

N2 CARRIER TELEPHONE SYSTEM TRANSMITTING AND RECEIVING GROUP UNITS

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1. GENERAL

1.01 This section describes the transmitting and receiving group units used in the N2 carrier telephone system. The N2 system employs transmitted carrier, double-sideband transmission with channels spaced 8 kc apart. Different cable pairs and different frequency bands are used for the two directions of transmission. The two frequency bands are termed high group and low group. The high group includes the frequency range 164 to 268 kc with carriers at 8-kc intervals from 168 to 264 kc. The low group includes the frequency range 36 to 140 kc with carriers at 8-kc intervals from 40 to 136 kc.

Modulating one group with 304 kc and choosing the lower sideband will produce the other group. The channels are numbered sequentially 1 through 13, where channel 1 carrier is 168 kc in the high group and 140 kc in the low group. The N2 system transmits 12 channels, channels 2 to 13, with channel 1 as an alternate.

1.02 The N2 channel equipment transmits and receives only the high-group frequencies. In order to transmit the low group onto the cable pair, the group transmitting unit must convert high-group frequencies to low-group frequencies by modulating them with 304 kc and choosing the lower sideband. Similarly, in order to receive the low group from the cable pair, the group receiving unit must convert the low-group frequencies to high-group frequencies by modulating them with 304 kc and choosing the lower sideband.

1.03 The terminal group equipment consists of a transmitting group unit and an associated receiving group unit. These units provide the desired frequency conversion and amplification for a group of 12 carriers and sidebands, between the terminal channel units and the cable pairs, in both the transmitting and receiving directions.

1.04 There are four types of group units.

- (a) The high-group transmitting unit
- (b) The low-group transmitting unit
- (c) The high-group receiving unit
- (d) The low-group receiving unit

1.05 A terminal which transmits the high group of frequencies must receive the low group. Therefore, a terminal which transmits the high group will contain one high-group transmitting unit and one low-group receiving unit. Similarly, a terminal which transmits the low group will contain one low-group transmitting unit and one high-group receiving unit.

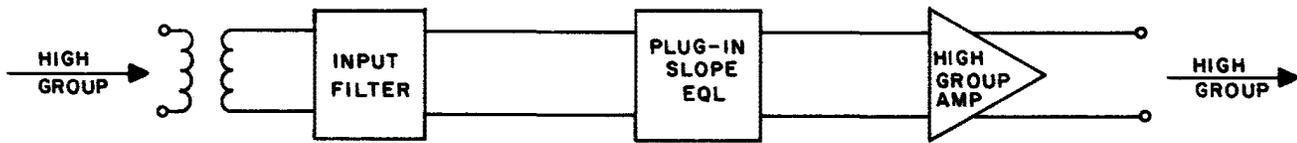
1.06 The transmitted signal is composed of a group of 12 carriers and sidebands. They are generated in the individual channel modem units in the high-group frequency range, and combined in the line-terminating unit. The transmitting group unit filters out unwanted frequencies, converts the signal to the low-group frequency range, if necessary, and amplifies the signal to the proper level for transmission to a cable pair. The signal is transmitted to the cable through the line-terminating unit.

1.07 The transmitting group unit contains a plug-in slope equalizer. This equalizer allows the transmitted signal to be pre-equalized to compensate for the cable-loss characteristic. The seven plug-in equalizers can provide group unit output slopes of 0, ± 3 , ± 6 , or ± 9 db for channel 13 with respect to channel 2.

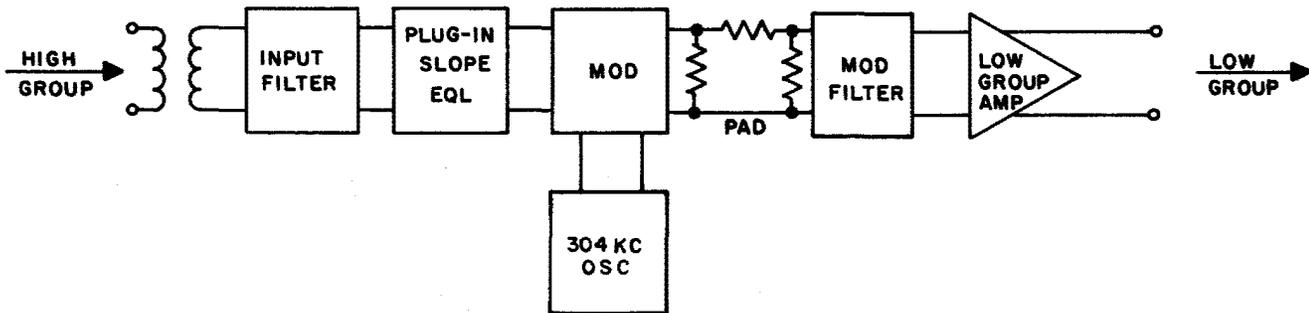
1.08 A signal received from the cable enters the terminal through the line-terminating unit. Here the level is adjusted by the receiving span pads. The receiving group unit filters out unwanted frequencies, converts the signal to the high-group frequency range, if necessary, and amplifies the signal to the proper level. The signal is then sent through the line-terminating unit to the individual channel filters in the modem units.

1.09 The receiving group unit contains a plug-in slope equalizer and slope switch which make it possible to adjust the output slope to zero, within 0.5 db.

1.10 The receiving group unit is provided with automatic gain regulation which keeps the total receiving unit output nearly constant even though the input power changes due to cable loss changes with temperature.

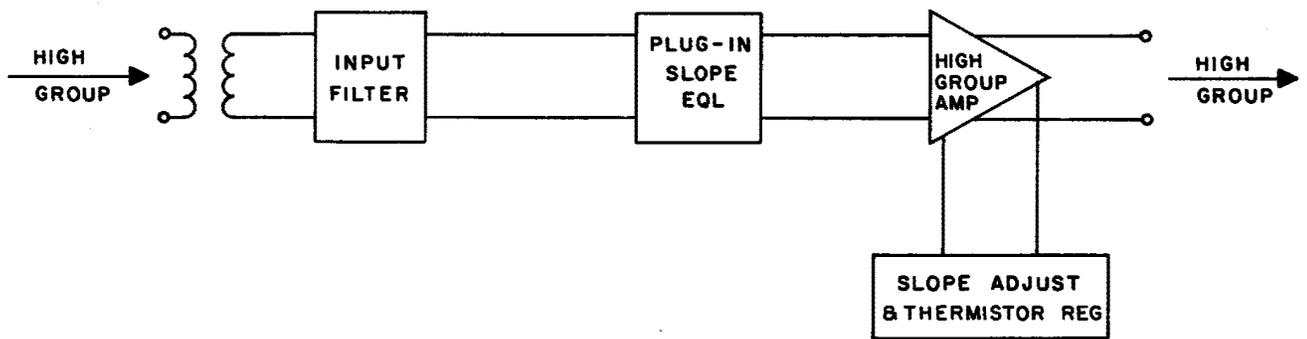


HIGH GROUP TRANSMITTING UNIT

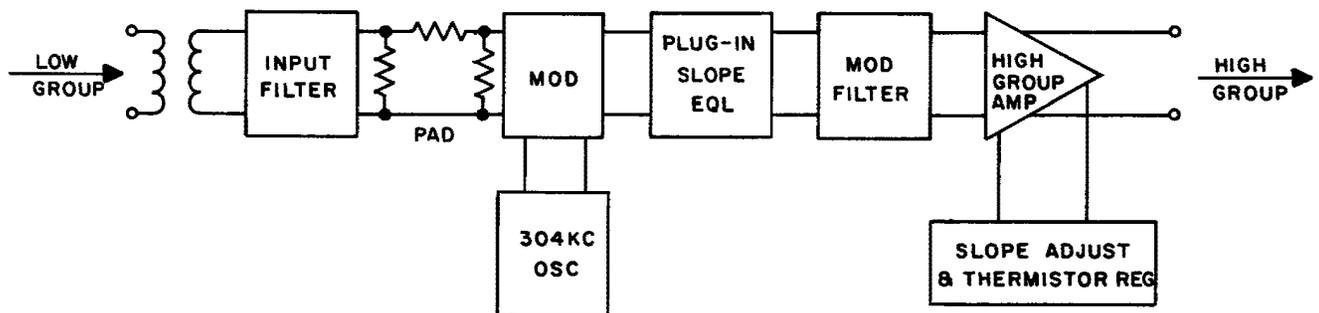


LOW GROUP TRANSMITTING UNIT

Fig. 1 - Block Diagrams of Transmitting Group Units



HIGH GROUP RECEIVING UNIT



LOW GROUP RECEIVING UNIT

Fig. 2 - Block Diagrams of Receiving Group Units

1.11 The receiving unit connects to a carrier alarm which operates on the total power of the received carriers so that a failure of the terminal, cable pair, or the repeaters will be noted immediately. The alarm circuitry is located in the terminal alarm unit.

1.12 The transmitting and receiving group units are protected from transverse lightning surges on the line by lightning-protection diodes in the line-terminating unit.

1.13 The group unit external connections terminate in a plug which is plugged into a jack in the terminal mounting. The connections include input and output, -21 volt power, circuit ground, and chassis ground.

2. CIRCUITS

2.01 Block diagrams of the four group units are shown in Fig. 1 and 2. In block form, they appear quite similar and actually many of the component blocks are identical. The two transmitting units have identical input filters and have amplifiers which are identical in form but differ because they handle different frequency ranges and have different output powers. The amplifiers in the two receiving units have only minor differences. The high-group transmitting and high-group receiving units use the same plug-in slope equalizers. The low-group transmitting and low-group receiving units use the same slope equalizers and have the same modu-

lator and 304-kc oscillator. All units use the same 0-db slope equalizer.

A. Input Filters

2.02 The outputs of the individual channel modulators are essentially square waves. The high-group bandpass filter, at the inputs of both transmitting group units, filters out the carrier harmonics so that the carriers applied to the cable are sinusoidal. This filter provides at least 50 db of attenuation to all harmonics of the desired N2 high-group signals. It also suppresses voice frequencies and low-group frequencies. The measured response of the filter is shown in Fig. 3. The nominal input and output impedance of the filter is 3000 ohms.

2.03 The input filters in the receiving group units select the desired frequency group and reject other group frequencies that may

be present due to cable crosstalk. They also reject frequencies above the high-group band that may be present due to pickup from other communication systems. This is particularly important in the low-group receiving unit, since unwanted signals 164 to 268 kc away from 304 kc, or its harmonics, may be modulated into the desired high-group frequency range. The bandpass filter in the high-group receiving unit passes the high group and provides at least 33 db of attenuation to low-group frequencies and frequencies above the high group. The low-pass filter in the low-group receiving unit passes the low group and provides at least 25 db of attenuation to the high group and higher frequencies. The measured responses of these filters are shown in Fig. 4 and 5, respectively. The nominal input and output impedance of the filters is 3000 ohms.

