TL MICROWAVE RADIO
DESCRIPTION
TRANSMITTER

1. GENERAL

1.01 The basic purpose of the TL radio transmitter is to develop approximately 100 milliwatts of modulated microwave power for transmission in the 10.7- to 11.7-kmc common carrier band. The carrier frequency of the transmitter is stabilized by maintaining constant klystron operating temperature using a vapor-phase cooling system. Klystron output signals are passed through an isolator and waveguide networks prior to application to the antenna system. RF monitoring facilities are provided to assist in transmitter tuning and maintenance.

1.02 The transmitter is capable of being frequency-modulated with either simple or composite baseband signals. Baseband information is first amplified in the transmitting baseband amplifier. The output from this wide-band amplifier is applied to the transmitting klystron repeller circuit to modulate the microwave output.

2. EQUIPMENT FEATURES

A. General

2.01 The TL transmitter is part of a combined transmitter-receiver panel which is mounted in a bay or cabinet together with the associated order wire and alarm (or diversity switch) and power equipment. The transmitter circuit incorporates two basic circuits: a transmitting baseband amplifier and a transmitter klystron with waveguide components. The entire transmitter-receiver panel is shock-mounted to minimize klystron vibration and any resultant undesired modulation.

B. Transmitter Baseband Amplifier

2.02 The baseband amplifier is a 3-stage transistorized amplifier with a nominal voltage gain of 28 ±4 db essentially flat from 200 cycles to 6.0 mc. It is designed to hold signal distortion and the effects of interference to a minimum. The input circuit is designed to accommodate a 75-ohm unbalanced signal and the low-impedance output delivers an unbalanced signal to the transmitting klystron. Means are provided for gain and bias adjustments. Test jacks are provided for measuring bias and for output monitoring.

2.03 The amplifier unit occupies a space approximately 4-1/2 inches long, 3-1/2 inches wide, and 1-1/4 inches deep. This unit is contained in an aluminum chassis and is mounted behind the removable meter and control panel. The 75-ohm coaxial input jack, the bias and gain controls, and test jacks are accessible through the wall of the meter and control panel housing. A Teflon plug and jack combination is used to

connect the amplifier output to the klystron coupling capacitor. Power is supplied to the amplifier through a pair of leads connected to a terminal block in the control panel housing. Baseband amplifier test jacks, controls, and input jack are shown in the lower right of Photograph A.

C. Transmitter

2.04 The transmitter consists of a klystron feeding through an isolator, a 20-db double directional coupler, and a channel dropping and combining network to the antenna system. One branch of the directional coupler feeds a power monitoring detector; the other, a frequency monitoring network. The physical appearance of the transmitter is shown in Photograph A.

D. Transmitter Frequency Stabilization

2.05 Transmitter frequency is held to better than ±0.05 per cent by maintaining a constant operating temperature for the transmitter klystron and by using well stabilized voltage sources. Temperature stabilization is accomplished by a vapor-phase cooling system.

2.06 The vapor-phase cooling system is a heat exchange system consisting of a boiler, a condenser, and an expansion bladder. The boiler is filled to a specified level, with an inert fluorochemical having a boiling point of approximately 214 F. Receiver and transmitter klystrons are mechanically clamped to the boiler in a manner to provide maximum heat conduction between members. Heat generated in the klystrons boils the fluid in the boiler, and the generated vapor rises through connecting tubing to the condenser where it is cooled, returned to a fluid state, and gravity-fed back into the boiler. In this manner all the excess heat generated in the klystrons is expended in the continuous process of changing the physical state of the cooling fluid. Effects caused by ambient temperature changes are minimized by the resultant changes in the flow rate of the cooling system. Looked at in another way, the stabilization process is a result of the fact that at constant pressure, the fluid has a constant boiling point at which the boiler and klystrons are maintained.

2.07 Both klystrons and the boiler unit of the vapor-phase cooling system are housed in a metal box approximately 7-1/2 inches wide, 6-3/4 inches high, and 5-1/2 inches deep. The box is lined with a heat-insulating material to minimize thermal losses through convection and radiation. The boiler is supported by a cast-metal angle bracket that is mounted on the rear wall of the housing and one klystron is held to either side of the boiler unit by a single metal clamp. Clamp pressure can be released by turning a single screw permitting rapid removal of the klystrons. The front cover of the box is removed by releasing the two Dzus fasteners at opposite corners of the cover. Klystron mechanical tuning controls are accessible through holes in the front cover and self-sealing slits in the insulation material. Photograph B shows the klystron and boiler housing with the cover removed.

