# TYPE N AND ON CARRIER REPEATERS - REPEATERED HIGH-FREQUENCY LINE
# GENERAL INFORMATION - DESCRIPTION OF TYPE N1 ELECTRON TUBE REPEATERS

CONTENTS PAGE



## 1. GENERAL

1.01 Issue 2 of this section describes the electron tube repeaters for the N1 carrier telephone system. They are used on a four-wire basis to transmit along the cable pairs the speech and signals of a twelve-channel system. Each of these channels is composed of a carrier with associated upper and lower sidebands. They are spaced at 8 kc intervals and are arranged into a low group frequency band and a high group band. The low group extends from 44 kc to 140 kc with channel 1 carrier at 136 kc and channel 12 carrier at 48 kc. The high group extends from 164 kc to 260 kc with channel 1 carrier at 168 kc and channel 12 carrier at 256 kc.

1.02 Two types of repeaters are used. They are designated High-Low, H-L and Low-High, L-H. The H-L repeater receives signals at high group frequencies from the line, translates them to low group frequencies, then suitably amplifies and regulates them for transmission at the desired output level. The L-H repeater functions similarly except it receives low group frequencies and transmits high group frequencies. Each repeater handles transmission in both directions. The action whereby the repeater transmits a different frequency band than it receives is termed "frequency frogging". It also is the basis for the nomenclature for the repeaters of Low-High, L-H and High-Low, H-L. The two types of repeaters are used alternately along the high frequency line, and they are so nearly alike, in respects other than frequency band, that except where specifically noted, the same discussion applies to both types.

1.03 The repeaters provide a nominal gain in each direction of 48 db for channel 1, with a slope across the band adjustable to about zero, two or four db. There are no other optional standard field adjustments in the repeaters as normally used. Line equalization and the differences in repeater spacings are compensated by the slope adjustment setting and by fixed flat pads. The nominal gain figure of 48 db for channel 1 is used for system analysis in determining signal levels, span pads and equalization. It is the average channel 1 gain of a L-H and a H-L repeater.

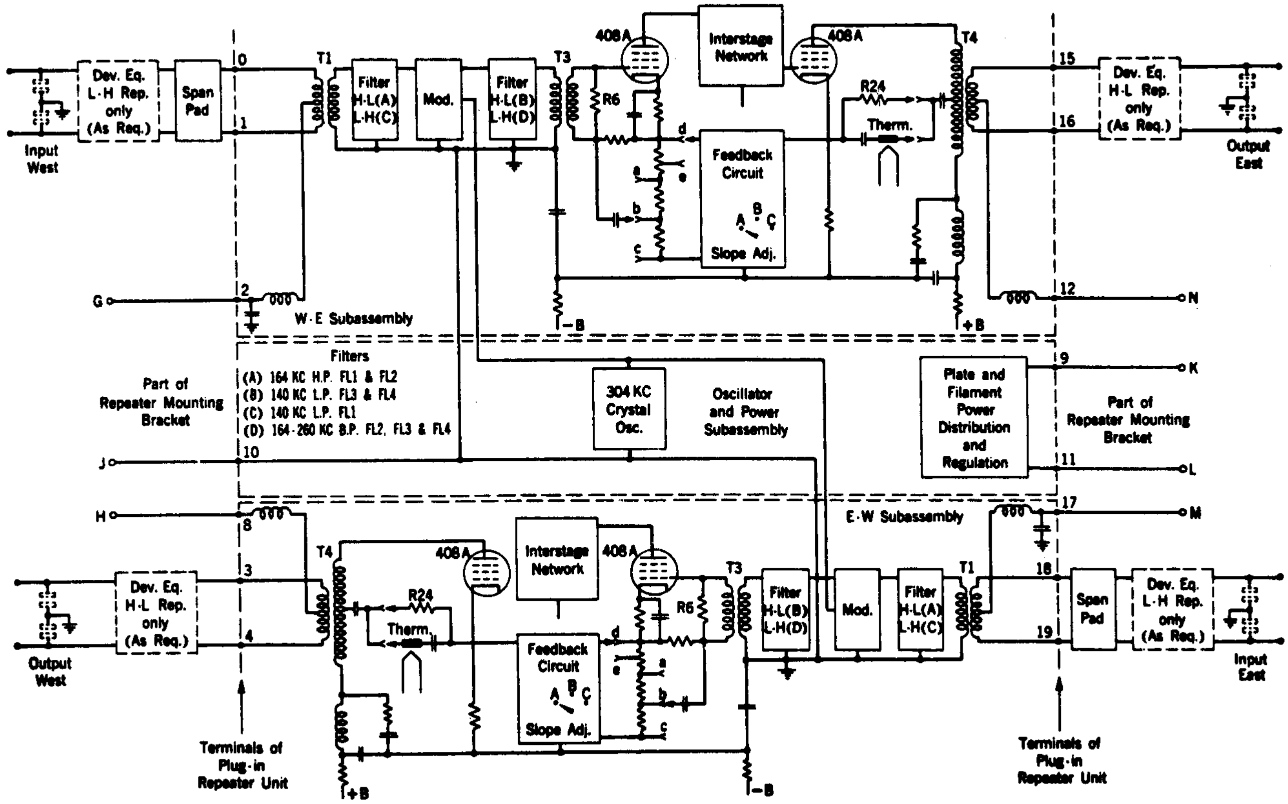


Fig. 1 - Type N1 Repeater Block Schematic

## 2. CIRCUIT

### (A) Over-all Repeater

2.01 A block schematic of the repeater is shown in Fig. 1. This figure shows the connections between the components of the repeater and the allocation of the repeater equipment among the three subassemblies. The basic performance of the H-L and L-H repeaters is the same except for the filters. These component differences are listed with the detailed discussion of the equipment concerned.

2.02 The signals are handled on a four-wire basis throughout and the circuits of the E-W and W-E subassemblies are identical. In passing through a repeater the signals are always modulated with the 304 kc group carrier and moved from the received band to the other frequency band, then amplified and applied to the line. To accomplish this, the input signals from the line are attenuated by the input span pad, if necessary, passed through an input filter to remove unwanted frequencies, then modulated with the 304 kc to change bands. The modulator output is passed through a second filter to suppress carrier leak and the unwanted sideband. The output of this filter is applied to the input of the regulating feedback amplifier. This amplifier automatically adjusts the gain by a thermistor regulator to maintain an output power that over the operating range is almost constant, and independent of the input power.

2.03 Only a small part of the equalization is accomplished by the repeater. Most of the equalization depends upon having approximately equal cable lengths between repeaters and the use of "frequency frogging" at each repeater. The residual slope equalization is adjusted by the Slope Adj. control in the amplifier.