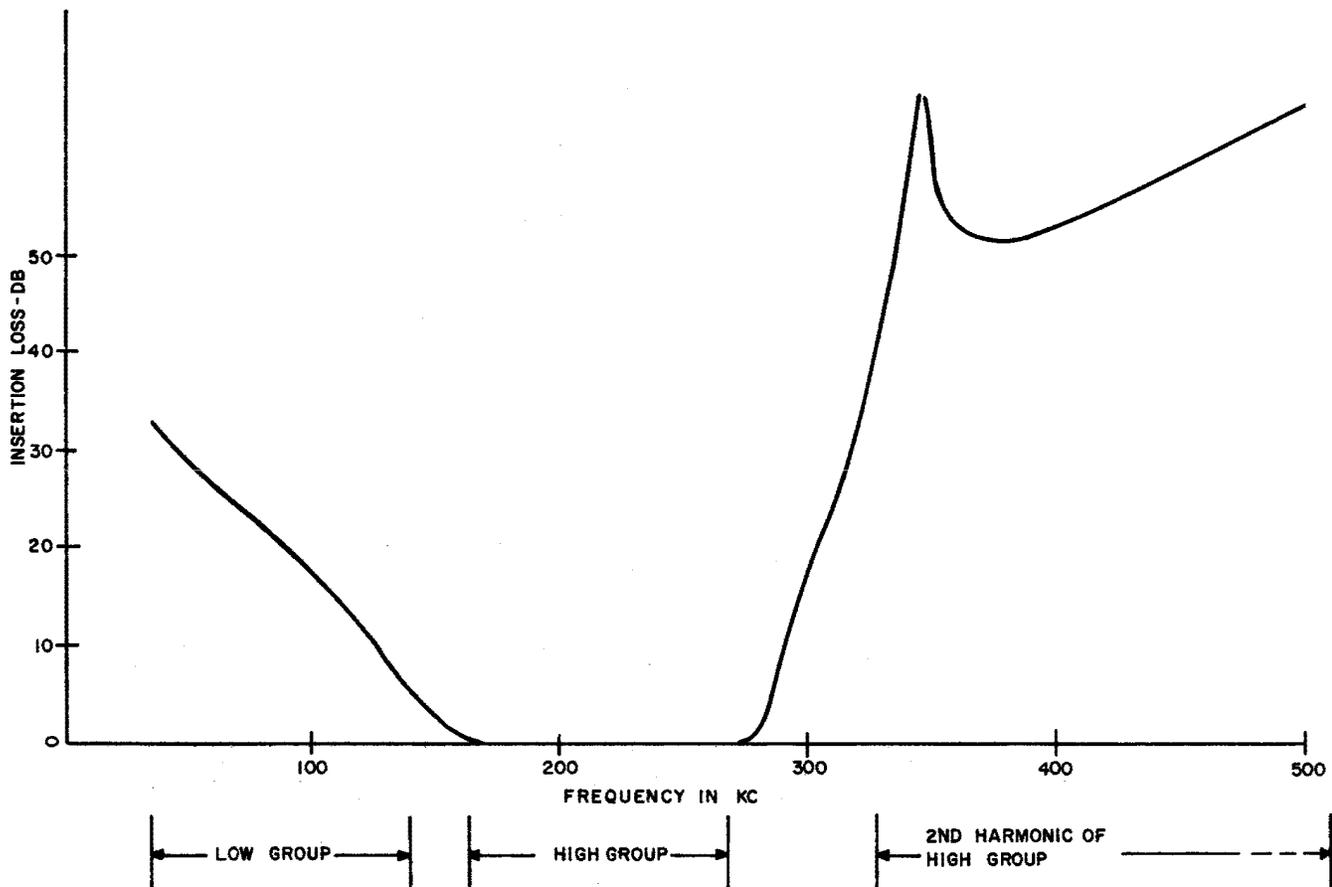


Fig. 3 - Insertion Loss Characteristic - High-group Transmitting and Low-group Transmitting Units Input Filter

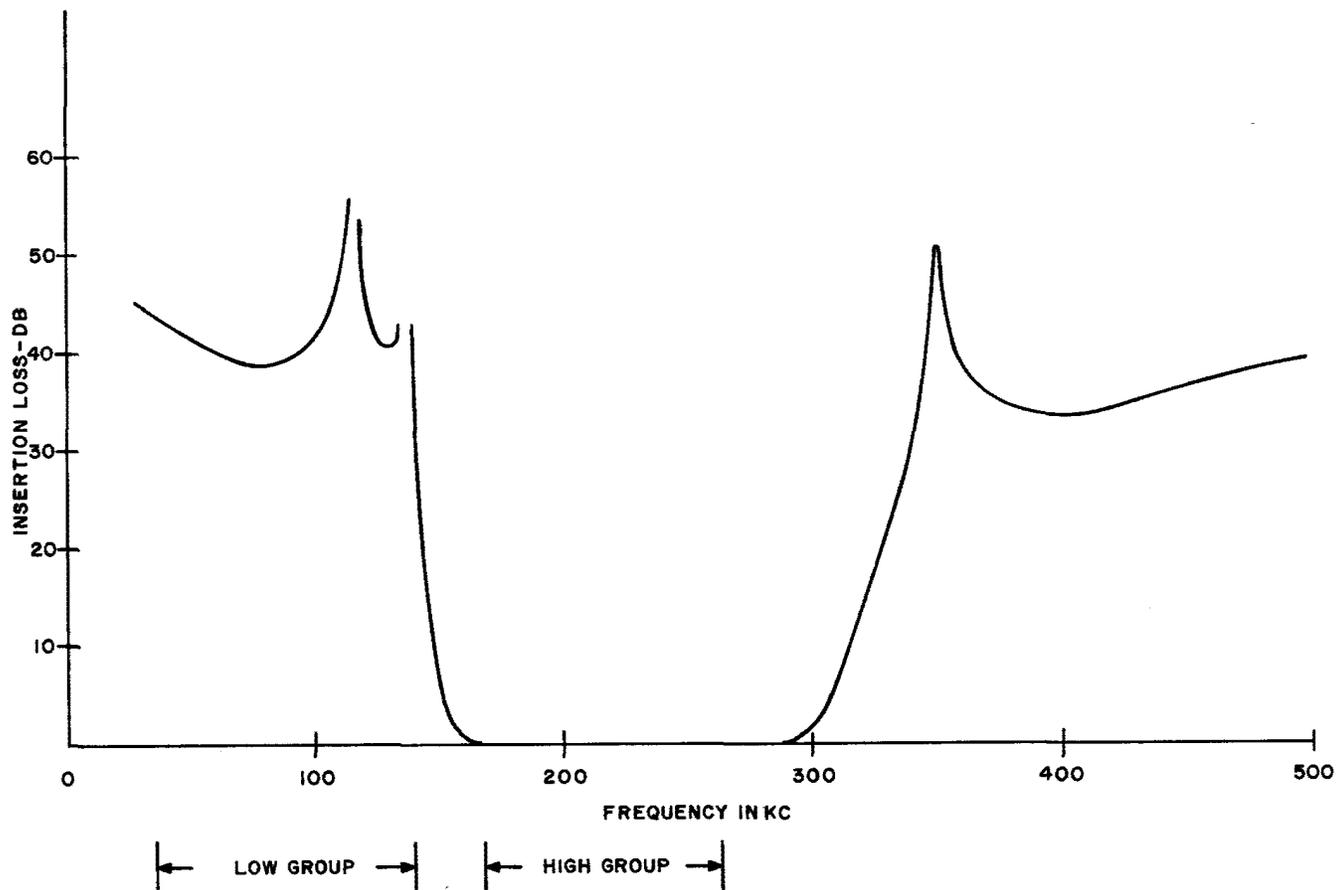


Fig. 4 - Insertion Loss Characteristic — High-group Receiving Unit Input Filter

B. Group Modulator

2.04 The group modulator is used in both the low-group transmitting and low-group receiving units. It converts one frequency group to the other by modulating the group with a 304-kc carrier. The modulator is followed by a filter to select the lower sideband (below 304 kc). The low-group transmitting unit receives signals in the high-group frequency range from the channel modulators and converts them to the low group for transmission on the cable. The low-group receiving unit receives signals in the low-group frequency range from the cable and converts them to the high group for the channel demodulators.

2.05 A simplified schematic of the modulator, together with the 304-kc oscillator, is shown in Fig. 6. The modulator is of the double-balanced type (input signal and carrier are both

balanced with respect to and do not appear in the output). It consists of four matched diffused silicon diodes connected between two transformers. The modulator action may be considered as a double-pole double-throw switch inserted in the signal path between the input and output transformers, and activated by the plus and minus voltages of the carrier. When the carrier voltage is positive on the right and negative on the left side (Fig. 6), carrier current flows through the two outer diodes and their impedance is made low. A signal present at the input will then flow directly through the modulator to the output transformer. During the next half cycle of carrier, the carrier potential is reversed and the carrier current flows through the inner diodes, making their impedance low. This is equivalent to reversing the path for signal voltages from the input to the output transformer at a 304-kc rate.

