TL-1 MICROWAVE RADIO
TRANSMITTER-RECEIVER BAY
DESCRIPTION

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1. GENERAL

1.01 The transmitter-receiver (TR) bay is the basic equipment unit of a TL-1 radio system. It provides the radio transmitting and receiving equipment for a single 2-way radio channel. Basically, the TR bay includes a microwave transmitter and receiver with power supply and auxiliary equipment. Auxiliary items include an order-wire and alarm panel or diversity switch panel as required. At terminals or dropping repeaters, the outdoor TR cabinet, illustrated in Fig. 1, may also contain certain multiplex terminal equipment. The TR packaged for outdoor installation is housed in an insulated steel cabinet measuring approximately 63 inches high, 47 inches wide, and 19 inches deep. For indoor installations, a TR bay is available in 7-foot or 9-foot racks as illustrated in Fig. 2. At a terminal station, one TR bay is required for nondiversity operation while two TR bays are needed for a diversity system. At a repeater station, two TR bays are required for nondiversity operation while four TR bays are needed for a diversity system.

1.02 ➧This section is reissued to add information for TL-1 systems that may now be equipped with either of the following:

(a) The J99296AA-2, List 3 modulator-preamplifier unit with the J99296G-2 receiver IF and baseband unit

(b) The J99296AA-2, List 3 modulator-preamplifier unit with the J99351E-1 IF amplifier unit and the J99351J-1 FM receiver unit.➧

1.03 Equipment for an order-wire and alarm system is composed of an alarm and control panel at the alarm center and order-wire and alarm panels at each radio terminal and repeater station. One alarm system can serve a maximum of ten hops for each TL-1 radio system. An additional alarm system is needed for each additional 2-way radio system. The following equipment units make up a complete TR bay:

(a) Transmitter-receiver panel

(1) Channel dropping and combining networks

(2) Receiver-modulator and preselection networks

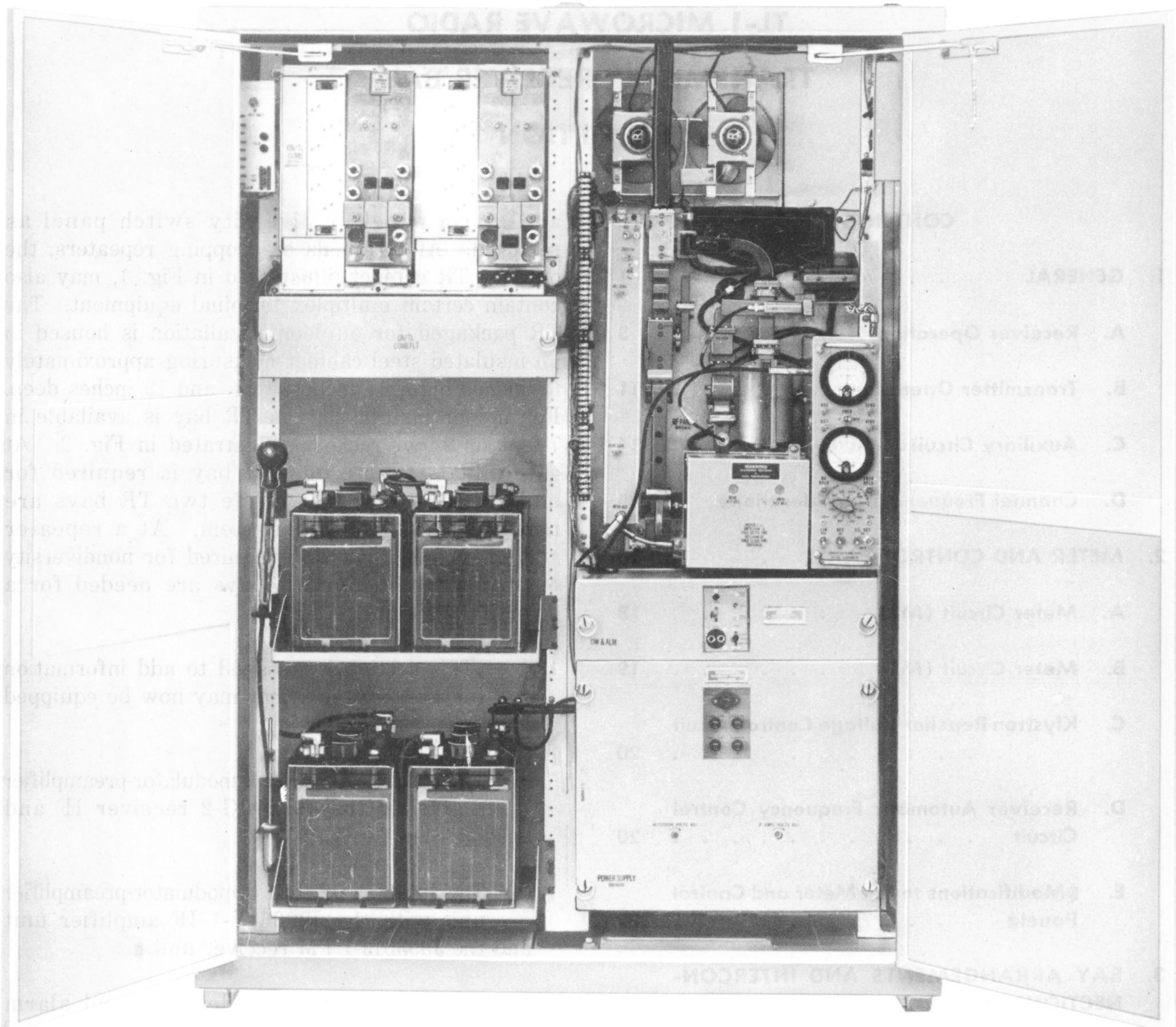


Fig. 1—J99262A Transmitter-Receiver Cabinet—Door Open View

(3) Receiver IF and baseband unit

(4) Transmitter baseband amplifier

(5) Transmitter and monitoring units

(6) Meter and control panel

(b) Power supply

(c) Four 6-volt storage batteries and charger

(d) Order-wire and alarm panel or diversity switch panel as required

(e) Multiplex equipment (when required at outdoor cabinet installations, terminals, and dropping repeaters).

1.04 The TR bay operates from 115-volt 60-Hz commercial power. An ac distribution circuit provides convenient outlets where the TL test set or other electrical equipment may be plugged in

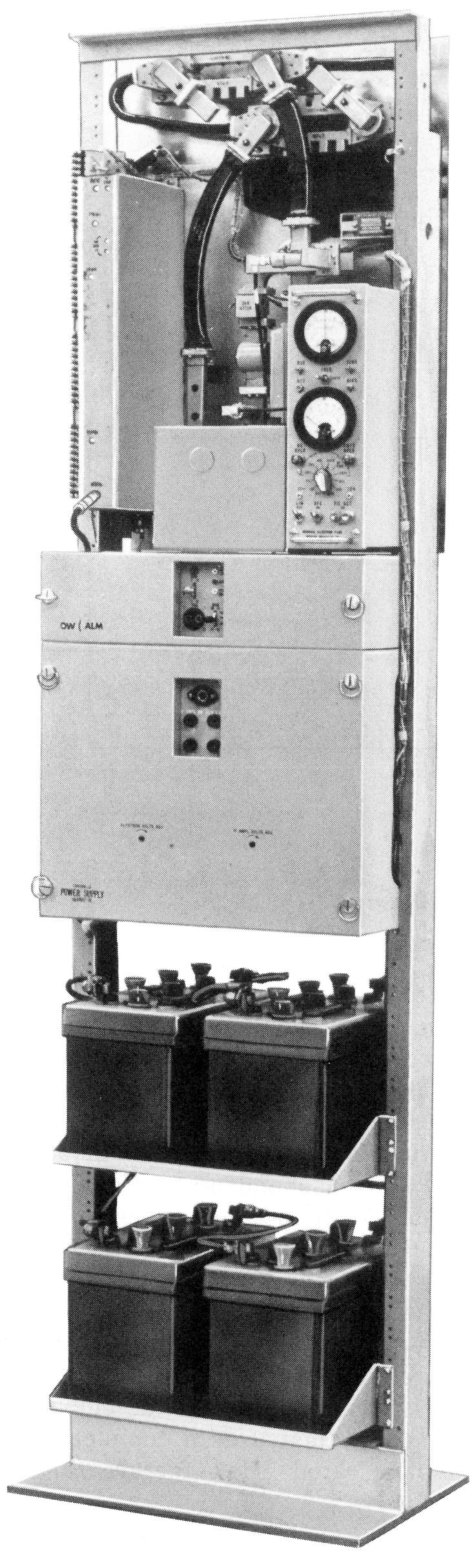


Fig. 2—J99262B Transmitter-Receiver Rack-Mounted, 7-Foot Bay

for maintenance testing. A ventilating fan within the outdoor cabinet operates under the control of a thermostat to keep the interior cabinet temperature from rising excessively.

A. Receiver Operation (Fig. 3)

1.05 ➧The receiver is equipped with either (a) the J99296F receiver modulator-preamplifier channel assembly (Fig. 4) or (b) the J99296AA, List 3 modulator-preamplifier (Fig. 5). If the receiver is equipped with (a), refer to 1.06 through 1.10. If the receiver is equipped with (b), refer to 1.06 through 1.08 and 1.11 through 1.14.

1.06 The three IF and baseband units available in a TL-1 system and described in this section are as follows:

(a) J99262G receiver IF and baseband unit—paragraph 1.15.

(b) J99296G IF and baseband unit—paragraph 1.21, Fig. 6 and 7

(c) J99351E-1 IF amplifier unit with the J99351J-1 FM receiver unit—paragraph 1.23, Fig. 8 and 9.➧

1.07 The incoming RF signal is received from an adjacent radio station in the circular feed of a parabolic antenna. This complex RF signal may contain from one to six radio channels on one or two polarizations. The signal is carried by the circular antenna waveguide to a polarization separation network or a round-to-rectangular transition, depending upon whether the signal contains one or two polarizations. With two polarizations, the separation network separates the vertically and horizontally polarized frequencies and launches them into rectangular waveguides. In the case of a single polarization, a transition is used to connect from circular to rectangular waveguide. The channels, now grouped by polarizations, are transmitted by rectangular waveguide runs to the TR bays. A maximum of three transmitters and receivers are fed by one waveguide run. The transmitted RF signals have the shorter path to the antenna and are coupled to it by channel dropping and combining networks. These networks are also used to connect the microwave receivers to the main waveguide run.

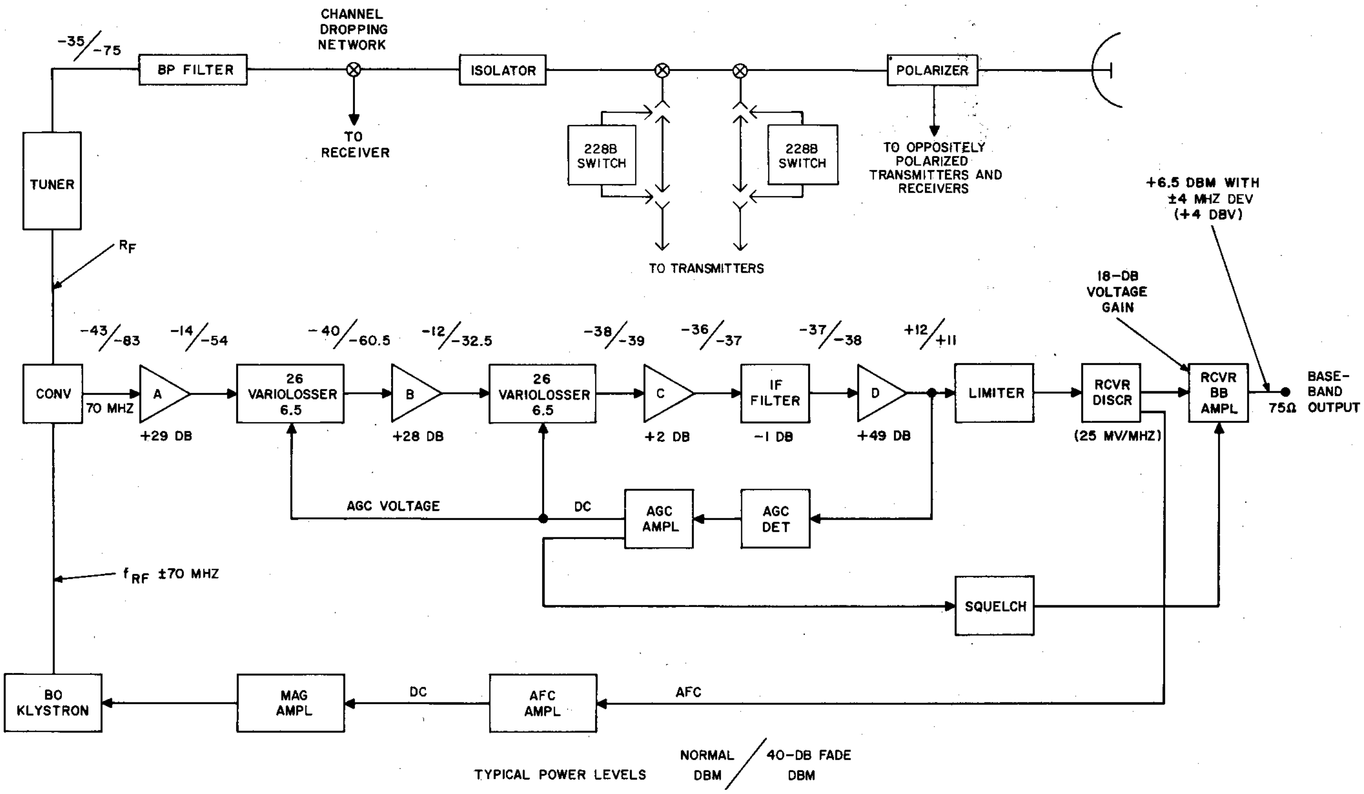


Fig. 3—J99262G Receiver—Block Diagram

1.08 In a particular bay, a channel dropping network selects its designated RF channel from the other channels and passes it on to its receiver. The remaining RF channels pass through the network. At the end of the waveguide run, selection is not required since only one RF channel is present, the others having been dropped. It is, therefore, applied directly to its receiver.