2.08 The condenser bladder is mounted on the transmitter-receiver panel behind the transmitter waveguide assembly and at the end of the condenser remote from the boiler. The purpose of the bladder is to seal the condenser system and at the same time provide enough flexibility to equalize the pressure inside and outside the system. Pressure inside the boiler will thus be very close to atmospheric resulting in a constant boiling temperature.

3. CIRCUIT DESCRIPTION

A. General

3.01 The transmitter circuit is designed to accept an input signal of −14 dbm from a 75-ohm unbalanced line for a peak-to-peak frequency deviation of 8 mc. The RF output is an 11-kmc frequency-modulated signal at a nominal power of 100 mw. A functional block diagram of the transmitter is shown in Fig. 1.

3.02 The output of the baseband amplifier is impressed on the repeller of the transmitter klystron, and the variation of the repeller voltage modulates the output frequency. The repeller sensitivity is such that a peak-to-peak frequency deviation of 8 mc requires not more than 5.5 volts of peak-to-peak output from the baseband amplifier. The transmitter baseband
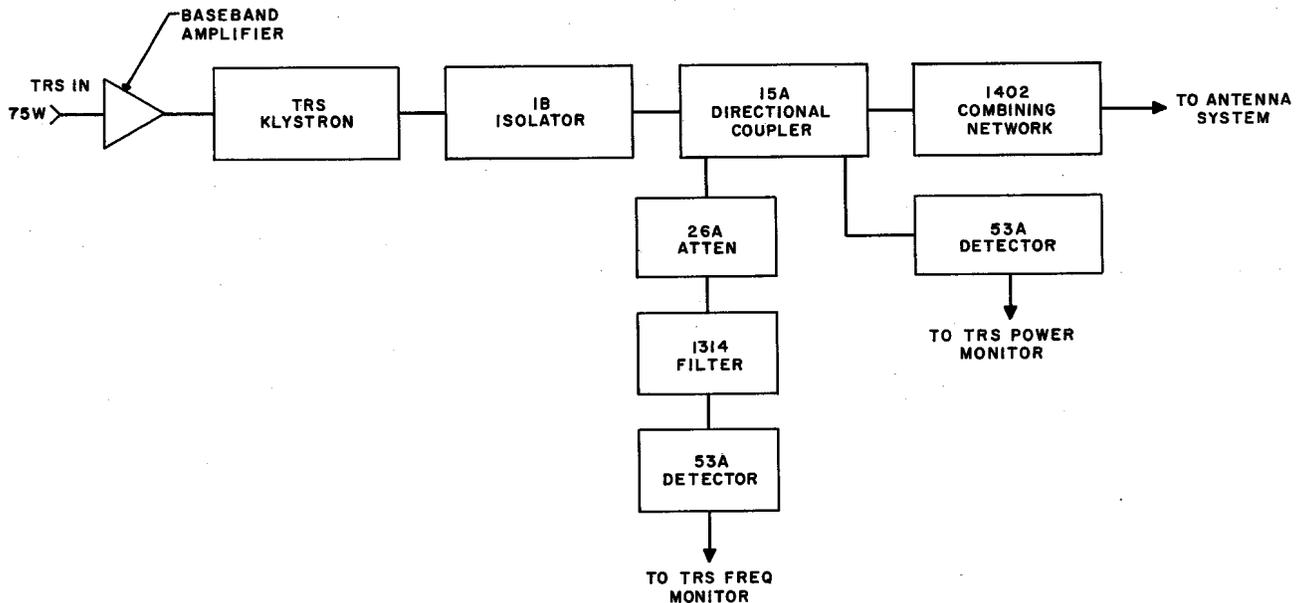
Fig. 1 — Functional Block Diagram of Transmitter

amplifier gain is adjustable over a limited range of ±4 db to allow for variations in repeller sensitivity.

3.03 The output of the transmitter klystron is connected to a double directional coupler through an isolator. The isolator has a forward loss of 0.85 db and a reverse loss in excess of 55 db which prevents reflections from the antenna system pulling the klystron frequency and causing intermodulation distortion. One portion of the transmitter output is dropped 20 db from the directional coupler, rectified, and is used to indicate transmitter power output. Another portion also reduced 20 db is fed via a waveguide network consisting of an attenuator, a high-stability frequency selective filter, and a detector, and is used to monitor transmitter frequency. Both power and frequency indications appear on the meter and control panel. The directional coupler also connects the klystron output to the antenna system through a channel dropping and combining network which permits

multiple transmitters and receivers to be connected to a single waveguide run.