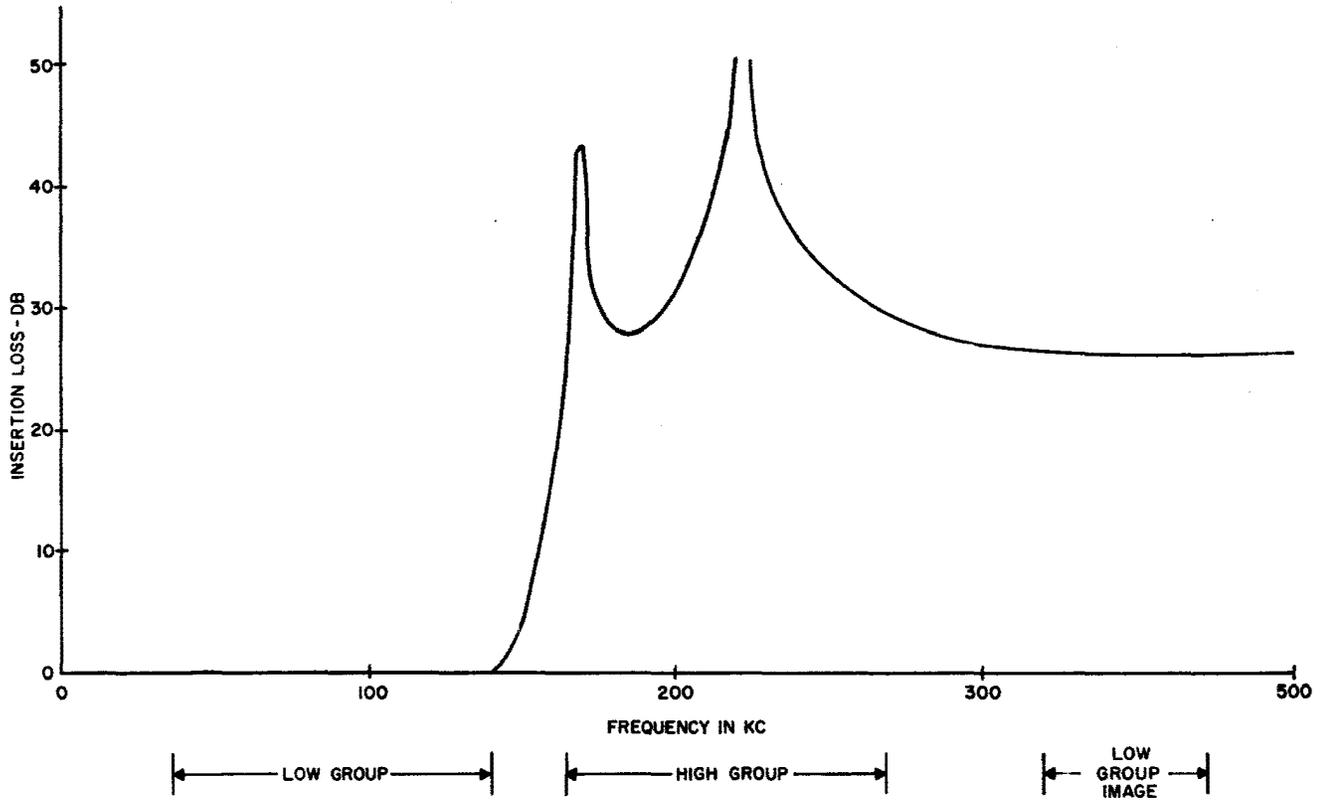


Fig. 5 - Insertion Loss Characteristic Low-group Receiving Unit Input Filter

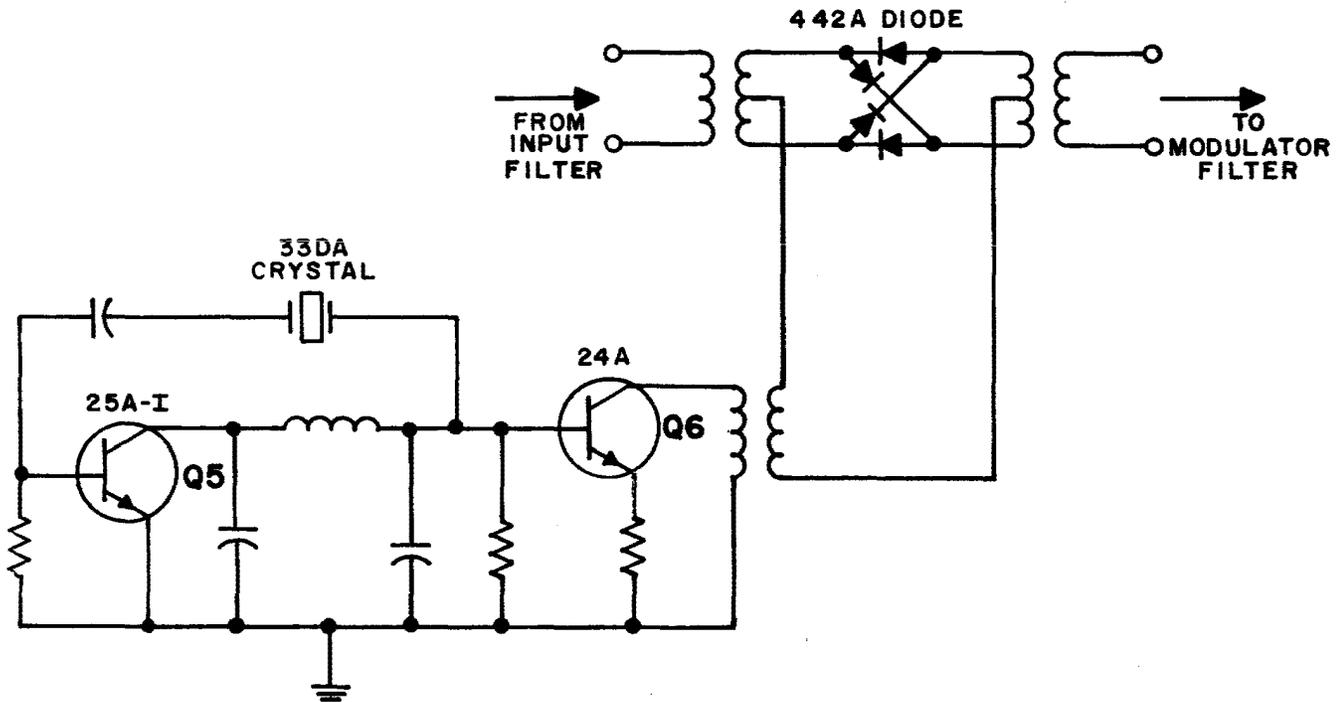


Fig. 6 - Schematic of Modulator and 304-kc Oscillator

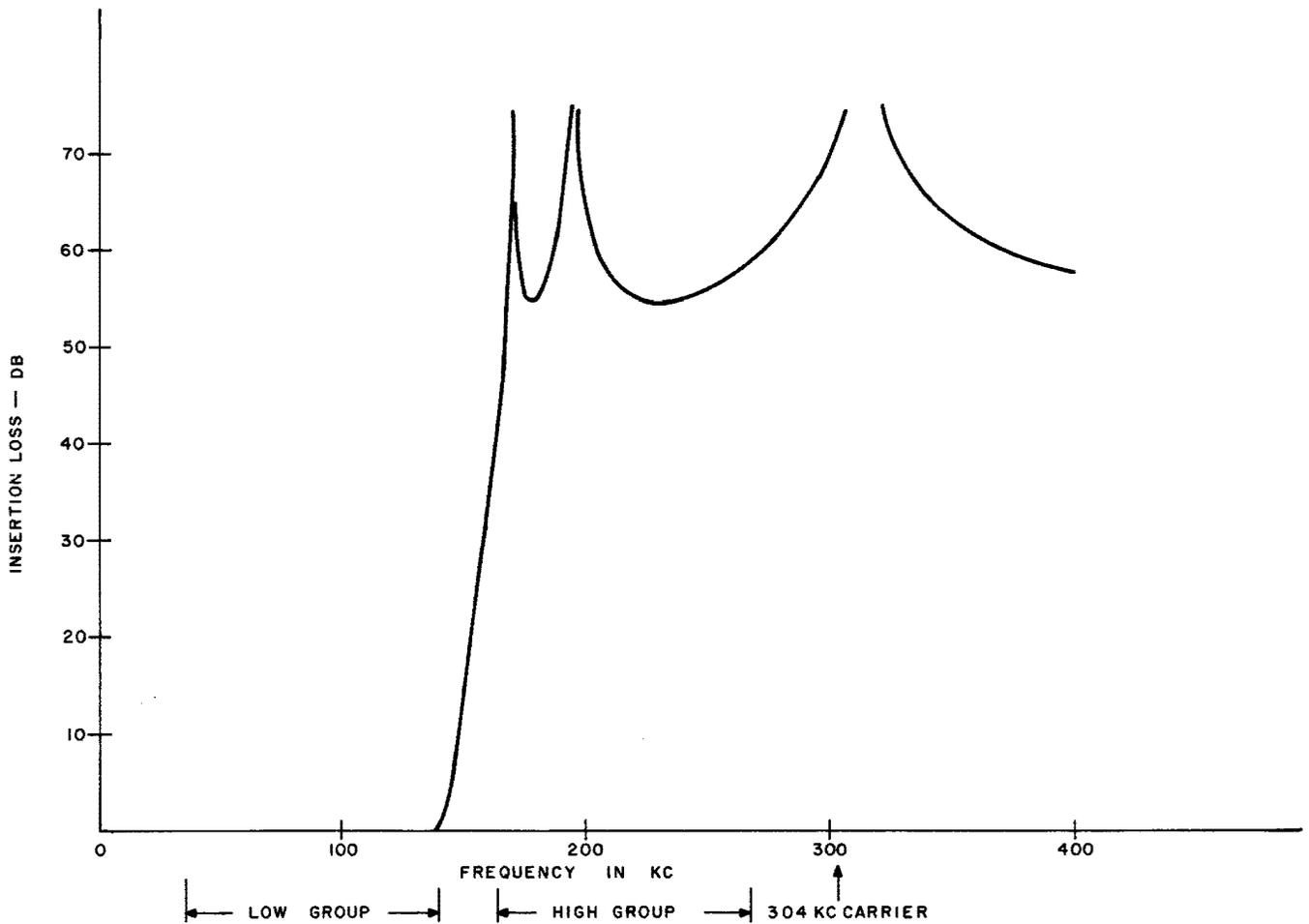


Fig. 7 – Insertion Loss Characteristic Low-group Transmitting Unit Modulator Output Filter

2.06 The output of the group modulator consists principally of first order modulation products, input signal leakage, and 304-kc carrier leakage. The last two items are due to imperfect balance of the diodes and transformers. The desired signal is the lower sideband. The upper sideband or image band contains as much power as the desired lower sideband and must be rejected by the modulator output filters. The modulator output frequencies for the low-group transmitting and low-group receiving units are tabulated as shown in table.

C. Modulator Filters

2.07 The modulator filters must pass the desired lower sideband produced by the modulator and reject all other unwanted modu-

lation products, especially the image band. It must also attenuate the input frequencies and 304-kc carrier leakage. The low-group transmit-

	LOW-GROUP TRANSMITTING	LOW-GROUP RECEIVING
	kc	kc
Desired Output	Low Group 36 to 140	High Group 164 to 268
Input Leakage	High Group 164 to 268	Low Group 36 to 140
Image Band	340 to 444	468 to 572
Carrier Leakage	304	304

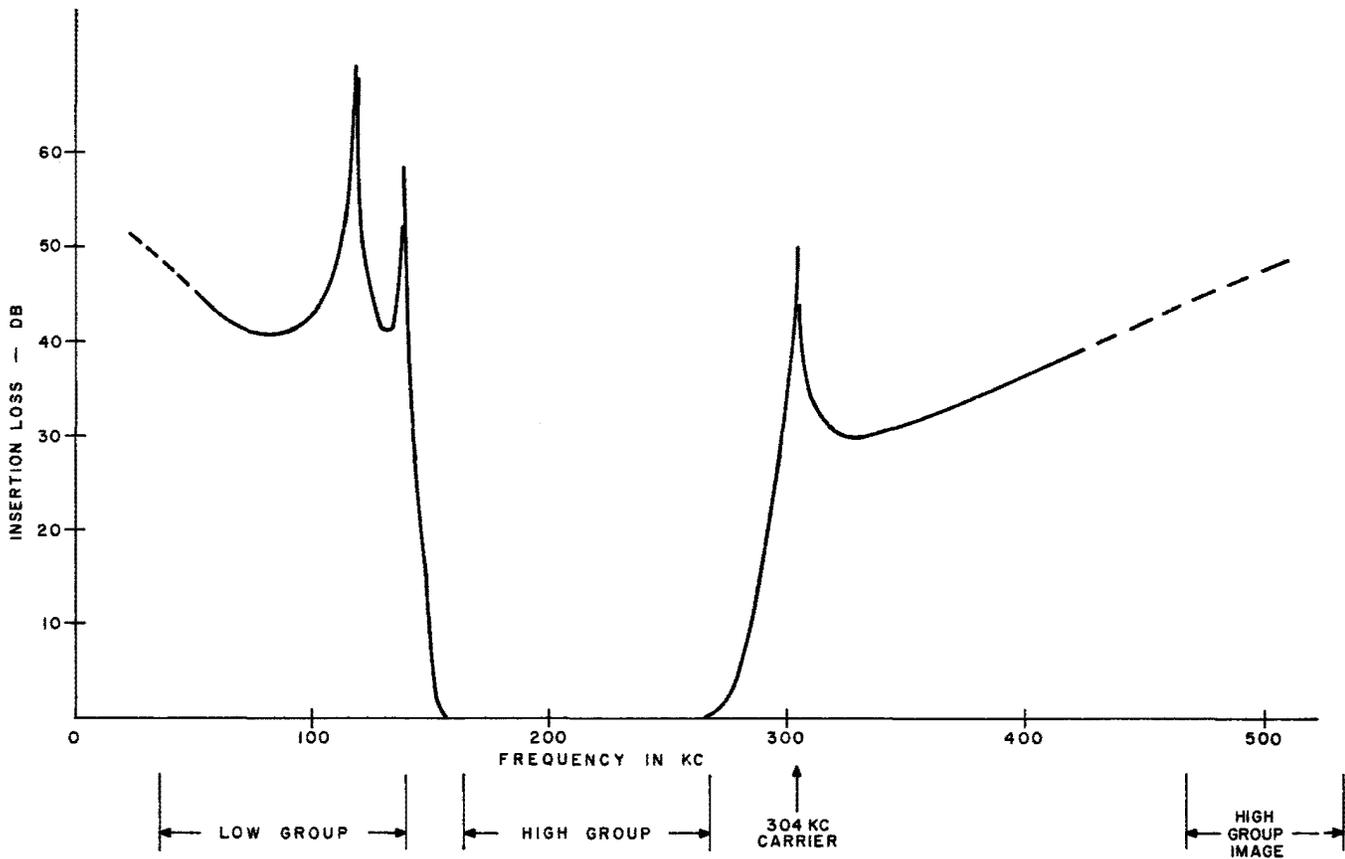


Fig. 8 – Insertion Loss Characteristic Low-group Receiving Unit Modulator Output Filter

