control, Timebase Chain

31.5. Amplifier Power Supply Type S30/1 (Signal Booster Rack)

The prepulse, together with MTI video, is fed into the signal booster rack and amplified in the MTI and prepulse amplifier prior to being fed into the cable drive modulator. In this unit both MTI video and prepulse are superimposed on to a 20 MHz carrier for suitable conveyance down landline to the upper base unit.

## Aerial Follower

31.6. RF Amplifier Type S24/1 (Post Cable Amplifier)

This unit which is a sub chassis of the aerial follower, compensates for land line losses and by detection removes the 20 MHz carrier.

31.7. Lock Pulse Separator.

Removes the MTI video and feeds the $T_o$ - 100µS display prepulse to the waveform generator (video) in the lower base unit.

Waveform Generator (Video)

31.8. The display prepulse is fed via the TRIGGER SENSITIVITY control (RV34) and the polarity correction links AB, through the NORMAL/TEST switch and transformer T8 to a delay circuit. In the CR787A system, the links remain in the 'delayed' position and the prepulse is delayed so that the timebase starts coincident with the transmitter firing at $T_o$. This delay is variable by TRIGGER DELAY control (RV35).

31.9. Range Mark Generator

Initiated by the range ring gate fed from the waveform generator (integrator) to the calibration oscillator, the range mark generator circuit produces range rings on the PPI at 1, 5, 10 and 25 nautical miles from the origin. Range rings are fed to an amplifier in the video mixer units of the two air traffic control displays.

31.10. Calibration Check

With the calibration test oscillator switched on, and NORMAL/TEST switch on 'TEST', the calibration oscillator can be corrected by means of a calibration check oscillator (80.89 kHz crystal). A small c.r.t. is used for visual comparison of the two oscillators and T4 in the calibration oscillator provides frequency adjustment. In order that a stable lissajou figure can be produced under these test conditions, a synchronising pulse is fed from the crystal test oscillator to the test trigger multivibrator.

Waveform Generator (Integrator)

31.11. The delayed prepulse fed to the integrator produces a range gate, variable in length by RV1 (timebase duration) to give a timebase 100 nautical miles in length, (1236µS). A splitter tube feeds the range ring gate to the waveform generator (video) and, via a cathode follower, bright up waveforms to the video mixer units of the air traffic control displays.

31.12. North Marker Generator

A version of the range gate is fed from a second splitter tube to the north marker generator circuit together with north marker data from the bearing resolver chain. The north marker bright up waveform is then fed to a north marker amplifier in the video mixer units of the air traffic displays.

31.13. X and Y Integration Units

The sine and cosine bearing data from the bearing resolver chain is fed to X and Y integrating circuits via the NORMAL/TEST switch. During the range gate time, integrating capacitors charge to the sine and cosine instantaneous values to produce the timebase. Gate phase splitters arrange for the integrating capacitors to be fully discharged between scans. Various controls assist in ensuring that the produced sawteeth start from earth potential and rise linearly. The X and Y sawteeth are then fed to the deflection amplifier units in the two display cabinets. Monitoring test points are provided where necessary and are shown on the chain diagram.

Sweep Generator Type S15/1 (Deflection Amplifier)

31.14. The X and Y integrated waveforms are fed from the waveform generator (integrator) to X and Y deflection amplifiers. In this unit the sawtooth input provides, via the master and slave amplifiers, a very linear rise or fall of current through the c.r.t. deflection coils in the display unit during scan time.

Control Indicator Type S13/1

31.15. This unit houses several controls affecting the deflection amplifiers:

a. The range switch SA1 which, through a combination of relays:

(1) Alters the feedback to V1 hence the gain and final timebase velocity.

(2) Keeps V1 grid at a constant d.c. level irrespective of range selected.

b. The OFFSET/CENTRE control switched to 'CENTRE' allows the centring of the spot to be effected by the preset X and Y centre controls (RV6 RV106). If placed to 'OFFSET', RV3 RV4 in the control unit provide offset facilities and trace expansion to 100 nautical miles on the three lower ranges 10, 25 and 50 nautical miles.