1.09 As shown in Fig. 3, an isolator is located between the channel dropping and channel combining networks. Its function is to prevent beat-oscillator leakage from passing through the polarization separation network and interfering with other receivers. The isolator, in general, is installed only when four or more bays operate off one antenna.

1.10 The selected signal enters the receiver through a bandpass image rejection filter and a waveguide tuner to a balanced diode modulator. The modulator-preamplifier contains a balanced crystal converter and a transistor preamplifier. The converter portion consists of a waveguide hybrid which mounts the input waveguide section and a waveguide attenuator through which the BO signal is introduced. The output branches contain matched crystal diodes. A coaxial jack is provided at the output of the preamplifier for a connection to the IF and baseband unit. Coaxial jacks are also provided for connections to the receiver control unit to permit reading the modulator crystal currents and for the power supply connection to the preamplifier. The complete receiver modulator-preamplifier channel assembly is shown in Fig. 4. This assembly is coded as the J99296F modulator-preamplifier channel assembly and must be tested and adjusted as a complete unit. The List 1 unit is rated "Manufacture Discontinue," (MD).

1.11 When a receiver is equipped with the redesigned modulator-preamplifier, the channel assembly consists of a bandpass filter, waveguide ferrite isolator, and a J99296AA, List 3 modulator-preamplifier (Fig. 5). The isolator replaces

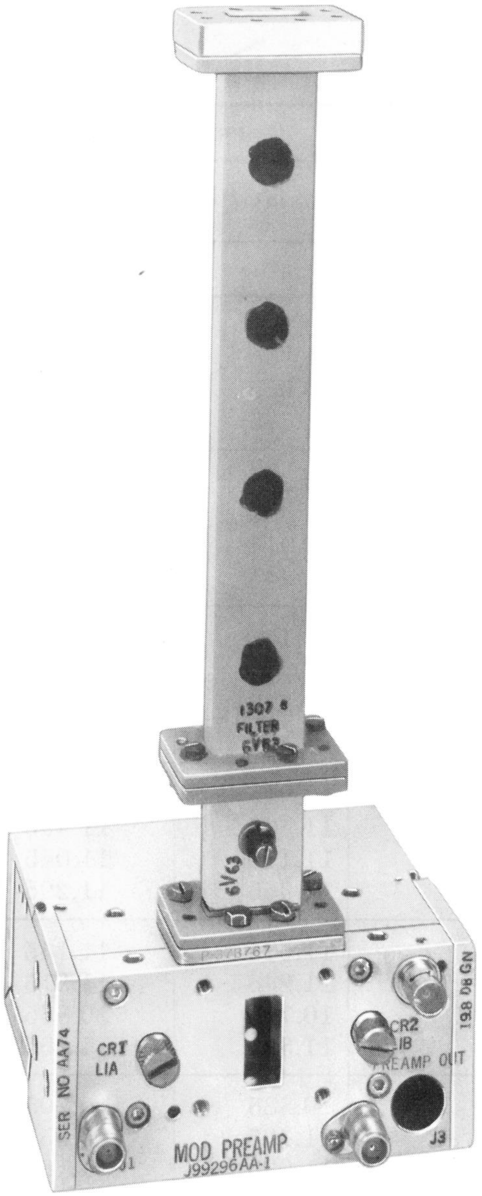


Fig. 4—J99296F Modulator-Preamplifier Channel Assembly With List 1 Modulator-Preamplifier

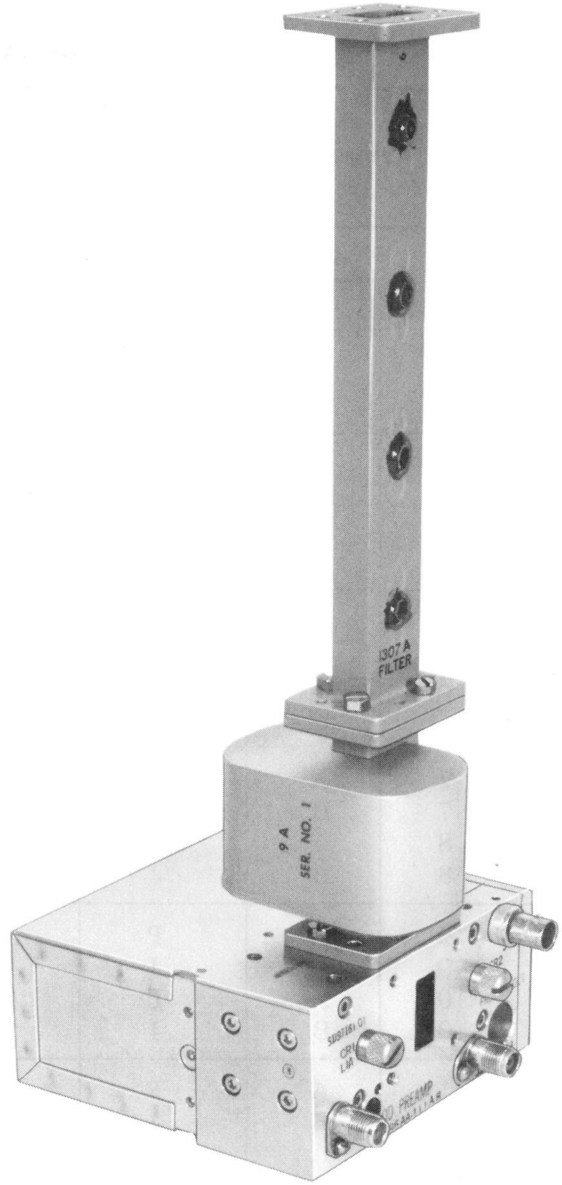


Fig. 5—J99296AA, List 3 Modulator-Preamplifier With Associated 9A Isolator and 1307 Filter

the frequency-sensitive waveguide tuner. The modulator-preamplifier contains a balanced crystal converter and a transistor preamplifier. A monitor jack has been added providing a bridged input at the interface of the modulator and first IF amplifier stage.

1.12 The J99296AA modulator-preamplifier is a balanced crystal converter, or mixer, which combines the incoming RF signal with the output from the beat oscillator to produce an intermediate frequency centered at 70 MHz. The IF output of the modulator is connected directly to the input of a low-noise preamplifier. The beat oscillator is under the control of the AFC circuitry, and its frequency may be higher or lower than the incoming signal frequency depending upon the channel number. Table A lists the channel numbers, the 1307-type filter and 1402-type network codes, and the incoming signal and BO frequencies.

TABLE A

NORMAL FREQUENCY PLAN

CHANNEL NUMBER			1307-TYPE FILTER AND 1402-TYPE NETWORK CODES	FREQUENCY	
				SIGNAL	BEAT OSCILLATOR
	OLD	NEW		GHz	
1	A	P	B	10.755	10.825
1	B	J	T	11.405	11.335
2	A	P	G	10.955	11.025
2	B	J	AD	11.685	11.615
3	A	P	H	10.995	11.065
3	B	J	AC	11.645	11.575
4	A	P	A	10.715	10.785
4	B	J	U	11.445	11.375
5	A	P	M	11.155	11.085
5	B	J	R	11.325	11.255
6	A	P	E	10.875	10.805
6	B	J	AB	11.605	11.535
7	A	P	F	10.915	10.845
7	B	J	AA	11.565	11.495
8	A	P	L	11.115	11.045
8	B	J	S	11.365	11.295
9	A	P	K	11.075	11.145
9	B	J	N	11.245	11.315
10	A	P	C	10.795	10.865
10	B	J	Y	11.525	11.595
11	A	P	D	10.835	10.905
11	B	J	W	11.485	11.555
12	A	P	J	11.035	11.105
12	B	J	P	11.283	11.355

1.13 The staggered frequency plan is intended primarily for use on converging or crossing routes in congested areas. It is not recommended to be used on the same antenna systems as the normal frequency plan. If it is necessary to do so, very careful consideration must be given to interference problems caused by adjacent channels and beat oscillator frequencies. The added frequencies are spaced 20 MHz from and midway between the existing channels. The frequencies start at 10.735 GHz and extend to 11.665 GHz as shown in Table B.

1.14 The output of the beat oscillator is fed into the E-plane junction at the relatively high level of approximately 0 dBm which is controlled by the 28A waveguide attenuator. The incoming carrier signal splits at the junction and is impressed on diodes CR1 and CR2 in opposite phase. Since the diodes are mounted in the waveguide with opposite polarities, they will conduct simultaneously, and a balanced switching action will be produced within the hybrid. Because of the symmetry of the hybrid, none of the BO output will appear at

TABLE B

STAGGERED FREQUENCY PLAN

CHANNEL NUMBER			1307-TYPE FILTER AND 1402-TYPE NETWORK CODES	FREQUENCY	
				SIGNAL	BEAT OSCILLATOR
	OLD	NEW		GHz	
1	C	E	AF	10.775	10.845
1	D	D	BA	11.385	11.315
2	C	E	AL	10.975	11.045
2	D	D	BH	11.665	11.595
3	C	E	AM	11.015	11.085
3	D	D	BG	11.625	11.555
4	C	E	AE	10.735	10.805
4	D	D	BB	11.425	11.355
5	C	E	AS	11.175	11.105
5	D	D	AW	11.305	11.375
6	C	E	AJ	10.895	10.825
6	D	D	BF	11.585	11.515
7	C	E	AK	10.935	10.865
7	D	D	BE	11.545	11.615
8	C	E	AR	11.135	11.065
8	D	D	AY	11.345	11.275
9	C	E	AP	11.095	11.025
9	D	D	AT	11.225	11.295
10	C	E	AG	10.815	10.885
10	D	D	BD	11.505	11.575
11	C	E	AH	10.855	10.785
11	D	D	BC	11.465	11.535
12	C	E	AN	11.055	11.125
12	D	D	AU	11.265	11.335

the signal input port of the hybrid, provided the diodes are perfectly matched. The signal at the H-plane junction divides in phase between the two hybrid arms containing CR1 and CR2. These signals are impressed on the diodes which are varying in impedance at the BO frequency and, as a result, frequency combinations of signal and BO frequencies are produced. Of all the possible combinations, only the difference and image frequencies are of significance. All the other frequency combinations are either at too high a frequency or too low a level to have any effect on the operation of the modulator. The difference frequency is the intermediate frequency of 70 MHz which is obtained by paralleling in phase the outputs of the two diodes. This signal is connected directly to the IF preamplifier.

J99262G Receiver IF and Baseband Unit

1.15 The IF signal is first amplified in a multistage wideband amplifier composed of amplifier sections A, B, and C. These sections introduce very little amplitude and phase distortion in the signal because their passband is very broad in comparison to that of the overall IF amplifier. Since the amplifier is fully transistorized, automatic gain control (AGC) is performed with two variolossers located between amplifiers A, B, and C. These devices are made up of biased diodes and present an insertion loss that varies with the received signal level. Their action causes the IF signal at the output of the second variolosser to vary only 1 dB over a 40-dB range of RF input power.

1.16 Complete IF bandpass shaping occurs in the IF filter following amplifier section C. This filter is also designed to equalize the small transmission deviations existing in the amplifier. The IF signal is boosted an additional 49 dB in amplifier section D which drives the limiter and the AGC circuits. For AGC purposes, a portion of the IF signal is diode detected, producing direct current which is amplified, and used to control the bias on the variolosser diodes.

1.17 After limiting, the IF signal is detected in a wideband frequency discriminator. The recovered baseband signal is then amplified in a baseband amplifier and brought out to a 75-ohm jack for application to multiplex terminal or radio transmitting equipment.

1.18 To compensate for frequency drifts in the transmitting and receiving klystrons, the frequency of the BO is controlled automatically, thereby keeping the IF signal centered at 70 MHz. A dc input signal for the automatic frequency control (AFC) is derived from the discriminator output. Polarized direct current is present at this point when the IF is other than 70 MHz. A dc signal at this point passes through a transistorized dc amplifier, is amplified in a magnetic amplifier, and then applied to the BO repeller to correct its frequency. The frequency will change in the direction that tends to null the discriminator dc output and therefore a fixed 70 MHz is maintained. In addition to AFC, the BO klystron is frequency-stabilized by a temperature control system that is described in 1.28.

1.19 A squelch circuit is incorporated in the receiver. This circuit cuts off the baseband amplifier when the RF carrier is reduced to or beyond a specific value by a fade or equipment failure. Excess noise is thus stopped before it can enter multiplex equipment where it could mix with good working circuits. The squelch circuit is activated by monitoring the dc biasing voltage of the AGC amplifier which is proportional to the RF input signal.

1.20 The baseband signal at the output jack now passes through the diversity switch and/or the order-wire and alarm and is then applied to either multiplex equipment or a radio transmitter.

J99296G IF and Baseband Unit

1.21 ♦The IF and baseband unit (J99296G), Fig. 6 and 7, is a transistorized plug-in component of the RF panel and provides an unbalanced baseband output signal from an unbalanced 70-MHz IF input signal. It includes the following.

(a) Amplifiers to raise the level of the 70-MHz frequency-modulated IF signal supplied to the unit from the modulator-preamplifier.

(b) Variolossers which serve as part of the AGC circuit to hold the IF output approximately constant with fading of the input signal.

(c) An IF bandpass filter to suppress unwanted frequency components outside the 60- to 80-MHz IF band.

(d) A limiter to remove amplitude modulation from the frequency-modulated IF signal before it is supplied to the discriminator.

(e) A discriminator to recover the baseband information from the frequency-modulated IF signal.

(f) A baseband amplifier to raise the signal to the level required for the connecting circuits.

(g) An AFC dc amplifier to transmit the differential output of the discriminator to the magnetic amplifier located on the receiver control unit. The output of the magnetic amplifier is applied to the BO repeller in a direction to maintain a constant 70-MHz intermediate frequency.

(h) An AGC detector and amplifier which, in conjunction with the variolossers listed above, serve to hold the limiter input approximately constant.

(i) A diversity drive circuit which provides a control voltage to operate the diversity switch circuit.

(j) A squelch circuit under control of the AGC circuit to mute the output of the baseband amplifier at a specified depth of fade. Simultaneously, the automatic frequency control loop is effectively opened to remove control and allow the beat oscillator to return to its approximately correct nominal operating frequency. With the AFC circuit disabled, the beat oscillator is prevented from locking at a new frequency under the influence of an adjacent channel carrier or extraneous carrier signal.