ting unit low-pass filter passes the low group and provides at least 55 db of attenuation to all unwanted frequencies. The low-group receiving unit bandpass filter passes the high group and provides at least 40 db of attenuation to all unwanted frequencies. The measured responses of the filters are shown in Fig. 7 and 8, respectively. The nominal input and output impedance of the filters is 3000 ohms.

D. 304-kc Carrier Oscillator

2.08 A schematic of the 304-kc carrier oscillator is shown in Fig. 6. The oscillator consists of a one-stage crystal-controlled transistor oscillator and one transistor buffer amplifier. The buffer amplifier is necessary in order to obtain sufficient carrier power and to shield the oscillator from the nonlinear modulator load. The oscillator contains a variable inductor to

compensate for the output capacitance tolerance of the oscillator transistor. The inductor is factory adjusted to yield the proper output voltage.

E. Plug-in Slope Equalizer

2.09 A plug-in slope equalizer is used in both the transmitting and receiving group units to compensate for slope in the cable-loss characteristic. The equalizer is plugged into a socket which is accessible when the group unit is removed from the bay. Seven different equalizers are available producing gain slopes of -9 , -6 , -3 , 0 , $+3$, $+6$, and $+9$ db for channel 13 relative to channel 2. All seven equalizers operate at a 3000-ohm impedance level in the high-group frequency band and are compatible with all four group units. In the low-group receiving unit, the equalizer is located just after the group modu-

lator; in all other units, it is located just after the input filter. In all units, it is located in the high-group portion of the circuit. In practice, only the negative gain slopes are needed in the low-group transmitting and low-group receiving units, and only the positive gain slopes are needed in the high-group transmitting and high-group receiving units. The slope equalizers are coded as shown in Table A.

2.10 In the group transmitting units, the slope equalizer is used to adjust the output of the group unit and, thus, pre-emphasize the transmitted signal. The *output slope* of the transmitting group unit is equal to the *gain slope* of the equalizer used. The flat loss of the equalizers has been adjusted so that the rms loss to a 12-carrier signal is 5.6 db for all equalizers when used in a transmitting unit. Thus, the total power output of a transmitting unit, when 12 channels are used, is the same no matter which slope equalizer or output slope is chosen (i.e., +12 dbm for high-group transmitting and +3 dbm for low-group transmitting).

2.11 In the group receiving units, the slope equalizer is used to help adjust the receiving output slope to zero. An adjustment switch SLOPE ADJ provides additional equalization (see 2.21). The rms loss of the slope equalizers when used in a receiving unit varies from 5.6

to 7.4 db for a 12-channel signal, depending on which slope equalizer is used. This difference is accounted for in the layout computations and is compensated by choosing the proper span pad.

F. Amplifiers — General

2.12 The amplifiers in the four group units are quite similar. They are all 3-stage transistor amplifiers with hybrid feedback connections at both the input and output. The input hybrid is used to improve the noise figure while the output hybrid is used to increase the maximum power handling capacity and, thus, to reduce the intermodulation distortion.

2.13 The three transistor stages are direct-coupled to conserve bias current. Temperature stability and stability with respect to component variations are achieved by minimizing the dc gain per stage and by judiciously placing diodes so that the temperature effects of diodes and transistors tend to cancel. The emitter voltage of a transistor in the last stage is the most critical point in the circuit because it sets the current in this transistor and, therefore, the clipping level. This voltage is factory set to 3.0 volts with respect to the -21 volt supply by adjusting a biasing potentiometer. After this voltage is factory set, it becomes a good indication of the condition of all transistors and diodes.

TABLE A				
CODE NO.	WHERE NORMALLY USED	GAIN SLOPE	INSERTION LOSS	
		CHAN 13 RELATIVE TO CHAN 2	CHAN 2	CHAN 13
		db	db	
364A	Low-group Transmitting and Low-group Receiving	-9	2.0	11.0
364B		-6	3.0	9.0
364C		-3	4.2	7.2
364D	All Units	0	5.6	5.6
364E	High-group Transmitting and High-group Receiving	+3	7.2	4.2
364F		+6	9.0	3.0
364G		+9	11.0	2.0

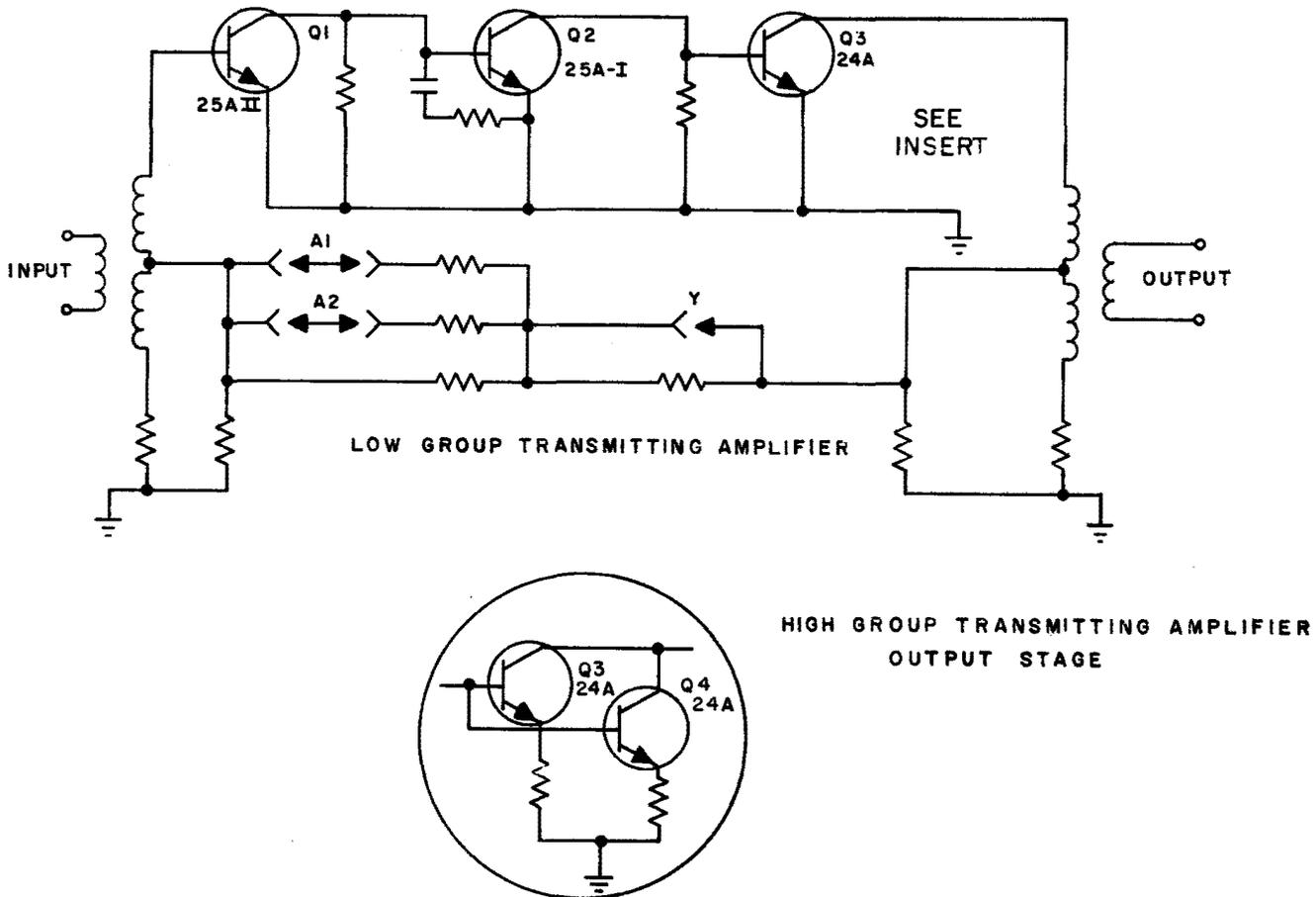


Fig. 9 – Simplified Schematic of Transmitting Amplifiers

G. Transmitting Amplifiers

2.14 The amplifiers in the two transmitting units are identical in form. A simplified schematic is shown in Fig. 9. They differ only in the frequency group amplified and the nominal output power. The low-group transmitting unit must deliver a nominal output power to the cable of +3 dbm and have a peak power handling capacity of +14 dbm. This requires only one transistor in the output stage. The high-group transmitting unit must deliver a nominal output power to the cable of +12 dbm and have a peak power handling capacity of +23 dbm, this requires two transistors in parallel in the output stage.

2.15 The gains of both transmitting amplifiers can be increased by 3 db by removing wiring option Y, which increases the resistance

in the feedback network. This is required when the transmitting unit is used as an alternate group unit in the group switching set. Wiring Y is initially provided on all transmitting group units. Wiring straps A1 and A2 provide two 0.5-db gain adjustment steps in the high-group transmitting unit and two 1-db steps in the low-group transmitting unit. These straps are cut as a factory adjustment to compensate for the accumulated manufacturing tolerance variations of all the circuit components.