### (B) Span Pad

2.04 The span pad is a 135-ohm resistance pad that is available in 2 db steps for mounting on the repeater mounting bracket at the time of installation. This pad is used to build out any particular cable span to the normal span loss of 46 db for low group transmission or 50 db for high group transmission. These losses are measured at the channel 1 carrier frequencies which are 136 kc and 168 kc respectively. These span losses coupled with the "nominal" repeater gains of 48 db for channel 1 provide the standard channel 1 repeater output carrier levels of -3 dbm for the L-H repeater and -5 dbm for the H-L repeater. It is an H type pad with a condenser in the shunt branch to provide d-c isolation between the tip and ring wires of the circuit for testing purposes.

(C) Repeater Input Coil

2.05 The repeater input coil T1 serves to match the impedance of the incoming 135 ohm line and that of the filters (3,000 ohms). It provides the simplex connection to the line for the purpose of obtaining or supplying power. It also aids in maintaining an adequate balance to the line to suppress longitudinal noise. A different coded coil is used in each type of repeater to handle the different frequency bands involved.

(D) Modulator Filters

2.06 Modulator filters are used at the input and output of the modulator to select the desired frequency groups. These filters are designated A, B, C and D and are assemblies of filter units in standardized cans called FL1, 2, 3 and 4.

2.07 The input filter to the modulator passes signals of the proper incoming group onto the modulator and rejects the unwanted group signals that are present at the repeater input due to crosstalk between the cable pairs. For instance, if the filter was not provided, direct near end crosstalk would occur between the west output and the west input. For the H-L repeater this filter is designated A. It is a high-pass filter with a configuration and characteristic, (measured between 3,000 ohm resistances) as shown in Fig. 2. For the L-H repeater this filter is designated C. It is a low-pass filter with configuration and characteristic as shown in Fig. 3.

2.08 The output filter from the modulator selects for transmission the lower sideband created by the modulator and rejects the upper sideband, all other modulation products and the signals of the group applied at the input of the modulator. The output filter includes a peak section to provide attenuation to the 304 kc carrier that is present due to imperfect modulator balance. For the H-L repeater this filter is designated B. It is a low-pass filter with a configuration and characteristic as

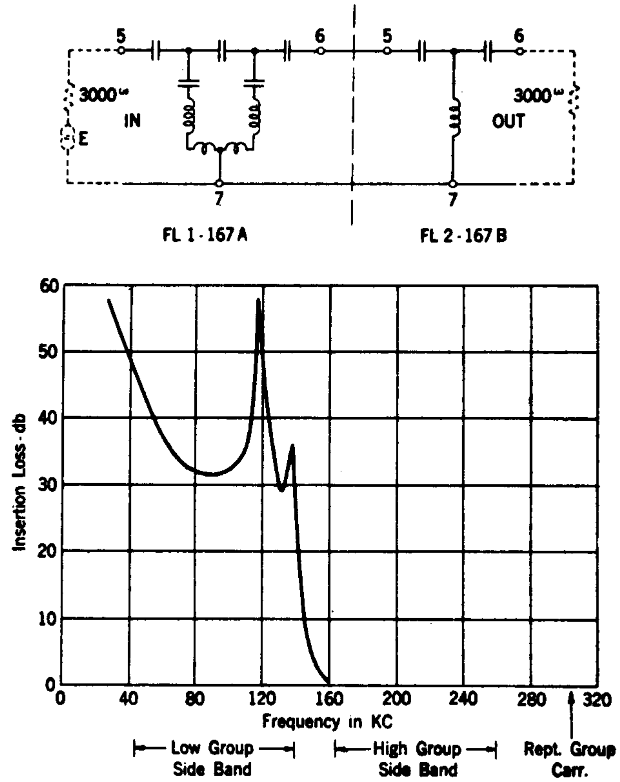


Fig. 2 - Schematic and Insertion Loss Characteristic of A Filter

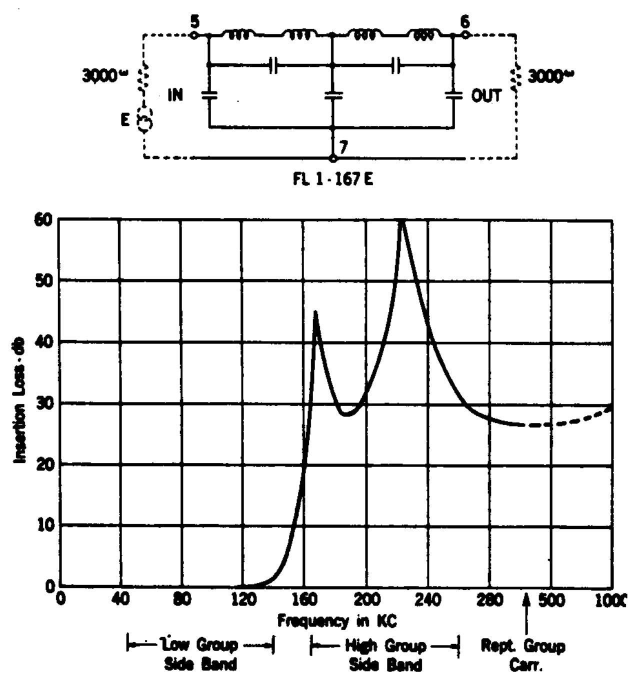


Fig. 3 - Schematic and Insertion Loss Characteristic of C Filter

shown in Fig. 4. For the L-H repeater this filter is designated D. It is a band-pass filter with a configuration and characteristic

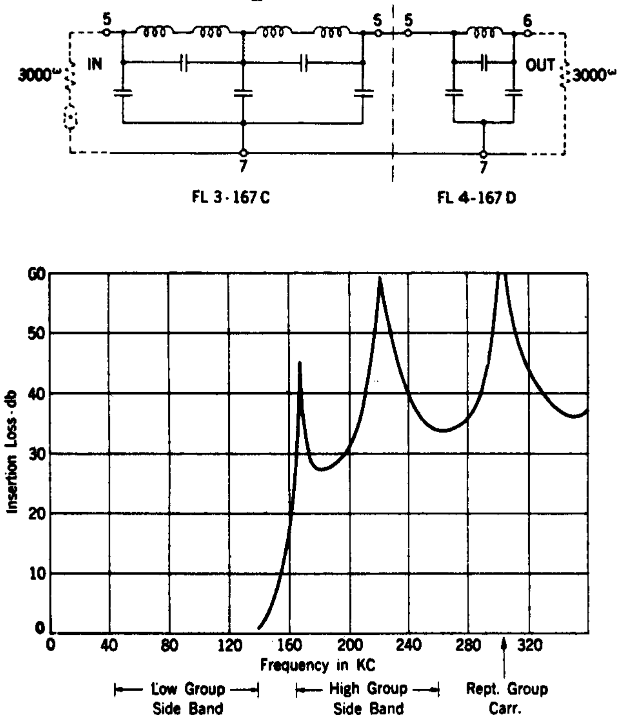


Fig. 4 - Schematic and Insertion Loss Characteristic of B Filter

as shown in Fig. 5 and is used to reject the upper sideband from the modulator and the low group input frequencies.