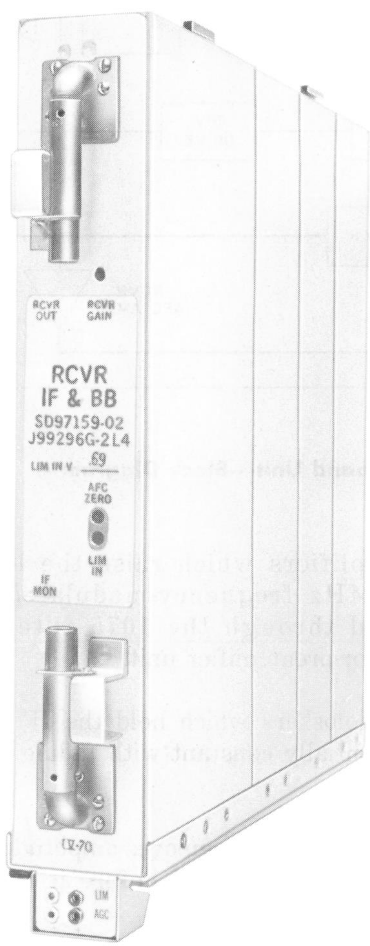


Fig. 6—J99296G IF and Baseband Unit

1.22 The IF and baseband unit includes panel adjustments and jacks as follows.

(a) The LIM IN control provides a means for adjusting the limiter input level.

(b) The AFC ZERO control provides a means for adjusting the differential voltage of the AFC circuit to zero when the IF signal is 70 MHz.

(c) The RCVR GAIN control is used to adjust the baseband signal output power.

(d) The IF GAIN control, provided only on the J99296G, L4 and L4A units, provides a means for adjusting the squelch point to correspond with a specific 70-MHz input level. This control is located on the back of the unit and is adjusted at the factory. However, it may be adjusted in the field on an out-of-service basis by removing the unit, making the adjustment, and replacing the unit as required, until the proper squelch point is established.

(e) The RCVR OUT jack provides the means for connecting the baseband output signal to the connecting circuits.

(f) The LIM IN (+) and (−) jacks provide a means for indirectly monitoring the limiter input level.

(g) The AGC (+) and (−) jacks provide a means for monitoring the AGC voltage other than the means provided by the meter AGC position. The voltage of the AGC (−) jack with respect to ground is approximately 6 volts and the difference between the two jacks (+) and (−) ranges from 0 to 1 volt depending on received signal strength.

(h) The IF IN jack, located on the bottom of the unit, provides the means of supplying the IF signal from the modulator-preamplifer unit to the IF amplifier.

(i) The RCVR OUT jack, located on the front of the unit near the top, provides the means for supplying the baseband output to the connecting circuits.

(j) The IF MON jack, located on the front of the unit near the bottom may be used for

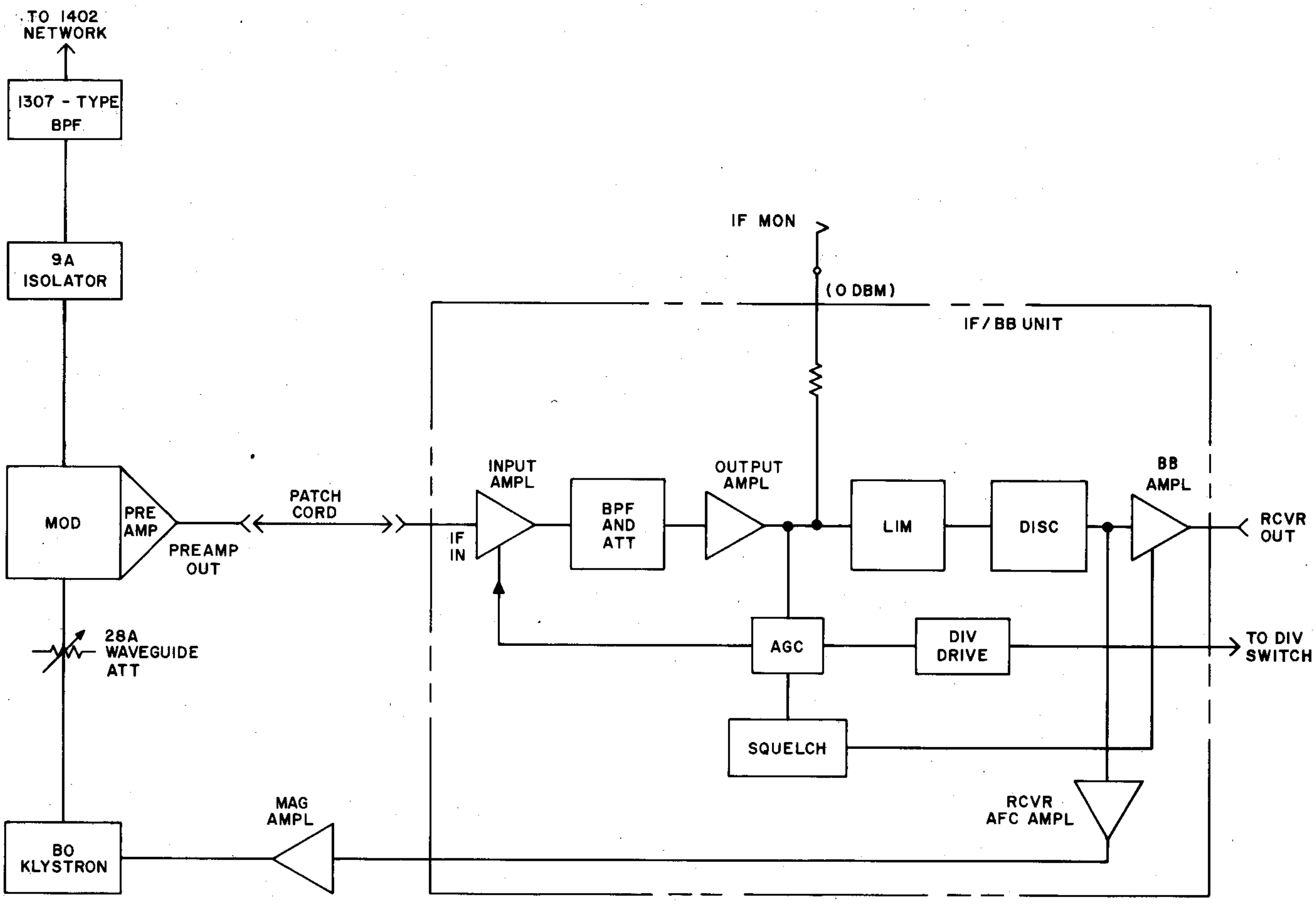


Fig. 7—Receiver Equipped With J99296G IF and Baseband Unit—Block Diagram

test purposes or to drive an IF repeater for possible connections to a TD-2 radio.

J99351E-1 IF Amplifier and J99351J-1 FM Receiver Arrangement

1.23 The IF amplifier and FM receiver arrangement (Fig. 8 and 9) is comprised of three individual units consisting of a 1075A filter, IF amplifier (J99351E), and FM receiver (J99351J) packaged together as a plug-in arrangement to replace the receiver IF and baseband unit (J99296G). The 70-MHz FM signal from the modulator-preamplifier unit is supplied through the 1075A filter to the IF amplifier and FM receiver units which, together, recover the baseband information from the IF signal. The baseband signal is amplified and supplied as an unbalanced output to the connecting circuits. The arrangement includes the following.

(a) Amplifiers which raise the level of the 70-MHz frequency-modulated IF signal supplied through the 1075 filter from the modulator-preamplifier unit.

(b) Variolossers which hold the IF output level essentially constant with fading of the input signal.

(c) A limiter which removes amplitude modulation from the IF signal before it is supplied to the discriminator.

(d) A discriminator which recovers the baseband information from the frequency-modulated IF signal.

(e) A baseband amplifier which raises the signal to the level required for the connecting circuits.

(f) An AFC dc amplifier which transmits the differential output voltage derived from the discriminator to the magnetic amplifier located on the receiver control unit. The output of the magnetic amplifier is applied to the BO repeller to maintain a constant 70-MHz intermediate frequency.

(g) An AGC detector and dc amplifier which hold the limiter input constant.

(h) A squelch amplifier which monitors the output of the AGC amplifier, compares it with a fixed reference voltage, and when a predetermined level is reached, squelches the baseband amplifier output, and activates the AFC squelch relay which prevents the beat oscillator from locking under control of an adjacent channel carrier or extraneous carrier signal.

(i) A diversity AGC amplifier which converts the polarity and sets the gain of an input from the AGC amplifier to operate a diversity switch.

(j) The IF filter (1075A) and associated cords for the IF amplifier and FM receiver units.

1.24 The IF amplifier and FM receiver arrangement includes cords, adjustments, and jacks as follows.

1075A Filter

(a) The IF input jack, designated either J1 or J2 provides the coaxial connection from the modulator-preamplifier unit. This jack is located on the rear of the filter enclosure.

(b) The IF output jack, designated either J1 or J2, provides the coaxial connection from the output of the filter to the input of the IF amplifier unit. This jack is located on the rear of the filter enclosure.

IF Amplifier (J99351E)

(a) The IF IN jack provides the means for connecting the output of the 1075A filter to the input circuits of the unit. This jack is located on the rear panel of the unit.

(b) The IF OUT jack provides a coaxial connection for patching the IF output of the IF amplifier unit to the RCVR IN jack of the FM receiver unit.

(c) The IF MON jack provides a means for monitoring or measuring the 70-MHz output of the IF amplifier unit. The level at this point is nominally 0 dBm and is normally terminated by a 469A plug (75 ohms).

(d) The AGC control provides a means for setting the IF output level applied to the limiter to −7 dBm for a prescribed IF input level.

(e) The SQCH control provides a means for adjusting the squelch point to correspond with a specific 70-MHz IF input signal level.

FM Receiver (J99351J)

(a) The RCVR IN jack provides a coaxial connection for patching the output of the IF amplifier unit into the input of the receiver unit.

(b) The RCVR OUT jack provides the means for supplying the baseband signal to the connecting circuits.

(c) The BB GAIN control provides a means for setting the level of the baseband signal supplied to the connecting circuits.

(d) The AFC ZERO control provides the means for adjusting the differential voltage of the AFC circuit to zero when the IF signal is 70 MHz.

Cords

Coaxial cords with connectors provide the means for interconnecting the filter, IF amplifier, and FM receiver units. A cord is also provided which adapts the RCVR OUT jack to the plug already provided in the RF panel.◀

B. Transmitter Operation (Fig. 10)

1.25 The transmitting circuit produces a frequency-modulated signal in the 11-GHz band at a power level of approximately 100 milliwatts. It is designed to accept a baseband input signal from a 75-ohm unbalanced source.

1.26 The baseband amplifier is a 3-stage transistorized feedback amplifier with a voltage gain of

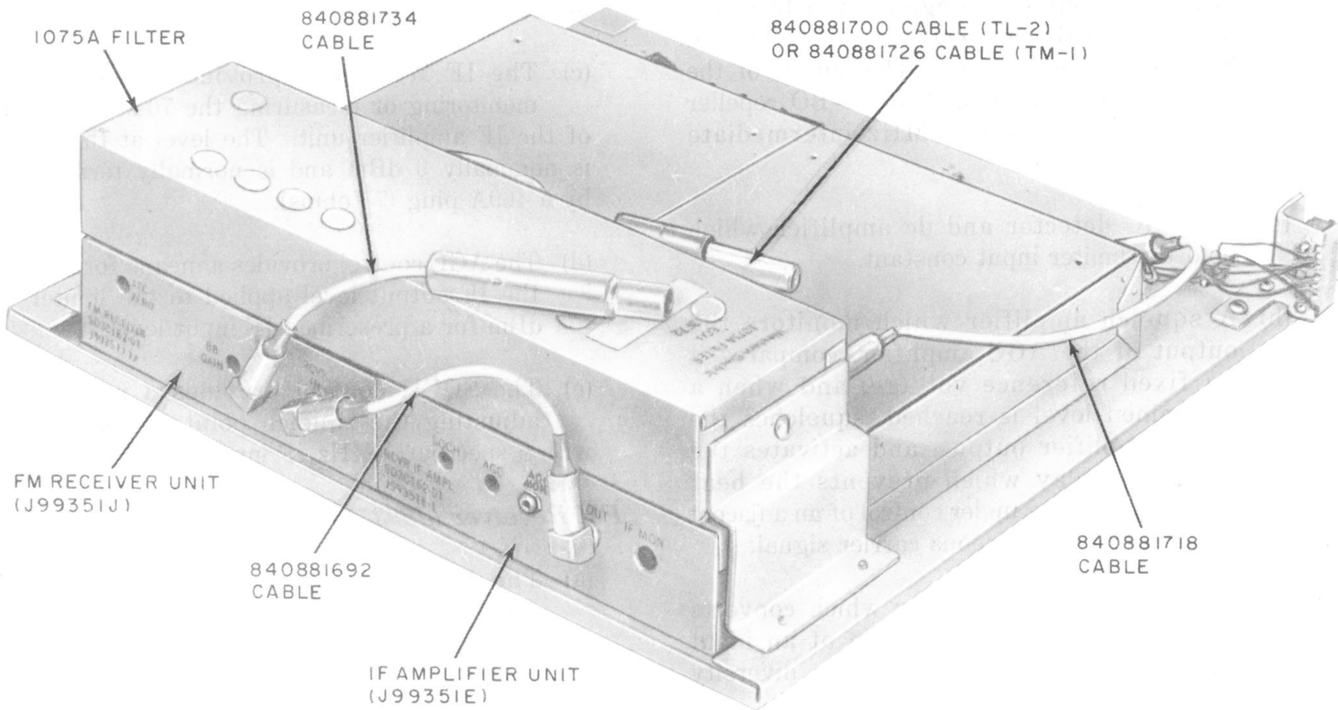


Fig. 8—IF Amplifier and FM Receiver Arrangement Consisting of 1075A Filter, J99351E IF Amplifier Unit, J99351J FM Receiver, and Associated Cables

approximately 28 dB and a bandwidth which is essentially flat from 200 Hz to 6 MHz. Here the baseband signal is amplified with a minimum of distortion and applied to the transmitting klystron repeller through a short length of wire. The varying amplified baseband signal linearly modulates the klystron-generated frequency. This FM signal is fed through a 1B isolator which has a forward loss of about 1 dB. The reverse loss of the isolator is approximately 55 dB and it, therefore, minimizes klystron frequency pulling caused by antenna and waveguide reflections. The RF signal then passes through a double directional coupler and on to the channel combining network. The two couplers are used to provide a frequency and power output indication. In the first coupler, the RF signal, 20 dB down from that in the through arm, is passed through AT2 and a very narrow bandpass filter tuned to the assigned transmitter frequency. The attenuator and filter, in conjunction with a meter on the meter and control panel, are used in adjusting the transmitter frequency and deviation. The RF signal in this leg is converted to direct current in DET 2, a diode detector, and then applied to M1 which gives a peak indication when the frequency is properly adjusted. The second coupler of DC 1 also contains an RF signal that is 20 dB down from that in the through arm. This signal is converted in DET 1 to direct current which gives a power output indication on meter M3.