Video Amplifier Type S17/1 (Video Mixer)

31.16. This unit accepts all inputs required to be fed to the display c.r.t. and control of the input where necessary is effected in the control indicator Type S13/1. Circuits and inputs affecting the final c.r.t. display are as under:

a. MTI/Normal Radar. Amplified in the video mixer and fed to c.r.t. cathode (see MTI Distribution Chain Diagram).

b. Normal Radar (Contrast). Amplified in the video mixer and fed to c.r.t. cathode (see Normal Radar Signal Chain Diagram).

c. Range Rings. Gain controlled by RV2 in the control unit S13/1 and, amplified in the video mixer unit, they are fed to the c.r.t. cathode.

d. Bright Up. Controlled by RV10 (BRIGHTNESS) in the control unit S13/1. The bright up waveform is amplified in the video mixer and fed to the c.r.t. grid.

e. North Marker. Controlled by RV9 (BEARING MARKER) in control unit S13/1. The north marker brightening waveform is amplified in the video mixer and fed to the c.r.t. grid.

f. Focus. Effected by the c.r.t. focus coils, the current through which is controlled by RV7 (FOCUS) in control unit S13/1, and V16, a focus current stabiliser.

g. X and Y Pre-centring. These controls, RV11 and RV12 (X and Y PRE-CENTRE) in the control unit S13/1, are normally capped and unused. In conjunction with the links and resistor network shown in the video mixer, RV11 and RV12 can adjust the direction and magnitude of a steady current through the pre-centring or anti-bow coils, thus ensuring a central spot should a new c.r.t. be fitted.

h. Other Facilities. Shown on the diagram, these facilities are available but not used at present.

Monitor Timebase Chain

31.17. The prepulse, sine, cosine and north marker data fed to the Pulse Generator Power Supply Type S18/2 (Base Unit) are utilised to provide a single monitor display at the aerial head, in exactly the same manner as previously described for air traffic control displays.

# CHAPTER 32

## TIMEBASE CHAIN, CIRCUIT ANALYSIS

### Introduction

32.1. The display prepulse at $T_o$ - 100 μS is fed from the Impedance Matching Network Type S1/1 to:

a. The radar head monitor display.

b. The combining circuits on the MTI and Prepulse Amp for processing and transmission along the land line to the air traffic control displays.

32.2. The circuit analysis of the units concerned in para 32.1b. is covered in the MTI Distribution Chain, Chapter 25.

### Air Traffic Control Displays

### Lock Pulse Separator (Aerial Follower)

32.3. The output from the Post Cable Amplifier consists of positive MTI video signals and negative display prepulse. The composite signal waveform is fed to diode V17 which blocks the positive video signals. The prepulse passes through V17 and produces a negative pulse across the primary winding of transformer T5. Inversion in T5 produces a positive pulse for application to the grid of amplifier V18. This valve shares a common load with blocking oscillator V19. The negative pulse across the primary of T6 is inverted and the positive pulse produced across the secondary triggers the blocking oscillator. The large positive pulse produced across R162 is fed to the electronic Marker Generator S21/1 (Waveform Generator Video).

### Electronic Marker Generator S21/1 (Waveform Generator Video)
### Sweep Generator S20/1 (Waveform Generator Integrator)

### Display Trigger Production

32.4. In the waveform generator (video), facilities are provided to allow either positive or negative input triggers to be accepted. The $T_o$ - 100 μS display prepulse from the lock pulse separator is delayed, so as to produce a trigger at, or a suitable time prior to, $T_o$.

32.5. The input trigger pulse is developed across RV34 (TRIGGER SENSITIVITY control) and a portion is picked off and fed via links to the transformer T8. These links allow the windings of T8 to be so arranged that a positive pulse is always applied to the grid of V50, the inverted negative pulse is fed via V44A and C130 to the grid of the delay phantastron V43. The anode potential of V43 is adjustable by RV35 acting through the anode catching diode V44B. By adjusting the h.t. on V43, the rundown time, and hence the width of the positive going square wave at V43 screen, can be adjusted. The fall at the trailing edge of this positive going screen waveform is arranged to occur at $T_o$ and is applied to the anode of the blocking oscillator V51B via SCR R401/C132. Inversion in transformer T9 causes the blocking oscillator to be triggered and the negative pulse at $T_o$ produced in its anode circuit is fed out to trigger the main range gate circuit in the waveform generator (integrator) chassis.