(E) Modulator

2.09 The modulator is the unit within each repeater that produces the "frequency frogging". It receives a frequency group, either low or high, and modulates it with the group carrier, 304 kc. Of the modulation products produced, the lower sideband is selected by the filters B or D. Thus for a low group input to the modulator this selected sideband is the high group and vice versa. A schematic of the W-E and E-W modulators, together with the common carrier frequency supply oscillator, is shown on Fig. 6. The modulator used is of the double balanced type (input signal and carrier both balanced from the output) consisting of a copper-oxide varistor CR1 connected between two repeating coils T2 and T5.

2.10 The modulator action may be considered as a double-pole double throw switch inserted in the signal path between the input and output coils, and activated by the plus and minus voltages of the carrier. When the carrier voltage is positive on the left and negative

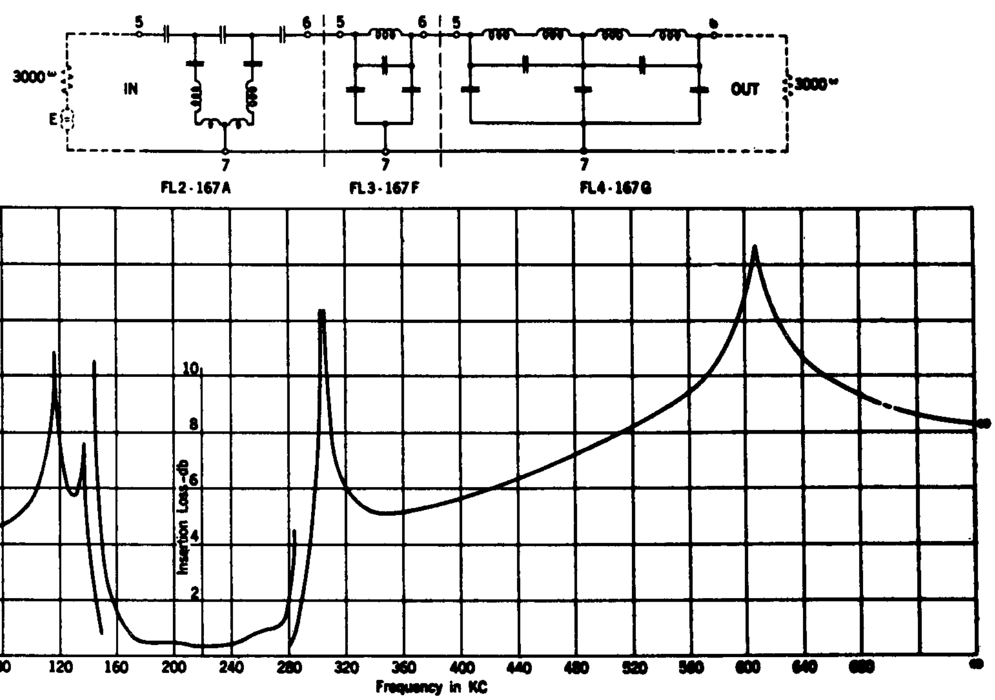


Fig. 5 - Schematic and **Insertion Loss** Characteristic of D **Filter**

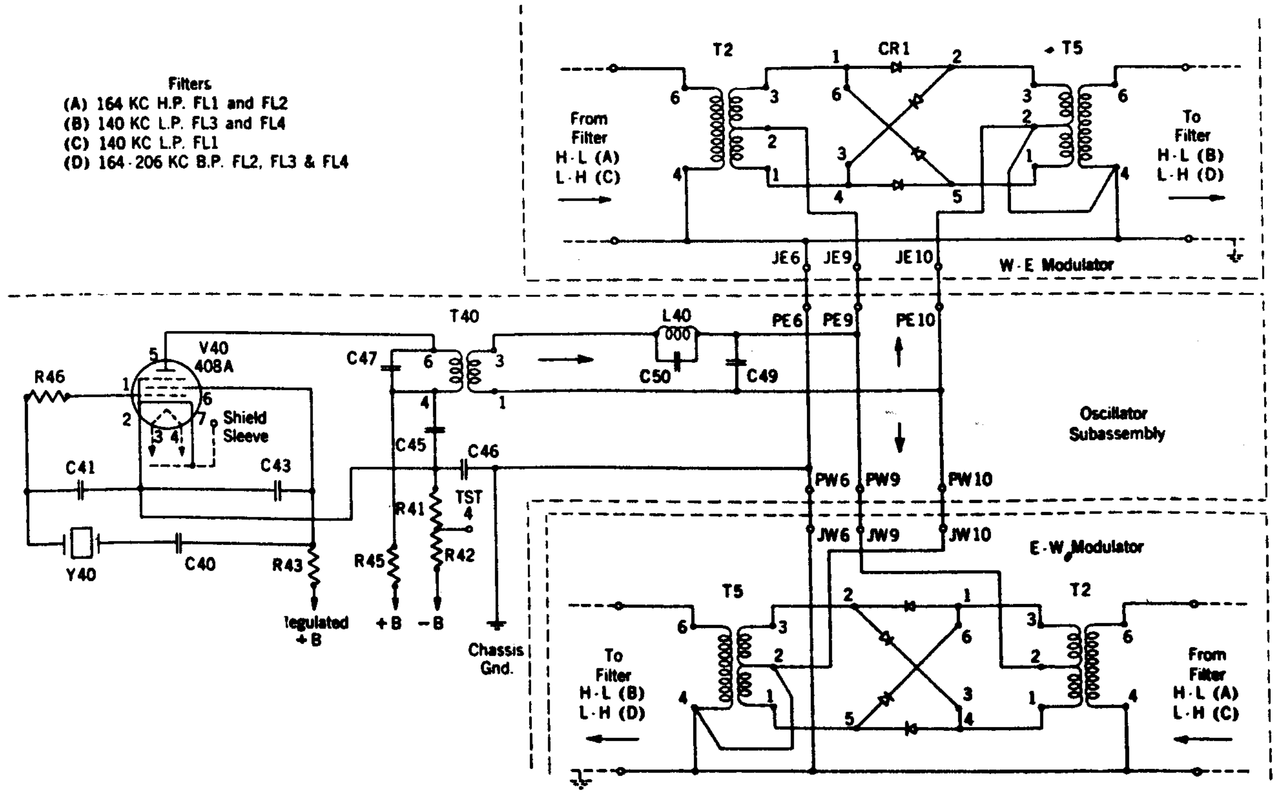


Fig. 6 - Oscillator-Modulator Circuits

on the right side (Fig. 6) carrier current flows through the transformer windings of T2 and T5 in parallel opposing and through the two outer rectifying elements. Their impedance is then 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 current flows through the inner rectifying units making their impedance low. This is equivalent to reversing the path for signal voltages from the input to the output transformer.