1.27 At the combining network, the transmitter signal is inserted in the main waveguide line and propagated toward the antenna along with the channels from other transmitters. Horizontally and vertically polarized signals are fed to the circular antenna waveguide feed through the polarization combining network. The composite signal is then propagated to the next station by the antenna.

1.28 The transmitting and receiving klystrons are stabilized against frequency drift by maintaining them at a constant temperature. This is performed by means of a vapor-phase cooling system. This system is composed of a small boiler located between the two klystrons, a condensing system, a tube that interconnects a boiler and condenser, and a rubber bladder. A fluorochemical liquid, having a boiling temperature of approximately

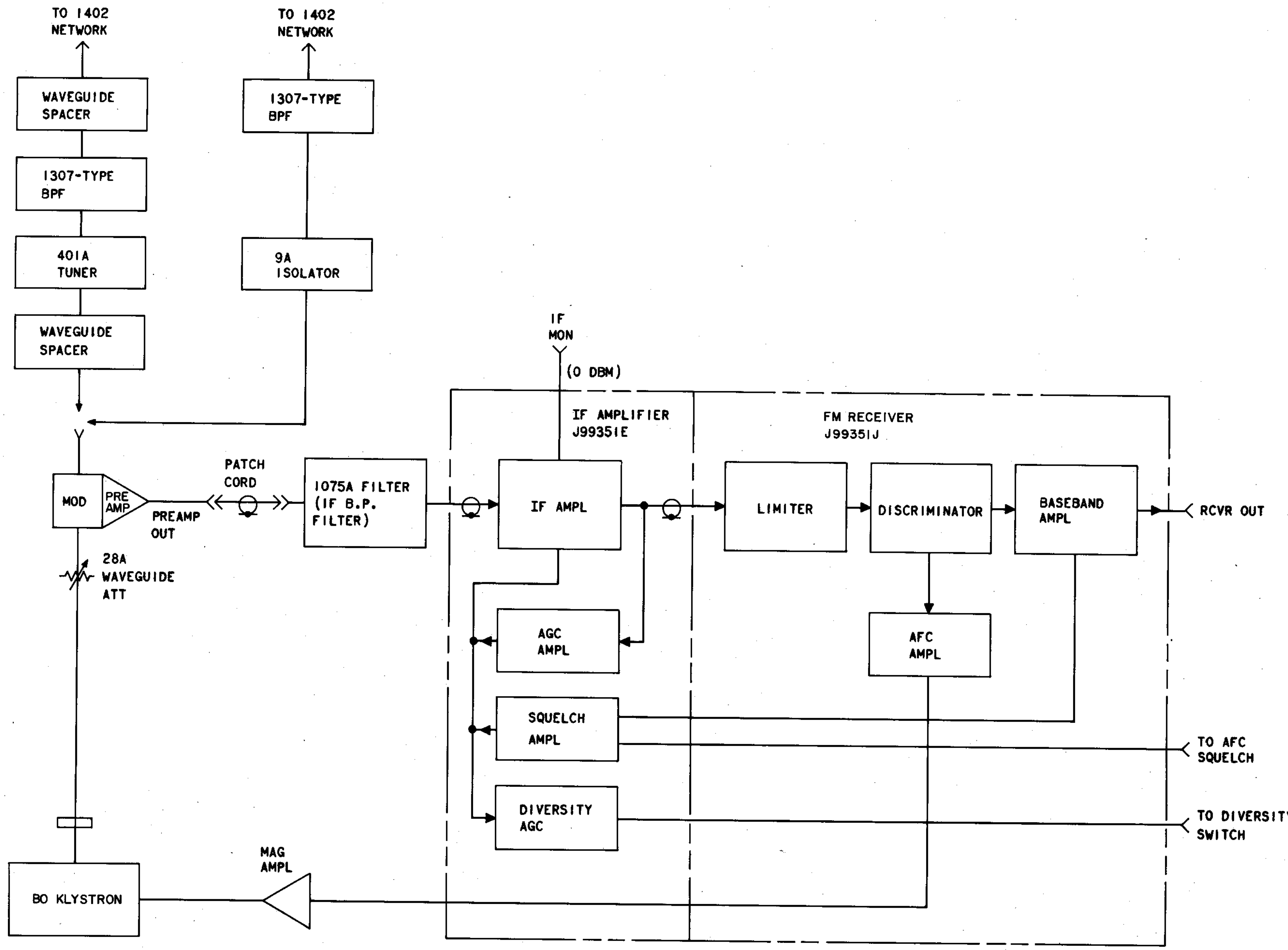


Fig. 9—Receiver Equipped With J99351E IF Amplifier Unit, J99351J FM Receiver, and 1075A Filter—Block Diagram

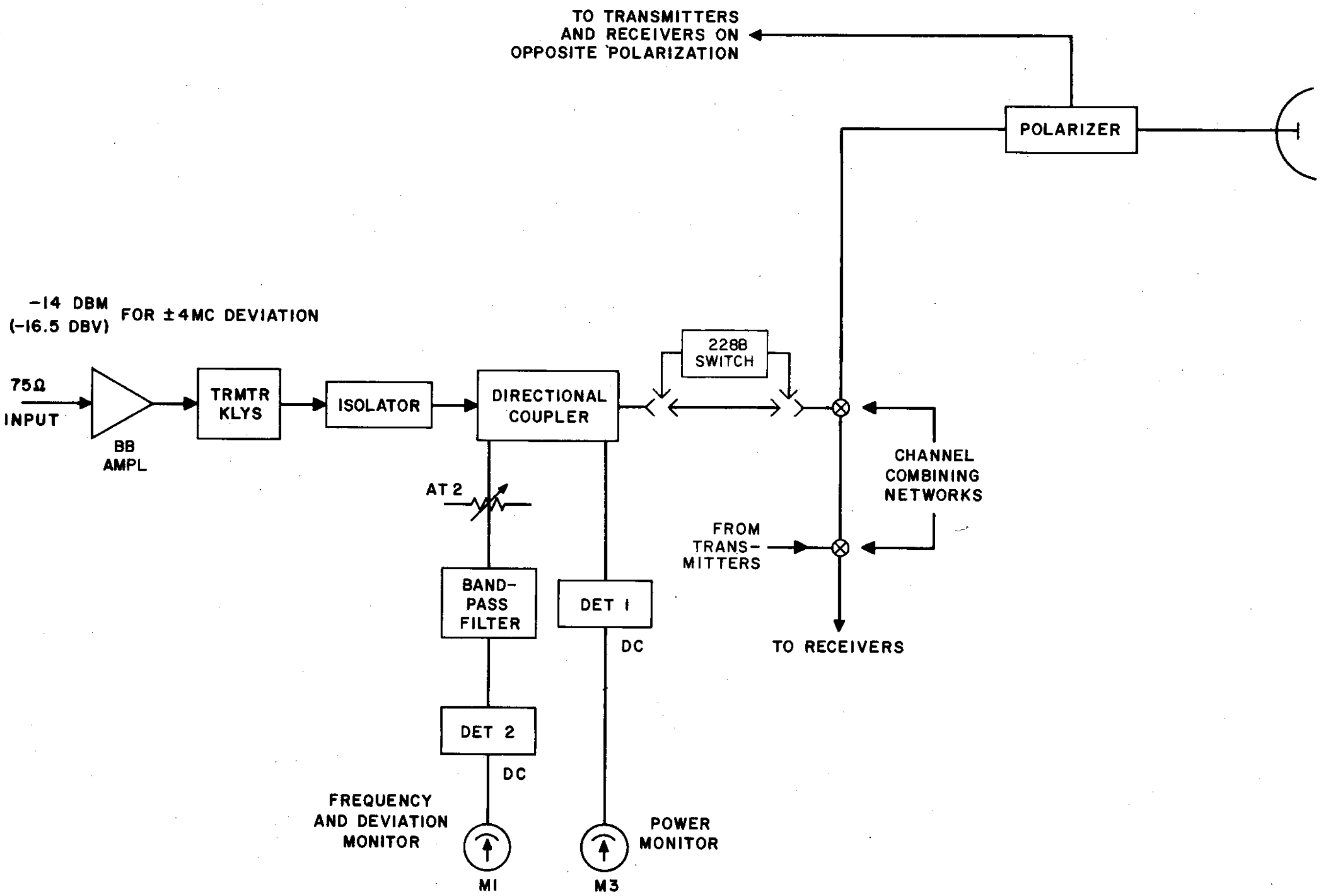


Fig. 10—Transmitter—Block Diagram

214°F, is contained within the system. In that boiler, heat energy generated in the klystrons boils and vaporizes the fluorochemical. The vapor travels through the tube up to the condenser where it cools, condenses, and then runs back to the boiler by gravity feed. Converting the fluorochemical from the liquid to vapor state occurs at constant temperature and continuously draws heat from the klystrons, thereby stabilizing the klystron temperature. Temperature variations in the TR bay environment cause minimum temperature change to the klystrons because an appropriate change in the rate of vaporization and condensation will then take place.

C. Auxiliary Circuits

1.29 The diversity switch unit continually monitors the two channels of a diversity pair and selects the better channel to deliver the baseband output signal, as illustrated in Fig. 11. Baseband switching occurs in the K4 relay controlled by the logic circuit which secures information on the quality of the radio channels from a fade comparator and two pilot monitors. The pilot monitors are bridged across the receiver outputs and detect the presence and absence of a 2600-Hz continuity tone. This tone is applied to the radio at a near-end terminal for alarm signaling purposes and passes through every radio bay and station in a radio system. Absence of this tone on one channel of a diversity pair indicates a failure in that channel, and the switching circuit selects the baseband signal from the good channel. When pilot tones are received by both pilot monitors, the fade comparator determines which receiver supplies the baseband. Transmission quality is compared here by finding which channel has a stronger RF input signal and, therefore, less noise. The better channel is selected on the basis of an AGC voltage comparison made in the fade comparator.

1.30 Order-wire and alarm signals are transmitted over the radio in the voice-frequency portion of the baseband spectrum. As shown in Fig. 11, these signals are separated from the multiplex at each station with split-apart filters and fed to the order-wire and alarm circuits. The complete baseband signal reappears at the output of a second split-apart filter which is turned around to combine. The composite signal is applied to the two transmitters through a split pad. In nondiversity systems, the same order-wire and alarm arrangements are used, but one of the split pad outputs is terminated since only one transmitter is utilized.

1.31 The design of the TL-1, operating in the 11-GHz band and the TM-1 operating in the 6-GHz band, has been coordinated to assure a convenient combination of the two systems in a crossband diversity system. The six 2-way broadband TL-1 channels are available for inband or crossband diversity operation.

D. Channel Frequency Considerations

1.32 The TL-1 radio system uses the 11-GHz frequency band between 10.7 and 11.7 GHz. This band is divided into 24 channels with 40-MHz separation between midchannel frequencies. On any one system hop, alternate channels (12 total) having 80-MHz separation are used. These channels are alternately polarized, giving 160-MHz separation between adjacent channels of the same polarization.

1.33 The adjacent radio paths use the alternate 12 channels, resulting in 40-MHz separation between channels on opposite sides of a repeater station. To provide adequate separation between transmitting and receiving frequencies at any one station, the upper half of the frequency band is allocated to transmitting when the lower half is receiving. Since transmitters work into receivers of the same frequencies, alternate repeater stations will receive in the upper half and transmit in the lower half of the frequency band (Fig. 12). In addition, the separation between the two channels adjacent to midband is 90 MHz instead of 40 MHz. This fulfills the requirement for a minimum

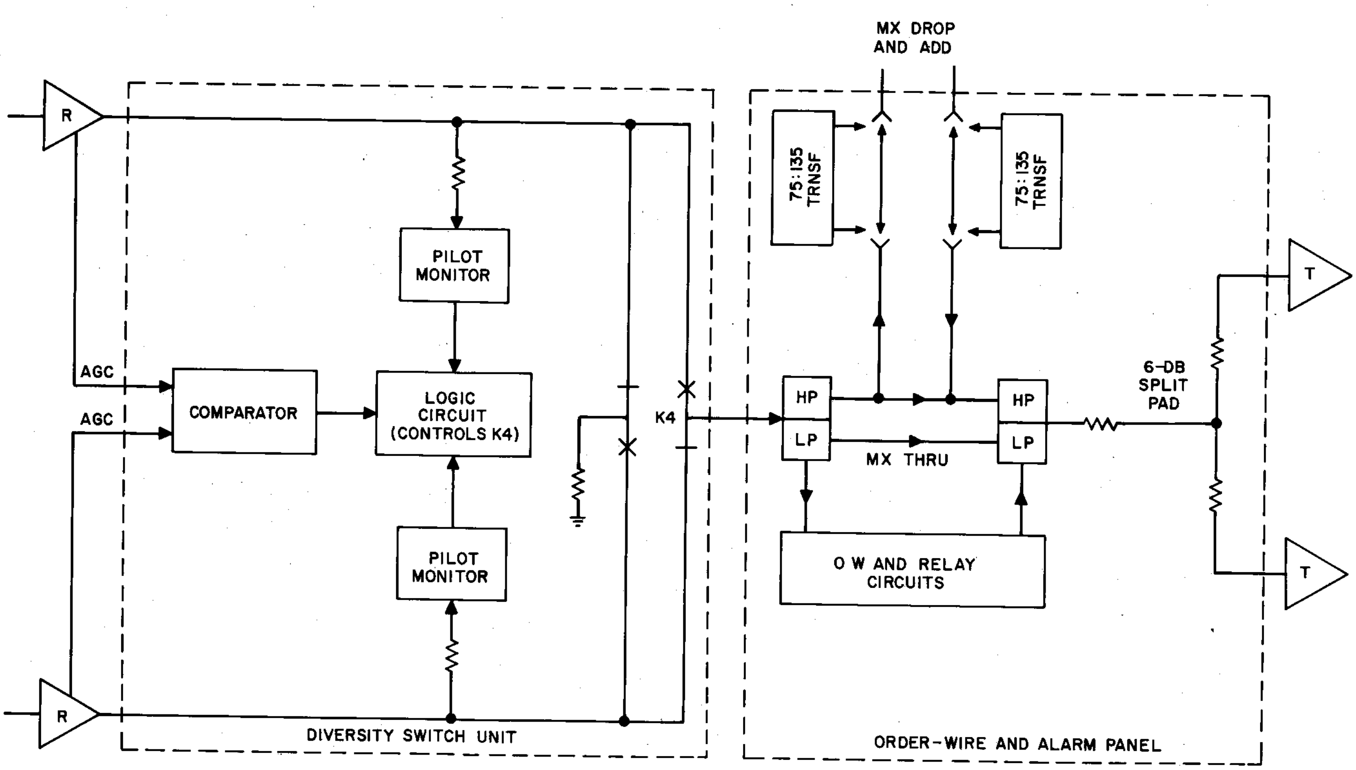


Fig. 11—Transmitter-Receiver Auxiliary Circuits—Block Diagram

separation of 130 MHz (90 + 40) between any transmitting and receiving channel combined at one antenna.