H. Receiving Amplifier

2.16 The two receiving group units have essentially identical amplifiers. A simplified schematic is shown in Fig. 10. The output of a receiving amplifier is fed into the 12 paralleled channel demodulator filters. The output impedance of the amplifier is very low compared to the

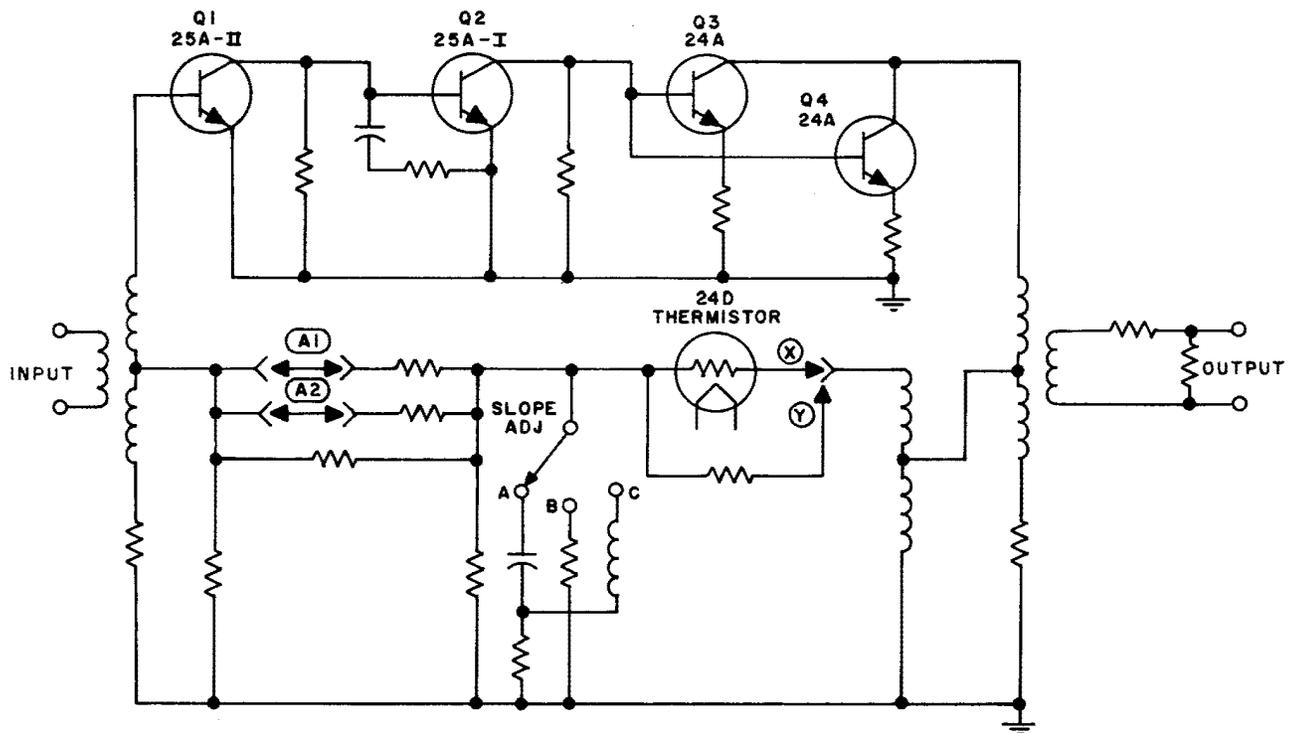


Fig. 10—Simplified Schematic of Receiving Amplifier

input impedance of the demodulator filters in order to reduce interaction between adjacent filters.

2.17 The gain of the amplifier is determined by the loss in the feedback network. The amplifier has a thermistor regulator in the feedback network which automatically adjusts the gain to maintain an output power which is almost constant over the operating range of input powers from the line. The output power is nominally -3 dbm and the thermistor holds it to within ± 1.5 db for a change in input level of ± 8 db. A typical regulation curve is shown in Fig. 11.

2.18 The thermistor consists of a thermistor pellet and an associated ambient temperature control for this pellet. The temperature of the thermistor pellet is controlled by the total power at the output of the group unit. The thermistor pellet is a negative temperature coefficient resistance unit whose resistance varies from approximately 1000 ohms to approximately 20,000 ohms for nominal group unit output powers. Un-

der abnormal transmission conditions, the resistance may vary from a few hundred ohms to upwards of 40,000 ohms. For a receiving unit having nominal gain, the thermistor resistance will be approximately 9000 ohms.

2.19 The thermistor regulator decreases group unit output power 3 to 5 times as fast as it increases it. The relatively slow reaction time of the regulator materially influences field use in that, after any transmission change, a waiting period is required before the circuit will stabilize within any desired measuring accuracy. An increase in input of 2 db requires a wait of approximately 4 minutes for correction to within 0.1 db of the final gain, whereas a decrease in input of 2 db would require a wait of approximately 14 minutes. A cold receiving unit when installed is at high gain and for normal input will have a high output; to obtain stabilization to within 0.25 db of the final output power requires approximately a 6-minute wait. Accuracy within 0.1 db requires a wait of 15 or 20 minutes.

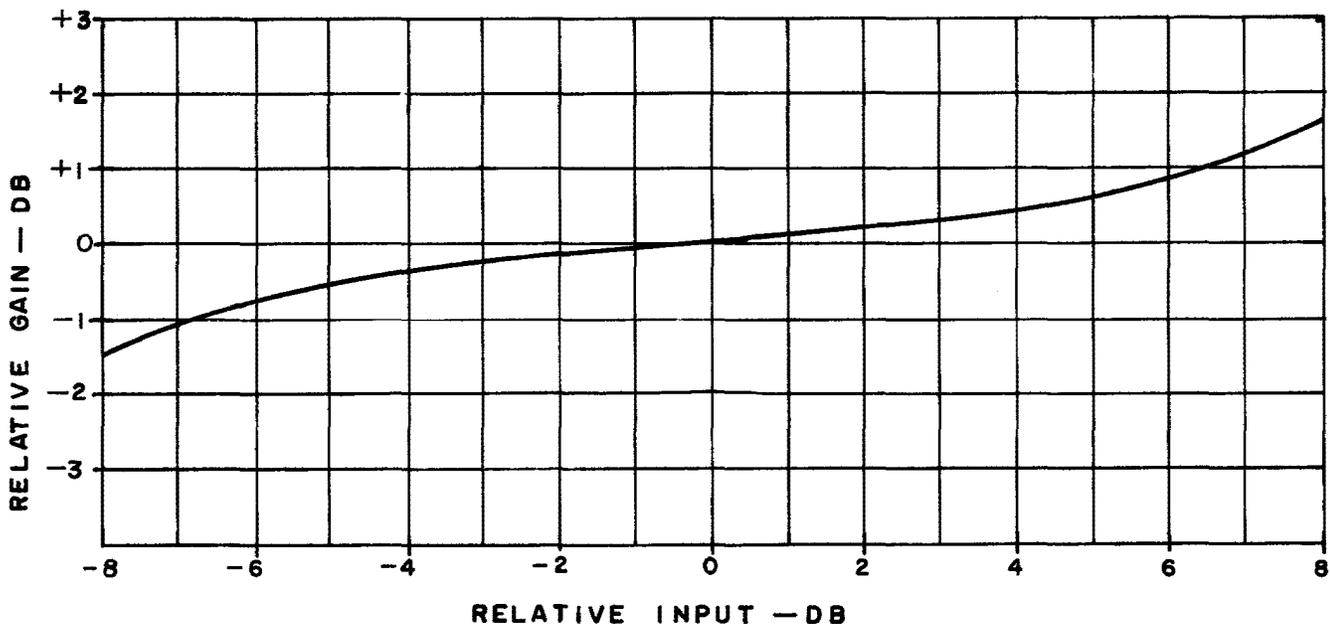


Fig. 11 - Regulation Characteristic of Receiving Amplifier

2.20 When a receiving unit is used as an alternate group unit in the group switching set or during maintenance tests, a fixed gain without regulation is desired. This condition is obtained by using Y option wiring which inserts a 20,000-ohm resistor in place of the thermistor. This resistor provides 6 db more amplifier gain than that provided by the thermistor at its mean operating resistance. This resistor is also used for manufacturing and repair testing. It is normally replaced by the thermistor (X wiring) for field installation. Wiring straps A1 and A2 provide two 0.5-db gain adjustment steps in the high-group receiving unit and two 1-db steps in the low-group receiving unit. These straps are cut as a factory adjustment to compensate for the accumulated manufacturing variations of all the circuit components.

2.21 The receiving amplifier contains a slope switch which provides manual control of the receive frequency characteristic in order to interpolate between the 3-db steps of slope provided by the plug-in slope equalizer (2.09). The adjustment switch SLOPE ADJ is in three steps designated A, B, and C, providing slopes of approximately 1 db, 0 db, and -1 db in gain, re-

spectively, for channel 13 with respect to channel 2. These adjustments are so arranged that for each setting the circuit has the same output power. Thus, a change in slope setting may be made on an operating system without affecting the thermistor regulating action.

3. TRANSMISSION PERFORMANCE

A. Transmitting Units — High-group Transmitting and Low-group Transmitting

3.01 The transmitting units receive the combined 12-channel signal from the line-terminating unit at a level of -43 dbm per channel, or -32 dbm total power from 12 channels, in the high-group frequency range. The measured output characteristics for the high-group transmitting and low-group transmitting units are shown in Fig. 12 and 13, respectively. The total power output of the high-group transmitting unit is +12 dbm. In Fig. 12 the high-group transmitting output is shown with four slope equalizers inserted, yielding output slopes of 0, +3, +6, and +9 db for channel 13 output with respect to that of channel 2. The total power output of the low-group transmitting unit is