B. Baseband Amplifier

3.04 The transmitter baseband amplifier is a 3-transistor feedback amplifier. The first stage, Q101, is a common base configuration; the second stage, Q102, is an emitter follower; and the third stage, Q103, is a common emitter circuit. Over-all shunt-type negative feedback gives a high degree of gain stabilization and leads to very low input and output impedances. Amplifier voltage gain is 28 ±4 db adjustable by the gain control R105. A bias adjustment, R103, is provided to set the output node of the amplifier to −7.0 volts as measured at the bias test jack J102.

3.05 A complete schematic of the baseband amplifier is shown in Fig. 2. Resistor R101 provides a 75-ohm input impedance and, along with R104, R105, and R111, sets the voltage gain. Potentiometer R103 adjusts the dc collector

voltage of Q103 to —7.0 volts, thereby minimizing distortion at high-output levels. Resistor R102 limits the current which R103 can draw from ground, and R106 draws sufficient current through R103 to mask out the effects of circuit element variations within the required tolerances and thus enables R103 to perform its function in all cases. Potentiometer R105 adjusts the voltage gain, which is limited on the low side by R104 and on the high side by R111. The bias current in Q101 is set by R109. Resistors R107 and R108 serve as a voltage divider to set Q101 base and emitter sufficiently far from ground potential so that the effect of dc drift due to Q101 is minimized, as is the loading on Q103 due to the feedback network. Varistor RV101, acting as a simple forward-biased varistor, compensates for temperature drift in

V_{EB} of Q101, since the sign of their temperature coefficients is opposite. Regulator CR101 eliminates the effect of supply-voltage variation on the biases, and R113 sets the nominal bias current in CR101. Resistor R114 sets the bias current in regulator CR102, which provides a low ac impedance along with a dc voltage step needed for obtaining sufficient voltages across the transistors, and R112 sets the bias current of Q102. Resistors R115 and R116 set the bias current of Q103, and R116 provides low-source impedance for the MON jack J103. Resistor R117 and capacitor C105 decouple the amplifier from the power supply. Resistor R118 helps to isolate the amplifier output from the effects of the parasitic capacity presented by the klystron and its coupling network. Resistor R119 performs a similar function with respect to the metering jack J102.
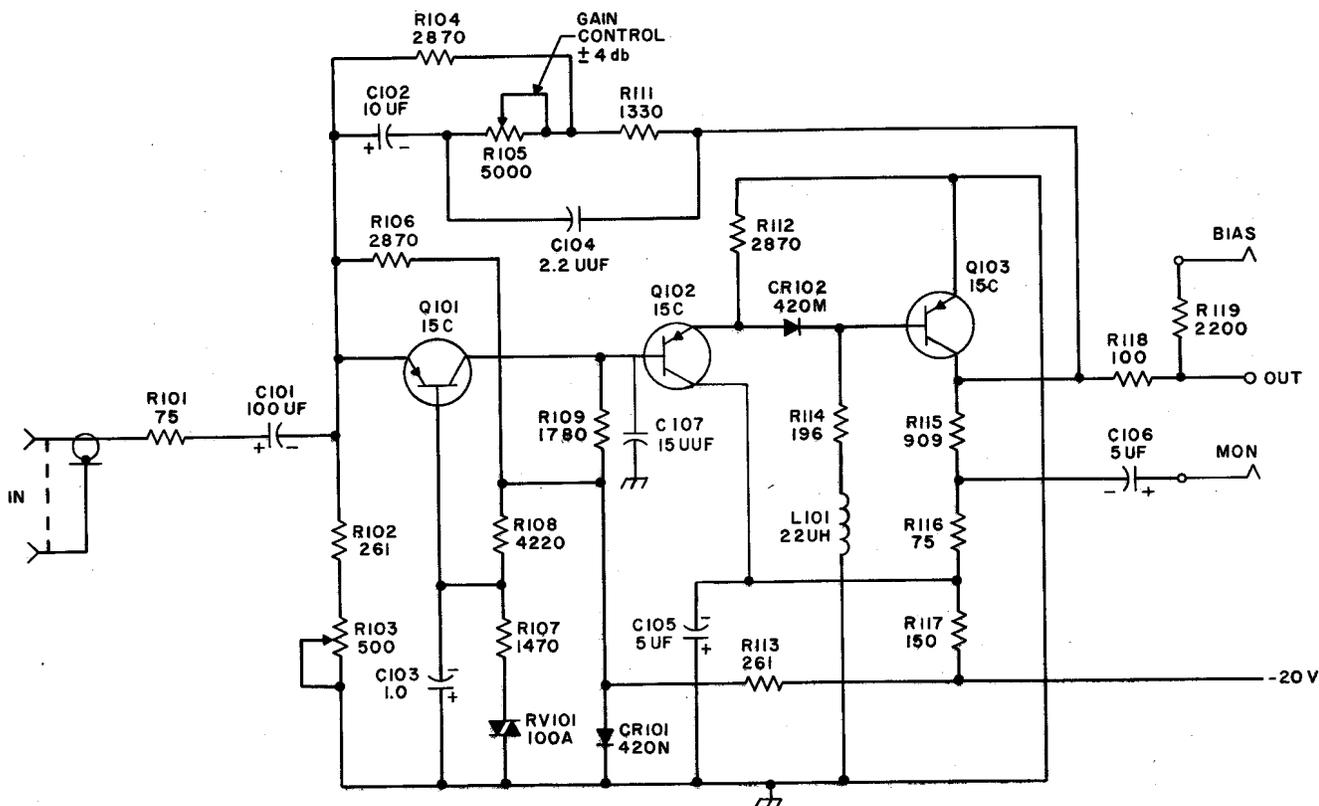