2.11 This switch action of the balanced modulator has the inherent function that many of the modulation products formed do not appear at the output terminals of the circuit. If the symbol v represents the incoming group of signals and c represents the 304 kc carrier, the modulation products formed within the modulator may be considered in four sets. These sets are:

$$n_o c \pm n_o v$$
$$n_o c \pm n_e v$$
$$n_e c \pm n_o v$$
$$n_e c \pm n_e v$$

where $n_e$ represents even integers and $n_o$ represents odd. Of these moduation products only the odd order set, $n_o c - n_o v$ appears at the output terminals of the modulator, all the other sets of modulation products are theoretically balanced out. As a perfect balance is not achieved practically some energy from the other sets of modulation products does appear at the modulator output terminals but considerably attenuated. In this modulator the incoming signal frequencies v, which are of the $n_e c + n_o v$ set, are suppressed about 20 db and the 304 kc carrier signal c which is of the $n_o c \pm n_e v$ set is suppressed about 40 db.

2.12 The repeating coil specified for T2 or T5 depends upon the type of repeater. A separate coil is used for each sideband group. Referring to Fig. 6 the L-H repeater has a low group sideband coil, T2, at the input to the modulator and a high group sideband coil, T5, at the output of the modulator. For the H-L repeater the same two coils are used but in reverse circuit positions. These coils have an impedance ratio of 3,000 ohms to 130 ohms and serve to match the impedance of the filters to that of the modulator and to change from an unbalanced filter circuit to a balanced modulator circuit. To maintain the proper balance in this circuit it is important that the only a-c ground connection to this modulator circuit be at T5 as indicated.

(F) 304 KC Carrier Oscillator

2.13 The carrier frequency used at each repeater is supplied by a 304 kc crystal oscillator. A schematic of this circuit is shown on Fig. 6. This oscillator employs a 408A electron tube and a quartz crystal to form the oscillating circuit. The plate of the tube is not included within the oscillating circuit but provides the coupling to obtain the carrier power for the modulators. This power passes through the output transformer T40 which matches the impedance of the oscillator and modulator circuits. By this means better stability of frequency and output power are obtained than if the plate of the tube and output transformer were directly in the oscillating circuit. The output transformer is tuned to provide discrimination against all but 304 kc. It also steps down the impedance to match that of the two CR1 varistors acting in parallel. Between the output transformer and the CR1 varistors there is a rejection filter L40, C49, C50 to further suppress all frequencies in this circuit above 304 kc and with a peak suppression at 608 kc.

2.14 The frequency of the oscillation is controlled by the crystal and is 304,000 cycles ± about 10 cycles within operating temperature ranges expected.

2.15 The screen voltage for the oscillator tube comes from the repeater regulated voltage supply (see Part 7E), in order to provide as stable a source as possible. This stabilization is not necessary for the plate excitation which comes from the non-regulated voltage used for the amplifier tubes. The cathode of this oscillator is maintained 20 volts above -B voltage by a resistance to keep the cathode and heater potentials within about 40 volts of each other.

(G) Amplifiers

2.16 The amplifiers for the H-L and L-H repeaters are alike in circuit functions and are represented in the simplified schematic in Fig. 1. A low group amplifier is used in the H-L repeater and a high group amplifier is used in the L-H repeater. The differences due to frequency ranges covered, apparatus codes and circuit connections are indicated on the repeater schematic Drawings SD-95122 and SD-95123. The amplifiers use two 408A pentode tubes stabilized by feedback and transformer coupled at both input and output. They have a thermistor flat gain adjustment and a slope control adjustment incorporated into the feedback circuit. The feedback circuit is connected into the amplifier as series feedback at the input and bridge type high-side hybrid feedback at the output.

2.17 The input to the amplifier is coupled to the modulator output filter by the amplifier input transformer T3. It has a 3,000 ohm low side impedance to match the impedance of the modulator output filter and a 20,000 ohm high side impedance thereby giving as much gain as is practical for the band width and frequencies used in this system. The impedance values of the transformer in the circuit are stabilized by the 20,000 ohm resistance termination, R6 on the high side. This transformer also serves to provide d-c separation of the grounded filter circuit from the amplifier circuit which may operate as much as 70 volts from d-c ground.

2.18 The interstage network is a simple impedance coupled circuit consisting of an inductance in the plate circuit, a 330,000 ohm grid leak and a coupling condenser between them. The inductances are anti-resonant with the tube and circuit capacitances in their respective low group and high group frequency ranges.

2.19 The coupling from the amplifier output to the line is obtained by the amplifier output transformer T4. This transformer being a hybrid coil also provides coupling to the feedback circuit. The output transformer for the H-L repeater has an impedance transformation from 6100 ohms at the plate of the tube to 135 ohms at the output and 4200 ohms at the feedback circuit. The L-H repeater output transformer has a transformation from 18,000 ohms at the plate to 2000 ohms at the feedback circuit and 130 ohms at the output. These impedance values are chosen to provide the desired level of the regulated output signal. The nominal values of 135 ohms for the low group output impedance and 130 ohms for the high group output match more closely the cable impedance over the frequency range than would a single value for both groups. The output transformer is not terminated in its correct resistance, but depends upon the feedback to produce the desired output impedance of 135 ohms to match that of the cable pair.

3. FLAT GAIN ADJUSTMENTS

3.01 A flat gain control of ± 1 db is obtained in each amplifier by the strapping options designated A, B and C which change the feedback. This control is used in manufacture to provide the nominal gain of 48 db for the channel 11 frequency.

3.02 **An increased flat gain of 6 db is available in the amplifier as a soldering adjustment by changing from d to e wiring.** This increased gain is obtained at the expense of a reduction in feedback and is accompanied with an increase in repeater modulation and noise equal to that of about four normal repeaters. This special gain adjustment is not recommended except for special cases and should not be used unless the inferior performance can be tolerated.

