RADIO ENGINEERING
MICROWAVE RADIO
11-GHZ SYSTEMS
TL-2

CONTENTS PAGE

CONTENTS PAGE

1. GENERAL

1.01 The TL-2 radio is a frequency-modulated (FM) microwave radio system designed to provide a highly reliable message transmission medium and a television capability. The TL-2 features compact design, high reliability, simplified maintenance, full-float battery operation, low cost, and is completely transistorized except for the transmitter and receiver klystrons.

1.02 The TL-2, in crossband diversity with TM-1, is designed to yield higher reliability, carry heavier message loads, give better noise performance, and furnish television capability in the short-haul field. It is intended to provide short-haul radio channels (1) in difficult geographical situations, (2) where cable or wire facilities would not prove economical, (3) where open wire requires replacement, (4) where existing cable routes are being exhausted, and (5) as spurs leading from heavy route microwave or cable systems. System performance objectives and possible problem areas are discussed in this practice to make engineering of the TL-2 system easier.

2. TRANSMISSION CHARACTERISTICS

2.01 The TL-2 radio channel design capacity is based on a received signal level no lower than −42 dBm and a 10 hop noise objective of 35 dBrnc0 (29 dBa0). A received signal of −45 dBm includes a 3-dB maintenance margin to allow for minor imperfections in system alignment and system degradation with age. Table A lists the TL-2 radio channel capacity.

2.02 The TL-2 system channel capacity is based on length, noise, and economics and is capable of accomodating more than 600 channels or more than ten hops dependent upon the particular application and the corresponding trunk noise. To meet the general objectives set forth for the system, transmission characteristics as listed in Table B were established.

TABLE A

TL-2 RADIO CHANNEL CAPACITY

TYPE OF LOAD	MESSAGE CIRCUITS	NUMBER OF HOPS
L Carrier	600	10
ON Carrier	96	10
N Carrier	48	10
Network television	*	6
Educational television	*	10

* One television channel per radio channel.

3. FREQUENCY PLAN

A. General

3.01 The TL-2 radio system uses the 1000-MHz frequency band between 10.7 and 11.7 GHz. This band is divided into 24 channels with 40-MHz separation between midchannel frequencies. In general, the frequency assignments and channel numbers are identical to those used in TJ and TL-1 radio systems.

3.02 Both the TL-2 and TM-1 systems normally employ a four-frequency plan using each RF frequency only once at a repeater. In any one direction of transmission, alternate channels having 80-MHz separation are used. To provide adequate separation between transmitters and receivers at any one station, the upper half of the frequency band is allocated to transmitting when the lower half is receiving. An adjacent station will be transmitting in the lower half of the band and receiving in the upper half. The upper and lower halves of the frequency band are separated by a 90-MHz guard band.

3.03 Polarization of adjacent channels alternates between vertical and horizontal to provide maximum frequency separation between channels of the same polarity. This method provides 160-MHz separation between adjacent channels of the same polarization. Overreach interference is reduced by alternating horizontal and vertical polarization of a given frequency. A frequency having a horizontal polarization in one hop will occur again two hops away but will be vertically polarized.

TABLE B

TL-2 TRANSMISSION CHARACTERISTICS

GENERAL	
RF frequency range	10.7 to 11.7 GHz
Frequency plan #1	Modified plan
Number of channels	24
Frequency plan #2	Staggered plan
Number of channels	24
Pre-emphasis	
Message	9 dB
Video	7 dB
Power requirements	
T/R (watts)	150
AC operation	1 phase — 120 volts
Reserve	Battery
DC operation	—24 volts
Ambient temperature range	+20° to +120°F
Maximum hops per alarm section	10
Relay rack	7 or 9 feet by 23 inches
TRANSMITTER	
Output power (minimum)	+20 dBm (0.1 watt)
Peak deviation	±5 MHz
Frequency stability	±0.05 percent (±5 MHz)
Input impedance	
Message and video	75 ohms unbalanced 124 ohms balanced
ON/N carrier option	135 ohms balanced
Sine-wave level in for reference deviation (±4 MHz)	—14 dBm
Video level in for reference deviation (±4 MHz)	—16.5 dBV
RECEIVER	
Input	—42 dBm
Noise figure	10.5 dB typical
Fade margin (minimum)	30 dB
Intermediate frequency (IF)	70 MHz
IF bandwidth (0.5 dB or better)	16 MHz
Effective noise bandwidth (3.0 dB)	20 MHz
Baseband width	10 Hz to 6 MHz
Output impedance	
Message and video	75 ohms unbalanced 124 ohms balanced
ON/N carrier option	135 ohms balanced
Sine-wave level out for reference deviation (±4 MHz)	+6.5 dBm
Video level out for reference deviation (±4 MHz)	+4 dBV
Differential gain (six hops of TV)	1.0 dB
Differential phase (six hops of TV)	1.0°

B. Modified Plan

3.04 In order to implement the preceding general requirements, a channel assignment and frequency allocation plan has been established. For this plan (see Table C), the 12 low-frequency channels are designated group A, or more recently, P. The 12 high-frequency channels are group B, or J. An example of this plan over four hops is shown in Fig. 1. Notice that channels (six maximum) transmitting north or east have odd numbers and channels (six maximum) transmitting south or west have even numbers. Also, all channels in one direction on a specific hop are designated P, in the opposite direction J, and on adjacent hops, reversed. The growth plan for TL-2 is shown in Fig. 2.

C. Staggered Plan

3.05 The staggered plan is a special plan used for intersecting TL-2 routes. This plan locates the radio channels half way between the normal frequencies and shifts all the P frequencies 20 MHz higher and the J frequencies 20 MHz lower. It does not increase the available number of channels on a given radio hop since a 160-MHz minimum frequency spacing must be maintained between channel separating networks in a given waveguide run. The 24 channels and receiver beat oscillator frequencies for the staggered plan are listed in Table D.

3.06 Mixing frequency plans is discouraged since it reduces the ultimate route capacity and may lead to interpanel frequency interference from beating oscillators. The frequency of the beat oscillator is kept within the assigned common carrier band, but may be above or below the frequency of the incoming RF carrier. The position of a particular beat oscillator is dictated by interference considerations. Before a frequency plan is selected, consult Sections 940-330-102* and 940-330-110 for information concerning microwave interference.

* This section may not be available. Consult the latest numerical index.

TABLE C

MODIFIED PLAN RF CARRIERS WITH BEAT OSCILLATOR FREQUENCIES

CHANNEL DESIGNATION			FREQUENCY — GHZ		BO RELATIVE POSITION
	OLD	NEW	SIGNAL	BEAT OSCILLATOR	
1	A	P	10.755	10.825	Above
2	A	P	10.955	11.025	Above
3	A	P	10.995	11.065	Above
4	A	P	10.715	10.785	Above
5	A	P	11.155	11.085	Below
6	A	P	10.875	10.805	Below
7	A	P	10.915	10.845	Below
8	A	P	11.115	11.045	Below
9	A	P	11.075	11.145	Above
10	A	P	10.795	10.865	Above
11	A	P	10.835	10.905	Above
12	A	P	11.035	11.105	Above

CHANNEL DESIGNATION			FREQUENCY — GHZ		BO RELATIVE POSITION
	OLD	NEW	SIGNAL	BEAT OSCILLATOR	
1	B	J	11.405	11.335	Below
2	B	J	11.685	11.615	Below
3	B	J	11.645	11.575	Below
4	B	J	11.445	11.375	Below
5	B	J	11.325	11.255	Below
6	B	J	11.605	11.535	Below
7	B	J	11.565	11.495	Below
8	B	J	11.365	11.295	Below
9	B	J	11.245	11.315	Above
10	B	J	11.525	11.595	Above
11	B	J	11.485	11.555	Above
12	B	J	11.285	11.355	Above

4. TRANSMITTER

A. General

4.01 The TL-2 radio transmitter (Fig. 3) frequency-modulates a baseband signal onto a microwave carrier in the 11-GHz common-carrier frequency band. The baseband signal is amplified by the transmitter baseband amplifier and applied to the repeller of the transmitter klystron. The klystron then produces a frequency-modulated RF signal which is passed through an isolator to a double-directional coupler. The directional coupler provides access for both frequency and power monitoring of the signal. The through arm of the directional coupler directs the RF signal to a manually operated waveguide switch which is provided to isolate the transmitter RF output from the antenna system during maintenance of the radio transmitter. From the waveguide switch, the signal passes through a combining network to the antenna system.

B. Transmitter Baseband Amplifier

4.02 The transmitter baseband amplifier is a part of the transmitter control and baseband amplifier unit. The transmitter baseband amplifier is designed to be able to modulate the transmitter to a ± 4 MHz peak-to-peak deviation with a -14 dBm sine-wave test signal. The output of the baseband amplifier is impressed on the repeller of the transmitter klystron. The transmitter baseband amplifier gain is adjustable over a range of ± 3.5 dB to compensate for klystron repeller sensitivity variations.

4.03 In order to provide a transmitter control and baseband amplifier unit which would be interchangeable for both TL-2 and TM-1 and to provide design improvements, a new unit was initiated. The resulting redesign, coded J99302J2 List 4, provides a single interchangeable unit which is physically and electrically suitable for both TM-1 and TL-2. However, transmission performance of the original unit, J99296J-1, is still good.

4.04 The new transmitter baseband amplifier is flat to within ± 0.1 dB from 50 Hz to 10 MHz. Amplifier linearity is improved. The differential gain and phase are negligible. The technique of noise loading, applied to control units, allows an evaluation of performance with regard to their contribution to overall system performance. Figure 4 shows the noise loading performance for typical units of new design at 70 kHz and 2438 kHz. Unit-to-unit variations and changes caused by extremes of temperature are considerably less in the new unit.

C. Klystrons and Associated Equipment

4.05 The klystron for the TL-2 radio system, used in both transmitter and receiver, is a WE457A reflex klystron. Specifications for this tube are listed in Table E. The estimated average life of a 457A klystron is 40,000 hours and the warranty period is 10,000 hours. A typical power output versus frequency plot for the 457A is shown in Fig. 5.

4.06 The frequency stability of the TL-2 transmitter is obtained in part by carefully controlling the temperature of the klystron. The radio equipment must operate in an environment of outside temperatures ranging from -40°F to $+120$°F. Over a 3-month maintenance interval, the range of ambient temperature is not likely to exceed 100°F. To meet the ± 0.05 percent frequency accuracy for TL-2, the klystron temperature must be held to ± 3°F. Klystron voltages must also be closely regulated.

4.07 A special feature of the 457A klystron is a closely controlled temperature coefficient which does not exceed ± 0.15 MHz per degree fahrenheit. This feature, in conjunction with the vapor-phase cooling system, makes the frequency relatively independent of ambient temperature.

4.08 A klystron protection circuit is available for TL-2 radio systems. The klystron protection circuit consists of a normally open temperature-operated switch in series with a current-limiting resistor connected from the 6-ampere inverter fuse to ground. Should the boiler temperature reach 265°F, the switch will close, blowing the inverter fuse. This removes all operating voltages from both klystrons. Without the thermostat action, both klystrons would be destroyed within minutes; thus, the blowing of the fuse does not add significantly to the radio channel outage time for this particular trouble condition.

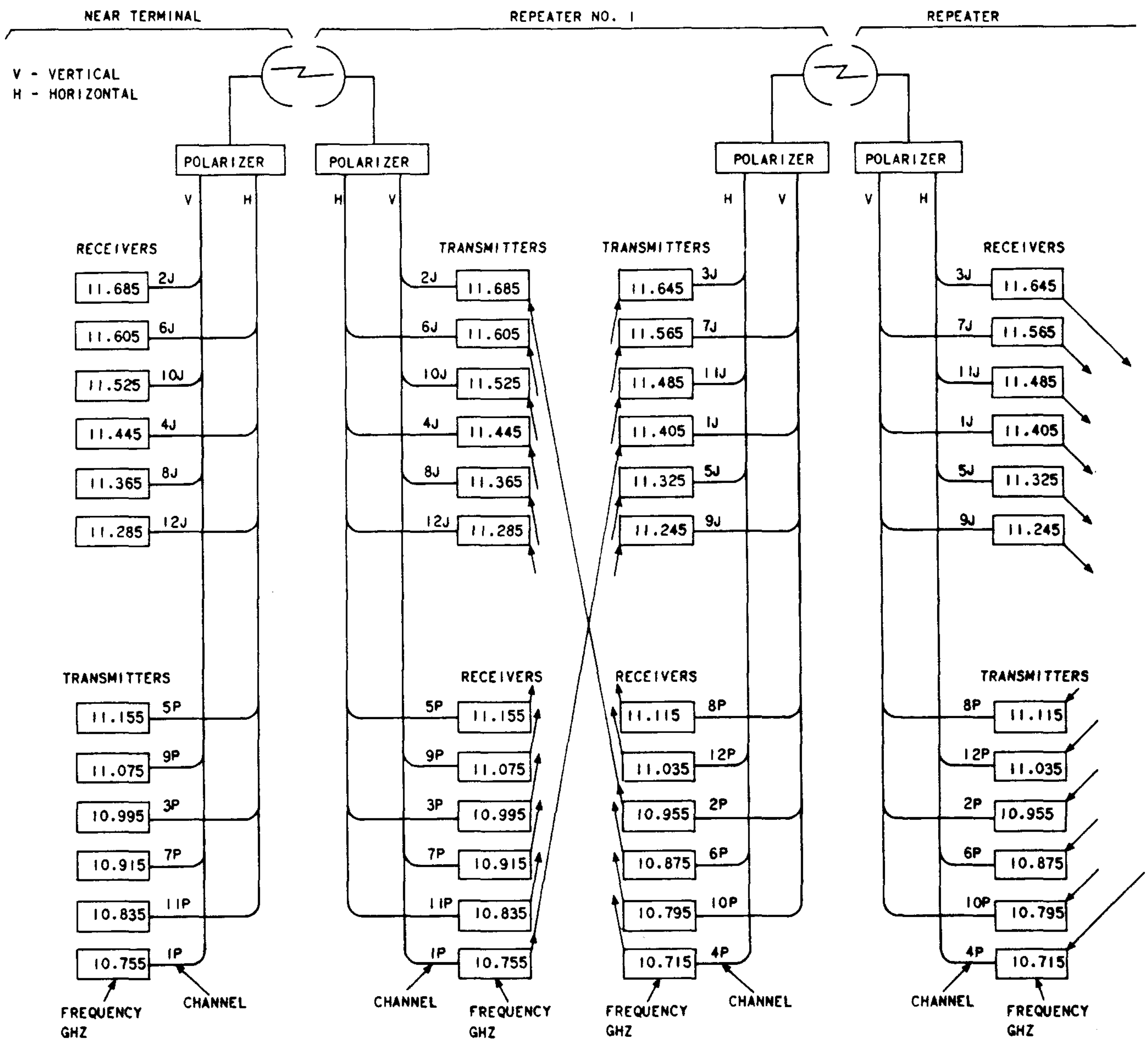


Fig. 1—Modified Frequency Plan TL-2 Radio System (Sheet 1)