1.34 In order to implement these generalized requirements, a channel assignment and frequency allocation plan has been established. For this plan, the 12 channels in the lower half of the total frequency band are designated group A (old designation) or group P (new designation). The channels are numbered 1A/P to 12A/P in accordance with a definite numerical plan which dictates the system growth. The 12 channels in the upper half of the total frequency band are designated group B (old designation) or group J (new designation) and are numbered 1B/J to 12B/J. The following explains the plan.

(a) Channels (6 maximum) transmitting north or east have odd numbers. Channels (6 maximum) transmitting south or west have even numbers.

(b) All channels transmitting in one direction on a specific hop are designated A/P; in the opposite direction, B/J; and on adjacent hops this is reversed.

(c) Channels are assigned and installed in numerical order within a directional group beginning with channel 1 or 2 (Fig. 13). Channels 1, 2, 3, and 4 are contained in the first diversity switching group; channels 5, 6, 7, and 8 in the second diversity group; and channels 9, 10, 11, and 12 in the last diversity switching group.

(d) In this plan, a single baseband signal (ignoring diversity switching) retains its basic number through a system, but changes its letter designation on adjacent hops. In addition, the polarization of a specific channel is shifted every third hop to minimize the adverse effects of overreach interference.

(e) The two channels within a protection group are oppositely polarized. This will permit maintenance and growth with a minimum interruption of service.

2. METER AND CONTROL PANEL

2.01 The meter and control panel, illustrated in Fig. 14 and 15, is a subassembly of the transmitter-receiver panel that provides means for

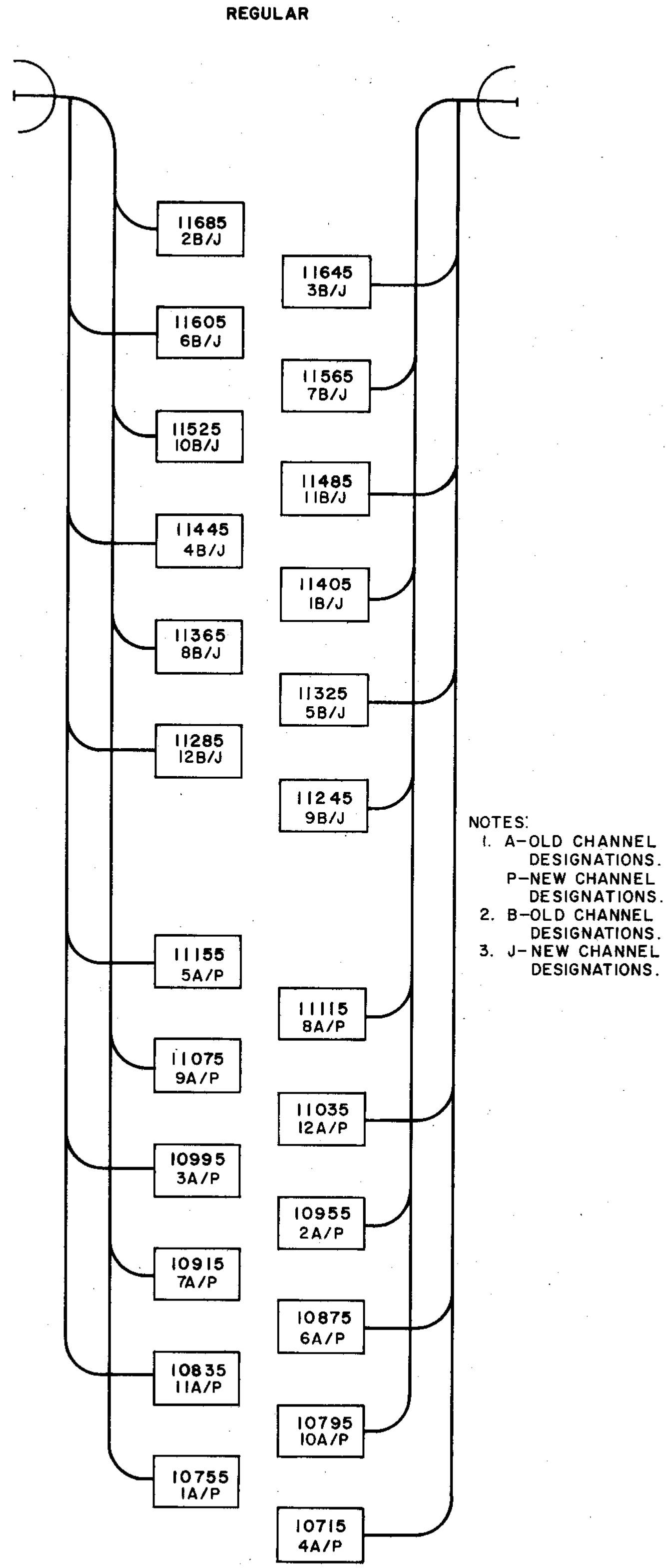


Fig. 12—The 11-GHz Frequency Plan—Block Diagram

11-GHZ PREFERRED GROWTH PLAN

CHANNEL DESIGNATION		GROWTH STAGE					
NEW	OLD	1	2	3	4	5	6
2J	2B	●	●	●	●	●	●
3J	3B				●	●	●
6J	6B					●	●
7J	7B		●	●	●	●	●
10J	10B			●	●	●	●
11J	11B						●
4J	4B				●	●	●
1J	1B	●	●	●	●	●	●
8J	8B		●	●	●	●	●
5J	5B					●	●
12J	12B						●
9J	9B			●	●	●	●
5P	5A					●	●
8P	8A		●	●	●	●	●
9P	9A			●	●	●	●
12P	12A						●
3P	3A				●	●	●
2P	2A	●	●	●	●	●	●
7P	7A		●	●	●	●	●
6P	6A					●	●
11P	11A						●
10P	10A			●	●	●	●
1P	1A	●	●	●	●	●	●
4P	4A				●	●	●

● DENOTES CHANNEL EQUIPPED

TM-1 PREFERRED GROWTH PLAN

CHANNEL DESIGNATION		GROWTH STAGE							
NEW	OLD	1	2	3	4	5	6	7	8
28U	28B								●
28C	28A								●
27U	27B				●	●	●	●	●
27C	27A				●	●	●	●	●
26U	26B						●	●	●
26C	26A						●	●	●
25U	25B	●	●	●	●	●	●	●	●
25C	25A	●	●	●	●	●	●	●	●
24U	24B							●	●
24C	24A							●	●
23U	23B			●	●	●	●	●	●
23C	23A			●	●	●	●	●	●
22U	22B					●	●	●	●
22C	22A					●	●	●	●
21U	21B		●	●	●	●	●	●	●
21C	21A		●	●	●	●	●	●	●
18U	18B								●
18C	18A								●
17U	17B				●	●	●	●	●
17C	17A				●	●	●	●	●
16U	16B						●	●	●
16C	16A						●	●	●
15U	15B	●	●	●	●	●	●	●	●
15C	15A	●	●	●	●	●	●	●	●
14U	14B							●	●
14C	14A							●	●
13U	13B			●	●	●	●	●	●
13C	13A			●	●	●	●	●	●
12U	12B					●	●	●	●
12C	12A					●	●	●	●
11U	11B		●	●	●	●	●	●	●
11C	11A		●	●	●	●	●	●	●

Fig. 13—The TM-1/11-GHz Preferred Channel Growth Plan for Crossband Diversity Application—Chart

making certain maintenance tests and adjustments and for monitoring various parameters within the TR bay without disturbing service. The major testing facilities contained in this panel are as follows:

(a) A meter to measure operating voltages and currents and transmitter power output

(b) A meter used for monitoring and adjusting receiver AFC (panel marked IF) and transmitter (panel marked XMTR) frequency and deviation.

2.02 The control panel components are assembled on an aluminum panel, and meters and operating controls are accessible from the front. Connections to the panel are made through two plugs, making it readily removable for servicing. Overall dimensions of the assembly are approximately 4 inches wide, 14 inches high, and 3 inches deep.

2.03 A schematic of the control panel is shown in Fig. 24. For descriptive purposes, this circuit is divided into four parts which are described in the following paragraphs. ➧In addition, the modifications to the meter and control panels of some TL-1 systems are described, beginning with paragraph 2.13.➧

A. Meter Circuit (M3)

2.04 This meter, in conjunction with switch S6, is used to measure power supply voltages, various currents, and transmitter power. These measured parameters are as illustrated in Table C.

2.05 The supply voltages are measured by switching the meter and series resistor R37, which results in a 30-volt full-scale voltmeter, to the appropriate resistor or combination of resistors in the bleeder string consisting of R28, R29, R31, R32, and R33. This circuit is shown in simplified form in Fig. 16. The regulated 20-volt supply, 27.6-volt battery voltage, and AFC amplifier voltage output are measured directly with the meter and R37. The −200 volt supply measurement is actually a measure of the difference between the −400 volts and what is designated as −600 on the circuit schematic. Minus 600 volts is obtained in the power supply by floating −200 volts below the −400 volts resulting in −600 volts to ground.

2.06 The 1A modulator diode CR1 and CR2 currents are measured directly with M3 used

Fig. 14—J99262K Meter and Control Panel

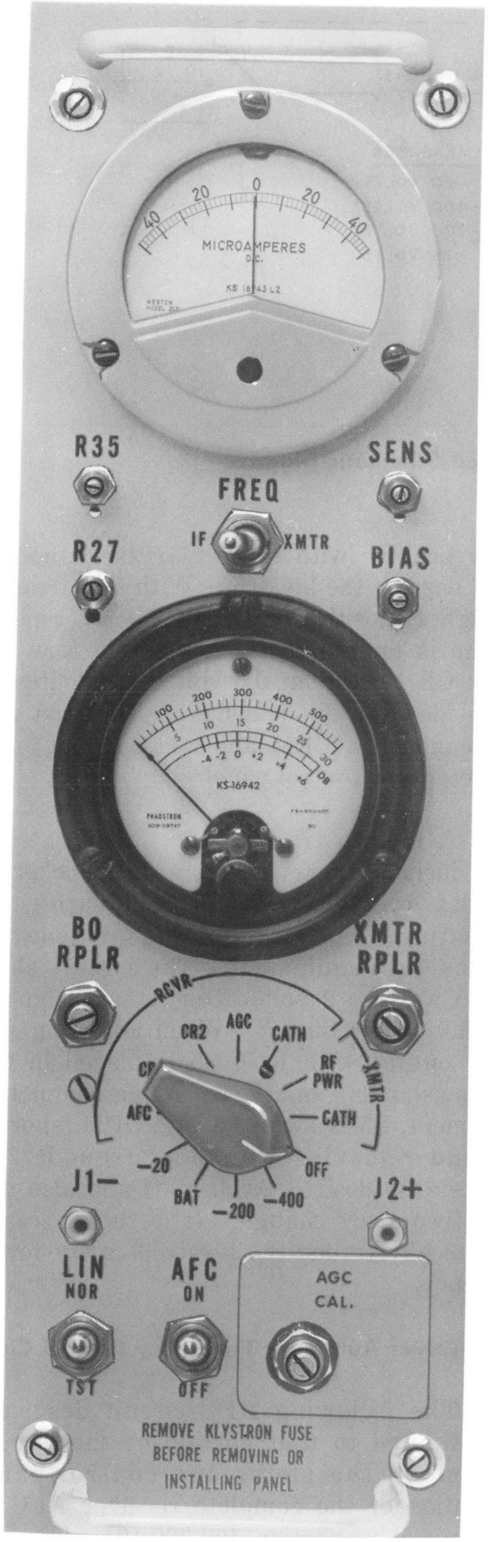


Fig. 15—J99262K Meter and Control Panel Equipped With Printed Wiring Board Assembly (ED-3C535-30)

TABLE C

S6 SWITCH POSITION	M3 INDICATION
1	−20 volt supply voltage
2	Receiver AFC voltage
3	CR1 converter diode current
4	CR2 converter diode current
5	Receiver AGC voltage
6	BO klystron cathode current
7	RF power output
8	Transmitter klystron cathod current
9	Off
10	−400 volt supply voltage
11	−200 volt supply voltage
12	Battery voltage

as a 50-microampere meter. Capacitors C9 and C11 act as smoothing capacitors in these two measurements. The cathode currents of the two klystrons, V1 and V2, are indicated by the voltage drop across cathode resistors R2 and R18. The two klystron cathodes are bypassed to ac ground by capacitors C1 and C6. Resistors R35 and R36 are used to calibrate M3 when it is used to measure transmitter power output via DET 1, the 53A power monitor detector. This provides a means for monitoring power output changes over periods of time. AGC voltage is measured directly with M3 converted to a 6-volt full-scale meter with multiplier resistor R34.