3.03 When the repeater is used for switching purposes or during maintenance tests a fixed gain without regulation is desired. This condition is obtained by using the resistance R24 shown in Fig. 1 in place of the thermistor regulator. This resistance provides a repeater gain for channel 1 of about 54 db instead of the 48 db provided by the thermistor at its mean operating value. The resistance is connected for manufacturing testing and will normally be replaced by the thermistor at the time of field installation. It will also be used when the repeater is used in the switching equipment and when locating circuit trouble.

## 4. REGULATION

4.01 The repeater regulation is flat with frequency and the control operates about the "nominal" repeater gain of 48 db for channel 1. This regulation is provided by a thermistor which varies the amount of feedback in the amplifier; hence its gain, and is connected into the amplifier circuit as indicated in Fig. 1. The thermistor is activated in proportion to the total power at the output of the repeater. This power is nominally +3 dbm for the H-L repeater and for the L-H +12 dbm. The thermistor holds the output power to within $\pm$ 1.5 db of the nominal value for a change in input level of $\pm$ 10 db for the L-H repeater and of $\pm$ 6 db for the H-L repeater. These regulating characteristics are shown in Fig. 7. The solid characteristics show the regulation performance of a single L-H and H-L repeater in terms of change of output from a mean condition vs. change in input. The regulating characteristic of the L-H repeater is better than that of the H-L repeater. This condition correlated with the higher level of carrier power at the output of the L-H repeater results when using high-side hybrid feedback at the amplifier output.

4.02 The repeater input variations corresponding to changes in loss of 8 miles of 19 gauge cable between temperatures of about $-15^\circ$F and $+110^\circ$F are indicated by the arrows marked a. The arrows marked b indicate the changes for temperatures of $-30^\circ$F and $+130^\circ$F. In a system these two types of repeaters are used alternately, and for any individual system the over-all regulation is materially influenced by the span length of the repeater sections, the percentage of underground cable and the particular distribution of these factors between the L-H and H-L repeaters. For a typical system layout with maximum spans of aerial cable and a uniform temperature change throughout the system, regulation at the output of the H-L and the L-H repeaters are shown in Fig. 7 by the dotted characteristics. The over-all system characteristics are poorer than those for an individual repeater. Except for the first repeater the input level change of the repeater is due to the change in cable attenuation plus the residual of changes from previous cable spans not completely removed by the regulation. The value of this residual accumulates in successive repeaters until an ultimate value is reached in the Nth repeater. This residual is not the same for the L-H and H-L. The over-all result at the Nth repeater is indicated by the circled numbers in Fig. 7.

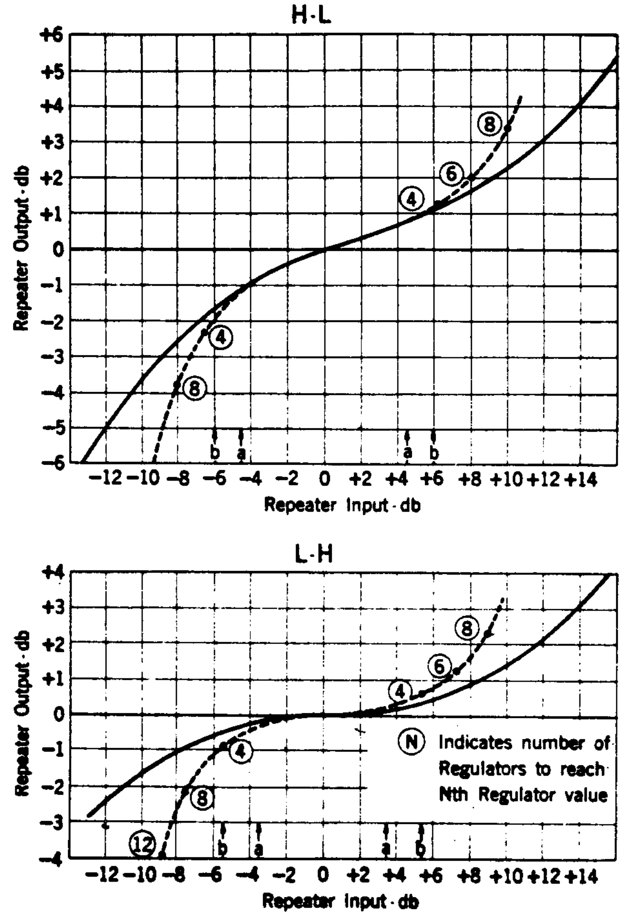


Fig. 7 - Regulation Characteristic of High-Low and Low-High Repeaters

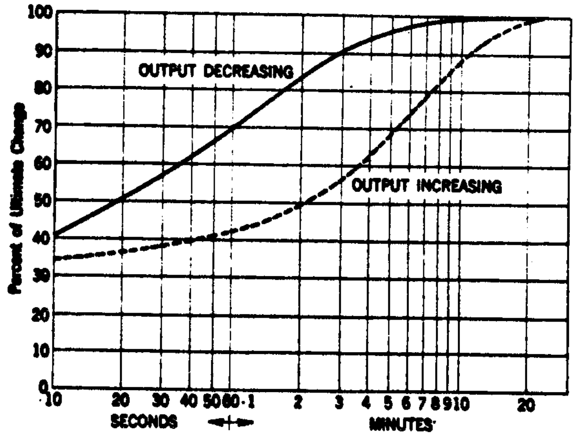


Fig. 8 - Thermistor Restoration Time

4.03 The thermistor regulator has a sufficiently long reaction time that channel voice current peaks, etc. do not alter the system regulation. The effect of this reaction time is plotted in Fig. 8 in terms of the time required for the regulator to attain a given percentage of its ultimate change after a transmission alteration. This reaction time is different in the two directions of regulator change, the regulator decreasing output three to five times as fast as it increases it. This reaction time 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. This waiting period is plotted in Fig. 9 in terms of stabilization within one quarter and also one tenth db measuring accuracy. The "Output Increased" curves apply for changes in output which the regulator restores to normal by decreasing the repeater gain while the "Output Decreased" curves apply for changes in output which the regulator restores to normal by increasing the repeater gain. Thus for one tenth db measuring accuracy a slope step change on a L-H repeater from B to A, about 1.5 db increase in output, would require a wait of about four minutes and a change from step B to C, about 1.5 db decrease in output, would require a wait of about fourteen minutes. A cold repeater when inserted is at high gain and will have a high output, so to obtain one quarter db accuracy of stabilization requires only about six minutes wait. Accuracy within one tenth db requires a wait of fifteen to twenty minutes.