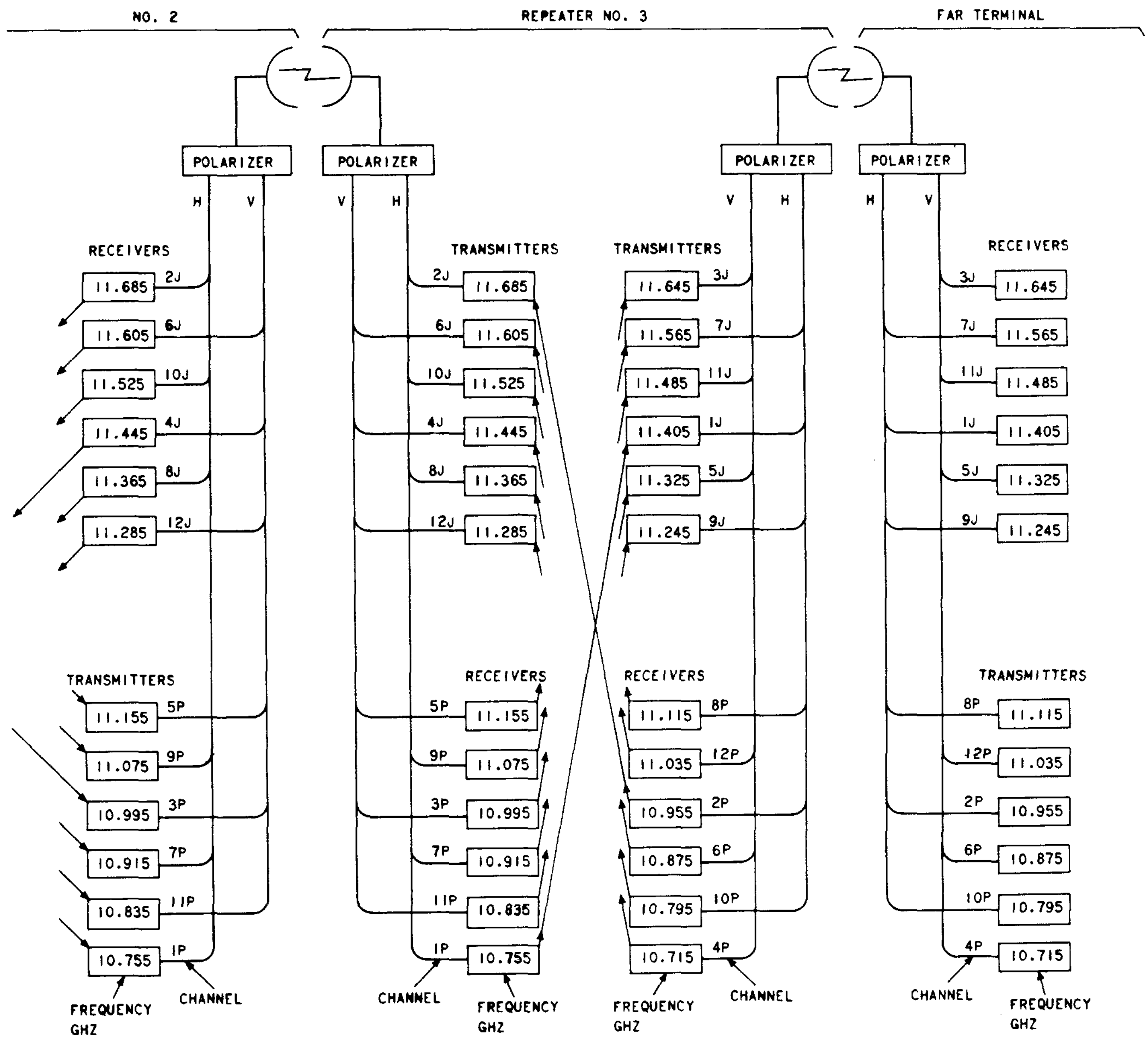


Fig. 1—Modified Frequency Plan TL-2 Radio System (Sheet 2)

CHAN NO.	GROWTH STAGE					
	1	2	3	4	5	6
2J	●	●	●	●	●	●
3J				●	●	●
6J					●	●
7J		●	●	●	●	●
10J			●	●	●	●
11J						●
4J				●	●	●
1J	●	●	●	●	●	●
8J		●	●	●	●	●
5J					●	●
12J						●
9J			●	●	●	●

CHAN NO.	GROWTH STAGE					
	1	2	3	4	5	6
5P					●	●
8P		●	●	●	●	●
9P			●	●	●	●
12P						●
3P				●	●	●
2P	●	●	●	●	●	●
7P		●	●	●	●	●
6P					●	●
11P						●
10P			●	●	●	●
1P	●	●	●	●	●	●
4P				●	●	●

● DENOTES CHANNEL EQUIPPED

Fig. 2—Modified Plan—Preferred Channel Growth

TABLE D

STAGGERED PLAN RF CARRIERS WITH BEAT OSCILLATOR FREQUENCIES

CHANNEL DESIGNATION			FREQUENCY — GHZ		BO RELATIVE POSITION
	OLD	NEW	SIGNAL	BEAT OSCILLATOR	
1	C	E	10.775	10.845	Above
2	C	E	10.975	11.045	Above
3	C	E	11.015	11.085	Above
4	C	E	10.735	10.805	Above
5	C	E	11.175	11.105	Below
6	C	E	10.895	10.825	Below
7	C	E	10.935	10.865	Below
8	C	E	11.135	11.065	Below
9	C	E	11.095	11.025	Below
10	C	E	10.815	10.885	Above
11	C	E	10.855	10.785	Below
12	C	E	11.055	11.125	Above

CHANNEL DESIGNATION			FREQUENCY — GHZ		BO RELATIVE POSITION
	OLD	NEW	SIGNAL	BEAT OSCILLATOR	
1	D	D	11.385	11.315	Below
2	D	D	11.665	11.595	Below
3	D	D	11.625	11.555	Below
4	D	D	11.425	11.355	Below
5	D	D	11.305	11.375	Above
6	D	D	11.585	11.515	Below
7	D	D	11.545	11.615	Above
8	D	D	11.345	11.275	Below
9	D	D	11.225	11.295	Above
10	D	D	11.505	11.575	Above
11	D	D	11.465	11.535	Above
12	D	D	11.265	11.335	Above

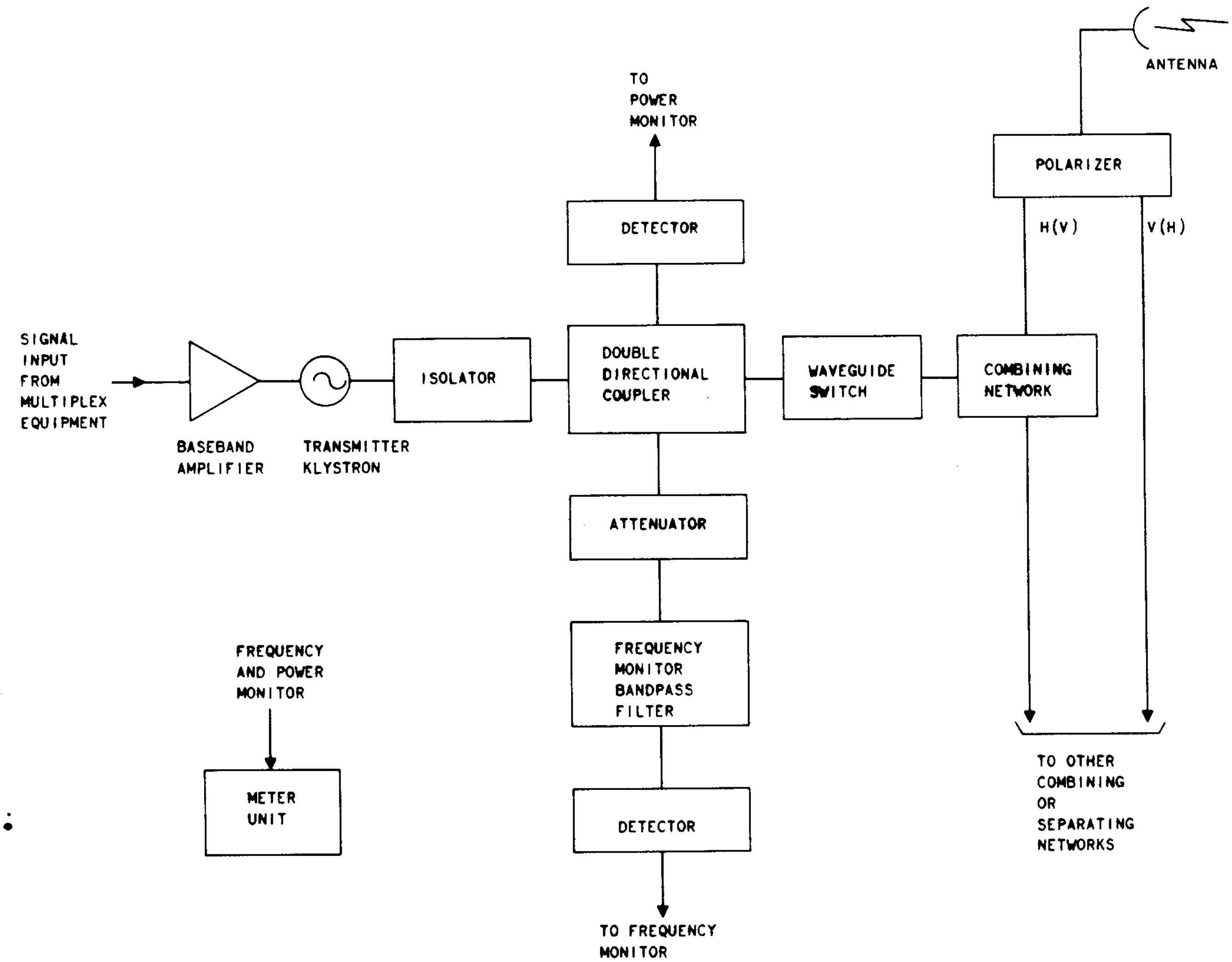


Fig. 3—Block Diagram—TL-2 Transmitter

D. Transmitter Isolator

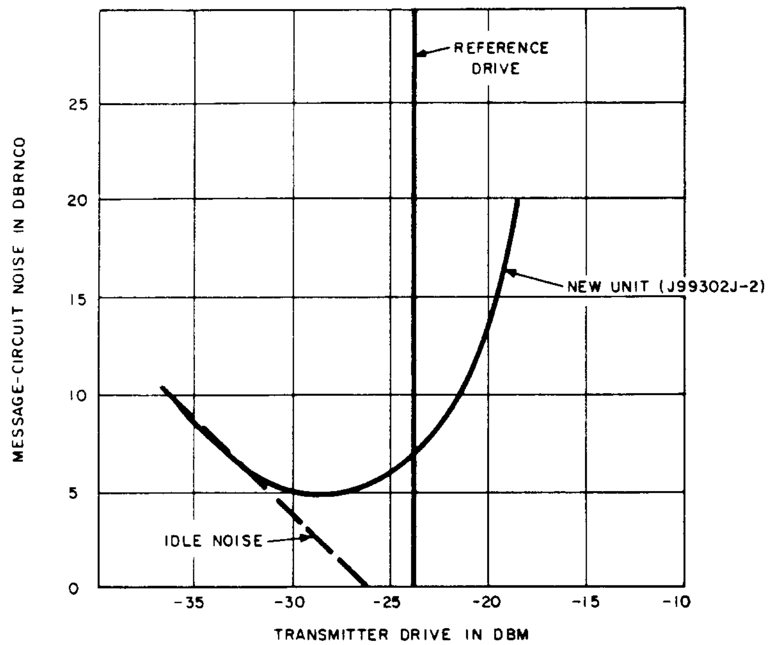
4.09 A high reverse-loss isolator is used as an impedance match between the klystron and the waveguide and antenna. Typical performance characteristics for the dielectric-loaded full-height E-plane isolator used in the TL-2 are shown in Fig. 6. Specifications for the 4A isolator follow.

4A ISOLATOR

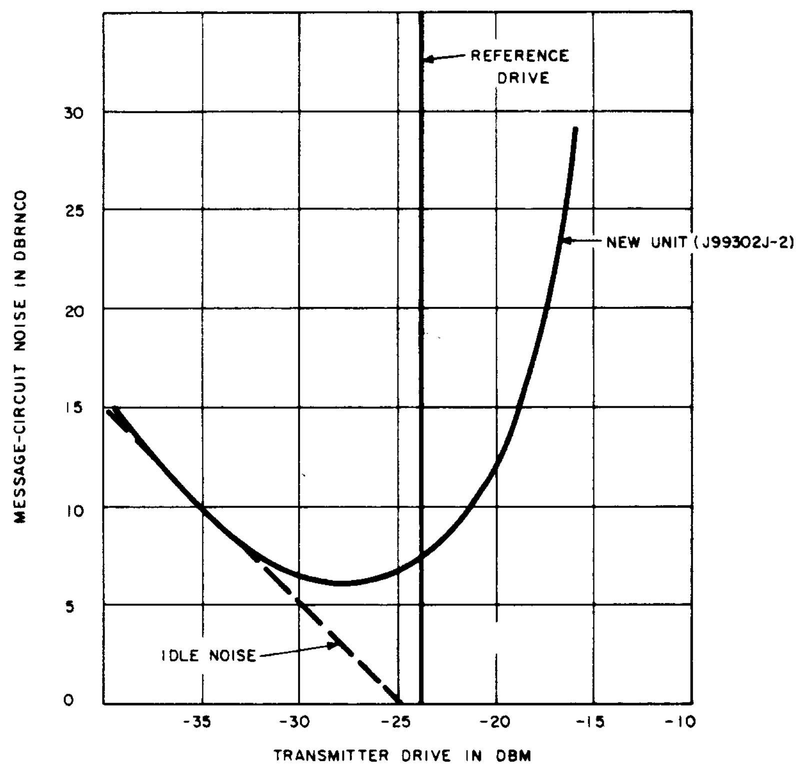
Forward loss	< 0.9 dB
Reverse loss	< 55.0 dB

E. Directional Coupler, Power Monitor, Frequency Monitor, and Waveguide Switch

4.10 In the TL-2 radio system the output of the isolator is connected to a double-directional coupler. The directional coupler provides two ports having outputs which are 20 dB down, relative to the main transmission path. One port channels RF energy which is used to measure transmitter power output and the other feeds a waveguide network which monitors transmitter frequency.



(A) NOISE CONTRIBUTION – SLOT AT 2438 KHZ



(B) NOISE CONTRIBUTION – SLOT AT 70 KHZ

Fig. 4—Noise Contribution of Transmitter Baseband Amplifier (600-Circuits Without Pre-Emphasis)

TABLE E

457A KLYSTRON TYPICAL OPERATING CHARACTERISTICS

RF power output	0.1 W (min)
Resonator voltage	400V
Repeller voltage	—115V
Repeller modulation sensitivity	2.3 MHz/volt
Electronic tuning range	100 MHz
Heater current	0.90 AMP
Cathode current	43 MA
Frequency-temperature coefficient	0.15 MHz/°F
Oscillating mode	3-3/4

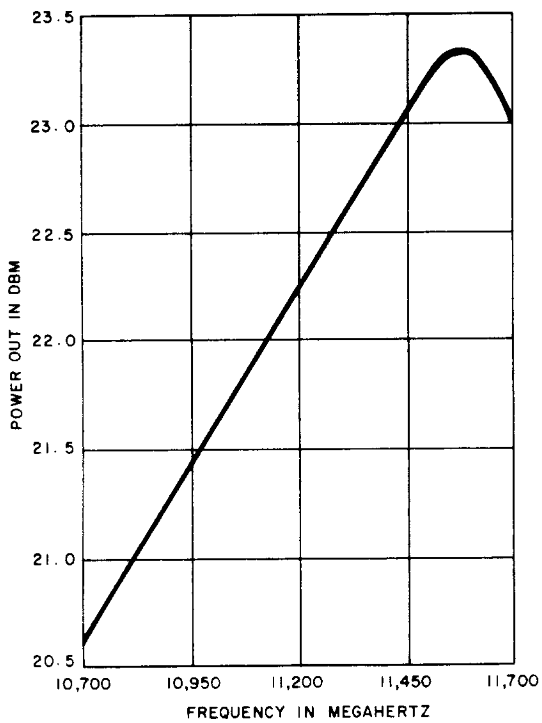


Fig. 5—Typical Power Output vs Frequency For the 457A Klystron

4.11 The transmitter power monitoring circuit consists of a detector whose output is indicated on a meter on the meter unit. After proper calibration, the lower scale of the lower meter on the meter unit indicates the transmitter klystron output less 20 dB. The adjustment of

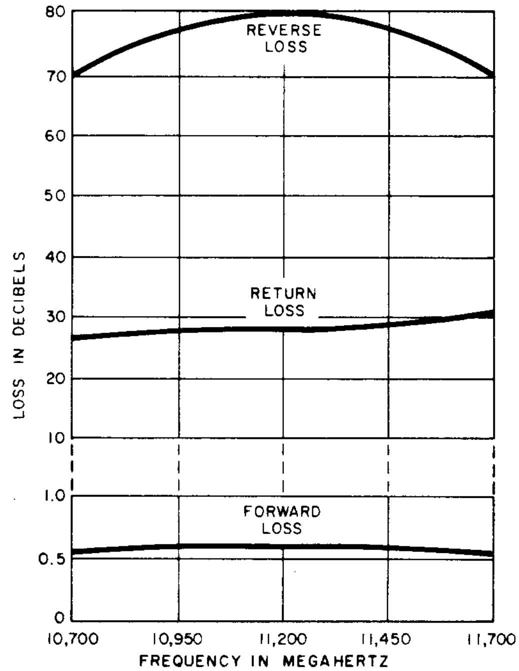


Fig. 6—Typical 4A Transmitter Isolator Characteristic

"DET 1 CAL" on the transmitter control unit references the meter reading to the klystron output.