32.6. For test purposes an internal trugger pulse is produced by the free running multivibrator formed by V49A and V49B. The h.t. to V49 is made via switch A, (TEST/NORMAL switch), and is only made on 'TEST'. The p.r.f. of the multivibrator is adjustable between 300 and 700 p.p.s. by RV32.

Range Mark Production

32.7. The display trigger is fed to V1 in the integrator via diode V2B; V2A removes any positive spike. The trigger initiates an anode run down in V1 and also a positive screen square wave. The anode potential of V1, hence the time of the run down and screen square wave width, is set by the TIMEBASE DURATION control (RV1). The positive going square wave from V1 suppressor is applied to phase splitter V3A from the cathode of which a positive going range gate is fed to inverter V51A in the waveform generator (video).

32.8. The integrating circuit C84, RV31, allows the leading edge of this negative going waveform to be adjusted so that it is applied to the suppressor of the calibration oscillator at the correct time to produce range markers. The waveform is d.c. restored negatively by V25B and is used to cut-off anode current in the calibration oscillator V26. Without the negative gate, V26 conducts but the feedback is not of the correct phase to sustain oscillations. When the anode current is cut-off the valve current flows to the screen and the circuit functions as a triode oscillator, the screen acting as the anode. The oscillator frequency is tunable between 80 and 89 kHz by a slug in the windings of the oscillator transformer.

32.9. The output oscillations are squared in V27A, and the square wave is differentiated by C67, R231 and the positive pips produced are used to trigger the blocking oscillator V27B. The posotive pulses produced in the cathode of this valve are the one mile markers and are fed to the grid of the output cathode follower V33.

32.10. The negative pulses produced at V27B anode are used to trigger the phantastron divider V29, the coupling being via the diode V28A and C71. The rundown time of the phantastron and hence the width of the square wave produced at its screen is set by RV25 acting through the anode catcher V28B. After inversion in V30A the falling leading edge of the square wave, occurring every five miles, is inverted in transformer T3 and cuts on the blocking oscillator V30B. Positive going five mile markers are fed to the grid of V33 from the cathode of V30B.

32.11. A positive trigger for the divider by two, (ten mile blocking oscillator) is also taken from the cathode of V30B. The grid of this blocking oscillator V31A is stabilised in its action by the diode V32A which clamps it at a potential just below cut-off whilst awaiting triggers at 10 miles, 20 miles, etc. Positive 10 mile markers are also taken from V31A cathode to the grid of the output cathode follower V33.

32.12. The 20 mile blocking oscillator V31B is triggered from the cathode of V31A and has its grid stabilised by diode V32B. Positive 20 mile markers are taken from the cathode of V31B to the grid of V33.

32.13. At the grids of the two parallel connected cathode followers (V33A and V33B) appear a mixture of 1 mile, 5 mile, 10 mile and 20 mile markers. The amplitude of the 1 mile markers is fixed, all the others are adjustable. The relative amplitudes of the mixed markers are set so that as the range marker control on the display is advanced the markers are displayed with graded brightness with the 20 mile markers brightest.

32.14. On position 11 of the monitor switch, a crystal oscillator, V47A, may be used to check the frequency of the calibration oscillator V26. The sine wave outputs of both oscillators are applied to the deflection plates of the monitor c.r.t., V48, so that when both oscillators are operating at the same frequency a single lissajou figure is produced. Since the calibration oscillator is gated it is necessary that both outputs are maintained in correct phase relationship so that a steady figure is displayed. For this reason a sample of the crystal oscillator is taken via MR6 to synchronise the internal trigger circuit V49. The TEST/NORMAL switch must be at 'TEST' in order to check the frequency of the calibration oscillator. RV33 controls the brilliance of the c.r.t.