B. Meter Circuit (M1)

2.07 This meter, used in conjunction with other controls, provides a means for monitoring and adjusting transmitter frequency and deviation and receiver AFC error voltage (panel marked IF). Figure 17 is a diagram of the M1 circuit. Transmitter frequency is measured by passing the RF output through bandpass filter FL2 and DET 2 which produces a dc voltage that is applied to M1. The selectivity of FL2 causes a peak indication on M1 when the assigned frequency is reached. Transmitter deviation is measured by observing the drop in the M1 power output indication relative to the unmodulated power output when a modulated signal is fed through FL2. To measure this output

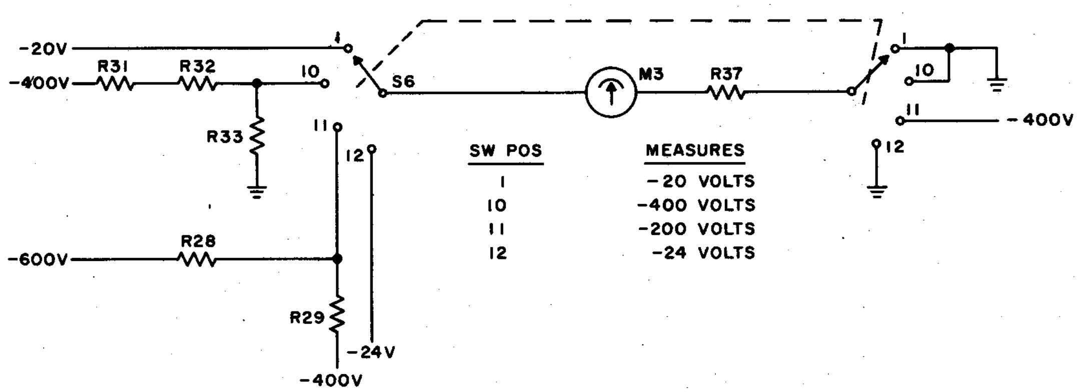


Fig. 16—M3 Metering Circuit—Simplified Schematic Diagram

reduction accurately, AT2 is used to provide a calibrated reference level change independent of detector accuracy. Deviation is adjusted by inserting a fixed level tone into the transmitter baseband amplifier and adjusting the amplifier gain control for a specified reduction of the M1 indication. Sensitivity of the adjustment is improved by an expanded scale feature provided by a bucking voltage obtained from the −20 volt supply. The bucking voltage is secured via R15, R16, and R17, with R16 giving control of the voltage. Increased sensitivity is obtained by decreasing R13 (SENS) which controls the current in M1. R14 is the detector load resistor.

2.08 The IF is monitored with S1 in the IF position, placing the meter across the AFC amplifier in the IF unit which is driven by the discriminator output. Meter M1 is a zero-center type; therefore, any departure from zero indicates a shift in the IF from its nominal value of 70 MHz.

C. Klystron Repeller Voltage Control Circuit

2.09 Klystron repeller voltages are adjusted with potentiometers R19 and R25, designated XMTR RPLR and BO RPLR, respectively, as illustrated in Fig. 18. For klystron protection, internal stops are provided at about 12,000 ohms which prevent the repeller voltages from being reduced to the same potential as the cathode. The swinger arms of the potentiometers are bypassed with capacitors C7 and C8 to reduce noise modulation of the klystrons. The cathodes are also placed on ac ground by capacitors C1 and C6. Diode CR1 and resistor R1 are placed between the BO repeller and cathode to prevent the repeller from becoming highly positive with respect to the cathode, which would destroy the klystron. With this arrangement, the highest positive potential that the repeller may assume is limited to the maximum forward drop across CR1, or about 0.6 volt. An identical circuit is provided for the transmitter klystron although the components, CR11 and R41, are not located on the meter and control panel.

2.10 A simple transmitter linearity circuit is included here that sets the repeller voltage for best ***average*** transmitter linearity, thereby eliminating involved adjusting procedures with complex test equipment. The circuit shifts the repeller voltage 2 volts after it has been adjusted for peak power output. When adjusting for peak power output with R19, S5 is placed in the TST position shorting out R22. After completing this adjustment, S5 is switched to NORM, shorting out R21 and removing the short from R22. This produces the desired 2-volt shift and also causes a small frequency change. It is then necessary to mechanically retune the klystron cavity for correct frequency.

D. Receiver Automatic Frequency Control Circuit

2.11 The following AFC circuit description is limited to that portion of the circuit that appears on the meter and control panel. A description of the complete receiver AFC system is contained in Section 409-300-104. The receiver AFC voltage corrects for frequency drifts and appears across R5, as illustrated in Fig. 19, where it is added onto the BO repeller supply voltage. The R5 voltage will change with frequency error in a direction such that a 70-MHz intermediate

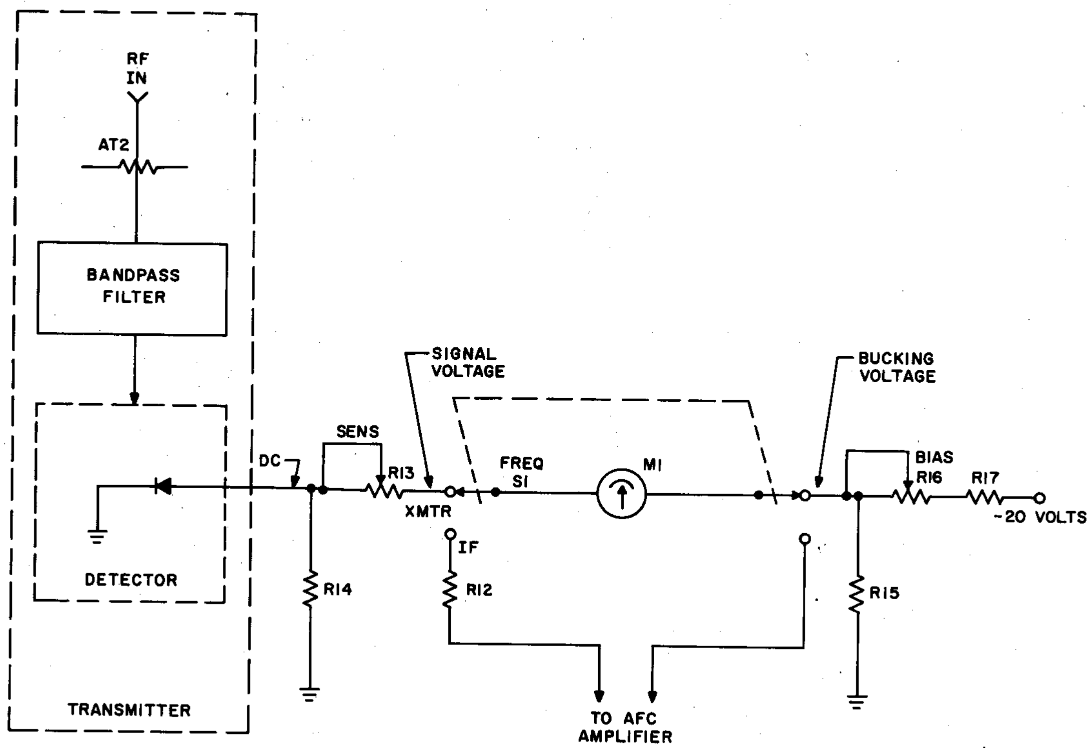


Fig. 17—M1 Metering Circuit—Simplified Schematic Diagram

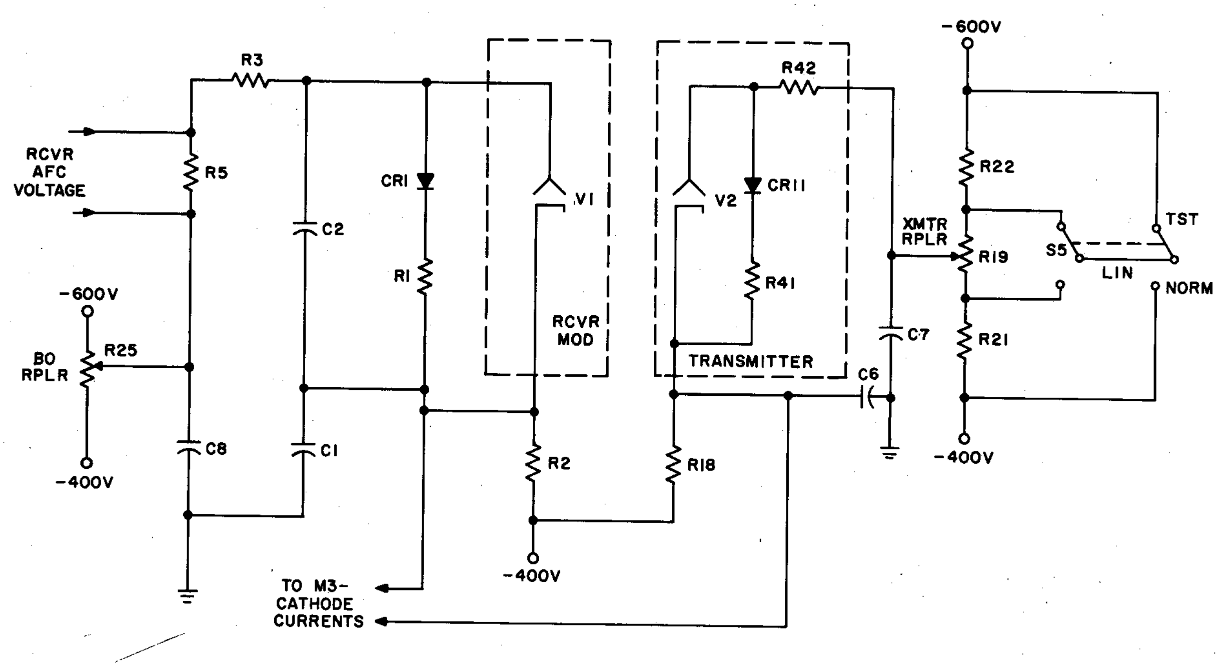


Fig. 18—Klystron Repeller Voltage Circuit—Schematic Diagram

frequency is maintained. Amplification of the receiver AFC error signal is applied as an input to the control winding of the amplifier through R9 and R11. The resistors limit the amplifier gain and prevent complete shorting of the control winding when the input is shorted by switch S2. The amplifier biasing winding draws current from the −20 volt regulated supply though R26 and R27. M3 is used to measure the amplifier output voltage during initial R27 bias-current adjustment. The AFC correcting voltage is obtained from an 1800-Hz square wave derived from the power supply. The square wave is fed through two windings having a reactance that is controlled by the input dc error signal. The square wave is rectified and, because of the variable reactance effect, appears at point 4 as an amplified version of the dc error signal. Because the AFC voltage at 4 is not clean direct current, it is filered by C5, R8, and C4 which form a pi-type filter. To keep the BO within its correct mode, the full AFC voltage is not applied to the repeller and, therefore, the voltage is divided by R5 and R7. Capacitor C3 is across R7 to improve the phase margin of the AFC loop and thereby protect the circuit from loop oscillations.

2.12 An AFC squelch circuit is provided for disabling the AFC circuit during deep fades to prevent AFC lockout. During deep fade conditions, relay K1 releases its short across R10, reducing the magnetic amplifier gain, thus preventing the AFC loop from shifting the BO off frequency. The control for relay K1 is initiated in the IF amplifier.

E. ➧Modification to the Meter and Control Panel

2.13 The addition of a printed-wiring board assembly (ED-3C535-30) modifies the TL-1 meter and control panel (Fig. 15) as follows.

(a) Additional filtering in the BO cathode circuit.

(b) A network to prevent oscillations in the AFC loop due to the new IF-to-baseband receiver arrangement.

(c) A reference voltage supply circuit which provides a reference voltage for the AGC metering circuit. This circuit is accessable from the front of the panel by means of a new AGC CAL control.

2.14 When the J99296G-2 receiver IF and baseband unit is used in the system. The addition of an external squelch relay is required to provide for squelching the baseband output when an excessive fade occurs. This relay is mounted on the adapter bracket that supports the receiver unit. This adapter bracket also contains the terminals that are required for electrical interface between the radio RF panel and the receiver IF and baseband unit.➧

3. BAY ARRANGEMENTS AND INTERCONNECTIONS

3.01 For reference purposes, the TR bays in a radio system are given a particular designation that is determined by their location in the system. This nomenclature is illustrated in Fig. 25 which shows the uses of the bays in the system and the paths taken by the multiplex, order-wire, and alarm signals.

3.02 The types of radio stations which make up a TL-1 route are as follows.

(a) ***Terminal Station:*** This is a terminal (Fig. 20) of the radio system which connects to wire facilities or message terminal equipment.

(1) ***Near Terminal (NT):*** The radio terminal which is nearest the attended control point.

(2) ***Far Terminal (FT):*** The radio terminal station farthest from the above attended control point.