4.12 The transmitter frequency-monitoring network consists of an attenuator followed by a frequency-monitor bandpass filter and a detector. The frequency-monitor bandpass filter is a stable Invar bandpass filter used as a reference cavity. The transmission characteristic of a typical reference filter is shown in Fig. 7. Specifications on the 1314-type bandpass filter follow:

1314-TYPE BANDPASS FILTER

Midband loss	< 2 dB
Bandwidth (5-dB point)	Approximately 5 MHz

A visual readout is obtained from a meter on the meter unit. When the unmodulated transmitter is "on frequency," the meter reading will be a maximum.

4.13 The waveguide switch used in the TL-2 is required in tests, such as the initial tuning of the klystron, where the transmitter must be disconnected from the antenna. The switch consists of a short section of waveguide with a narrow slot to accept a double-ended vane.

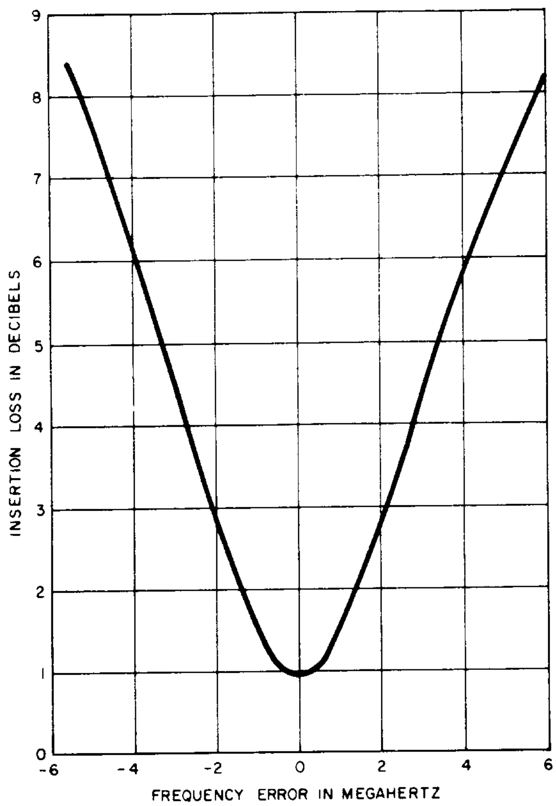


Fig. 7—Transmission Characteristic of a Typical TL-2 Reference Filter

F. Channel Combining Network

4.14 The channel combining network is a 1402-type waveguide network used for either channel separation or combination. Transmission through a network (ports A and C) is nearly lossless for all channels except for the assigned channel where the through-loss is very high but the loss to the drop (ports A and B) is low. The transmission characteristic of a typical TL-2 channel combining network is shown in Fig. 8.

5. RECEIVER

A. General

5.01 The TL-2 radio receiver (Fig. 9) accepts frequency-modulated signals in the 10.7- to 11.7-GHz band and delivers signals at baseband frequencies to a 75-ohm unbalanced line. A channel dropping network separates a particular RF signal from the composite received signal. From the channel dropping network, the signal enters the receiver through a bandpass filter (for further channel selection) and either a waveguide tuner or an isolator for application to the modulator-preamplifier. The RF signal is converted to a band centered around 70 MHz and amplified in the modulator-preamplifier. The 70-MHz IF signal is fed to the IF and baseband unit. This plug-in unit contains IF amplification, an IF band-shaping filter, an automatic gain-control (AGC) circuit, an automatic frequency-control (AFC) circuit, a limiter, a discriminator, a squelch circuit, and a baseband amplifier. The output of the receiver is the baseband signal at a 75-ohm coaxial jack on the IF and baseband unit.

B. RF Components

5.02 As the signal enters the TL-2 receiver from the antenna assembly, the first unit encountered is the 1402-type waveguide network used as a channel dropping network (described in Part 4F). This network drops the desired channel and permits the remaining channels to pass through, essentially unattenuated, for selection in similar networks on other RF panels on the bay.

5.03 The incoming signal passes through a 1307-type bandpass filter. The 1307-type filters are of two types; a 3-cavity filter and a 4-cavity filter. Three-cavity bandpass filters are used in all cases, except for the last receiver in a lineup, if the standard frequency plan is followed. This results in the 4-cavity filter always being used with channels 1P, 1J, 2P, 2J, 3P, 3J, 4P, and 4J. Midband loss of a 3-cavity filter is 0.7 dB, and 0.9 dB for a 4-cavity filter. A representative transmission characteristic for either bandpass filter may be seen in Fig. 10.

5.04 The RF signal from the filter encounters either a tuner or an isolator. In early TL-2 production, a tuner was used. The 401A Edwards tuner was adjusted for an optimum impedance into the bandpass filter. Thus, in this earlier design, the modulator-preamplifier assembly was a frequency-sensitive entity.

5.05 Redesign of the TL-2 receiver modulator-preamplifier resulted in replacement of the 401A Edwards tuner with a 9A isolator. The use of the isolator makes the modulator-preamplifier a broadband device, and a bandpass filter, an isolator, and a modulator-preamplifier may be assembled and used without making overall adjustments. A

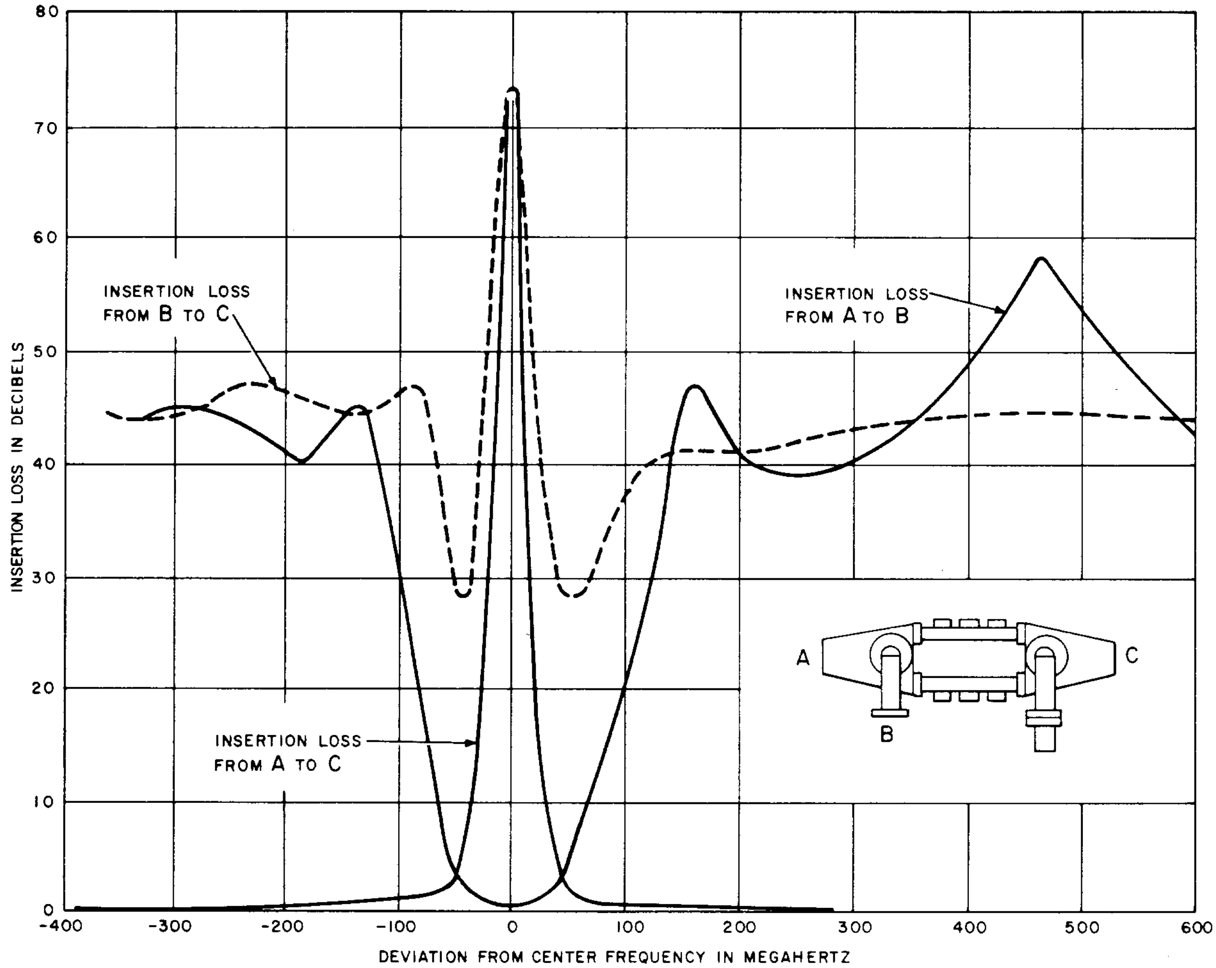


Fig. 8—Transmission Characteristic of Typical TL-2 Channel Combining Network

typical receiver-isolator characteristic can be seen in Fig. 11.

5.06 The modulator-preamplifier receives the RF signal from either the tuner or the isolator. In the modulator, the signal is combined with the output of the beat oscillator to produce the 70-MHz IF signal which is amplified in a low-noise IF preamplifier. The modulator-preamplifier contains a balanced crystal converter and a transistor preamplifier. The beat oscillator is one of the reflex klystrons discussed in Part 4C. Beat oscillator power at about 0 dBm is applied to the modulator at a waveguide port. The nominal conversion gain of the modulator-preamplifier is 18 dB and its noise figure, referred to the input of the mixer, is 10.5 dB.

5.07 A filter-equalizer may be installed at this point to limit the IF bandwidth of the receiver. The 783A filter-equalizer which is used in the TM-1 receiver may also be used here to reduce interference from adjacent channels when nonstandard frequency growth is necessitated. Data on the 783A filter follows:

783A FILTER

Bandpass	70 ±6 MHz
Return loss	23 dB
Inband attenuation	2 dB

Figure 12 is the 783A filter characteristic. If the List 4 J99296G-2 unit is part of the bay equipment, the 783A filter need not be used.

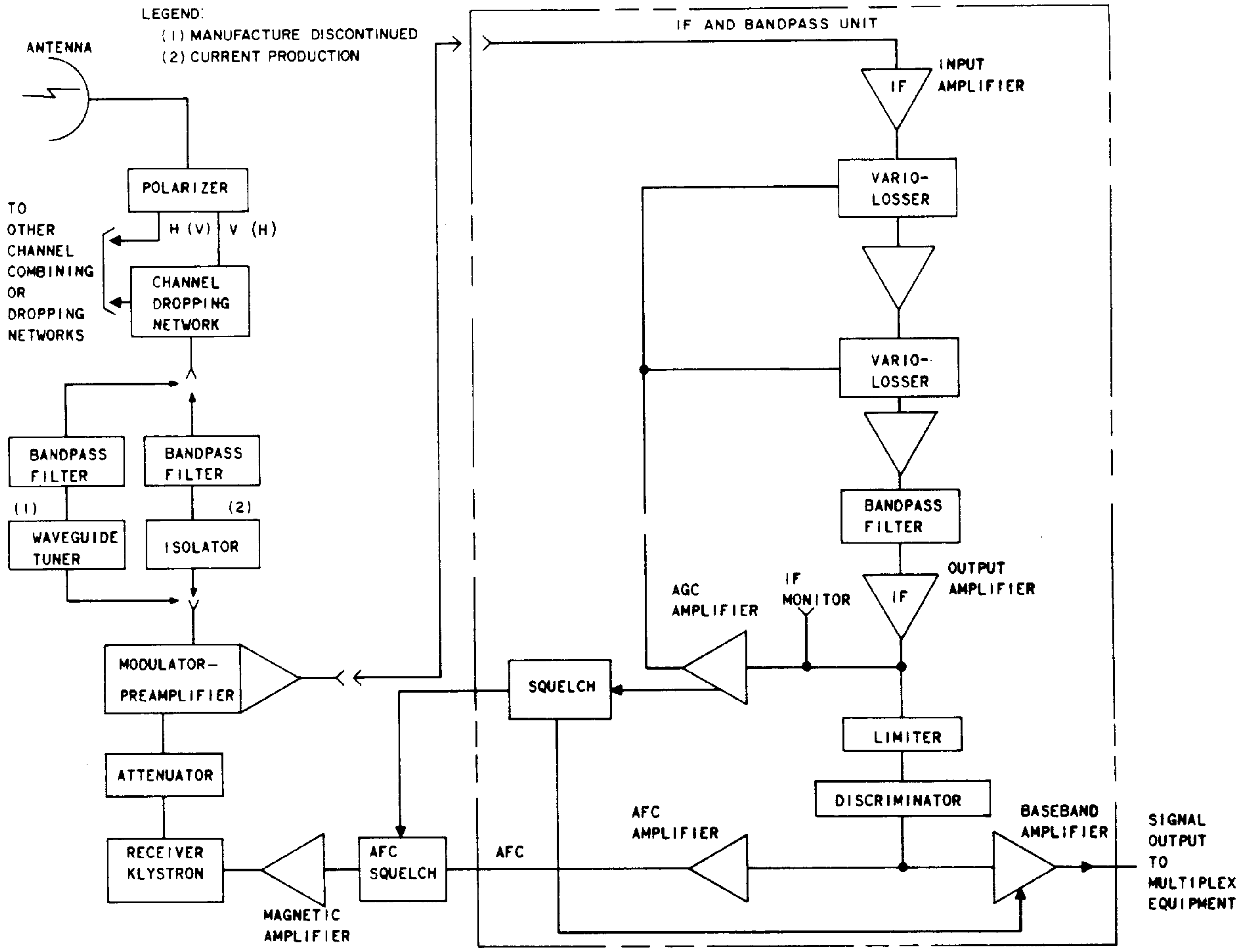


Fig. 9—Block Diagram—TL-2 Receiver

C. IF and Baseband Unit

5.08 The IF and baseband unit, J99296G, is a transistorized plug-in unit containing additional IF amplification, vario-lossers which serve as part of the AGC circuit, an IF bandpass filter, a limiter, a discriminator, a baseband amplifier, an AFC circuit, and a squelch circuit. The 70-MHz signal from the modulator-preamplifier is applied to the IF and baseband unit for additional amplification under the control of the AGC circuit, for band-limiting by an IF bandpass filter, and for further amplification by a high-level IF output amplifier which builds the signal to the power required for limiting. After limiting, the baseband signal is recovered in a frequency discriminator and amplified in a baseband amplifier which provides an unbalanced output of 75 ohms.