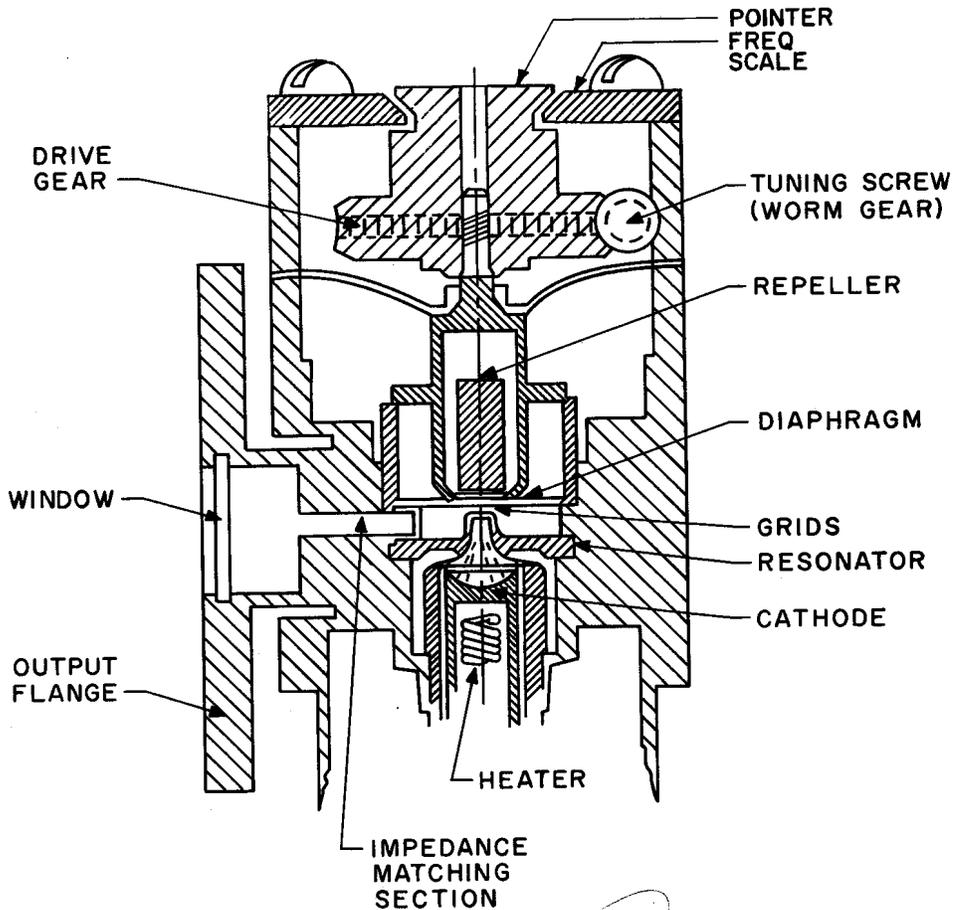Fig. 2 — Transmitter Baseband Amplifier Schematic

3.06 Capacitors C101 and C106 merely block dc currents; C102 prevents the gain adjustment from affecting the biases; C103 grounds the base of Q101 to alternating current, thereby reducing noise and lowering the input impedance of Q101; and C104 provides feedback shaping at high frequencies. Inductor L101 improves power-output capability at 6 mc.

C. Transmitter

3.07 A complete schematic diagram of the transmitter is shown in Fig. 7 and a simplified schematic of the transmitter klystron circuit is shown in Fig. 3. The 11-kmc microwave frequency is generated by the 457A reflex klystron V2 which has a nominal output of 100 mw (+20 dbm). A diagrammatic cross section of the klystron is shown in Fig. 4 (not to scale).