(b) ***Repeater Station:*** An intermediate station where the signal is received, amplified, and transmitted. This station may be equipped to drop and add groups of message channel circuits. A repeater consists essentially of two terminals operating back to back. For purposes of identification, these equipments are identified as follows:

(1) ***Near Repeater (NR):*** The transmitter-receiver equipment which transmits toward the near terminal and receives from the near terminal

(2) ***Far Repeater (FR):*** The repeater station equipment which transmits toward the far terminal and receives from the direction of the far terminal

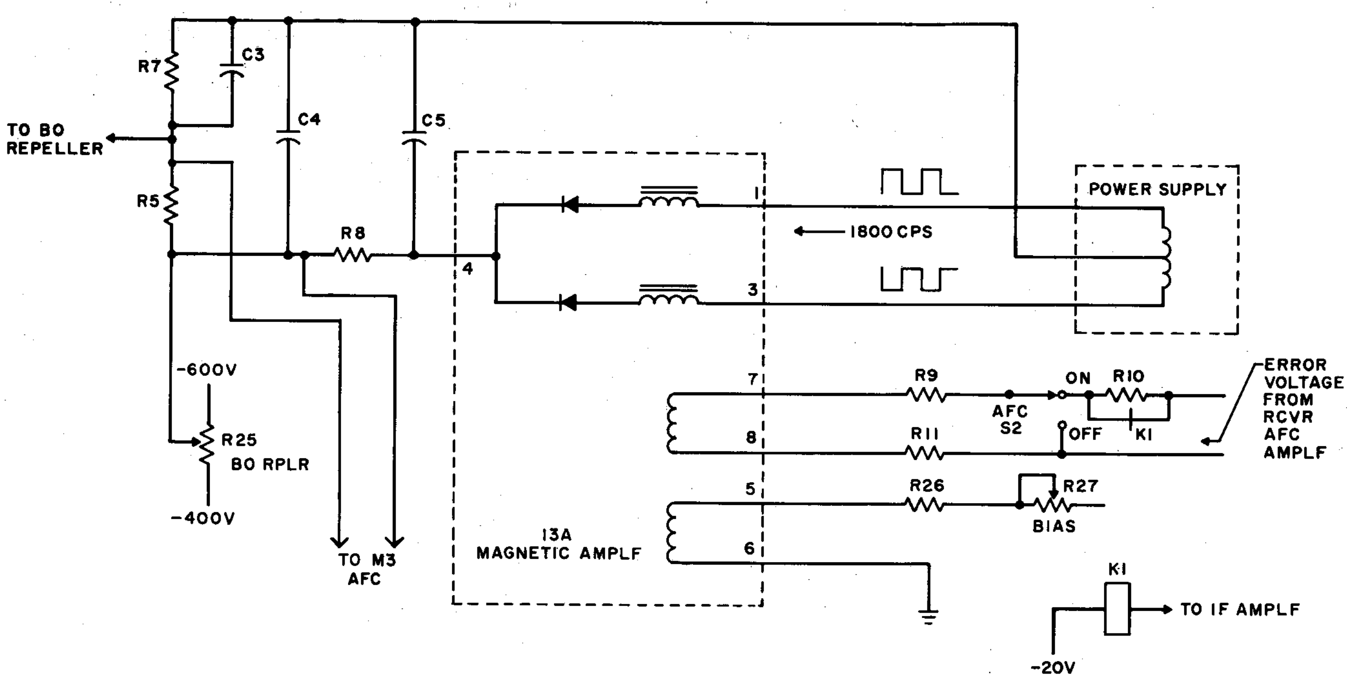


Fig. 19—Receiver Automatic Frequency Control Circuit—Schematic Diagram

(3) ***Spur:*** The radio equipment at a repeater station which accommodates transmission to a radio spur or branch route.

3.03 Waveguide interconnections between the antenna and TR bays vary and depend upon whether the system is diversity or nondiversity, whether the location is an indoor or outdoor installation, and the number of channels in a system. For example, when only one polarization is utilized in an antenna, as with a 2-channel nondiversity system, a transducer is used in place of the polarizer. Also, the isolator between transmitters and receivers is installed only after a system reaches a certain size. Waveguide interconnections and bay arrangements for all of the different cases are illustrated schematically in Fig. 26 and 27.

3.04 Two baseband interconnections are needed from the transmitter and receiver to the diversity switch panel or order-wire and alarm panel. These connections are made directly from the input and output jacks of the trasmitter and receiver to a terminal strip on either of the other two panels. In diversity systems, an AGC voltage connection is made between the receivers and the diversity switch panel. This connection is made via TSA, a 48-terminal connector in the TR bay.

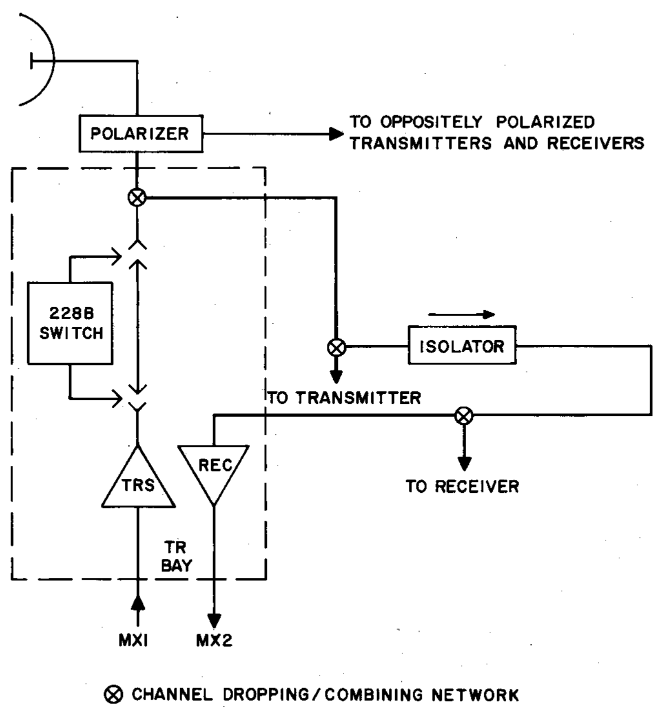


Fig. 20—Typical Terminal-Type Transmitter-Receiver Bay Arrangement—Block Diagram

The baseband signal and AGC voltage paths are shown for a typical diversity system at a repeater station as illustrated in Fig. 21.

4. CHANNEL DROPPING AND COMBINING NETWORKS

4.01 Transmitters and receivers are connected to the antenna waveguide runs by means of channel dropping and combining networks (Fig. 23). The networks extract or insert one channel while allowing others to pass through without interference. The combining networks, utilized by the transmitter, are located nearest the antenna while the dropping networks appear in the latter half of the waveguide run. The last receiver in a run does not require a network because the only signal in the guide at this point is the one intended for this receiver. That is, other received signals are droppped before this point, and the transmitted signals do not travel backward, but travel only toward the antenna.

4.02 A network is composed of two hybrid junctions, two identical band-reflection filters, and a waveguide terminating section. Figure 22 is a block diagram that illustrates the action of a channel dropping network. Each of the hybrids is analogous to a low-frequency hybrid coil and operates as follows. An input signal in line C, incident on the hybrid, is divided equally and with equal phase into side ARMS A and B, but does not appear in D or reappear in C. Also, signals in A and B are incident on the hybrid; a wave proportional to their vector sum will appear in C and a wave proportional to their vector difference will appear in D. A signal in the input ARM incident on the junction will, therefore, be divided into the side arms and travel on to the two band-reflection filters. These filters are designed to reflect frequencies lying within a specific channel band and pass all other frequencies. Frequencies outside of the reflection band of the two filters will pass through the filters to ARMS A and B of the output hybrid. Here they will have equal phase and amplitude, their vector difference will be zero, and none of the power will enter D. The two signals will combine and pass through C to the succeeding receivers. The signal lying within the band of the reflection filters will be reflected back to ARMS A and B of the input hybrid. The two signals arrive at these connections in opposite phase since one of them has traveled twice over an extra quarter wavelength of line. Their vector sum will be zero, and no power appears in terminal C of the input hybrid. All of the power appears at terminal D as the dropped channel.

4.03 Conversely, this circuit inserts signals lying within the band of the reflection filters in the main line without interfering with any of the signals passing though it at other frequencies. For combining purposes, a transmitter output signal would enter the upper hybrid, as illustrated in Fig. 22, through ARM D. It would then split into the side ARMS A and B with a 180-degree phase shift and travel down the arms to the filters. Here the signals are reflected and arrive at ARM C in phase and, therefore, add and pass into the main waveguide to the antenna.

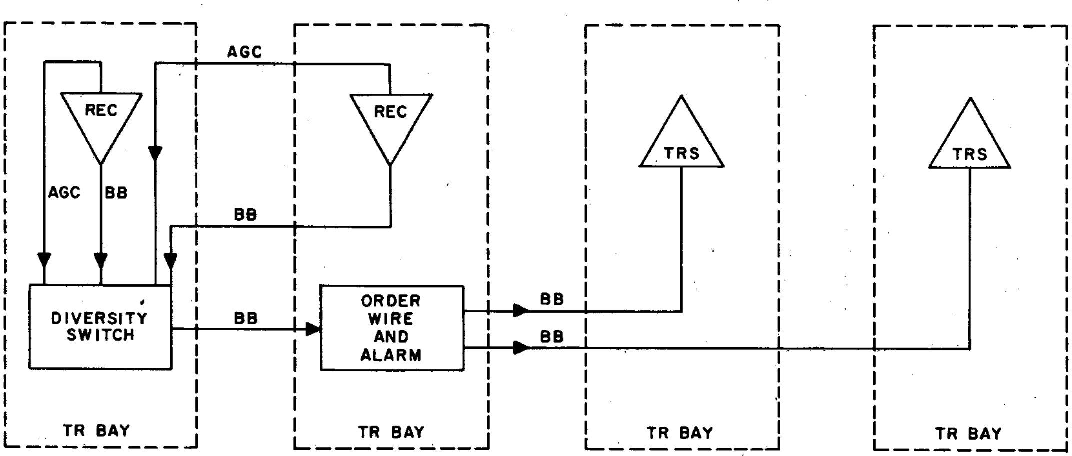


Fig. 21—Automatic Gain Control and Baseband Signal Paths—Block Diagram

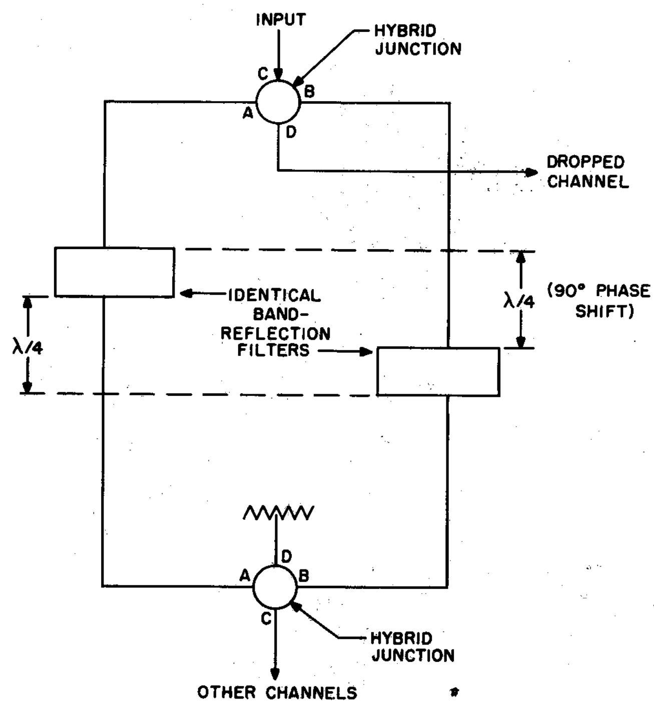


Fig. 22—Channel Dropping Network—Block Diagram

4.04 Figure 23 is an illustration of the 1402-type channel dropping and combining network. The hybrid junctions, located at both ends, are composed of an E ARM (C), two side arms (A and B), and H ARM (D) which is conjugate to the E ARM. The E ARM waveguide is split by a wedge to form the two side arms. The H ARM is coupled to the side arms by means of two coaxial waveguide probes that are themselves coaxially connected. Tuning studs are located within the hybrid to minimize reflections caused by discontinuities in the wedge, probe, etc. The channel-reflection filters are located between the side arms of the two hybrid junctions. Different filters are used for different channels. There are 24 different codes of reflection filters required for the 24 radio channels.

5. REFERENCE LIST

5.01 The following drawings are related to this section:

SECTION	TITLE
SD-3C250-01	TL-1 Radio Changes for 600-Circuit Loading
SD-97035-01	TL-1 Radio—Application Schematic
SD-81507-01	TL-1 Radio—Power Supply Circuit
SD-97038-01	TL-1 Radio—Transmitter-Receiver Circuit
SD-97039-01	TL-1 Radio—Receiver IF and Baseband Circuits
SD-97045-01	Station Grounding—AC Power and Lightning Protection Circuit
SD-97042-01	TL-1 Radio—Diversity Switching Circuit
SD-97056-01	ON Carrier Telephone—Application Schematic for Combining Circuits for Use with TL-1 Radio
SD-95296-01	TL-1 Carrier—Application Schematic for Radio Applications
SD-95296-01	TL-1 Carrier—Application Schematic for Radio Applications
SD-97100-01	TL-1 Radio Alarm Encoder Circuit
SD-97041-01	TL-1 Radio Order-Wire and Alarm Circuit
SD-81557-01	Power Service and Distribution Circuit for TL-1 Radio Stations
SD-81559-01	Air Navigation Obstruction Lighting Circuit for TL-1 Radio