5.09 The original IF and baseband unit (List 1) has been modified to provide a unit with a television capability. This second generation unit (List 2) was in turn updated to provide a unit (List 3) with temperature compensation for crossband diversity applications. This unit is required for all TL-2 diversity applications where revertive switching is employed.

5.10 The latest unit (List 4) is a result of the redesign of the IF and baseband unit to improve transmission performance and facilitate maintenance. Principal advantages resulting from this redesign are as follows:

(a) Improved linearity and reduced envelope delay distortion

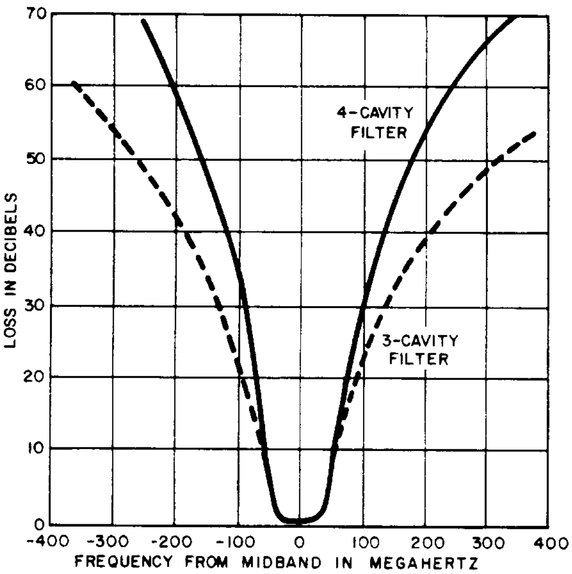


Fig. 10—Representative Transmission Characteristic of TL-2 Bandpass Filters

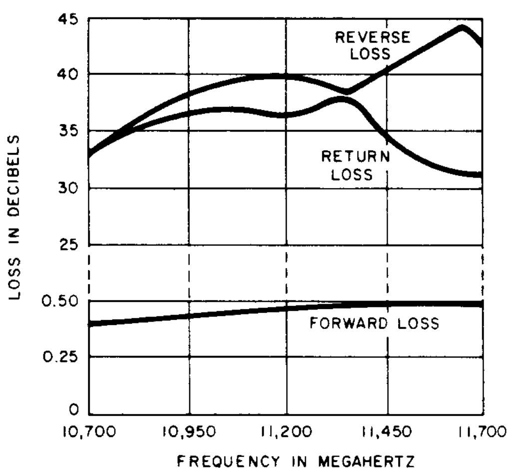


Fig. 11—Typical Characteristics for a Receiver Isolator

(b) Improved IF amplifier overload performance

(c) Improved limiter performance

(d) Better performance stability with temperature variations

(e) Reduced idle noise

(f) Means for adjusting the squelch point in the field

(g) Improved IF selectivity.

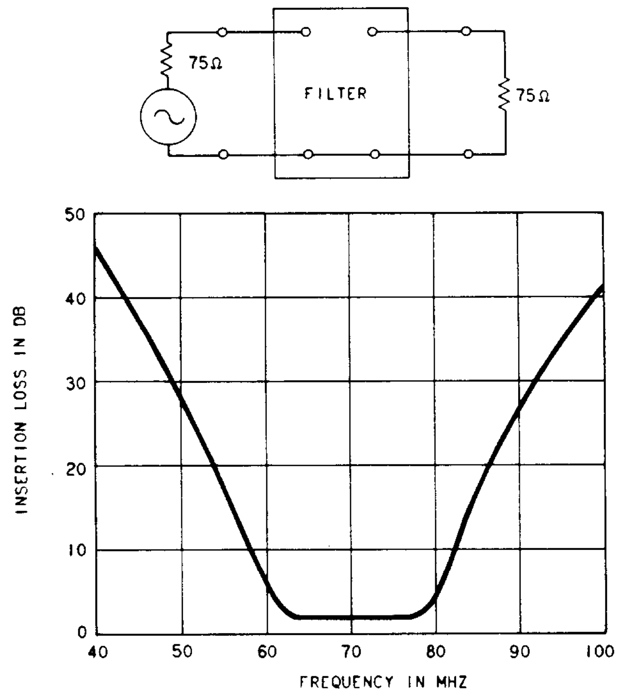
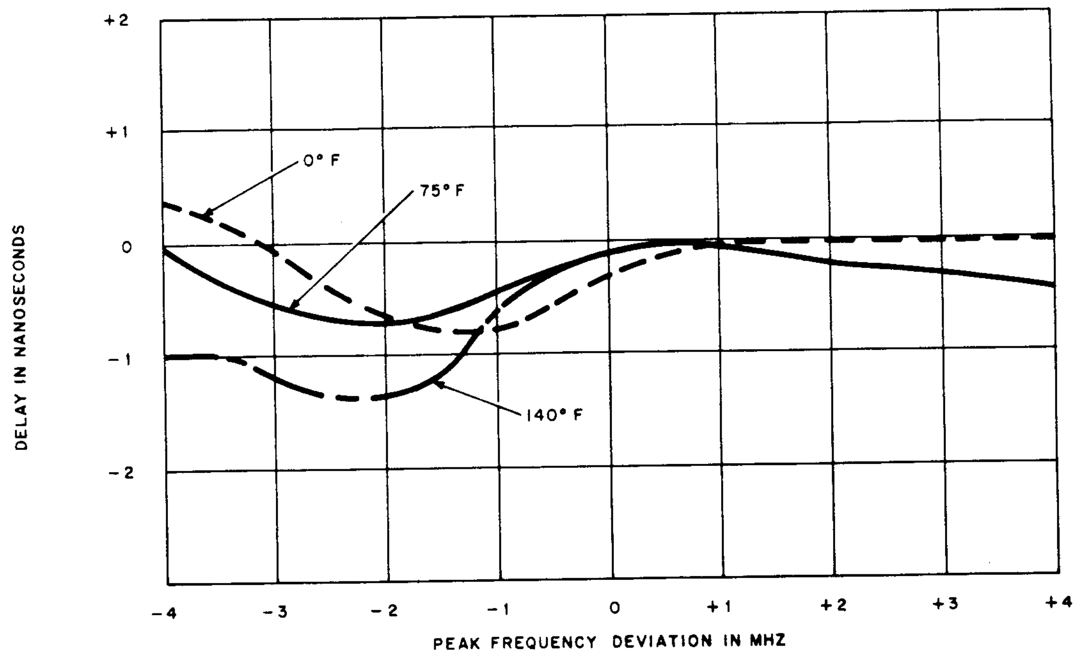


Fig. 12—783A Filter Characteristic

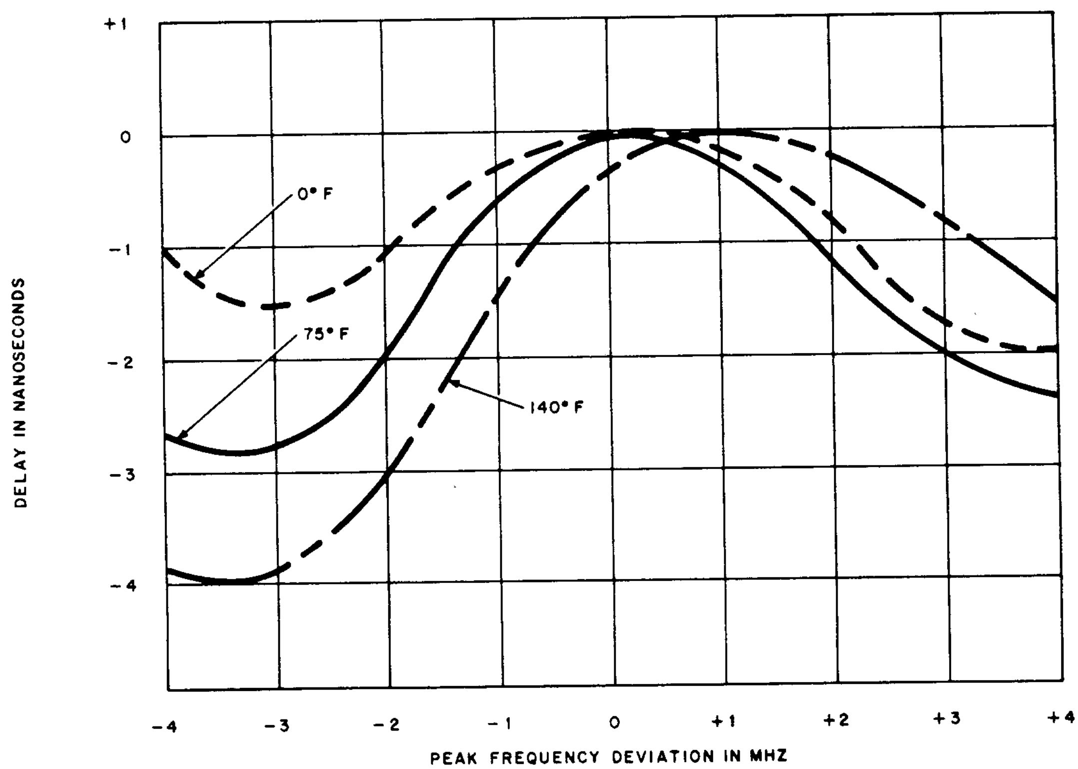
5.11 Redesign of the IF and baseband unit has reduced the receiver nonlinearity from about 2.5 percent to less than 0.5 percent. Receiver intermodulation noise contribution with pre-emphasis and reference drive, caused by the 0.5-percent nonlinearity, is less than 8 dBrnc0. The new receiver intermodulation noise is negligible (about 16 dB below the pre-emphasized idle noise for a typical radio hop).

5.12 The envelope delay distortion (EDD) contributed by early units, at room temperature, ranged as high as 3 to 4 nanoseconds with an 8-MHz peak-to-peak deviation. The corresponding delay for the List 4 unit is one nanosecond or less. This results in message-channel noise (pre-emphasized) due to EDD of approximately 12 dBrnc0. Figure 13 (A and B) shows the delay contribution of both the new and the old units to a typical radio hop.

5.13 The output stages of the IF amplifier have been modified to provide about 3-dB greater dynamic range, minimizing a possible overload condition. The effects of IF overload appear in two forms; (1) intermodulation noise is increased and (2), the limiter operation and EDD become quite sensitive to dc voltage and temperature.



(A) NEW UNIT - LIST 4



(B) OLD UNIT-LIST 1, 2, OR 3

Fig. 13—If and Baseband Unit—Delay Distortion

Improvement of IF output amplifier overload capability has minimized the effect of these factors in limiting system performance at temperature extremes.

5.14 Improvement of the limiter circuit has significantly reduced AM to PM conversion. In addition, the amount of limiting in the new unit exceeds 40 dB over the entire baseband frequency range. Limiting in the old unit was approximately 20 dB.

5.15 Some radio hops, which had worked well after alignment, operated in a degraded condition when the ambient temperature shifted appreciably. This reduction of performance was caused primarily by changes in discriminator linearity with temperature. The discriminator and limiter have been redesigned to achieve a high degree of linearity over the entire operating temperature range.

5.16 In addition to improving the linearity, redesign of the limiter-discriminator has reduced the idle noise contributed by the IF and baseband unit about 1 dB at reference drive. The corresponding idle-noise contribution of the List 4 unit is about 16 dBrnc0 at room temperature.

5.17 The List 4 unit also contains a manual control to permit field-setting the squelch level on an out-of-service basis. This has minimized the number of units returned to the factory for minor squelch adjustments.

5.18 Figure 14 compares the IF selectivity characteristic of a List 4 unit with that of a List 1, 2, or 3 unit.

5.19 The overall noise performance of a radio hop with the new List 4 unit and that of a typical unit before redesign is summarized in the noise-loading curves shown in Fig. 15 and 16. These curves compare the 600-circuit noise-loading performance of the new and the old IF and baseband units at room temperature and at extremes of temperature. These curves indicate that the contribution of the new unit is 6.5 dB below the current overall hop requirement of 25 dBrnc0 at the 360-kHz slot and 7 dB below this requirement at 2438 kHz. In contrast, the noise contribution of the old unit under worst temperature conditions exceeds the overall hop requirement by 4.5 dB at 360 kHz and by 0.5 dB at 2438 kHz.

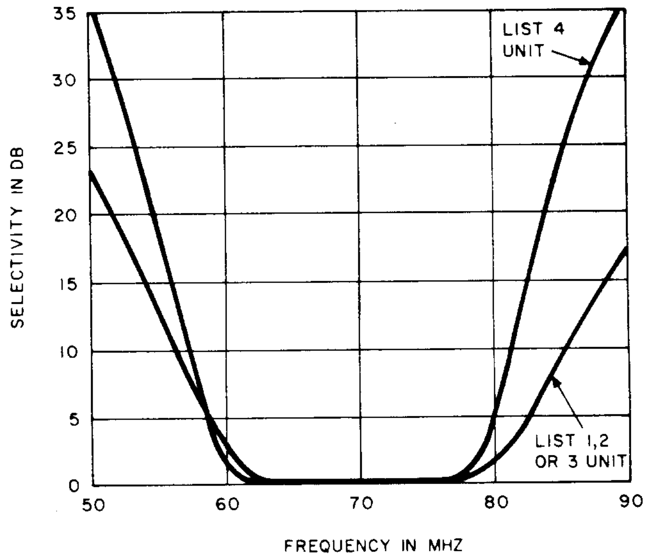


Fig. 14—Selectivity of IF and Baseband Units

5.20 An IF output is available from the IF and baseband unit at the IF MON jack for monitoring purposes or to permit an IF connection at 70 MHz to other microwave systems. The power output at this point is 0 dBm.

5.21 The final stages of the IF and baseband unit make up the receiver baseband amplifier. The receiver baseband amplifier is designed to provide both television and telephone service. Also, the receiver amplifier provides adequate linearity for the amplifier to contribute negligible intermodulation noise, differential phase, and differential gain. The normal sine wave output of the receiver baseband amplifier is +6.5 dBm for a 4-MHz deviation of the RF signal.