3.08 In principle, the 457A klystron operates like any other reflex klystron with a few particular features for TL applications. The body of the klystron is designed to have smooth, flat sides to provide good thermal contact with the boiler of the vapor-phase cooling system.

The movement of the tuning diaphragm is accomplished by a worm-gear tuning control which operates a gear train through an approximate 5:1 reduction to permit microinch adjustments. The tuning sensitivity is nominally 100 mc per revolution and the fully clockwise position corresponds to the highest tunable frequency.

3.09 A special feature of the 457A klystron is a closely controlled temperature coefficient which does not exceed ±0.15 mc per degree Fahrenheit. It is this feature, in conjunction with the vapor-phase cooling system, that makes the frequency relatively independent of ambient temperature.

3.10 To eliminate the need for external impedance-matching transformers, the klystron cavity is connected to the output flange through a built-in impedance-matching section. The repeller is fixed in position and does not move in the process of mechanical tuning. To assist in the concentration of the electron beam from the cathode, the emitting surface is made concave to produce beam focusing.

Fig. 3 — Simplified Schematic of Transmitter Klystron Circuit

DRIVE
GEAR

WINDOW

OUTPUT
FLANGE

POINTER
FREQ
SCALE

TUNING SCREW
(WORM GEAR)

REPELLER

DIAPHRAGM

GRIDS
RESONATOR

CATHODE

HEATER

IMPEDANCE
MATCHING
SECTION

Fig. 4 — Cross Section of a 457A Klystron

3.11 The typical operating conditions for the 457A reflex klystron are as follows:

Frequency Range	10.7 to 11.7 kmc
Power Output	100 mw (minimum)
Mode	3-3/4
Modulation Sensitivity	1.5 mc per volt min
Repeller Input Capacity	6 uuf (maximum)
Resonator Voltage	Ground
Cathode Voltage	—400 volts
Repeller Voltage	—490 to —530 volts
Heater Voltage	6.3 volts
Heater Current	0.88 amp

The minimum power output of the klystron is 100 mw, and the average tube has an output which varies with frequency, being greatest at the upper end of the frequency band.

3.12 Since the resonator is a part of the body of the tube, which connects to the waveguide assembly, it is maintained at ground potential. The cathode and one side of the filament are returned to —400 volts, and the repeller is biased between —490 and —530 volts. The other side of the filament is returned to —410.5 volts, and the filament potential is dropped to a nominal 6.3 volts through a series resistance. The output of the baseband amplifier is impressed on the repeller through a blocking capacitor. Diode CR11 and resistor R41 between the repeller and cathode prevent the repeller from becoming positive with respect to the cathode, thereby preventing klystron damage.

3.13 The output of the transmitter klystron is fed through a 1B isolator, A1, which has a 0.85–db loss to the transmitted signal and a high loss (greater than 55 db) to signals reflected from the antenna system. If the reflected signals got back to the klystron repeller, the resultant pulling of the klystron frequency would produce nonlinearity in the modulation process and introduce intermodulation distortion. The isolator is the field displacement type, and a cross-sectional diagram of the unit is shown in Fig. 5. The ferrite bars which have a resistive coating are parallel to the narrow edge of the waveguide. In the low-loss direction, the electric field within the guide is as shown by the dotted lines in Fig. 5. Since this field is almost zero at the ferrite bars, the resistance coating has little effect on the transmission, and the loss is low. In the high-loss direction, however, the electric field is not zero at the ferrite bars, as shown by the solid line of the figure. As a result, the resistive coatings on the bars absorb energy and attenuate the signal.

3.14 Following the 1B isolator is the 15A directional coupler DC1. This unit has three outputs. The first provides a low-loss through path to the antenna system or a channel dropping and combining network. The sec-
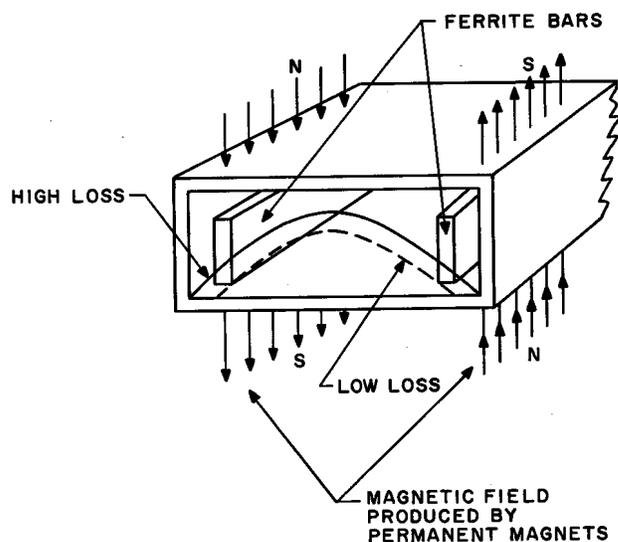

Fig. 5 — Cross Section of a 1B Isolator

ond, a pick-off arm, has a loss of 20 db and feeds the transmitter frequency monitoring network. The third output also has a loss of 20 db and feeds the transmitter power monitoring circuit.