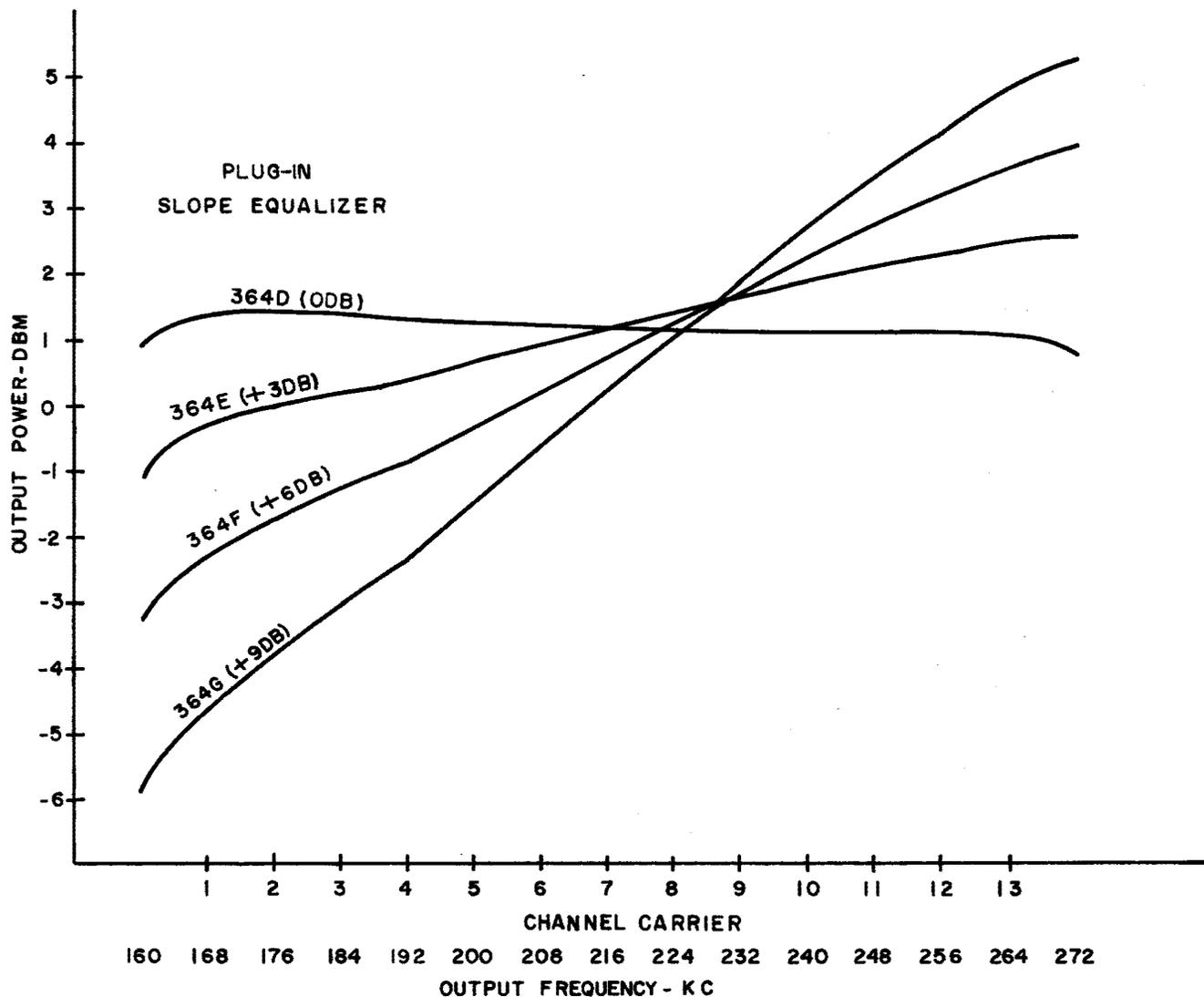


Fig. 12 – High-group Transmitting Unit Output Power versus Frequency

+3 dbm. In Fig. 13 the low-group transmitting output is shown with four slope equalizers inserted, yielding output slopes of -9 , -6 , -3 , and 0 db for channel 13 output with respect to that of channel 2.

B. Receiving Units — High-group Receiving and Low-group Receiving

3.02 The receiving units receive the signal from the cable at a slope and level which depends on the line repeater adjustments and lengths of cable. The total input power can be adjusted by the selection of the proper receive-

ing span pad in the line-terminating unit. The slope of the incoming signal may be adjusted to 0 ± 0.5 db by the selection of the proper plug-in slope equalizer and SLOPE ADJ switch position. The measured power gains of the high-group receiving and low-group receiving units are shown in Fig. 14 and 15, respectively. The gains are shown for the nominal value of thermistor resistance and for B slope settings. The power gain of the high-group receiving unit (for the above condition), minus the slope equalizer loss, is 48.7 db. With the 0-db slope equalizer inserted, the gain is 43.1 db. The power gain of the low-group receiving unit (for the above condi-

tions), minus the slope equalizer loss, is 39.7 db. With the 0-db slope equalizer inserted, the gain is 34.1 db. In Fig. 14, the high-group receiving unit gain is shown with four slope equalizers inserted, yielding gain slopes of 0, +3, +6, and +9 db for channel 13 with respect to channel 2. In Fig. 15, the low-group receiving unit gain is shown with four slope equalizers inserted, yielding gain slopes of -9, -6, -3, and 0 db. The relative gain of the receiving amplifier is shown in Fig. 16 for the three slope switch positions. This adjustment provides relative slopes of 1, 0, or -1 db to interpolate between the 3-db slope steps of Fig. 14 and 15. Thus, gain slopes are obtainable in 1-db steps from -1 to +10 db for the high-group receiving unit, and from -10 to +1 db for the low-group receiving unit.

4. TESTING ARRANGEMENTS AND FACILITIES

4.01 The testing facilities for the group units are arranged so that all tests may be made on an in-service basis. The tests include:

- (a) Transistor emitter current tests.
- (b) Measurement of the total carrier power at the output of transmitting and receiving group units.
- (c) Measurement of the individual carrier power output of the transmitting and receiving group units.
- (d) Switching a stand-by group unit into the circuit without service interruption to make the regular group unit available for out-of-service maintenance or replacement.

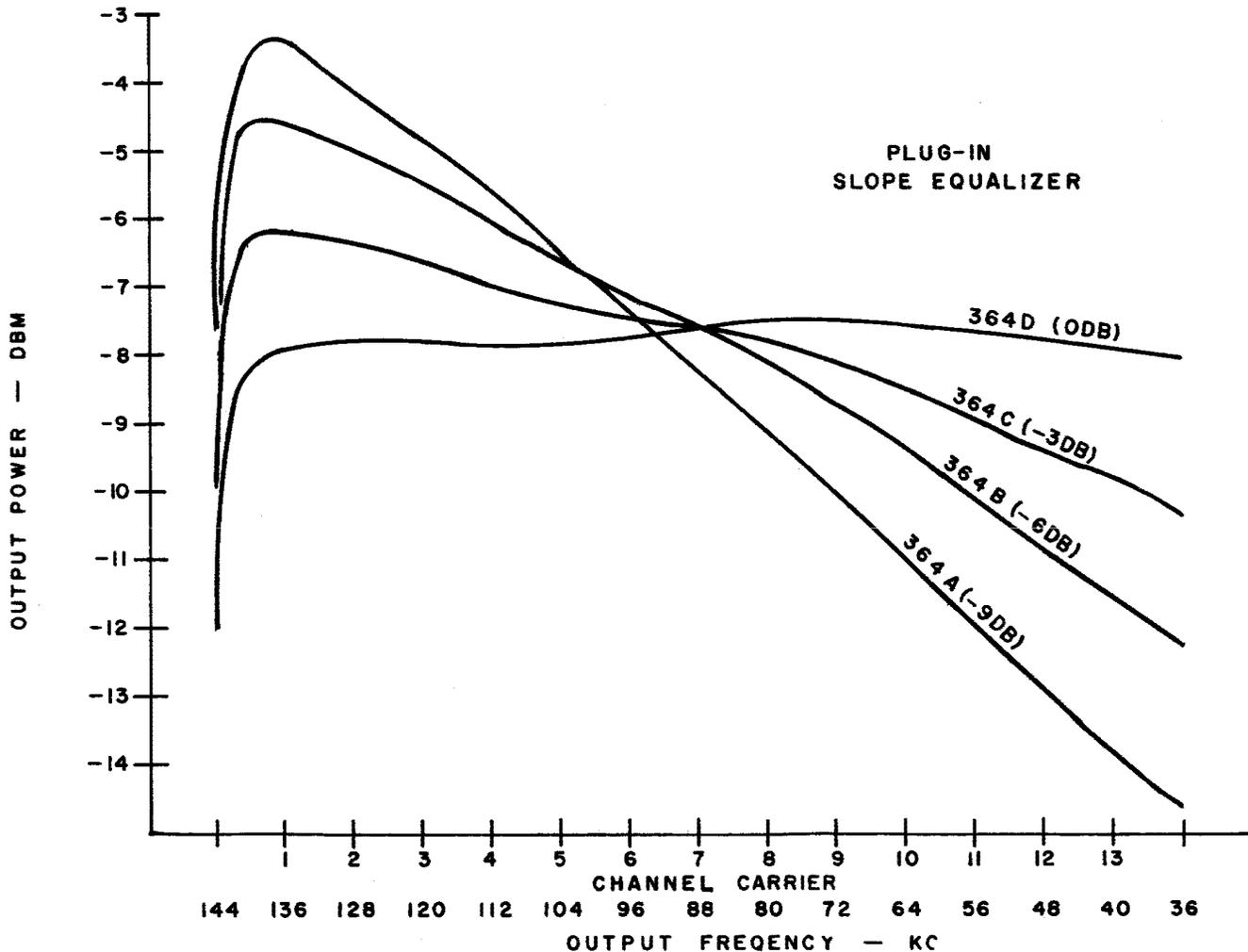


Fig. 13 - Low-group Transmitting Unit Output Power versus Frequency

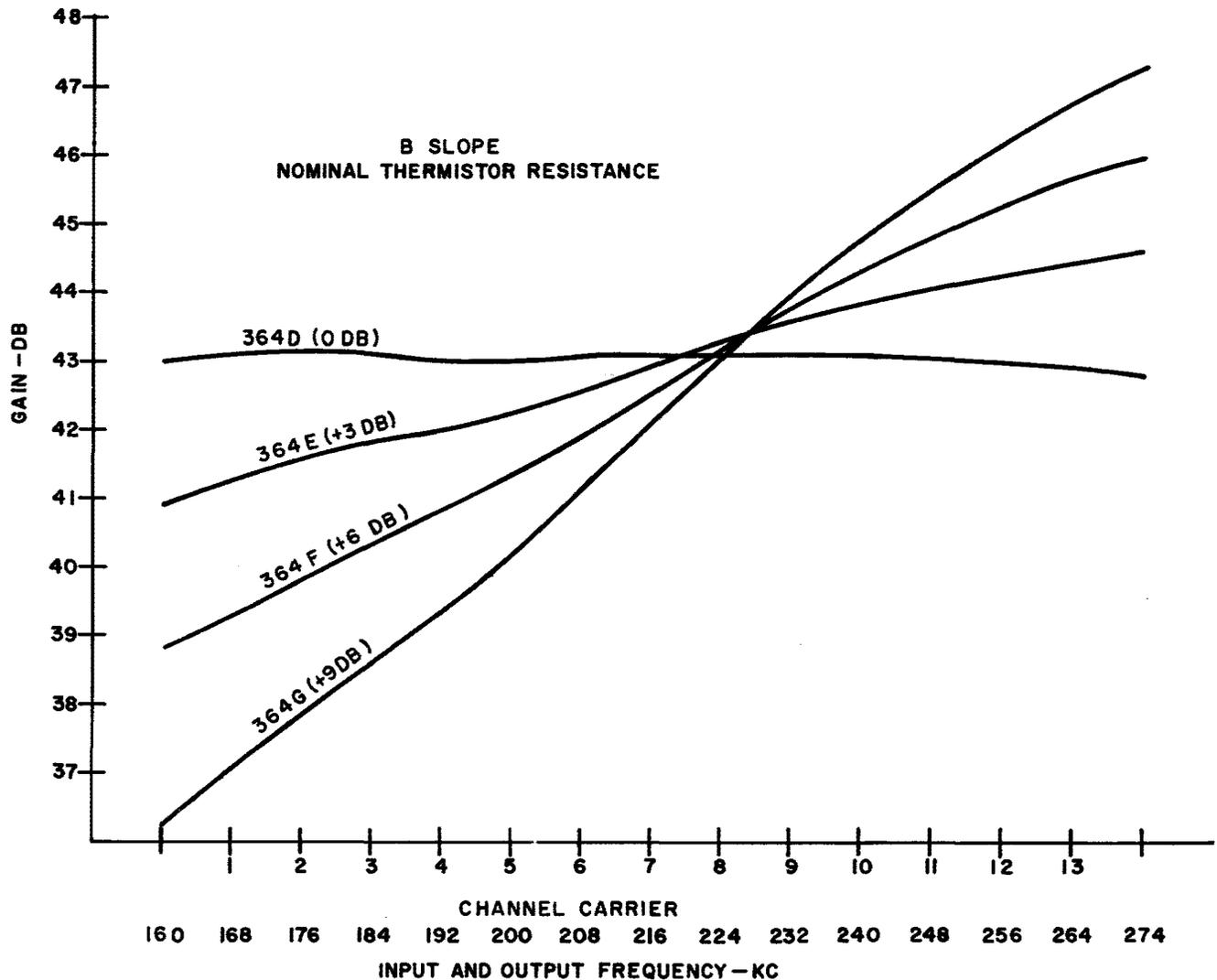


Fig. 14 - High-group Receiving Unit Gain versus Frequency

When accuracy is desired, the measurement of individual carrier powers at the output of a transmitting group unit should be made on a terminated basis, which requires removing the unit from service.