6. ANTENNAS AND WAVEGUIDE SYSTEMS

A. General

6.01 Cross-modulation noise caused by waveguide echoes is an important consideration in engineering short-haul radio systems. Assuming there are no impairments in the waveguide runs, echo distortion is dependent upon the return losses of the antenna and radio equipment, waveguide loss, and propagation time in the waveguide. If the equipment return loss is fixed by design and the waveguide loss and propagation time are a

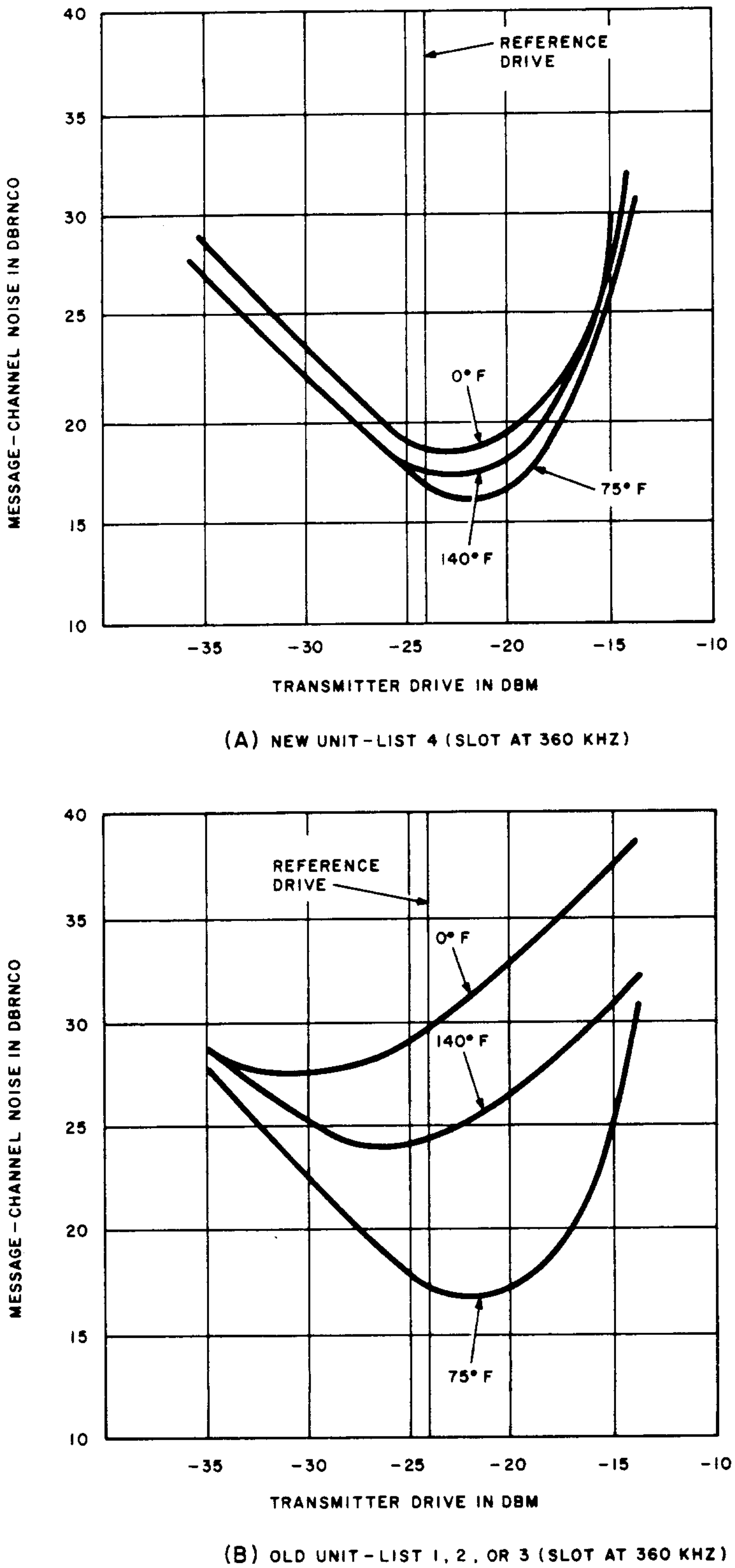
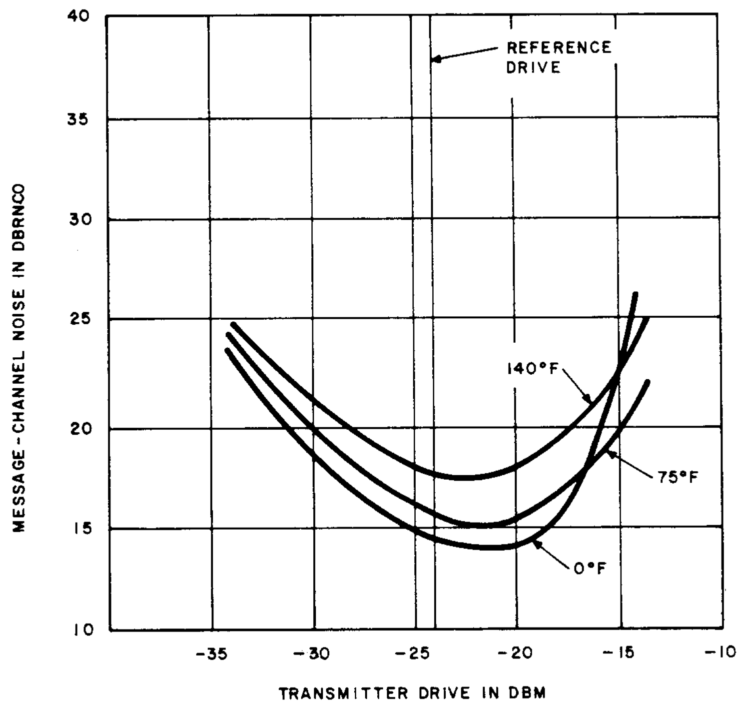
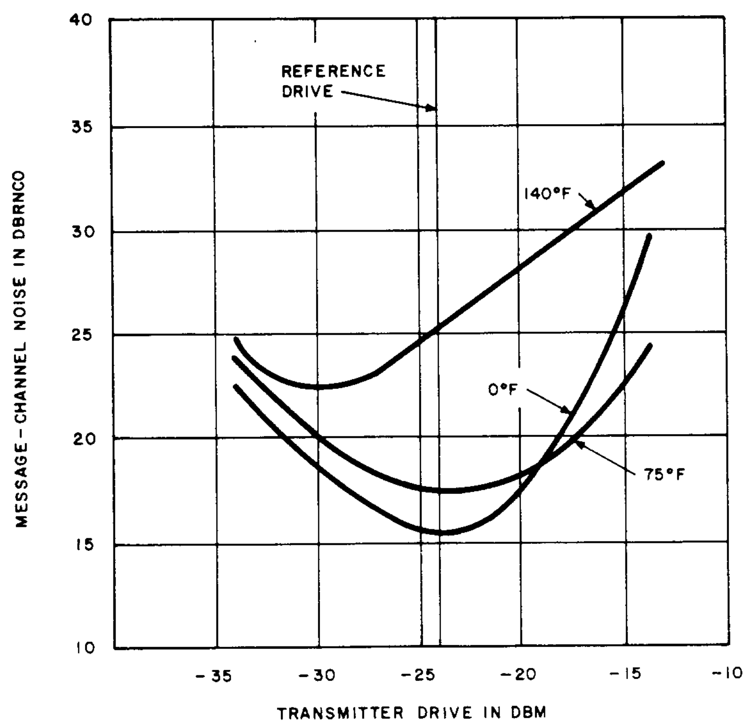


Fig. 15—600-Circuit Noise Loading (Pre-emphasized)



(A) NEW UNIT - LIST 4 (SLOT AT 2438 KHZ)



(B) OLD UNIT - LIST 1, 2, OR 3 (SLOT AT 2438 KHZ)

Fig. 16—600-Circuit Noise Loading (Pre-emphasized)

function of waveguide type and length for a specific case, the principal controls available to the engineer are a choice of antenna type (with a given return loss) and waveguide length.

6.02 Avoiding unnecessarily long waveguide runs and internal reflections in the waveguide systems is of extreme importance in short-haul microwave systems. In addition to degrading the signal-to-noise performance because of waveguide losses, runs in excess of 50 feet increase the possibility of echo distortion on heavily loaded systems. Waveguide echoes are the result of radio frequency impedance mismatches or discontinuities. These mismatches are evidenced by poor return losses of such items as the radio equipment, components of the waveguide run, the antenna, and any other discontinuities in the radio path. The return loss of the parabolic dish antenna and the radio equipment is such that echoes should be down from the main signal by 50 dB or more. A significantly larger echo will degrade the performance severely if the impedance mismatches at the antenna and at the radio equipment are separated by sufficient waveguide (75 feet or more). In heavily loaded microwave systems using periscope type antennas or parabolic-type direct radiators on short towers, it is recommended that waveguide runs be limited to about 50 feet. Usually, high modulation noise in TL-2/TM-1 systems is a result of echo or trapping effects inadvertently built into the antenna and waveguide systems. These cases are discussed in detail in Section 940-320-102. P.E.M. 9392 discusses waveguide design requirements.

6.03 Several types of antennas and antenna systems are available for the TL-2/TM-1 diversity pair. A listing of the antennas and a reference for detailed information on each is contained in Table F.

6.04 When the horn reflector is used, a microwave systems combining network is required. For details of systems combining networks and the horn reflector antenna, see Sections 940-340-132* and 940-340-154* respectively.

B. Parabolic Antennas and Associated Filters

6.05 A single frequency 10-foot parabolic antenna, KS-15852, is available for use by the TL-2 radio system. When the TL-2 is used in crossband diversity with TM-1, antennas providing for both frequencies are used. The original antennas available for diversity operation provided for dual polarization in the 11-GHz band and plane polarization in the 6-GHz band on three separate rectangular waveguide feed lines. The 6-foot version of this 3-port antenna is designated KS-19530 and the 10-foot 3-port parabolic antenna is KS-19529.

TABLE F

ANTENNAS

DESIGNATION	DIAMETER (FEET)	POLARIZATIONS (6 GHZ)	POLARIZATIONS (11 GHZ)	BSP REFERENCE
KS-15852	10	0	2	402-435-200
KS-19530	6	1	2	940-340-162*
KS-19529	10	1	2	940-340-161*
KS-20012	6	2	2	940-340-163*
KS-20013	10	2	2	940-340-164*
KS-15676	Horn reflector	2	2	940-340-154*
KS-20409	6	2	2	940-340-165*
KS-20410	10	2	2	940-340-166*

* This section may not be available. Consult the latest numerical index.

6.06 In September, 1965, a change was initiated to minimize intermodulation noise caused by 11-GHz energy coupling into the 6-GHz waveguide at the antenna feed structure. In installations using KS-19529 and KS-19530 dual-frequency antennas, a 1330A filter was added to the 6-GHz waveguide run. Typical insertion losses for the 1330A, when properly terminated, follow:

1330A FILTER

Maximum loss (6-GHz band)	0.25 dB
Minimum loss (11-GHz band)	37.0 dB

6.07 Although the 1330A filter did its intended job, subsequent baseband load tests indicated a new transmission irregularity had been introduced. An investigation revealed that the 6-GHz waveguide run between the antenna feed structure and the 1330A filter forms a resonant chamber for parasitic 11-GHz energy causing irregularities in the 11-GHz channel transmission path. It was determined that a resistive vane, used in a 6-GHz waveguide attenuator and set for about 0.5-dB loss, inserted immediately adjacent to the antenna feed structure, is effective in controlling delay distortion arising in the region of resonances.

6.08 In May, 1966, a new 1334A filter was developed for use at locations where it was impractical to change antenna feed assemblies. Typical characteristics for the 1334A filter follow:

1334A FILTER

Insertion loss (6-GHz band)	0.6 dB
Return loss (6-GHz band)	30.0 dB

6.09 In January, 1967, a new waveguide filter was standardized to provide a final solution to the "long-pipe" reflection and "short-pipe" resonant chamber difficulties encountered while using the 3-port crossband parabolic antenna. The 1330A and 1334A filters used as an interim solution were discontinued for this application. This new type waveguide filter, KS-20148, which was designed for absorption at 11 GHz has the following characteristics:

KS-20148 FILTER

Insertion loss (6-GHz band)	0.15 dB
Return loss (6-GHz band)	38.0 dB

6.10 In July, 1967, two dual-frequency 4-port antennas were made available for use by 6- and 11-GHz systems. These antennas, listed as KS-20012 and KS-20013, permit maximum radio route growth on short-haul systems equipped for crossband diversity operation. A KS-20148 filter is required for each 6-GHz port on these antennas.

6.11 In January, 1970, two improved performance versions of the dual-frequency 4-port antenna became available. These antennas are listed as KS-20409 and KS-20410. No external filtering is required with these antennas.

C. Waveguide and RF Component Losses

6.12 Table G contains the insertion losses of the various components between the transmitter output and receiver input, together with rectangular waveguide loss. The TL-2 uses WR-90 rectangular waveguide.

TABLE G

TL-2 WAVEGUIDE AND COMPONENT LOSS

ITEM	LOSS (DB)
Transmitter isolator, waveguide switch, and channel combining network	1.30
Channel dropping network, RF filter, and receiver isolator	1.55
Channel dropping network (through-arm)	0.15
WR-90 waveguide	
(rigid)	0.04/ft
(flexible)	0.07/ft

6.13 It is suggested that a TL-2 component loss of 3.6 dB be applied in path calculations. This is based on expected worst-channel component loss for a channel in the third position in a bay.

7. CALCULATION OF RECEIVED CARRIER POWER

7.01 An example of the calculation of received carrier power over a 20-mile hop and utilizing either a periscope antenna system or a direct radiator is shown in Table H.

TABLE H

CALCULATION OF RECEIVED CARRIER POWER

	PERISCOPE ANTENNA	DIRECT RADIATOR
*Path Loss (20 miles)	–143.5 dB	–143.5 dB
Waveguide Component Loss	– 3.6 dB	– 3.6 dB
Waveguide Loss		
(1) Inside (40 feet)	– 1.6 dB	– 1.6 dB
(2) Outside (100 feet)	—	– 4.0 dB
Loss of Two 10- by 15-foot Reflectors	– 0.8 dB	—
Loss of Two Radomes	– 1.8 dB	– 1.8 dB
Losses	–151.3 dB	–154.5 dB
Transmitter Power (minimum)	20.0 dBm	20.0 dBm
Gain of Two (KS-20410) 10-Foot Antennas	92.8 dB	92.8 dB
Gains	112.8 dB	112.8 dB
Receiver Carrier Power	– 38.5 dBm	– 41.7 dBm
Maintenance Margin	– 3 dB	– 3 dB
Path Design Received Carrier Power	– 41.5 dBm	– 44.7 dBm

* See Section 940-310-101.

7.02 A minimum received carrier power of –45 dBm (including a 3 dB maintenance margin) at the input to the modulator-preamplifier is required to meet system design requirements. The received signal level, as a new RF channel is added to the system may be calculated with the data provided in Table G. Figure 17 depicts the addition of channels to a TL-2 system.

7.03 In the example of Fig. 17, assuming the conditions of Table H for a periscopic antenna system, the received signal level for each channel at the first channel combining network can be calculated using Table G. As additional channels are added, the received level at this point decreases by about 0.15 dB from the preceding one.

7.04 At the receiver converter, the signal levels are reduced by approximately 0.3 dB. Each added receiver is at the same level as the preceding one, however.