3.15 The transmitter frequency monitoring network consists of a 26A attenuator AT2 followed by a 1314 stable Invar filter FL2 and a 53A detector DET 2. The selectivity of the bandpass filter FL2 causes a peak indication on the meter, M1 on the meter and control panel, when the frequency is properly adjusted.

3.16 The transmitter power monitoring circuit consists of a 53A detector DET 1, the output of which is indicated on the meter, M3 on the meter and control panel. M3 is calibrated to show RF output.

3.17 A linearity switch S5 is provided for shifting the transmitter repeller voltage 2 volts after the repeller voltage has been adjusted for peak power output. This ensures the best average transmitter linearity without using complex test equipment and involved adjusting procedures. The voltage shift is accomplished by short-circuiting R22 and opening the short circuit across R21 during the adjustment of XMTR RPLR, R19. After adjusting R19, switch S5 is returned to its normal position where the short circuit is removed from R22 and placed across R21 causing a 2-volt shift in repeller voltage. It then becomes necessary to mechanically retune the klystron cavity to the correct frequency.

3.18 Transmitter deviation is measured by observing the drop in the output power relative to the unmodulated power output when a modulated signal is transmitted through filter FL2. To measure this output reduction accurately, attenuator AT2 is used to provide a calibrated reference level change independent of detector accuracy. By this means, deviation can be adjusted by inserting a known level tone into the transmitting baseband amplifier and adjusting the amplifier gain control for the appropriate carrier level reduction at the output of FL2. The sensitivity of this adjustment is improved by providing an expanded scale feature with a bucking voltage applied to meter

M2 by resistors R15, R16 BIAS, and R17. Increased sensitivity is obtained by decreasing the resistance of R13 (SENS) in series with the output of the 53A detector DET 2 which works into a 10,000-ohm load R14. A simplified schematic diagram of the detector portion of the deviation measuring circuit is shown in Fig. 6.

3.19 Means are provided for testing filament activity on the transmitting klystron by selecting the appropriate klystron with S4 and pressing the momentary contact switch S3. A timer motor M2 short-circuits the filament supply voltage to the chosen klystron for a period of 20 ±1 seconds, at the same time a dummy load is substituted for the klystron filament to minimize power hits due to sudden load changes on the supply. The cathode current as read on M3 by selecting the proper meter position with S6, is observed during this period of time. If at the end of the 20-second period the cathode current falls below a specified value, it will be an indication that the klystron is approaching the end of useful life and should be replaced. A simplified schematic of the activity circuit is shown in Fig. 3.

3.20 The repeller supply voltage for the transmitting klystron is supplied through the 39,000-ohm resistor R42. Noise on this supply voltage will be filtered by the half-section filter combination of R42 and C21 which goes to ground through the low-impedance output of the transmitting baseband amplifier. The prime function of capacitor C21 is to couple the output of the transmitting baseband amplifier to the repeller of the transmitting klystron.
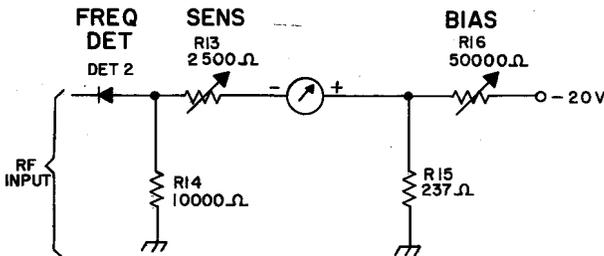