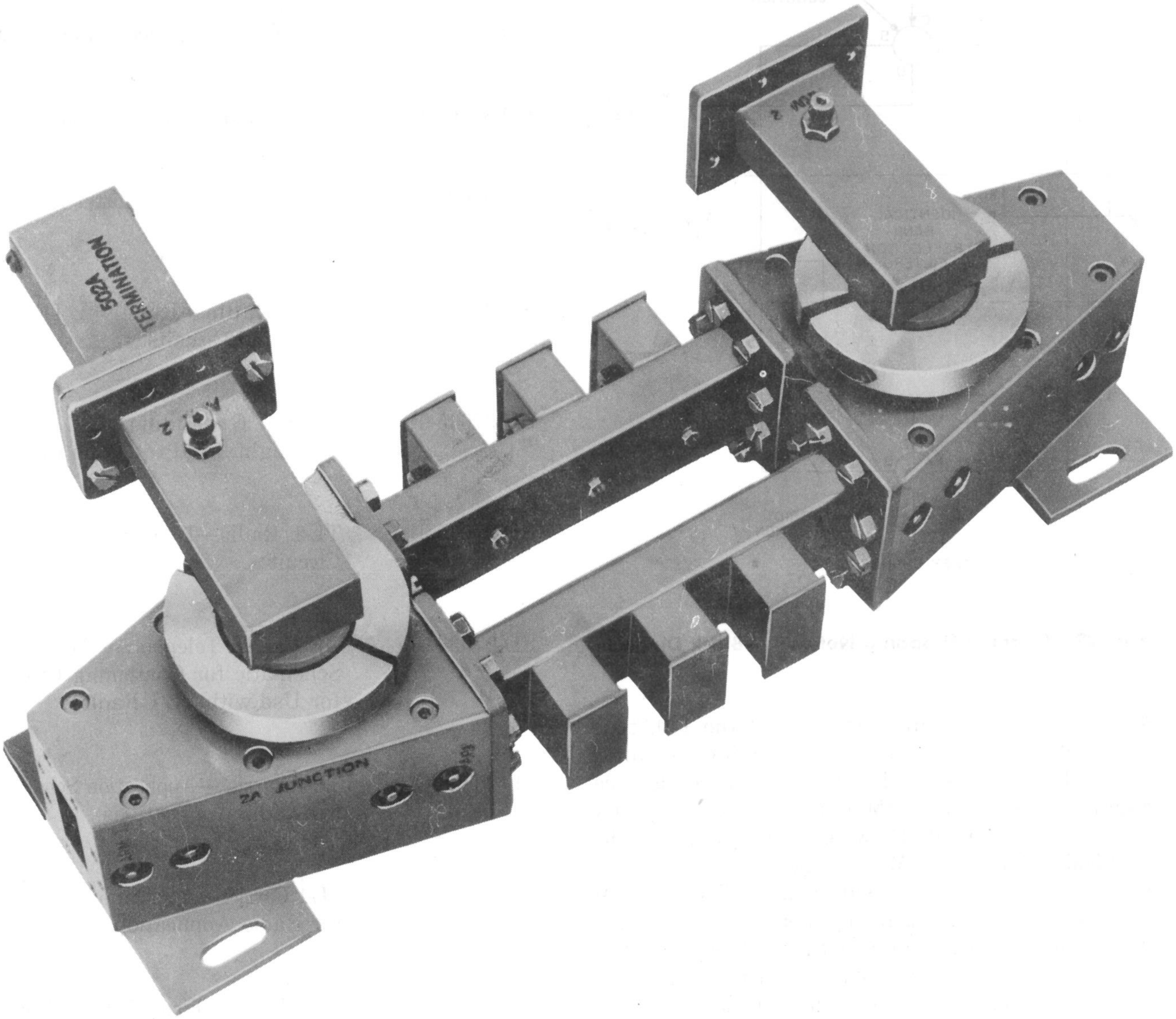


Fig. 23—1402-Type Channel Dropping and Combining Network

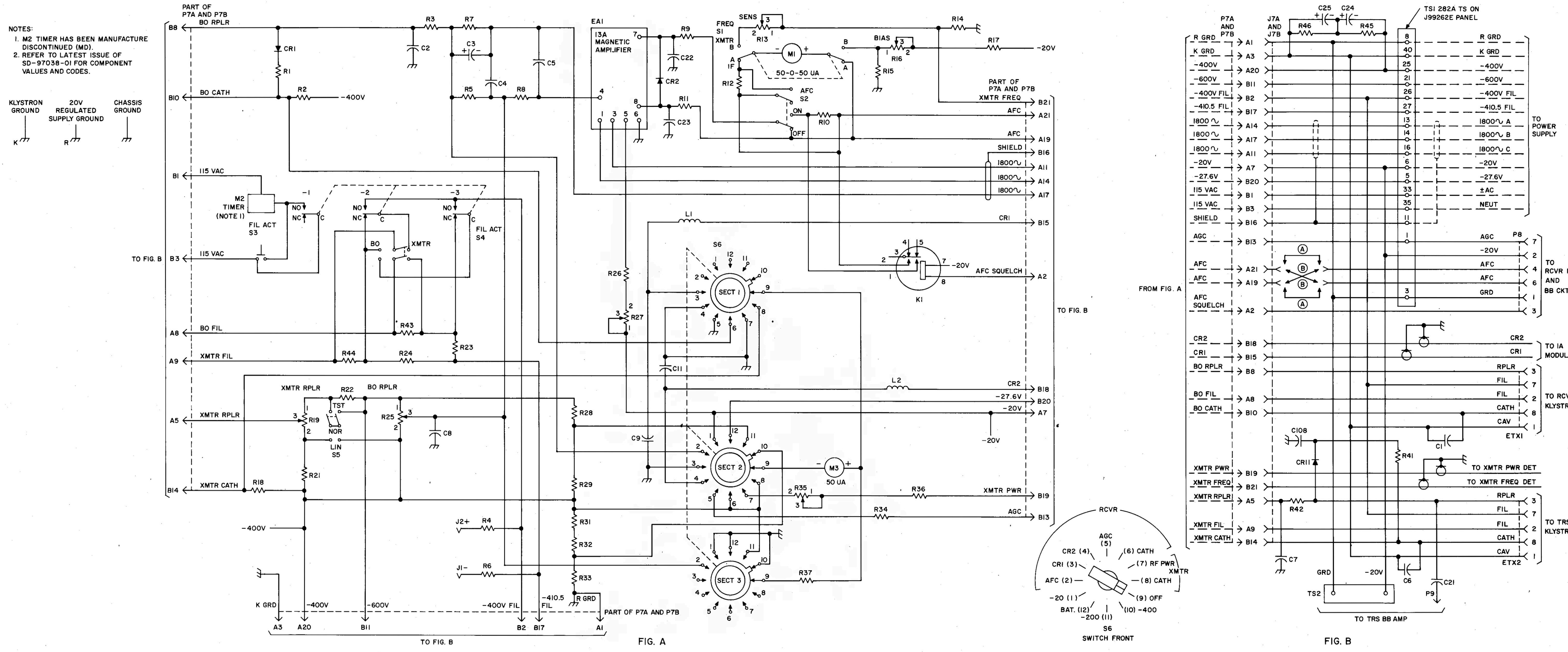


Fig. 24—Typical Meter and Control Panel Circuit—Schematic Diagram

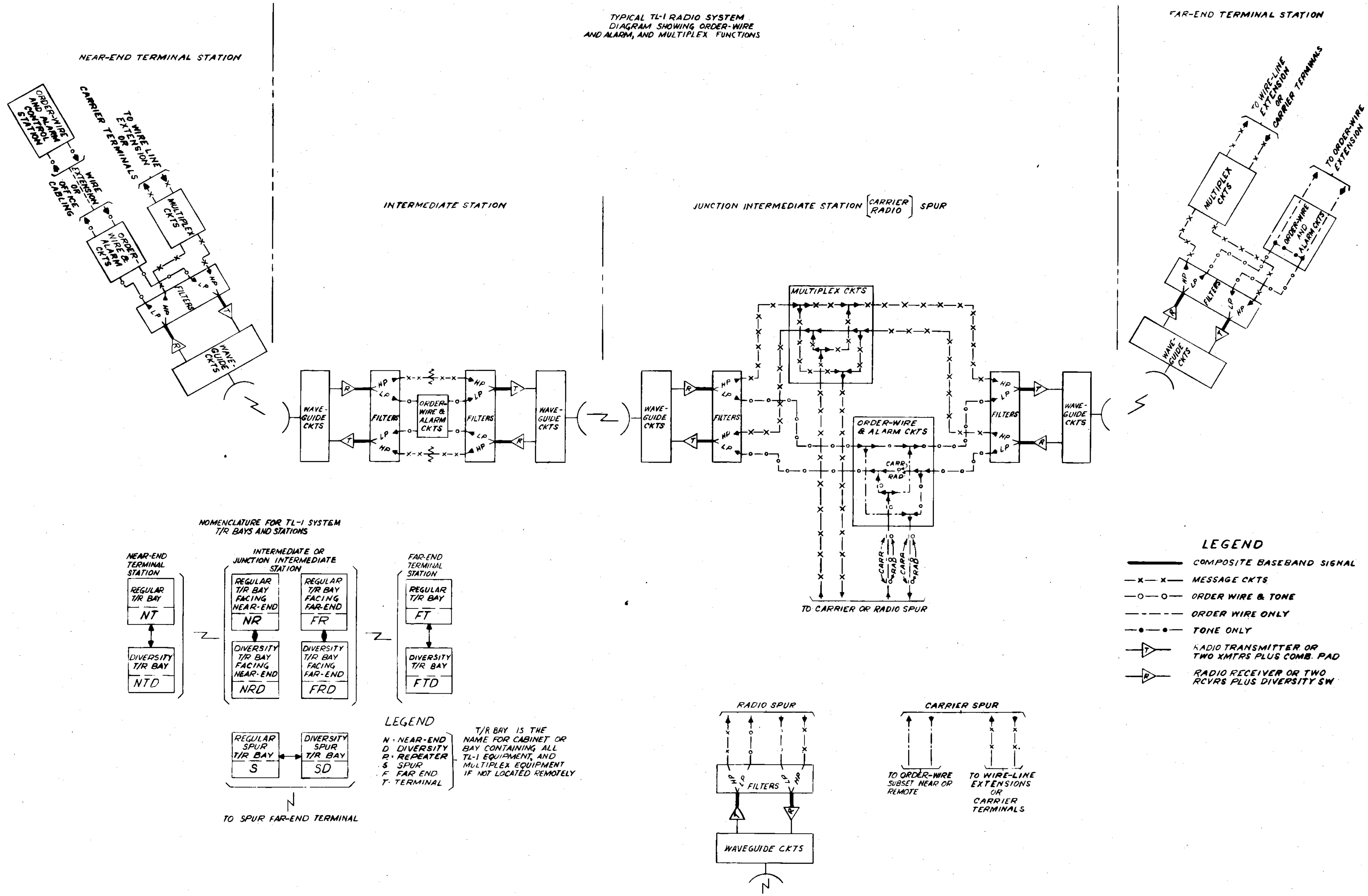


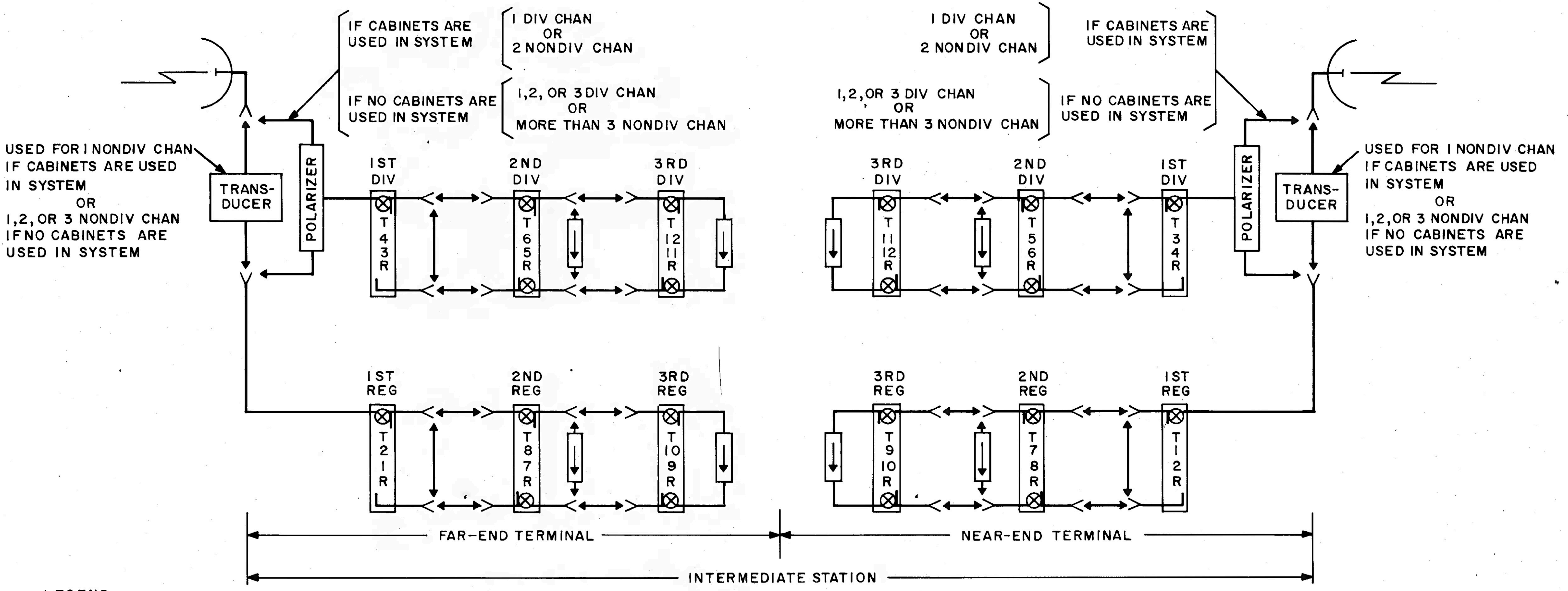
Fig. 25—Typical TL-1 Radio System—Functional Block Diagram

LEGEND

1. ⊗ IS A CHANNEL DROPPING/COMBINING NETWORK.
2. ▭⇒ IS AN ISOLATOR.
3. A BASIC LETTER AND ITS PRIME LETTER CONSTITUTE AN EQUIVALENT 4-WIRE CIRCUIT (XX', YY' & ZZ') WHICH MAY BE CONNECTED TO A 2-WIRE LINE CIRCUIT THROUGH THE USE OF A HYBRID.
4. RECEIVERS PAIRED FOR PROTECTION ARE COMBINED AT A DIVERSITY SWITCH.
5. TRANSMITTERS PAIRED FOR PROTECTION ARE COMBINED AT A SPLIT PAD.
6. H - HORIZONTAL SIGNAL POLARIZATION
7. V - VERTICAL SIGNAL POLARIZATION
8. T - TRANSMITTER RADIO EQUIPMENT
9. R - RECEIVER RADIO EQUIPMENT

T/R BAY ARRANGEMENT AND FREQUENCY PLAN
FOR AS MANY AS { 3 TWO-WAY DIVERSITY CHANNELS / 6 TWO-WAY NONDIVERSITY CHANNELS

Fig. 26—Transmitter-Receiver Arrangement and Frequency Plan—Block Diagram



LEGEND

1. ⊗ IS A CHANNEL DROPPING/COMBINING NETWORK
2. [→] IS AN ISOLATOR
3. RECEIVERS PAIRED FOR PROTECTION ARE COMBINED AT A DIVERSITY SWITCH
4. TRANSMITTERS PAIRED FOR PROTECTION ARE COMBINED AT A SPLIT PAD
5. T—TRANSMITTER RADIO EQUIPMENT
6. R—RECEIVER RADIO EQUIPMENT

GROWTH PATTERN

FOR T/R BAYS 1 TO 6: TWO-WAY NONDIV CHANS AND 1 TO 3 TWO-WAY DIV CHANS

Fig. 27—Transmitter-Receiver Growth Pattern—Block Diagram