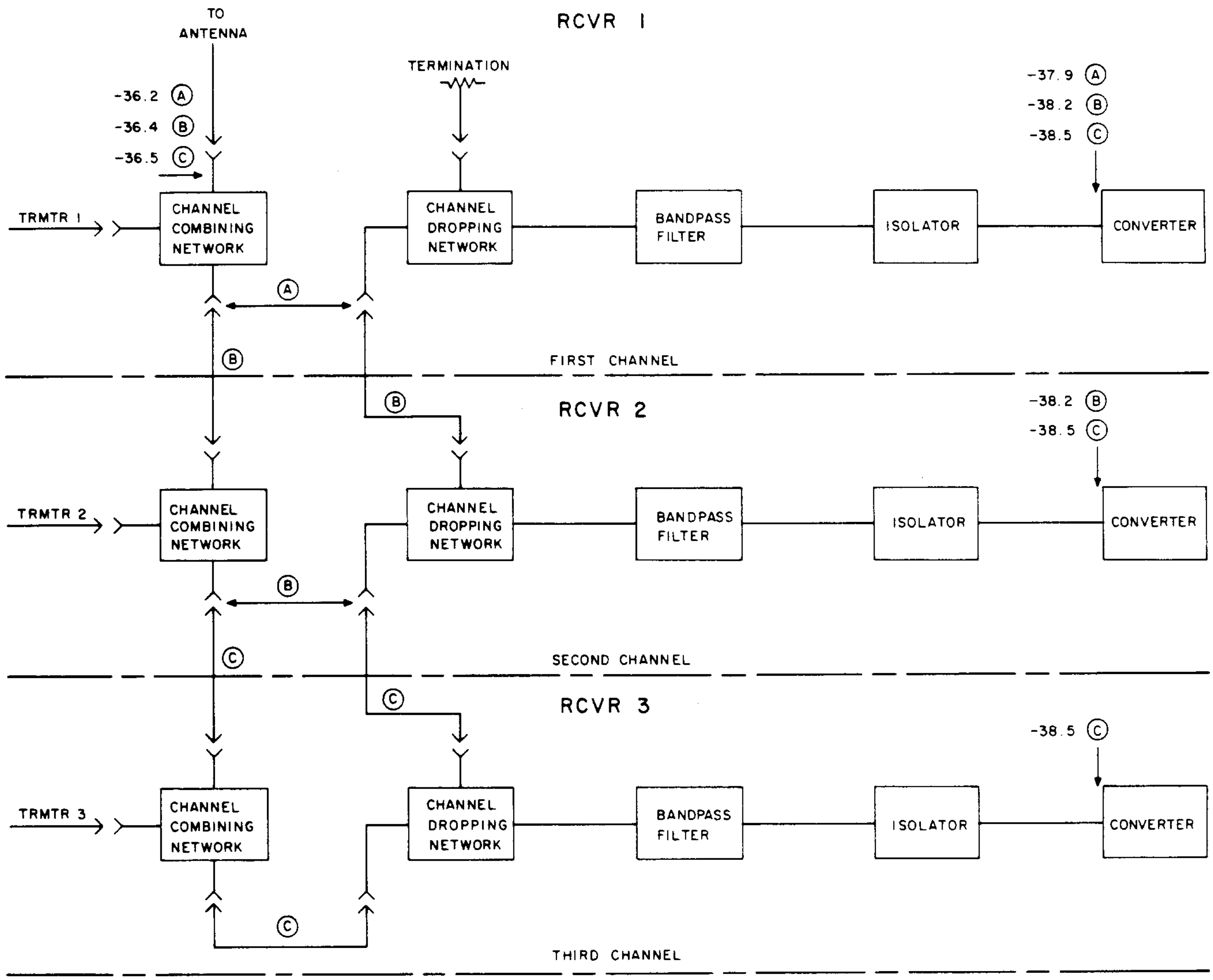
8. TRANSMISSION PERFORMANCE

A. Noise

8.01 Noise in the TL-2 system based on factory measurements of transmitter-receiver units consists of the following:

FM thermal noise	24.0 dBrnc0
Klystron noise	10.0
Modulation noise	20.0
Total noise	25.6
Pre-emphasis advantage	3.5
Expected per-hop noise performance	22.1 dBrnc0

The pre-emphasis characteristic is shown in Fig. 18. Message channel noise versus transmitter input drive for various L-carrier channel loadings is plotted in Fig. 19.



FOR (NO. OF)	TRANSMITTERS AND RECEIVERS USE OPTION
1	(A)
2	(B)
3	(C)

	LEVEL AT RCVR		
	OPTION (A)	OPTION (B)	OPTION (C)
RCVR 1	-37.9	-38.2	-38.5
RCVR 2		-38.2	-38.5
RCVR 3			-38.5

Fig. 17—Sample Calculations—Received Signal Level With Growth

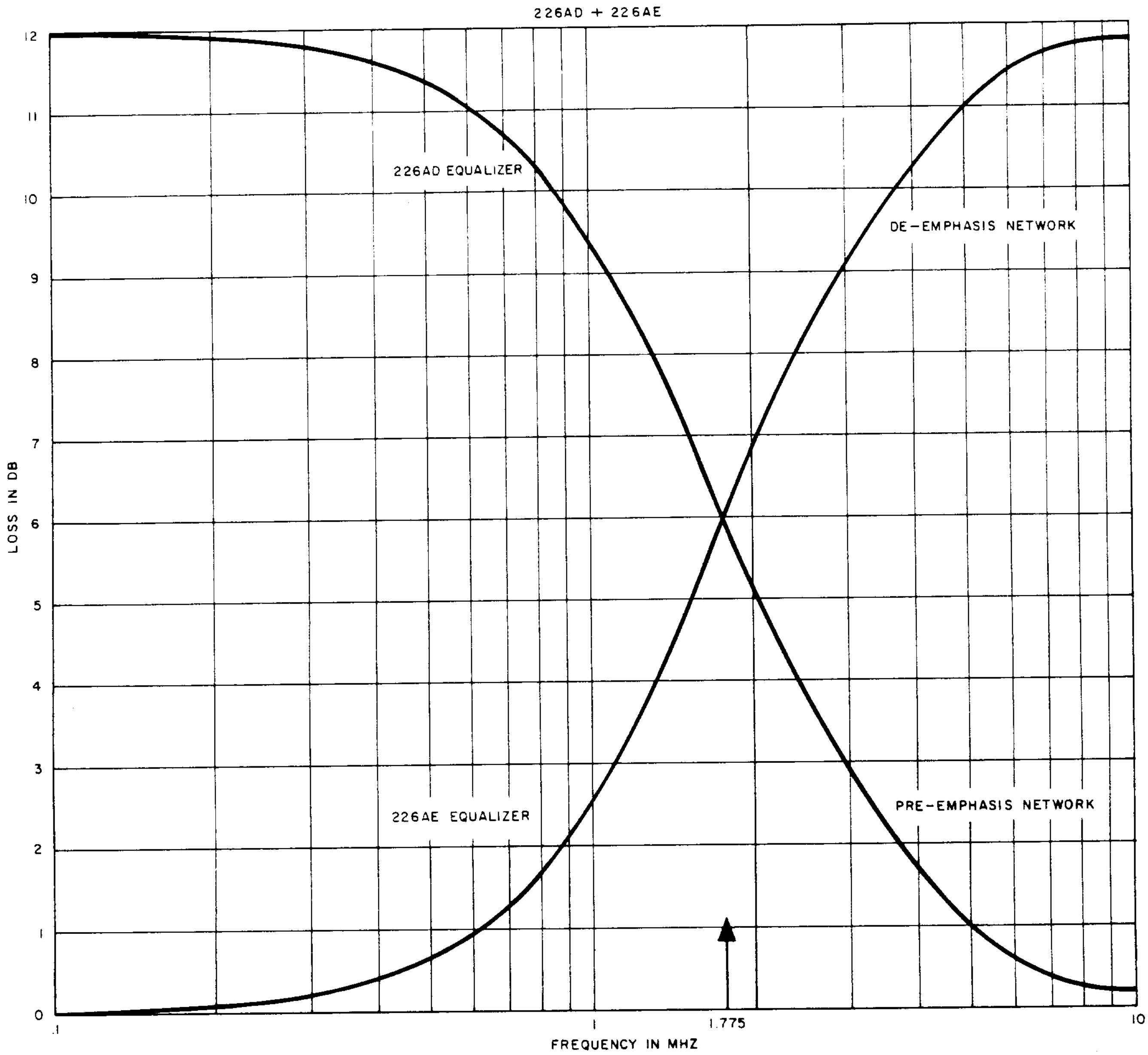


Fig. 18—Pre-Emphasis and De-Emphasis Characteristics—Message Service

8.02 Typical noise-loading results for TL-2 under conditions of 600-circuit loading, 5-MHz peak deviation, and standard 9-dB pre-emphasis are presented in Fig. 20. Notice that the noise level in the lowest frequency carrier circuits does not vary with the received signal level.

8.03 When the system is installed, it should be tested for noise performance based on full-channel loading with pre-emphasis, regardless of intended loading. This allows proper planning for future growth. The expected noise performance with less than 600-circuit loading depends on the position of the supergroups within the baseband. The drive levels for less than 600-circuit loading assume that channel growth starts from the bottom supergroup and extends upward continuously. Under these conditions, pre-emphasis is optional for 1- to 360-circuit loading and is specified for heavier loading. With the broad latitude of applications possible using TL-2, it is impractical

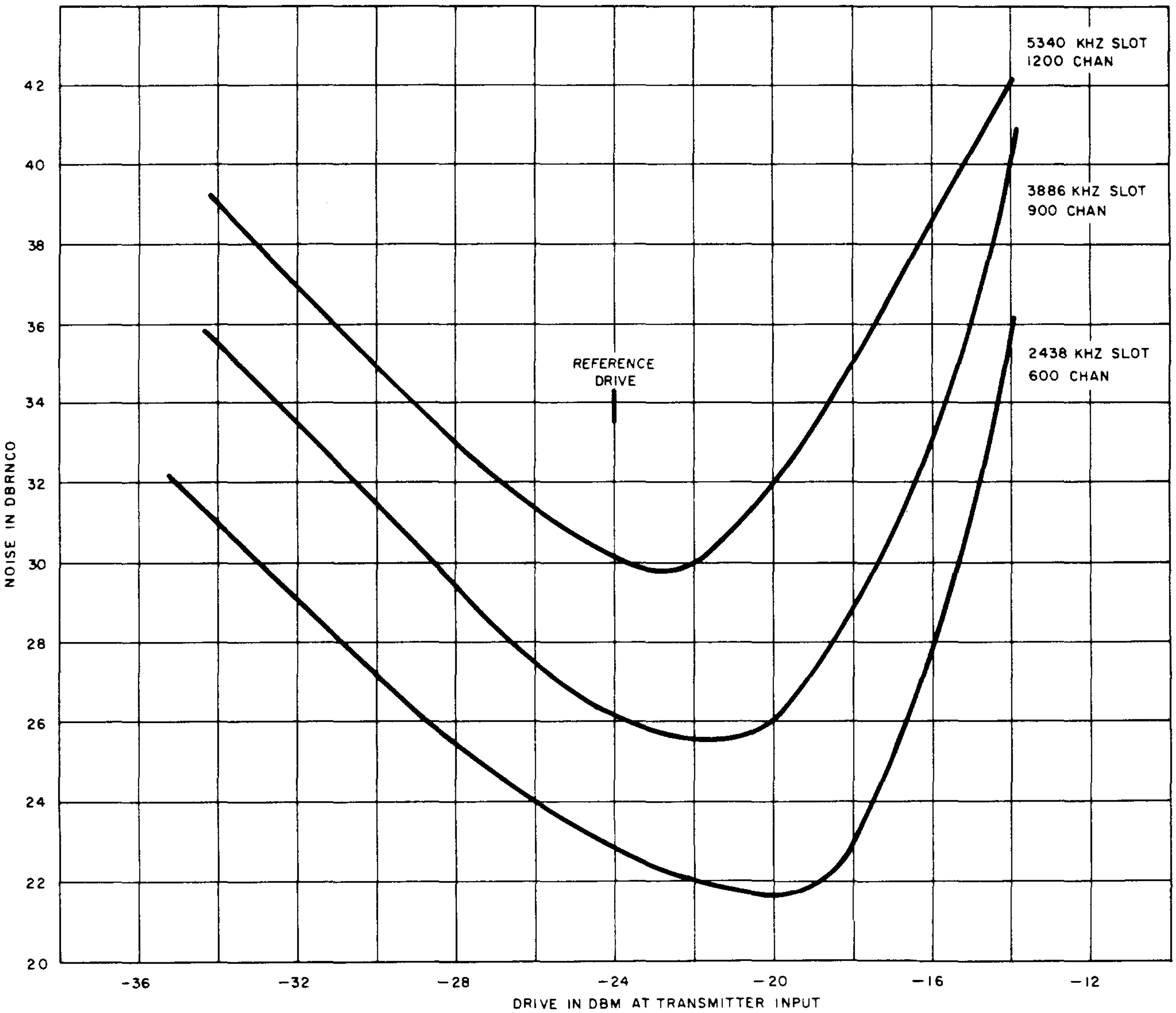


Fig. 19—Typical Noise Load Curves at −42 dBm Receiver Modulator Input

to make rigid rules for both the application of pre-emphasis and adjustment of drive levels. The following is a suggested method for predicting approximate noise performance with less than full loading.

(1) Refer to Fig. 21 to obtain approximate per-hop idle noise versus baseband frequency. To obtain the idle noise, use the highest modulating frequency and the received signal level curve without pre-emphasis. Notice that there is a family of curves dependent on received signal level. It may be necessary to interpolate to obtain a value corresponding to a signal level whose curve is not shown. Add the results for each hop in the system on a power (not voltage) basis to obtain the expected total idle noise.

(2) From the results of Step 1, and noting the frequency location in the baseband of the supergroups to be used, using Fig. 22 check to see if pre-emphasis will result in a more uniform sharing of noise between top and bottom circuits. Note that as loading increases, modulation noise will increase the total noise in the upper frequency circuits more than in the lower frequency circuits.

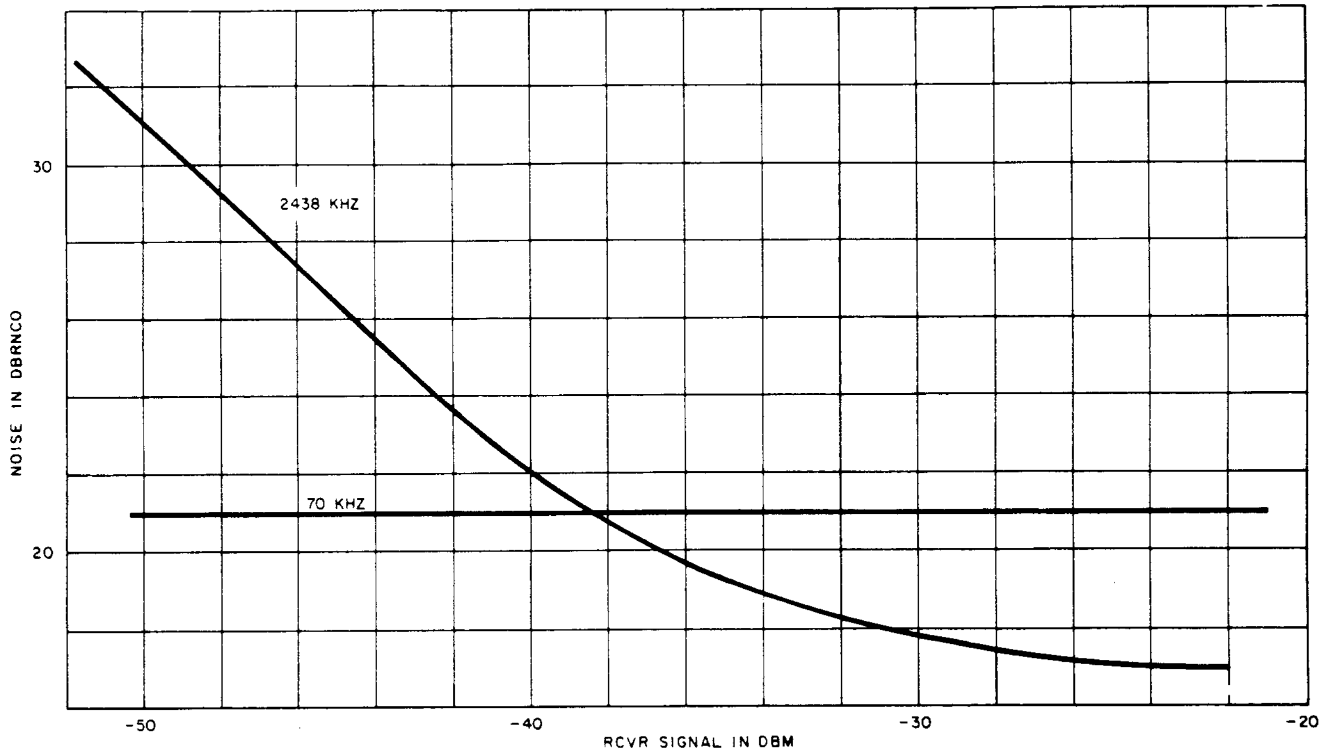


Fig. 20—Typical Noise Loading Performance for 600-Circuit Loading with Pre-Emphasis

(3) For less than 600-circuit loading, the noise obtained from performing Steps 1 and 2 may be decreased to reflect the higher per-circuit drive under these conditions.