North Marker Generator

32.15. The north marker circuit obtains its input from a micro-switch in the Synchro Assembly S1/1 which closes when the aerial passes through 0°. The circuit consists of V22, V23 and V24.

32.16. V22 is normally held cut-off at both its grid and its suppressor. Closing of the micro-switch short circuits R177 and raises V22 grid but cannot produce anode current since the suppressor is still held below cut-off. At $T_0$ the positive range gate from V4 screen lifts the bias on V22 suppressor. During the range gate therefore the north marker will appear as a negative pulse at the anode of V22. This pulse is applied to the monostable multivibrator V24A, V24B. The natural period of this monostable vibrator is much longer than the maximum range of the equipment and it produces a positive going pulse at the cathode of V24A. The static state of V24A cut-off, V24B conducting, is reversed by the negative pulse from V22 fed via C46 to the grid of V24B cutting this valve off and establishing current in V24A. The north marker output is taken from V24A cathode to the brightener mixer circuit in the video mixer on the viewing unit.

32.17. To ensure that only one trace is brightened, a negative end of scan pulse from V3B is applied via C44 and diode V23B to the grid of V24A. This returns the flip flop to its stable state. The lagging, falling edge of the anode waveform at 24B anode (corresponding to the end of scan point), is fed back to the grid of V22. It is d.c. restored by V23A and ensures that V22 is cut-off in case the micro switch is still closed. Without this the pulse at V22 grid could continue until the next range gate appeared at V22 suppressor. Should the micro switch close during a range gate application to the suppressor grid, C41 transfers the screen fall to the grid. The grid will rise exponentially and the next suitable range gate to the suppressor grid will trigger V24.

Main Scan Brightness

32.18. The main brightener waveform is produced in the parallel connected V7A and V7B. The negative going range gate from the anode of V3A is used to cut-off V7, which is normally heavily conducting. The positive going square waves from V7 anode are taken to the brightener mixer circuits of the video mixer chassis on the viewing unit.

End of Scan Pulse

32.19. A pulse is also produced to mark the end of scan time, ie the end of the range gate. The negative going square wave at V3A anode is differentiated by C5, R20 and applied to the grid of V3B. This valve is normally cut-off so that the negative spike at $T_0$ has no effect but the positive spike marking the end of the ramge gate cuts on V3B and produces the negative going end of scan pulse at V3B anode which is fed to the north marker circuit, and the waveform generator video.

Recap Para 32.7.

32.20. The range gate is a positive going square wave of precise width taken from the suppressor of V1 and fed to the grid of the phase splitter V3A. The negative range gate at V3A anode is used to cut off V4. This valve connected between earth and -500 V is normally conducting heavily but for the period of the range gate is cut-off, and its anode, being d.c. coupled to the grids of two further phase splitters V5 and V6, rises far enough for these two valves to be cut on for the period of the range gate. V5 and V6 therefore produce positive square waves at their cathodes and negative square waves at their anodes, the widths of these square waves corresponding to the duration of the range gate. The outputs from V5 are used to gate Y integrator circuit and those from V6 gate the X integrator. The Y integrator circuit consists of V8 - V14 and the X integrator comprises V15 - V21. Both circuits are identical and only the X channel will be described.

32.21. The X integrator valve is V15 and C33 the integrator capacitor. The input to the integrator is derived fro m the sine/cosine potentiometer which rotates in sympathy with the aerial and produces voltages proportional to the sine and cosine of the aerial bearing. DC voltages of equal amplitude but opposite polarity are applied across the windings of the potentiometer. Two wipers are spaced 90° apart and are aligned so that when the aerial is at a position corresponding to 0° the wiper producing the sine output is at zero volts and the wiper producing the cosine output is as +50 volts d.c. maximum. As the aerial rotates the voltages at the wipers will vary between +50 V and -50 V but are always 90° out of phase. These voltages are fed to the X and Y integrator circuits. The sine input is applied through a matchi ng resistor network to the grid of V15 and to one plate of C33. In between traces the clamp diodes V16 and V17 are conducting and form a short circuit across C33. The sine input can have no effect upon the grid voltage of V15 whilst the clamps circuit is operating.