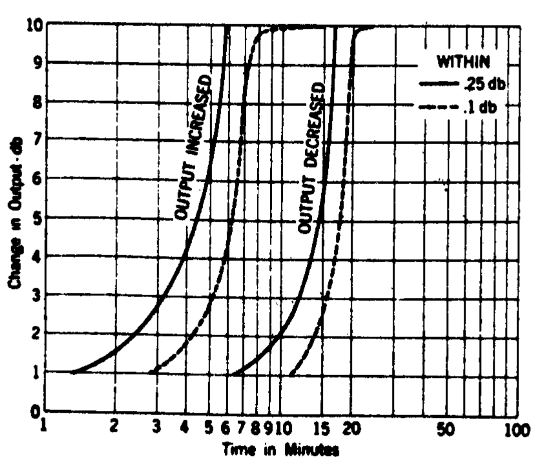


Fig. 9 - Stabilization Time (within .25 DB and .1 DB of Final Value)

4.04 The total output powers of +3 dbm and +12 dbm for the H-L and L-H repeaters, respectively, are the summation of the channel carriers with their associated sidebands. The channel carriers slope from -5 dbm for channel 1 to -12 dbm for channel 12 in the H-L repeater and from -3 dbm for channel 1 to +4 dbm for channel 12 in the L-H repeater. The channel sideband powers are composed of the 3700 cycle signalling tone or the speech energy. The signalling tones are each 15 db below the channel carrier and when present in "on hook" condition add about .25 db power to it. The energy of the speech is about 8 to 15 db below the carrier power, and so does not add appreciably on a long time average to the carrier powers.

4.05 The thermistor unit consists of a thermistor pellet and an associated ambient temperature control for this pellet. A schematic of this unit is shown as Fig. 10. The thermistor pellet is a negative temperature coefficient resistance unit that varies over its normal operating range from about a thousand ohms to about twenty thousand ohms. Under abnormal transmission conditions, it may vary from a few hundred ohms to upwards of forty thousand ohms. For a repeater having the "nominal" gain of 48 db for channel 1 the thermistor will always be about nine thousand ohms. This value is referred to as the "design" value.

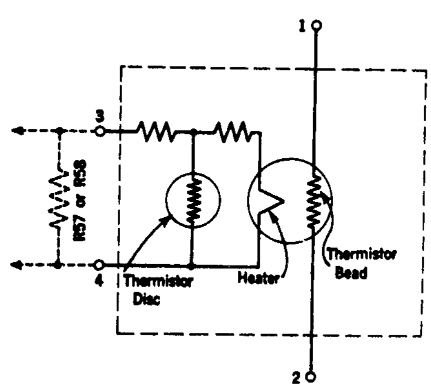


Fig. 10 - Thermistor Schematic

4.06 To obtain the "design" value of pellet resistance additional power is required above that which is provided by the transmitted group levels of +3 dbm or +12 dbm. This power varies with each thermistor pellet and is individually adjusted (in manufacture). The variations in this power are measured in terms of the temperature produced at the bead when no transmitted carrier and sideband power is present. As this temperature is materially affected by the ambient temperature at which the pellet operates, the heater network is temperature compensated to maintain the pellet at its particular desired value. This temperature is called the "thermostated temperature", and in general is between 135°F. and 185°F. This temperature compensation is obtained by a disc thermistor in the heater network which varies the power dissipated in the pellet heater with the ambient temperature. The power for the heater network is obtained from the regulated supply for the electronic tube heaters. This ambient temperature control permits the regulating thermistor to be used at operating temperatures between -20°F and +130°F without appreciable change in its operating performance. Beyond these temperature extremes the regulating level will vary with increasing temperature producing decreasing repeater output level. The thermistor pellet is isolated by blocking condensers to exclude from it unwanted power from d-c leakage between the pellet and the ambient temperature control network.

## 5. SLOPE ADJUSTMENT

5.01 The amplifier slope adjustment provides the manual control of the amplifier frequency characteristic to obtain the desired slope across the band for equalizing the residual slope. The adjustment is in three steps designated A, B and C. These steps permit a characteristic slope, falling within the range of a given repeater, to be equalized to within ± 1 db. The B setting is considered the normal condition of slope adjustment to equalize for approximately 7.5 mile spans of 19 gauge cable. For spans of cable different from this value the steps are used as necessary to maintain adequate equalization of the system. The repeater gain frequency characteristics for these three slope settings are given for L-H repeater by Fig. 11 and the H-L repeater by Fig. 12. The gain values of channels 1 and 12 are not representative to determine the effective slope of these characteristics as the values of these channels in the L-H repeater have been designed to compensate for departures in these same channels in the H-L repeater. The slope characteristics provide for both repeaters the "nominal 48 db gain for channel 1" for all three slope steps. For the L-H repeater it provides slopes of about 0 db, -1.5 db and -3.0 db of gain for channel 12 with respect to channel 1 for steps