4.02 Transistor emitter current tests may be made with a KS-14510, List 1 volt-ohm-milliammeter. The test points are provided on the face of the individual group units. The *voltage* measured from an emitter test point to the -21 volt test point effectively measures the emitter current of that transistor. Any change in emitter current indicates a change in the current gain of that transistor or a change in biasing circuit component values due to aging or temperature change. The voltage from the emitter

of Q3 to the -21 volt test point is especially sensitive to degradation of the amplifier circuit components. It is factory set to exactly 3 volts at room temperature and, therefore, is not affected by initial component tolerances. Its value will be affected only by component degradation and ambient temperature changes.

4.03 The output terminals of the transmitting and receiving group units are accessible at the switching jacks on the face of the line-terminating unit. The two transmitting jacks are XMTG, J1 and J2, while the two receiving jacks are RCVG, J3 and J4. The individual and total carrier power outputs may be measured by bridging meters across the output terminals. Special cords are available to connect the proper

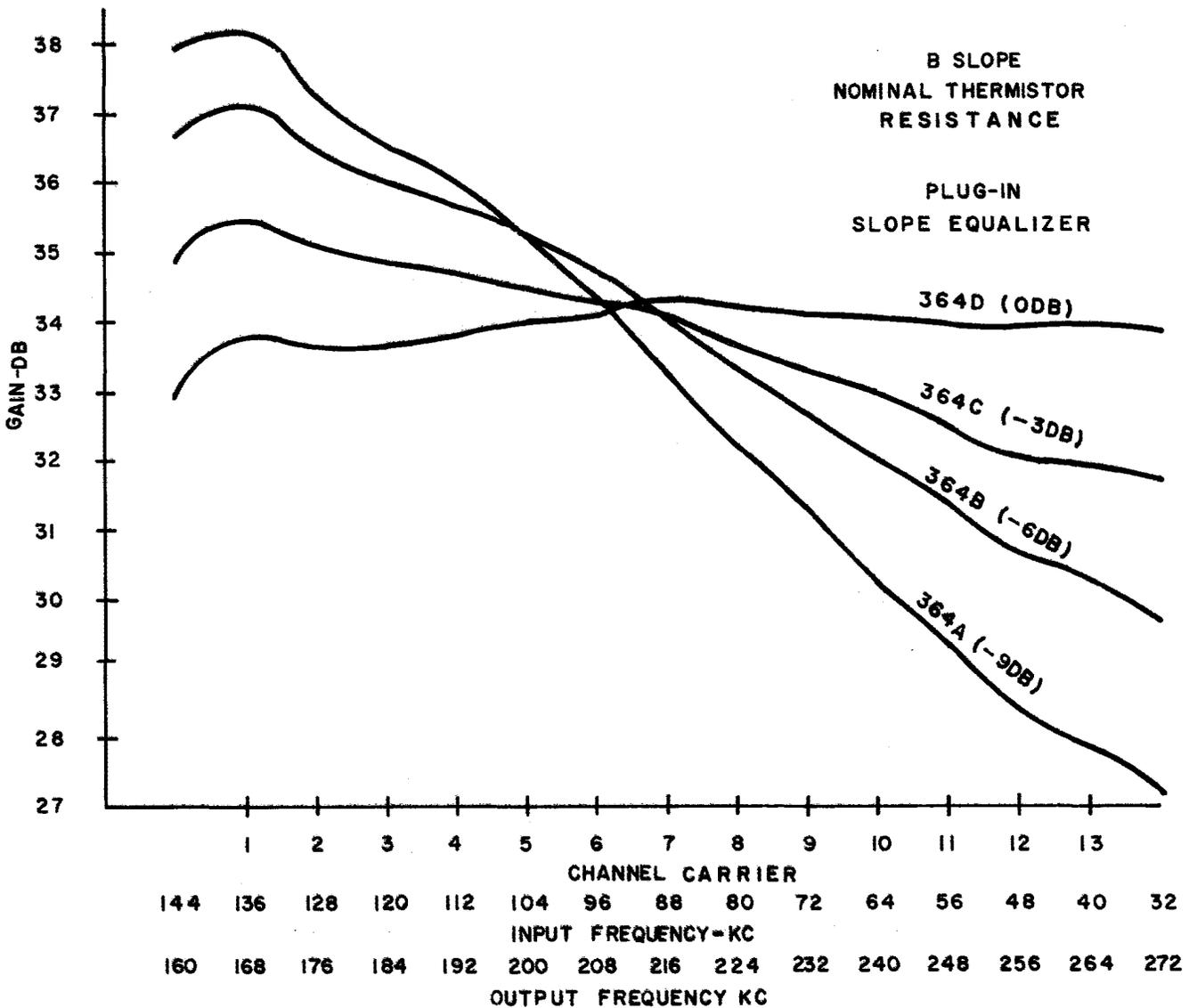


Fig. 15 - Low-group Receiving Unit Gain versus Frequency

meters to the switching jacks to make these measurements.

4.04 The total carrier power output of a transmitting group unit may be measured with a 2J repeater test set. This measurement provides an easy check that the transmitting group unit is working properly. To check that each individual carrier is being transmitted correctly and that the output slope is correct, the individual carriers must be measured with a selective detector.

4.05 The total carrier power output of a receiving group unit may be measured with a vacuum tube voltmeter. This measurement provides an easy check that carriers are being received from the repeatered line, and that the receiving group unit is regulating properly. To obtain information about line equalization, the individual carriers must be measured with a selective detector.

4.06 When the replacement of a group unit is necessary, it may be accomplished without interruption of service on the system by use

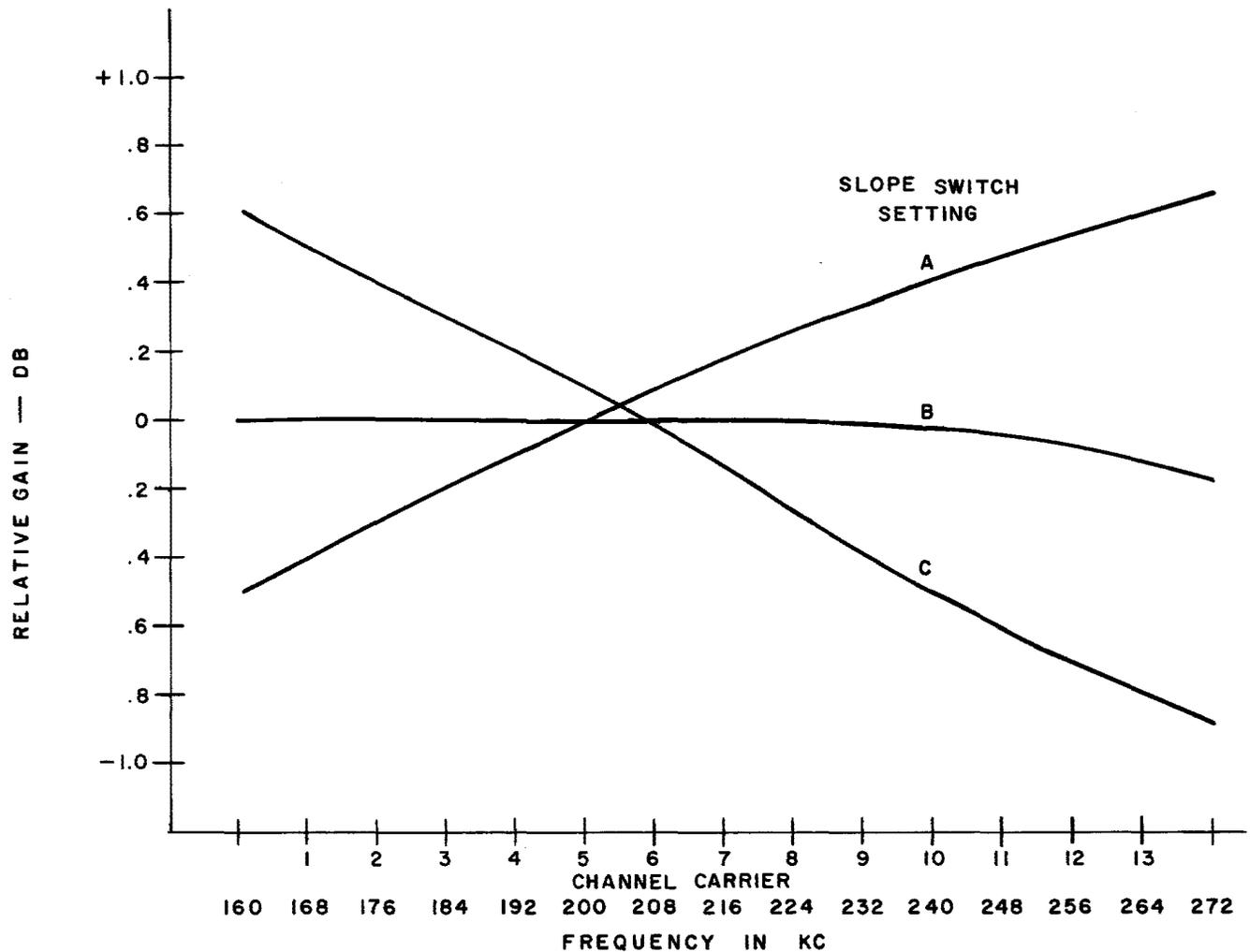


Fig. 16 - Relative Gain versus Frequency Characteristic Controlled by Slope Switch of Receiving Amplifier

of the N2 switching set. A cord built into the test set connects the switching set to the appropriate group unit switching jacks on the line-terminating unit. Power for the switching set is derived from the TEST PWR jack on the face of the alarm unit. The switching set contains the necessary switches and gain adjustments so that an alternate group unit may be switched into the terminal circuit in place of the regular group unit. The regular unit may then be removed, repaired, or replaced. The alternate group unit is a regular group unit with a special wiring option. In the transmitting group units the Y wiring is removed, as shown in Fig. 9, increasing the gain by 3 db. In the receiving group units the thermistor (X wiring) is replaced by a

20,000-ohm resistor (Y wiring), as shown in Fig. 10, which yields a gain 6 db higher than nominal.

5. EQUIPMENT

5.01 The transmitting and receiving group units are separate plug-in items. A photograph of high-group transmitting and low-group receiving units is shown in Fig. 17. These units are plugged into the terminal mounting side by side. Fig. 18 shows a high-group receiving unit partially opened. The slope equalizer unit shown with it must be provided separately. Fig. 19 shows a slope equalizer removed from its housing.