32.22. At $T_0$ when the range gate begins, the diodes are gated off by the square waves from V6, This consists of a positive square wave at V17 cathode and a negative square wave at V16 anode. V15 grid now tends towards the sine potential from the sine/cosine potentiometer. The potential at V15 anode between gating waveforms is about +240 volts; this anode voltage will vary about this level positively or negatively according to the polrity of the sine input. The integrator action produces a sawtooth waveform of maximum amplitude of 150 volts. At the end of the range gate the diodes conduct and rapidly discharge C33; this is the flyback.

32.23. The voltage swing at V15 anode is fed to the cathode follower V18A. This valve has V19A connected as a constant current valve in its cathode circuit, this arrangement allowing the starting level of the sawtooth waveform to be shifted from +240 volts to zero volts without varying the amplitude of the sawtooth. This sawtooth is fed to another cathode follower V18B which also has a constant current valve, V19B, in its cathode. The feedback loop to the other plate of C33 is completed from V18B cathode. RV20 in the cathode of V18B is the zero level control and ensures that the waveform applied to the output driver V20 does vary with respect to zero. The output cathode follower V20 also employs a valve, (V21), as a cathode load to improve linearity. The sawtooth output is taken to the deflection amplifiers on the viewing unit.

32.24. The deflection amplifiers convert the sawtooth input voltages from the integrators into sweep currents for the deflection coils. DC coupling is used and the use of high gain amplifiers plus a large amount of negative feedback ensures good frequency response and an accurate current copy of the input waveform. The components of the deflection amplifiers are mounted on a hinged chassis on the right hand side of the display c.r.t. (as viewed from the tube face). The X and Y channel amplifiers are identical in circuitry and operation and only the X channel is described here.

32.25. The master amplifier consists of V1 and V2A. When the input from the waveform generator unit (integrator) is a positive going sawtooth. This waveform is amplified and inverted in both V1 and V2A so that an amplified positive sawtooth is applied to the grids of the parallel connected output amplifiers V3 and V4. The X deflection coil is connected to the junction of the anodes of V3 and V4 with the cathodes of V5 and V6. These four valves are connected in two parallel pairs in series between the +330 V and the -330 V rails. The positive waveform at the grids of V3 and V4 drives current through these valves via the deflection coils to earth. This results in a fall in voltage at the anodes of V3, V4 which is fed via C14, R32, R33 to the grid of V8B in the slave amplifier circuit. The slave amplifier consists of V8B and V7. The fall at V8B grids appears in an amplified form at V7 anode and is fed to the grids of V5 and V6. This lowers the current in these two valves and since that current was being drawn through the X deflection coil in opposition to the sweep current, it therefore assists the main amplifiers V3 and V4. The gain of the amplifiers is controlled by RV3 in series with the X deflection coil. Limiting for a positive going input is provided by V2B; this valve is biased at its grid by the MAIN AMP LIMIT control (RV2) and for small inputs is cut-off. Its cathode is connected to the junction of R28 and the earthy end of the X deflection coil. As described above the positive input waveform lowers the potential at this point. When the junction falls sufficiently V2B cuts on and its anode voltage starts to fall. When V2B cathode is driven sufficiently negative its anode falls to a very low potential and as the anodes of V2A and V2B are d.c. coupled then the master amplifier V2A cannot pass any further drive to the grids of V3 and V4. The point at which this limiting occurs is set by RV2.

32.26. With a negative going input sawtooth from the waveform generator ( integrator) this falling waveform is amplified in the master amplifier V1, V2A and when applied to the grids of V3 and V4 it reduces their current, thus raising their anode potential. This rise is fed to the slave amplifier V8B and V7 and the amplified rise is applied to the grids of V5 and V6. Current is now drawn through the X deflection coil by V5 and V6 in the opposite direction to that flowing when the input waveform was positive going. Limiting action is provided with a negative input by the diode connected V8A. This prevents the grid of V8B from rising above the level set by the Slave Amp Limit control RV4.