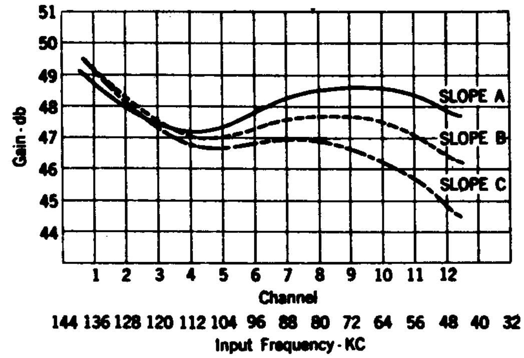


Fig. 11 - Typical Low-High Repeater Gain Characteristics

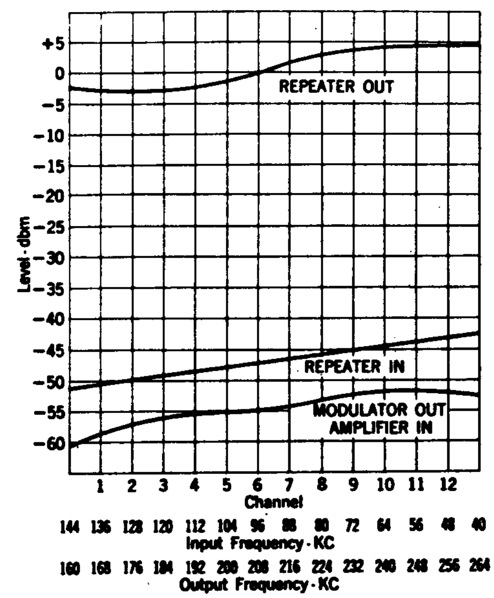


Fig. 11A - Typical Low-High Repeater Operating Level Diagram

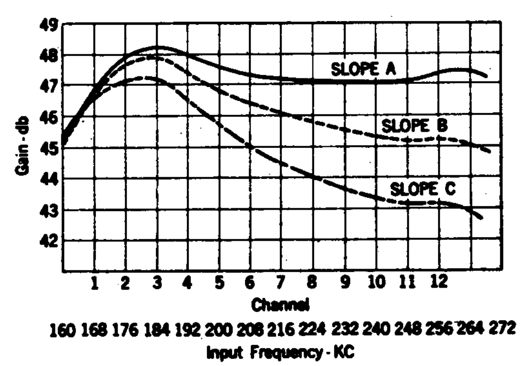


Fig. 12 - Typical High-Low Repeater Gain Characteristic

A, B and C respectively. For the H-L repeater it provides slopes of about 0 db, -2 db and -4 db of gain for channel 12 with respect to channel 1 for steps A, B and C respectively. These performance curves are for an operating temperature of about 70°F. The repeaters have a small change in frequency characteristic as operating temperatures depart from that value. This temperature effect is still under study.

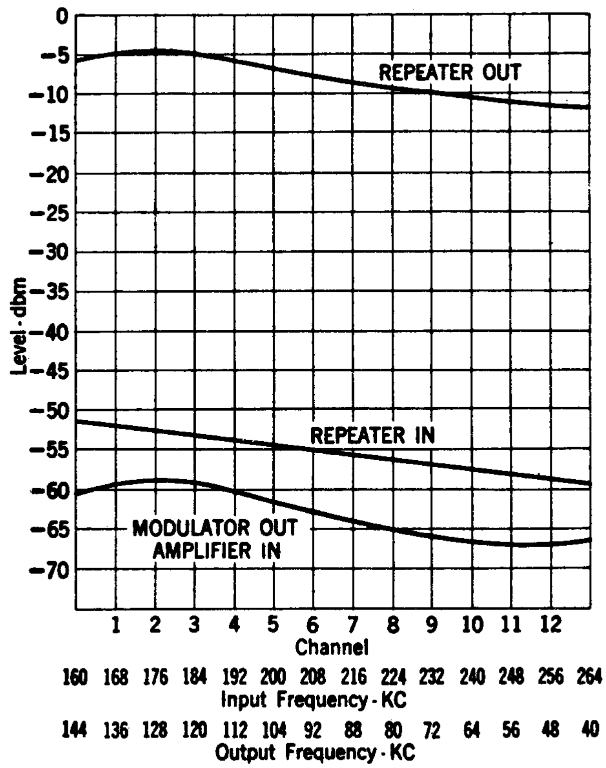


Fig. 12A - Typical High-Low Repeater Operating Level Diagram

5.02 The slope changes are produced by varying the amplifier feedback with a slope network. These networks produce similar repeater performance but differ electrically for the two amplifiers as shown by Figs. 13 and 14.

5.03 The repeater gain characteristics are designed on the basis that the sum of the gains of a L-H and a H-L repeater will match the loss of two cable spans rather than that each repeater will compensate for just the individual span preceding it, and also that the characteristic of each repeater will compensate for deviations in the other. This procedure permits a saving in circuit elements but results in different repeater gain frequency characteristics for the H-L and L-H repeaters. The channel 1 gain of a L-H and a H-L repeater average to the nominal repeater gain of 48 db, but for the H-L repeater the gain is about 1 db low and for the L-H repeater about 1 db high.

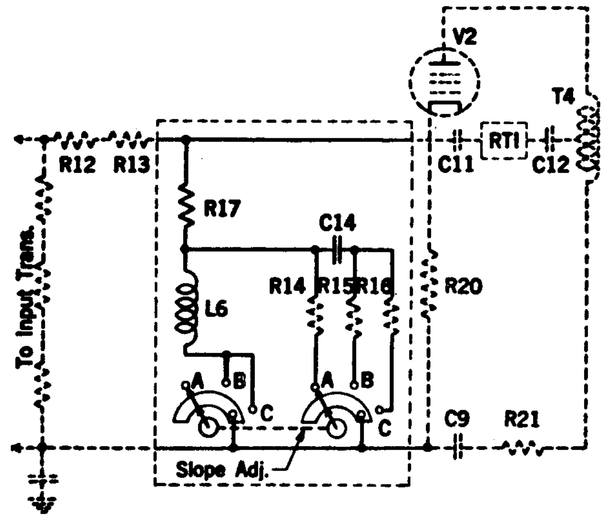


Fig. 13 - Low-High Repeater Slope Circuit

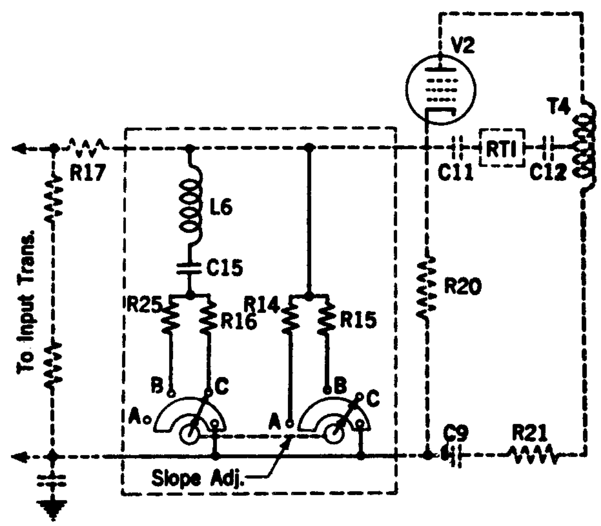


Fig. 14 - High-Low Repeater Slope Circuit

5.04 The transmission levels in typical L-H and H-L repeaters are shown in Fig. 11A and 12A respectively. These levels are plotted in dbm with the repeater slope switch on position A. There is shown the signal level vs. frequency at the input to the repeater, at the junction of the modulator output and amplifier input and at the repeater output. The input and output powers are measured at 135 ohm impedance and the amplifier input power at 3000 ohm impedance. The repeater input characteristic is assumed to be a smooth slope and the shaping of the two sections of the repeater is shown. The modulator section has about 8 db loss and the repeater has a nominal 48 db gain.