CIRCUITS	CORRECTION (DB)
600	0
480	0
360	−0.5
240	−0.5
120	−1.5

The effect of the standard 9-dB pre-emphasis characteristic on idle noise can be seen in Fig. 18. Its effect on modulation noise is dependent on the products involved, but may be assumed to be approximately the same as for idle noise.

B. Overload

8.04 The TL-2 receiver J99296AA List 1 and 2 will overload at input signal levels in the region of −26 dBm. The J99296AA List 3 will overload in the −20 dBm region. If the signal level is high and other conditions prohibit the use of smaller antennas, attenuation must be placed in the waveguide system to control the signal level. Under no circumstances should the transmitter repeller voltage be used to detune the klystron or the transmitter waveguide switch be partially operated to reduce transmitted power. The result of overload is high intermodulation noise.

C. Linearity and Delay

8.05 The linearity and delay characteristics of the receiver are determined by factory adjustments and are expected to hold for the life of the equipment. The linearity of the transmitter klystron is adjustable to optimize overall hop linearity.

D. Television

8.06 The TL-2 radio system is designed to carry a television channel. When planning a TV route, design for a minimum received carrier power of −42 dBm.

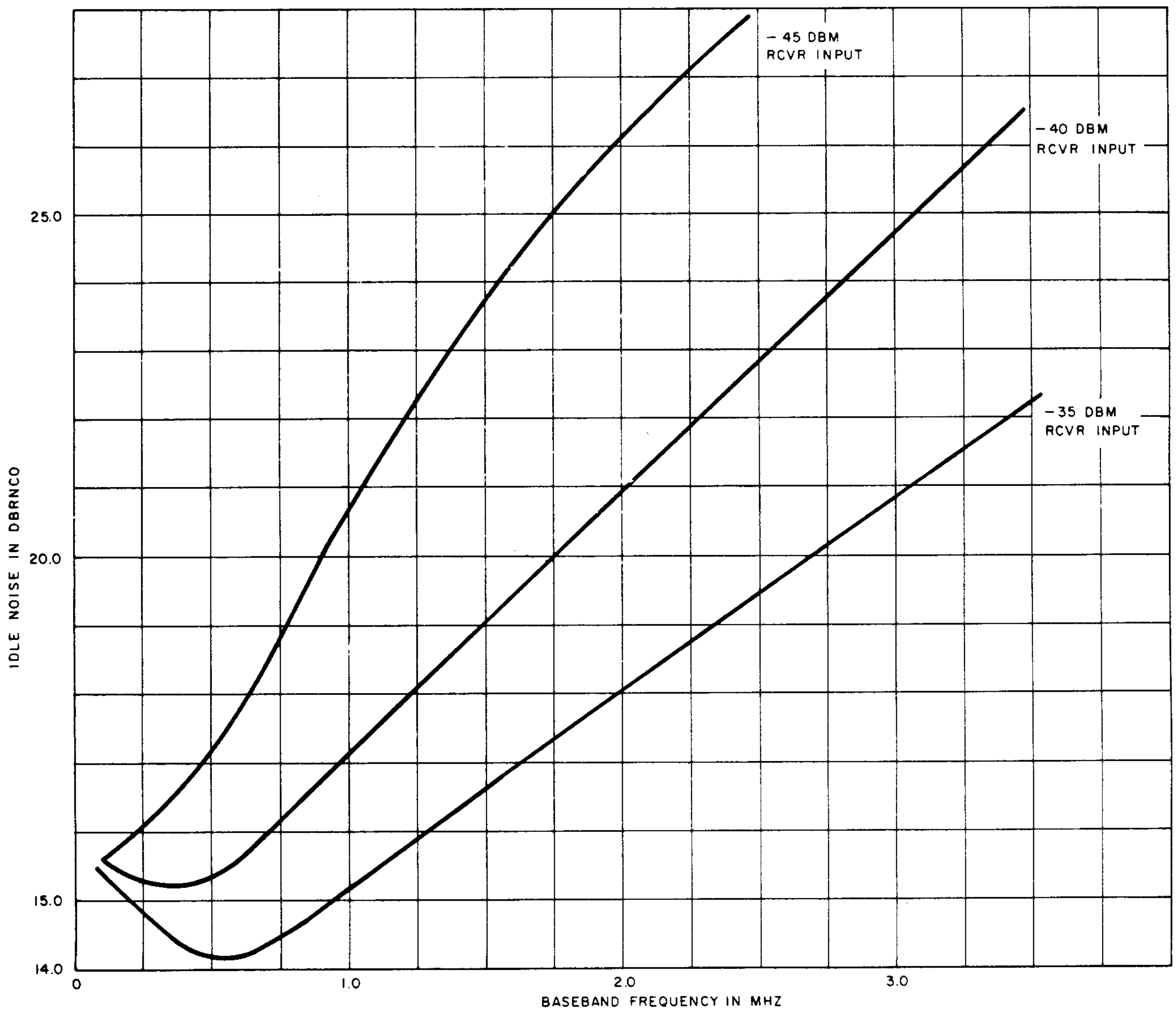


Fig. 21—Idle Noise Per Hop Without Pre-Emphasis

8.07 System alignment is quite different between television and message service. Optimum linearizing for message is not optimum for video. For television transmission the transmitter klystron is adjusted to minimize differential gain. Not only is the procedure different, but optimum klystron tuning for television transmission is not the same as the klystron tuning that minimizes cross-modulation in message systems.

8.08 In addition to the basic RF panel, IF and baseband equalization is required to meet TV transmission objectives. There are basically four types of baseband equalization and two types of IF equalization. The baseband equalization consists of pre-emphasis, low frequency, midband, and high frequency. The IF equalization consists of linear and parabolic differential phase compensation. These equalizers are mounted on a video panel located directly below its associated RF panel. The video panel replaces the order wire and alarm or the diversity switch panel normally provided with message systems.

8.09 A new video panel has been designed to replace the older models of this unit. This new panel provides the equalization and signal

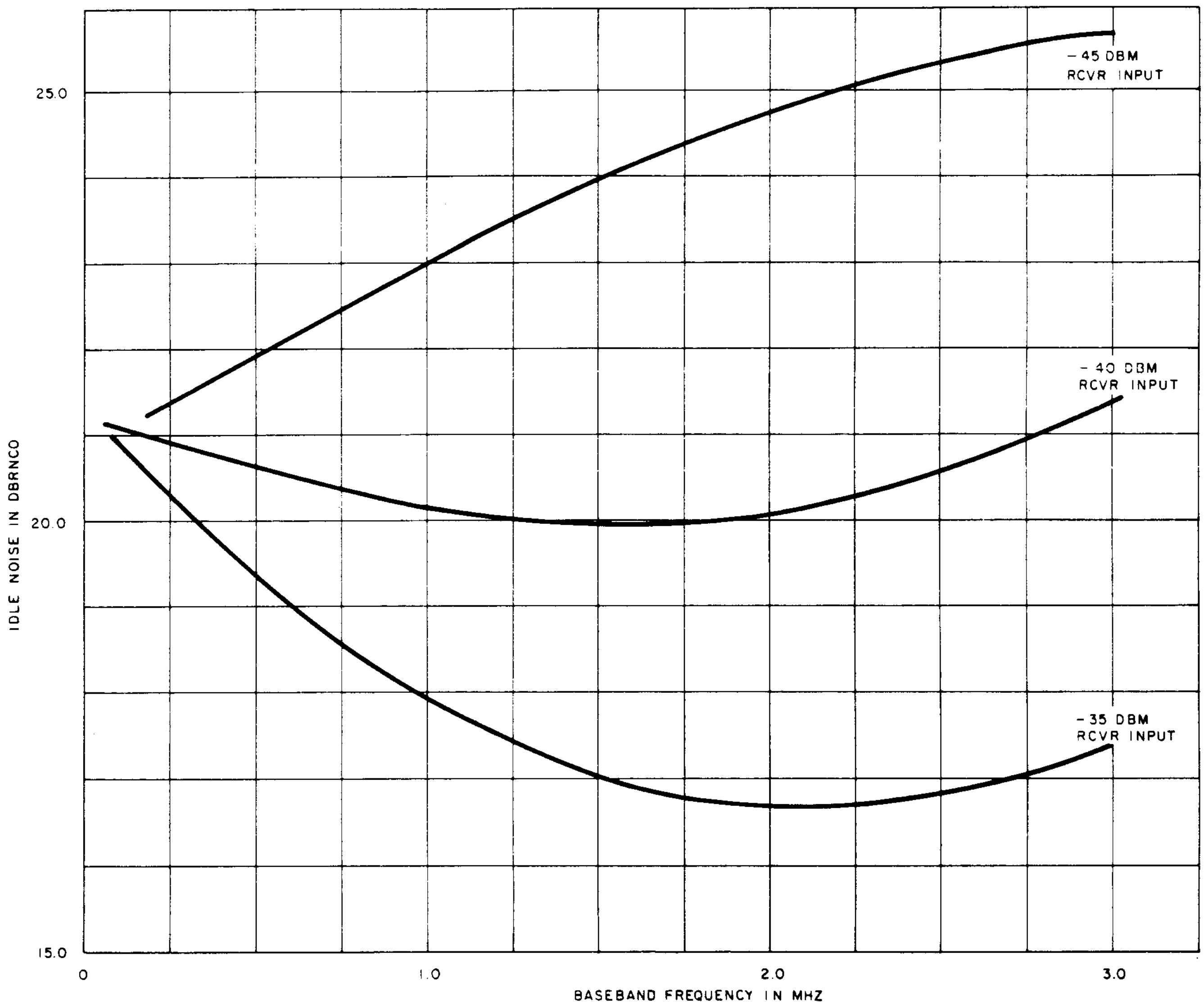


Fig. 22—Idle Noise Per Hop Calculated With Pre-Emphasis

level flexibility necessary to meet and maintain broadcast quality color television transmission standards on short-haul radio routes. For details on both the old and the new video panels, consult Sections 409-400-125 and 409-400-126.

8.10 Differential phase is minimized by the use of delay equalizers. These equalizers are selected from a family of equalizers at the time a system is installed, based on differential phase measurements. The equalizers are inserted between the output of the preamplifier and input to the IF and baseband unit at some repeater locations.

8.11 Differential phase and gain performance can be improved by the use of pre-emphasis. Television systems utilizing TL-2 are operated at a peak deviation of 4 MHz with 7 dB of pre-emphasis. The pre-emphasis characteristic for television transmission is shown in Fig. 23.

8.12 By adjusting the transmitter klystron and by using auxiliary delay equalizers and the new video panel, it is possible to obtain differential gain and phase performance of ±1.0 dB and ±1.0 degree for six hops.

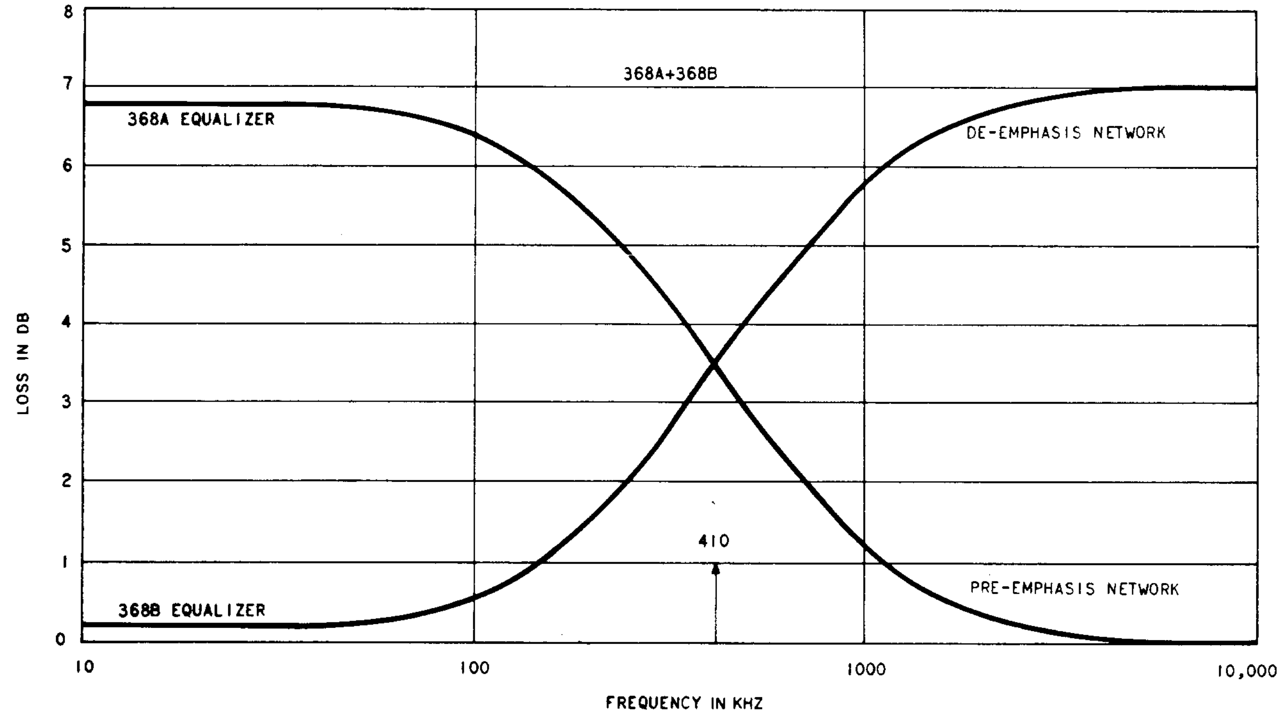


Fig. 23—Pre-Emphasis and De-Emphasis Characteristics—Television Service

E. Noise Objective

8.13 TL-2 in diversity with TM-1 is designed to provide noise performance of 35 dBrnc0 (29 dBa0) or better for 10 hops, with 600 L channels. In order to achieve a better distribution of noise performance, especially on long-haul circuits involving up to 4 short-haul links, the 10-hop TL-2/TM-1 objective applies to total radio noise (fluctuation plus intermodulation) and is to be prorated by hops. The noise objectives which apply to various length systems for the maximum number of circuits anticipated are shown in Table I.

8.14 One of the transmission objectives specifies that the radio system will contribute less than 25 dBrnc0 of noise per hop in the worst circuit. On systems whose performance just meets the objective, the noise contribution of waveguide echoes should be restricted to something less than 0.5 dB of the intermodulation noise. In these cases, up to 16 dBrnc0 of noise per hop can be allocated to echo distortions. If RF mismatches resulting in echo distortion occur equally at both ends of the hop, the noise objective per antenna system should be no more than 13 dBrnc0.

TABLE I

TM-1 NOISE OBJECTIVES

NUMBER OF SYSTEM HOPS	NOISE IN WORST CIRCUIT (DBRNC0)	TYPICAL NOISE IN WORST CHANNEL (DBRNC0)
1	25.0	22.0
2	28.0	25.0
3	29.8	26.8
4	31.0	28.0
5	32.0	29.0
6	32.8	29.8
7	33.4	30.4
8	34.0	31.0
9	34.5	31.5
10	35.0	32.0

9. DIVERSITY TECHNIQUES

A. Definitions

9.01 The following terms are used when discussing diversity techniques and must be defined.

9.02 ***Regular and Diversity:*** These terms are physical equipment designations and do not in themselves define operational features. They are important in identifying wiring options and specific equipment arrangements and apply equally in the case of both bistable and revertive switch applications. A diversity bay is the radio bay on which the diversity switch panel is mounted. The radio channel assigned to this bay is the diversity channel. The diversity switch panel is normally not mounted in the regular bay. This bay will mount an order-wire and alarm panel, a video panel, or no auxiliary panel at all. The radio channel assigned to this bay is the regular channel.