Fig. 6 — Simplified Schematic of Detector Portion of Deviation Measuring Circuit

4. TRANSMISSION CHARACTERISTICS

A. General

4.01 The transmission characteristics for the baseband amplifier and transmitter are as follows.

B. Video Frequency Characteristics

4.02 The video frequency characteristics of the baseband amplifier are as follows:

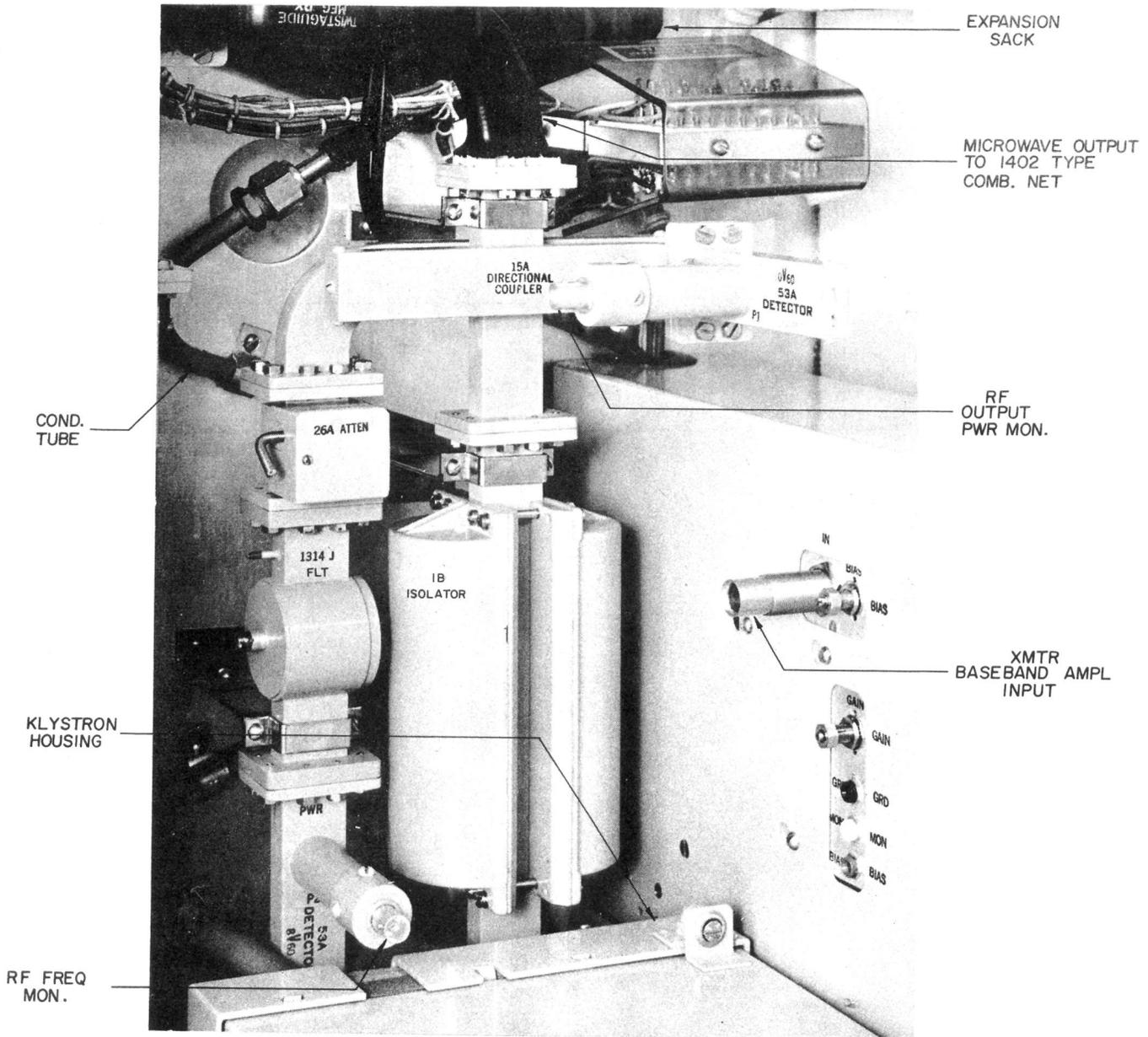|	
Input Impedance	Unbalanced 75 ohms
Input Level	−14 dbm for ±4 mc peak-to-peak deviation
Output Level	+15 dbv
Voltage Gain	28 ±4 db
Gain-frequency Response	±1 db from 200 cps to 1 kc ±0.2 db from 10 kc to 6 mc
Transmission Band	200 cps to 6 mc