SECTION 362-805-100

6. LIST OF DRAWINGS

6.01 The following schematic and equipment drawings (not attached) provide detailed information:

DESIGNATION	SUBJECT
ED-97107-30	High-group Transmitting Subassemblies
ED-97108-30	Low-group Transmitting Subassemblies

DESIGNATION	SUBJECT
ED-97109-30	High-group Receiving Subassemblies
ED-97110-30	Low-group Receiving Subassemblies
SD-99701-01	High-group Transmitting Circuit
SD-99702-01	Low-group Transmitting Circuit
SD-99703-01	High-group Receiving Circuit
SD-99704-01	Low-group Receiving Circuit

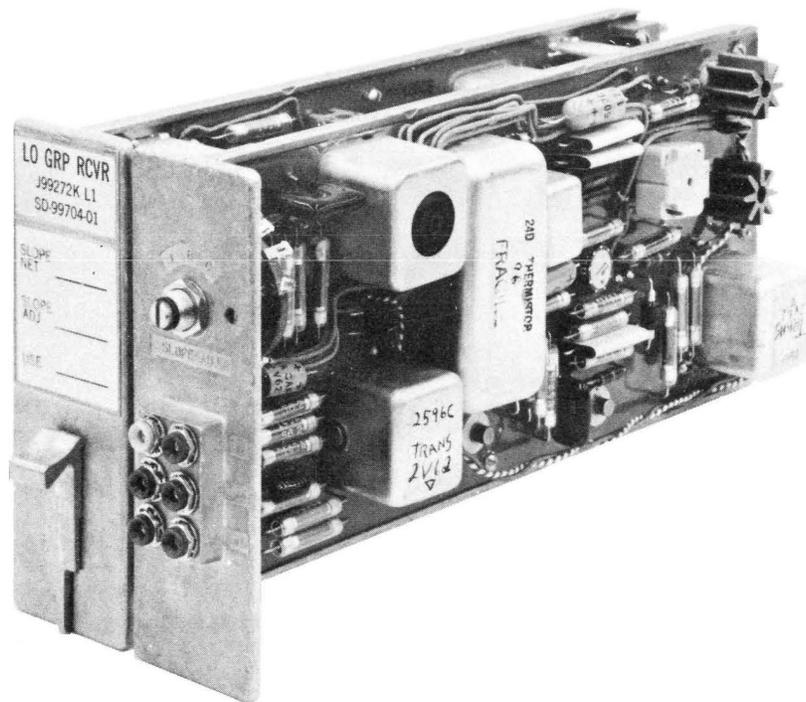
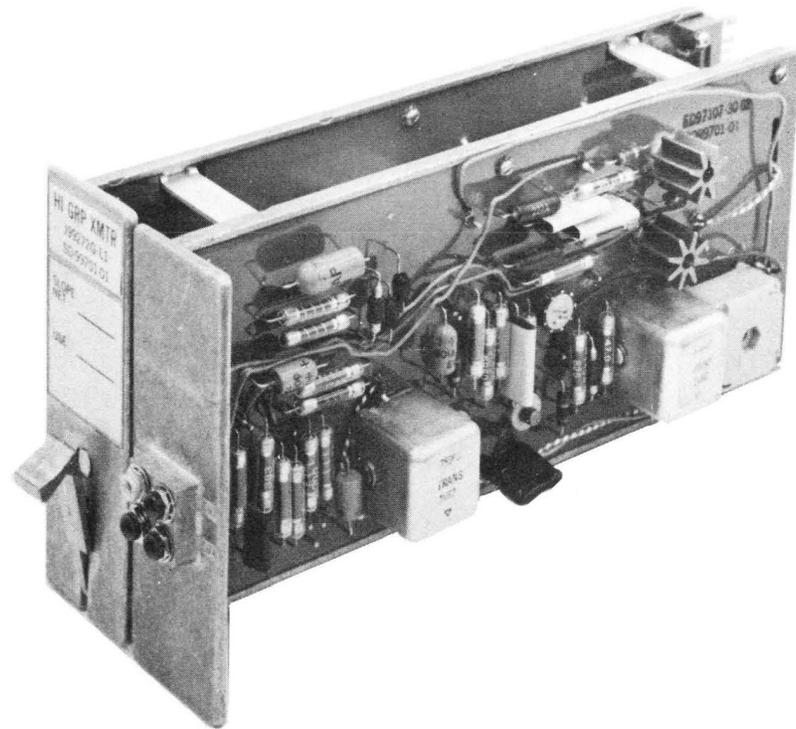


Fig. 17 – High-group Transmitting and Low-group Receiving Units

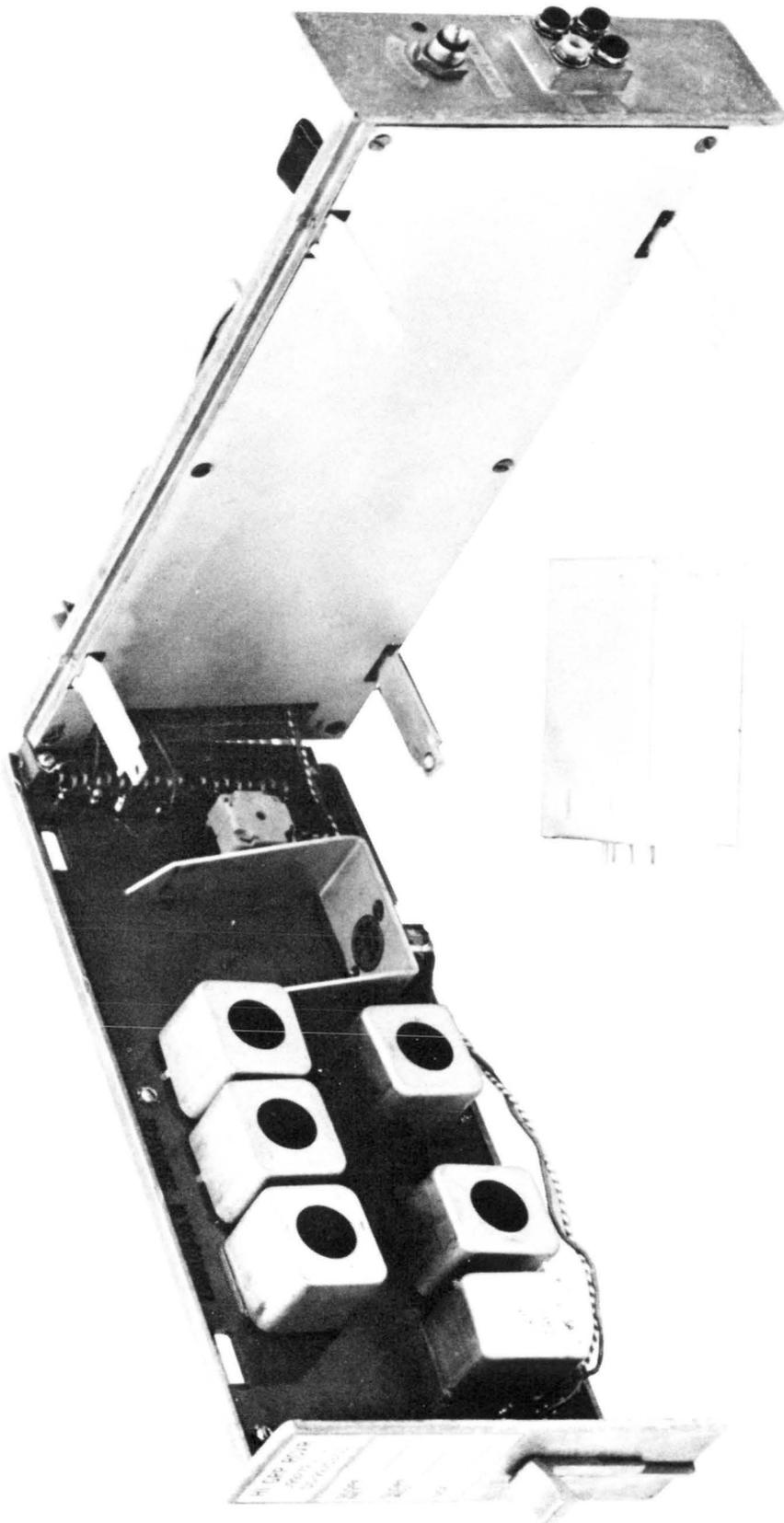


Fig. 18 — High-group Receiving Unit — Partially Opened

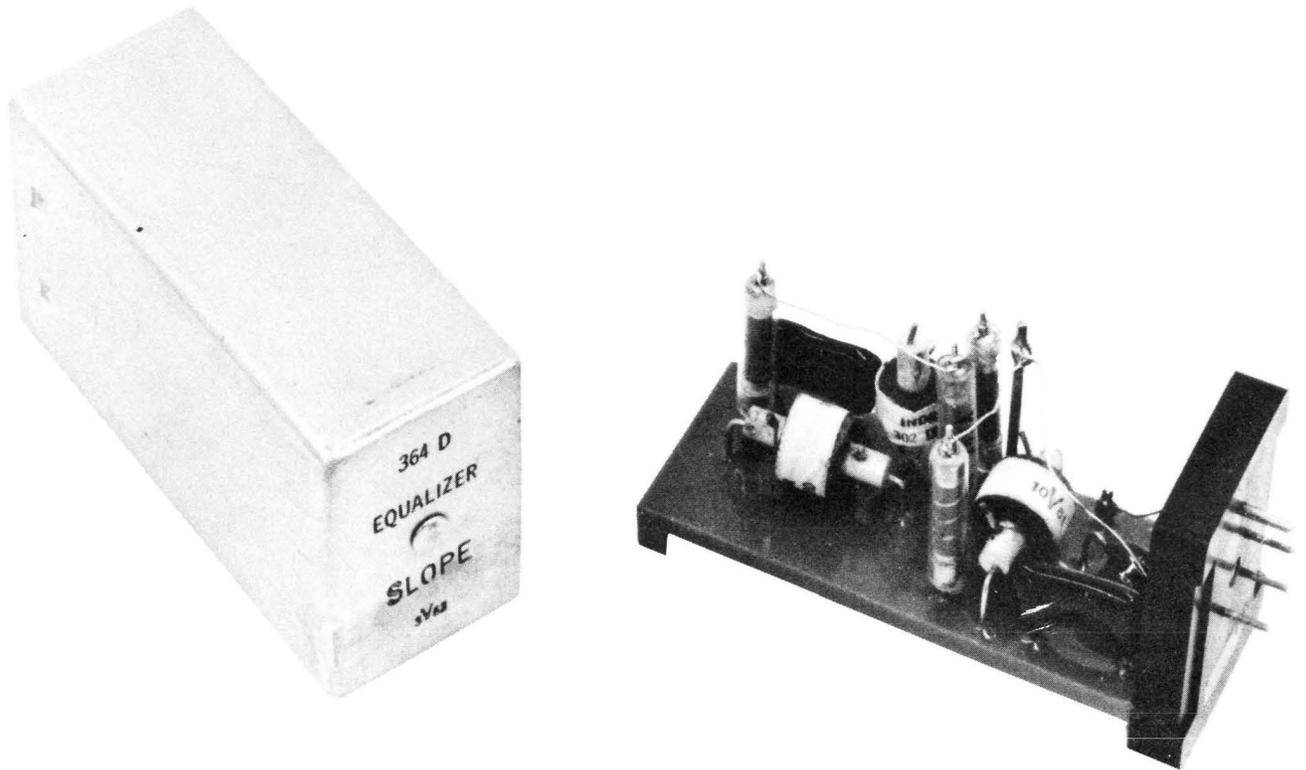


Fig. 19 – Slope Equalizer — Can Removed