9.03 ***Preferred and Nonpreferred:*** These are operational terms that have no fixed relation to equipment arrangements. The preferred channel is the radio channel to which the system will revert at all times except when it is in trouble. The nonpreferred channel is the radio channel to which the system will switch only when the preferred channel is in trouble. When the trouble is cleared, the system will revert back to the preferred channel. The preferred channel may be assigned to either the regular or diversity bay depending upon a wiring option. This option is selected on the basis of which radio channel of a diversity pair will deliver the better transmission performance under normal radio path conditions. The channel engineered with the better performance will receive the preferred channel assignment.

B. General

9.04 The diversity switch unit automatically or manually establishes the through baseband transmission path from the better of two receivers in a diversity pair. The baseband connection is made through a pair of make-before-break wire-spring relay transfer contacts that provide a noninterrupted or hitless switch under fading conditions. The two signals are in phase as a result of the inverter in the transmitter baseband amplifier. Any level changes resulting from the double termination or signal strength differences are insignificant.

9.05 Two factors control the switch; the presence or absence of pilot tone or the variation of AGC voltage. The switching is controlled by a relay logic circuit which is supplied receiver status information through two receiver pilot monitors and a fade comparator circuit. The pilot monitors are selective amplifier detectors which monitor 2600-Hz pilot tones at the output of each receiver baseband amplifier. A 3-dB drop in pilot amplitude from an adjustable reference level will initiate the switching action. The comparator circuit measures receiver IF input levels by monitoring the receiver AGC voltages.

9.06 An optional wire-line connection for active channel identification and forced-switch feature is available.

C. Bistable Switch

9.07 The bistable switch option is used where the two channels forming a diversity pair are nearly equal in performance. The switch does not prefer either channel and remains switched to one until that channel fades considerably below the other (approximately 15 dB) or fails entirely.

D. Revertive Switch

9.08 The revertive switch option is best used where a significant performance difference (5 or 6 dB) exists between the two channels of a diversity pair. Switch transfer and closure on the protection channel takes place only during periods of failure or deep fading on the preferred channel and reverts to the preferred channel when trouble on it clears.

9.09 The operation of the revertive switch may be illustrated by means of Fig. 24. If a point whose coordinates are given by the received power of channel A (preferred) and channel B (protection) falls in the shaded area, the switch will select channel A. If that point falls in the crosshatached area, it will switch to channel B. If the point falls in the clear area, the switch will not operate—it will hold whatever position it has. The width of both corridors shown in Fig. 24 is adjustable.

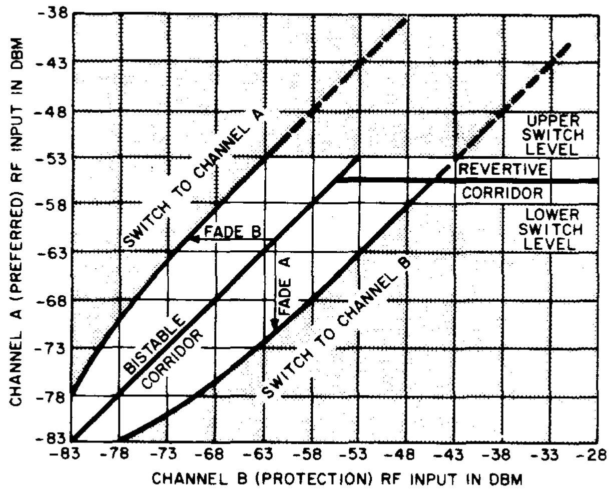


Fig. 24—Typical TM-1/TL-2 Revertive Switch Characteristic Based on RF Inputs

9.10 The bistable switch operates similarly except that the bistable corridor is extended as indicated by the broken lines and all the area below the corridor is assigned to channel B.

10. ORDER WIRE AND ALARM

10.01 The TL-2 order-wire and alarm services are necessary to ensure reliability, improve maintenance and alignment procedures, and satisfy FCC requirements for unattended radio station operation. The remote alarm circuits report troubles to an alarm control center and the order wire provides a voice communication circuit between stations.

10.02 The line facility for the order-wire and alarm circuits is derived from the VF portion of the radio baseband. As a result, when video service is provided, order-wire and alarm facilities must be supplied by other means.

10.03 Facilities are provided for the measurement of multiplex circuit levels and order-wire and alarm transmission levels. The required multiplex circuit levels are included in Section 409-400-101.*

10.04 The device used to combine the multiplex and the order-wire information is the split-apart filter. The 505U split-apart filter is an unbalanced low-pass high-pass filter. The high-pass section operates between 75-ohm impedances and the low-pass section operates between a 75-ohm input and a 600-ohm output impedance. The split-apart filter characteristic is shown in Fig. 25.

10.05 Hybrids are provided for dropping and reinserting multiplex signals at repeaters. The good low-frequency response of the hybrid permits convenient use of the baseband spectrum between 30 and 60 kHz on routes where frequent drops of a few circuits can be made in the presence of through-circuits in the higher frequency carrier assignments. At terminals where a hybrid is not used, a 3.5 dB pad is supplied to preserve the multiplex transmission levels. At through repeaters, neither hybrid nor pad is required or provided. A 14.5 dB pad is supplied.

10.06 Transmission levels assume continuous circuit growth starting in the lowest supergroup assignment. If a different supergroup growth pattern is utilized, the circuit levels selected should correspond to the number of circuits represented by the highest supergroup used, regardless of the actual circuit load.

10.07 Pre-emphasis networks should be used on radio channels carrying more than 240 message-type circuits. If the initial load requirement on a radio channel is less than 240 circuits but is expected to exceed 240 circuits in the near future, it is advisable to provide pre-emphasis from the beginning. Figure 18 shows the pre-emphasis and de-emphasis curves for 600-message circuit loading.

11. POWER REQUIREMENTS

11.01 The TL-2 system consumes approximately 170 watts of power for one transmitter-receiver combination. The primary source of power for the TL-2 is commercial alternating current. Power to the system is maintained during commercial power outages through the use of batteries which are an integral part of the power plant. The batteries are charged to float voltage and act as a filter for the output of the rectifier unit when commercial power is present. Continuous power is provided to the radio bays since the batteries are always in the circuit and no transfer of source is required when a power failure occurs. Sufficient reserve is normally provided to carry the system for approximately 24 hours. An external ac connection is provided for a portable power source for use during extended commercial power outages.

*This section may not be available. Consult the latest numerical index.

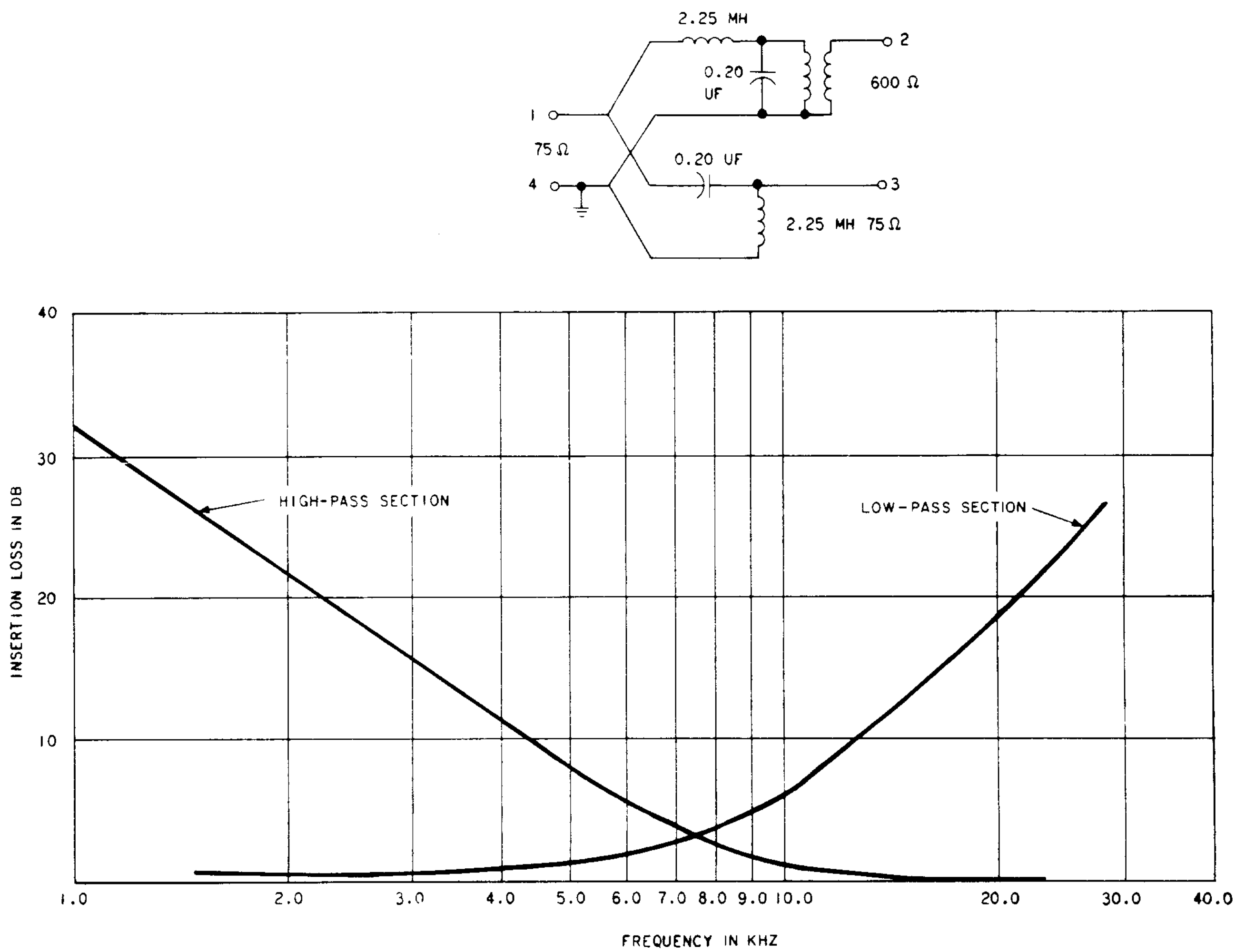


Fig. 25—505U Split-Apart Filter Characteristic

11.02 Two battery charger circuits are available for use with TL-2, one with a 16-ampere 27.6-volt output and the other with a 48-ampere 27.6-volt output. Each TL-2 RF panel (one transmitter, one receiver) requires up to 6 amperes maximum. The 16-ampere charger is used with single-unit bays and mounts in the bay. The 48-ampere charger is used with multiple-unit bays and mounts in a separate 7-foot bay which also contains the batteries.

11.03 The −24 volt office battery may be used to power the radio equipment in central office locations. When the central office battery is used, an external filter on a radio panel basis is included to prevent power supply noise from entering the central office. However, before using a battery bus from the central office battery to the TL-2, an investigation of the cost should be made. The cost of the battery plant may be less than the cost of an extended-length battery bus.

12. CONSIDERATIONS—CONJOIN OF TL-2 AND ANOTHER 11-GHZ RADIO SYSTEM IN MID HOP

12.01 In some cases it may be desirable to interconnect a TL-2 with other radio equipment. This is done with a midair link and requires considerable prior planning.

12.02 Some of the factors that should be considered are the polarization, received signal level, and IF bandwidth. Each system must be compatible with the polarization transmitted by the other. The received signal level must be held within the range of the receiver. This may be accomplished, in some instances, by limiting the power delivered to the antenna by the other system. The IF bandwidth used by each system must be specified.

12.03 Radio drive level information must be exchanged. Baseband drive level and peak deviation are both important. The number of message circuits or the required system loading may modify the drive-level information.

12.04 Pre-emphasis information must be exchanged. The type of pre-emphasis used by each system must be investigated. System loading may determine whether pre-emphasis is necessary, in this instance.

12.05 It is desirable to noise-load field-test each system with particular emphasis on the midair link. A check for equalization problems, including special baseband compensation, should be made. Squelch problems, if any, should be investigated.

12.06 There may be a difference in the alarm systems involved. An agreement must be reached on which system will alarm the interconnecting link. Order-wire and pilot transmission level information must be exchanged. It may be necessary to exchange equipment for the generation of a pilot on either end. It is also desirable to interconnect the order-wire circuits.

13. EQUIPMENT DESIGN

13.01 The TL-2 basic equipment mounting arrangement is either a 7- or a 9-foot 23-inch bay. A 7-foot bay will accomodate up to six receivers or six transmitters, or three receiver-transmitters. A 9-foot bay is available for as many as 4 receiver-transmitter combinations. Power supply, order wire and alarm, diversity switch, and video panels are also mounted in these bays. The floor mounting of the TL-2 bay is 15 inches deep.

13.02 In common with TM-1, TL-2 battery and charger equipment is mounted in a separate 7-foot 30-inch cabinet. Each battery plant can supply four receiver-transmitter units of TL-2 or TM-1.

13.03 Where growth is limited, equipment for a single two-way radio channel and battery plant may both be mounted in a single bay. Both TL-2 and TM-1 will utilize the same outdoor cabinet. The cabinet will be 57 inches wide, 77 inches high, and 22 inches deep. The cabinet will house up to four receivers or four transmitters, or two receiver-transmitters. It could accommodate a TL-2 receiver-transmitter plus a TM-1 receiver-transmitter.

13.04 The KS-19274 equipment shelter provides both transportable and mobile type shelters in a variety of lengths. Available lengths in the transportable shelter are 7, 12, 16, 20, 24, and 28 feet. Equipment arrangements are limited to the first 16 feet, thus allowing optimal use of the remaining length. The mobile shelter is 16 feet long with tandem axle, leaf springs, and four wheels; a towing eye is provided which will allow connection to Bell System vehicles equipped with towing hooks. The mobile shelter is intended for TL-2 radio applications of emergency restoration in the 11-GHz frequency band and for use in special pickup work.

14. PORTABLE EQUIPMENT

14.01 The portable TL-2 units and associated mobile shelter were developed to provide a short-haul microwave radio transmitter and receiver that could be quickly and easily set up at various locations. They are intended primarily for emergency restoration of radio, cable, or open-wire facilities, but should also find application when providing temporary service or TV pickup.

14.02 Portable TL-2 consists of standard TL-2 radio equipment mounted in lightweight, weathertight, aluminum cases which can be hand carried. The cases are designed for (1) stacking vertically in free-standing groups or for (2) bay mounting on special bays in a trailer. The trailer is a standard KS- shelter arranged for vehicular use and described in 13.04.

14.03 The portable arrangement of TL-2 provides the same transmission characteristics as the standard version for fixed installation. Standard TL-2 plug-in units are used throughout. Frequency-conscious elements are equipped with quick-disconnect clamps for rapid changing of RF channel assignments in the field.

14.04 The portable packages can be powered from either a commercial ac source or a 24-volt battery plant. The trailer contains a 390 ampere-hour battery plant plus charger and has outside connections for obtaining 115-volt ac from either a power line or a mobile generator.

15. REFERENCES

BELL SYSTEM TECHNICAL JOURNAL—The TM-1/TL-2 Short Haul Microwave Systems—Jan. 1966

AA388.171	Short-Haul Radio Systems
AA388.158	TL-2 Radio—Transmitter-Receiver Equipment
409-400-102	TL-2 Transmitter-Receiver Cabinet and Bay
409-400-103	TL-2 Transmitter
409-400-104	TL-2 Receiver
409-400-125,126	Video Panels
409-403-503	System Tests—Television Transmission
409-403-505	System Tests—600 Circuit—Noise-Loading