C. Transmitter Characteristics

4.03 The transmission characteristics of the transmitter are as follows:

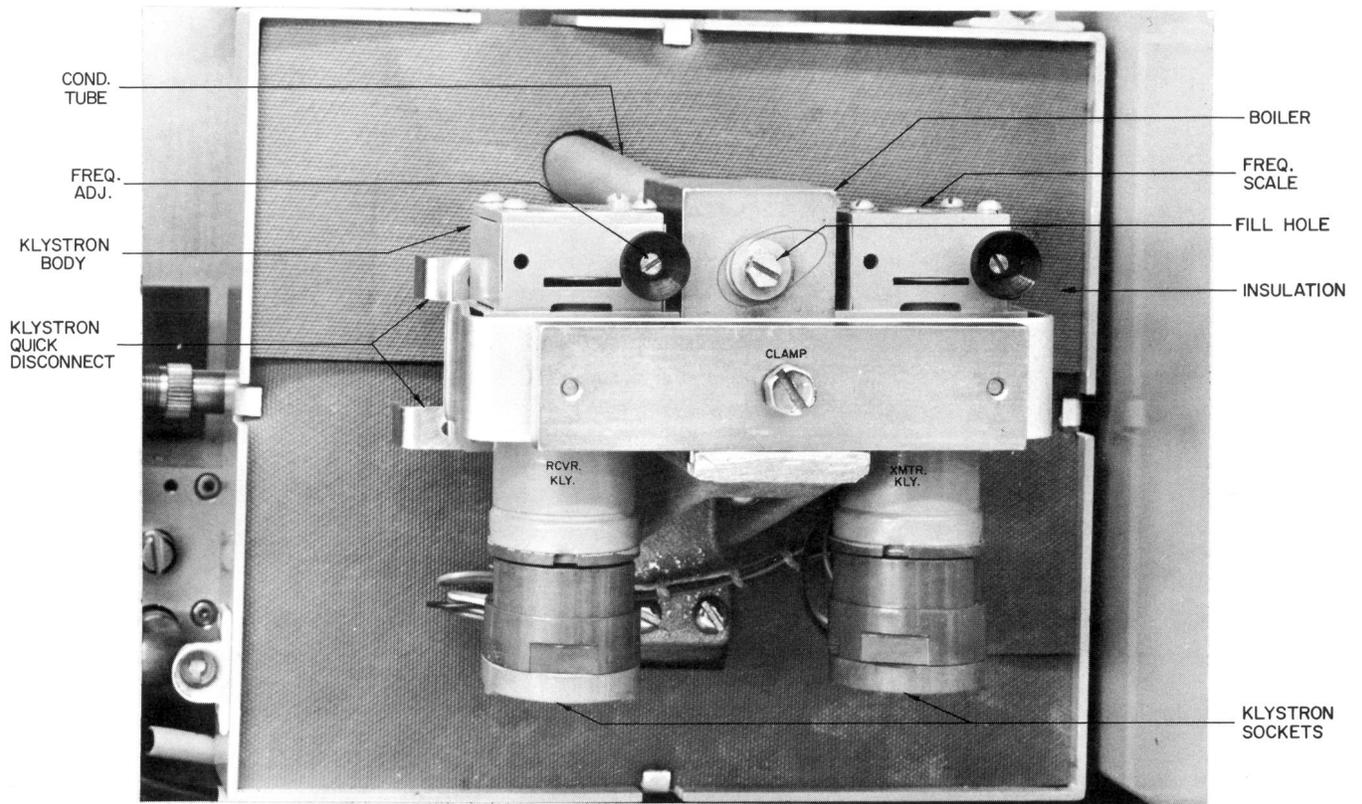|	
Klystron Frequency	Tuning Range 10.7 to 11.7 kmc
Type of Modulation	FM
Maximum Deviation	±6 mc
Linearity of Deviation Characteristic	3 per cent over an 8-mc band
Adjusted Deviation Sensitivity	−14 dbm equals ±4 mc
Power Output	100 mw nominal

4.04 Table A lists the transmitted carrier frequency associated with each channel.

TABLE A	
CHANNEL NO.	FREQUENCY
	kmc
1A	10.755
1B	11.405
2A	10.955
2B	11.685
3A	10.995
3B	11.645
4A	10.715
4B	11.445
5A	11.155
5B	11.325
6A	10.875
6B	11.605

TABLE A (cont)	
CHANNEL NO.	FREQUENCY
	kmc
7A	10.915
7B	11.565
8A	11.115
8B	11.365
9A	11.075
9B	11.245
10A	10.795
10B	11.525
11A	10.835
11B	11.485
12A	11.035
12B	11.285

Transmitter

COND.
TUBE

FREQ.
ADJ.

KLYSTRON
BODY

KLYSTRON
QUICK
DISCONNECT

BOILER

FREQ.
SCALE

FILL HOLE

INSULATION

CLAMP

RCVR.
KLY.

XMTR.
KLY.

KLYSTRON
SOCKETS

Klystron and Boiler Assembly

Fig. 7 — Typical Transmitter, Receiver, and Control Panel