32.27. Negative current feedback to the grid of V1 is taken from across R28 and RV3, via a network consisting of R43, 46, 47 and 48, C1, 2, 3 and 4, as selected by the range relays. The amount of feedback ,and hence the gain, is controlled by RV3 and is adjusted to balance that of the Y channel amplifiers. Negative feedback is also applied to V8B, the feedback voltage being taken across R23 and applied to V8B via C13, R24. The series connected diodes V9A and V9B limit the extent of the coil overswing voltage rising in the positive direction to +330 volts. The heaters of the diodes are held at +165 V to minimise the danger of heater, cathode insulation breakdown.

32.28. The display may be offset by up to 100 miles in order that a more detailed survey on a particular area might be made. The offset voltage is obtained from the X OFF-SET (shift) control (RV13), on the indicator front control panel and is applied to V1 via a resistive network. This voltage is added to the re-centre voltage, which ensures that the off-set position of the display remains constant when the range switch is altered. The offset voltage changes the standing d.c. level throughout the amplifier and changes the standing current in the deflection coil, hence moving the centre of the display.

Video Amplifier S17/1 (Video Mixer)

32.29. For introduction to circuit analysis of the video mixer unit refer to MTI Distribution Chain, Circuit Analysis, Chapter 24.

Protection Circuits

32.30. Switching power to other units in the equipment may momentarily upset the outputs from the stabilised power units resulting in unwanted sudden changes of brightness on the display. To prevent this the grid of V17B, the shunt control valve of the +70 V rail, is returned to the -330 V rail through a long time constant circuit R109, C44; this ensures that should the -330 V rise towards earth V17B grid cannot follow immediately; if it could the lowering of the +70 V line would simulate an input signal and raise the c.r.t. brightness. A similar effect would be apparent if the h.t. line to V4 and V5, the +330 V rail, were to fall. To avoid this the +330 V rail is connected via C47 to the cathode follower V6B; any fall in the +330 V rail thus appears at V5 grid and offsets any rise fed from V1, V3, V4 to the grid of V5. The diode MR3 is included to ensure that when the equipment is first switched on, the rising +330 V rail is not passed via V6B lowering the cathode of the tube and causing burns on the tube face.

32.31. The brightener waveform from the waveform generator is applied to the grid of V14B and the north marker pulse to the grid of V14A. The anodes of these two valves are strapped and connected to the amplifier V15. The positive going brightener and north marker pulses are from from V15 anode to the grid of the c.r.t. The amplitude of brightener pulse applied to V15 is controlled by biasing V14B with RV5 so that a pulse of 40 V amplitude is produced at the output from V15. The level above which this pulse is produced is set by the brightener level control acting on the screen of V15. DC coupling is employed between V15 and the c.r.t. grid and the front panel brightness control sets the anode voltage of V15, ie the c.r.t. grid potential. The diode MR2 is a positive d.c. restorer for the grid of V15 and C46 is included as further protection against brightening of the c.r.t. by unwanted surges. Any tendency for the -330 V rail to rise is fed via C46 to the grid of V15, thereby lowering the c.r.t. grid.

32.32. A fine control of the display focusing is effected in the video mixer unit. The focus coil current flows through V16, this valve being connected in series with the focus coil between the +330 V and -330 V rails. Varying the grid potential of V16 varies the focusing current.

32.33. As mentioned previously in the CR787A installation, not all facilities present in the indicators are used. This is the case with V12B, V13A and V13B. The grids of these valves are therefore returned to the -330 V rails via 1.8 meg ohm resistors, with no inputs they remain cut-off.

## Anti-Bow Coils

32.34. Outputs are also taken from resistive networks in the video mixer unit to anti-bow coils around the neck of the c.r.t. The resistive networks are connected to the +330 V and -330 V rails and feed the coils via the pre-centre controls on the indicator control panel. These controls are adjusted using a bearing test set to ensure minimum radial distortion of the trace.

## Monitor Display

32.35. The sin/cos data for the monitor display is originated in a sin/cos potentiometer housed in the aerial machine cab and turned by the aerial turning motor at 12 r.p.m. With this exception the display is produced in exactly the same manner as the air traffic control displays.