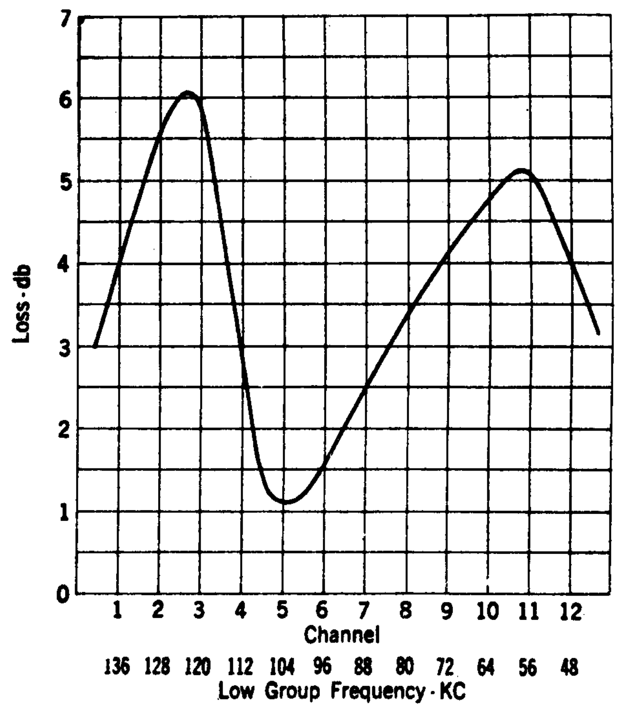


Fig. 15 - Characteristic of Deviation Equalizer for 19 Gauge Cable

## 6. DEVIATION EQUALIZER

6.01 The summation of the losses of the two adjacent cable spans includes small slope and bulge components. Compensation for these components for 19 gauge .062 mf cable is designed into the repeater characteristics but the balancing action for the bulge component is not complete. The remainder of the bulge characteristic is present as a systematic variation and is equalized by a deviation equalizer. The present design of the deviation equalizer compensates for about six repeaters when using 19 gauge quadded cable with 7.5 mile repeater spacings and has a characteristic similar to that shown in Fig. 15. For other gauge cables or other repeater spans, the spacing of the deviation equalizers may vary. It is expected that systems using other than 19 gauge quadded cable will be of such short length as to require no different design of equalizer or even none at all. The design of such deviation equalizers is still under study. The equalizer is of the balanced type having 135 ohm input and output impedances. It is always connected into the line section transmitting the low group frequencies. It should be introduced into the carrier line near the middle of the group of repeaters for which it is to correct in order to hold the line level deviations to a minimum. Simplex power to the repeaters passes around the equalizers by a strap between midpoints of an input and output transformer.

## 7. POWER ARRANGEMENTS

7.01 The repeater power circuit is designed so that local battery, or battery power transmitted over the cable may be used. This circuit consists of two parts, the power supply with the power cross-connections and the voltage regulator circuit.

### (A) Power Supply

7.02 The power for a repeater at a powered repeater station is obtained from the +130 volt battery only. The power for transmission over the line to a non-powered repeater station is obtained from both the +130 volt and -130 volt batteries. This power is introduced through longitudinal choke coils onto the d-c simplex of the quad or two pairs assigned to the system. Connection is made at the center points of repeater input and output transformers. The pair that carries the plus or minus voltage is determined by the arbitrary rule that the d-c current flows in the same direction as the direction of transmission. Thus at a powered repeater station the plus voltage is applied to the repeater output pair and the minus voltage to the repeater input pair; and at a non-powered repeater station the plus voltage is obtained from the repeater input pair and the minus voltage from the repeater output pair.

7.03 The power connections to the simplexes are made at the center tap of the appropriate repeater input and output coils through the longitudinal choke coils $L_1$ and $L_5$, Fig. 16. These leads are brought out to terminals for the power supply cross-connections. In each battery lead there is at the power supply panel a 130 ohm current limiting resistor and in the minus voltage lead a 100 ohm variable resistor. This variable resistor compensates for different line resistances to provide for the normal adjustment 140 volts at the non-powered repeater point.

### (B) Power Supply Cross-Connections

7.04 The power supply cross-connections vary among the several supply systems used, and to make the repeater universally applicable, all the power leads are available for interconnection as required. A typical system is given in Fig. 17. This system shows the circuit connections for a locally powered repeater station feeding power to the adjacent remotely powered repeater station in each direction. The cross-connections at the remotely powered repeater station show how the longitudinal leads that are not used to transmit power are a-c grounded through a condenser. This grounding requirement also exists at locally powered repeater stations.

7.05 These power cross-connections are made at terminals G through N of the terminal strip on the repeater mounting bracket. These

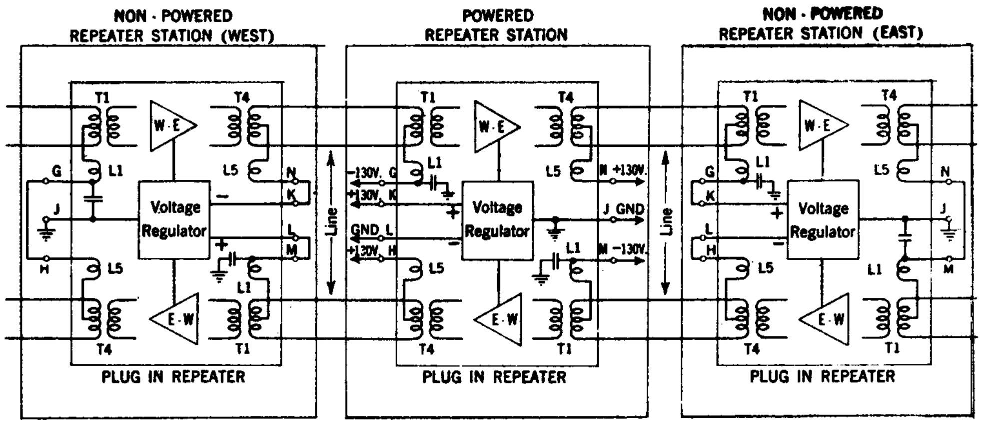


Fig. 16 - Power Supply System

terminals are shown in Fig. 1. The details of these cross-connections for individual repeaters for the several power arrangements are indicated in Figs. 17A, B, C, D, E and F.

(C) Locally Powered Repeater Station

7.06 Figs. 17A, B, C and D apply at a locally powered repeater station. The connections in Fig. 17A are for power to the local repeater only. Those in Fig. 17B are for power to a local repeater and for transmitting power to the adjacent repeater to the west. Those in Fig. 17C are for a local repeater and for transmitting to an adjacent repeater to the east, and those in Fig. 17D are for a local repeater and for transmitting to the adjacent repeaters both east and west.

(D) Remotely Powered Repeater Station

7.07 Figs. 17E and F apply at a remotely powered repeater station. The connections in Fig. 17E are for power received over the cable from a locally powered repeater station to the west. Those in Fig. 17F are for power received from the east.

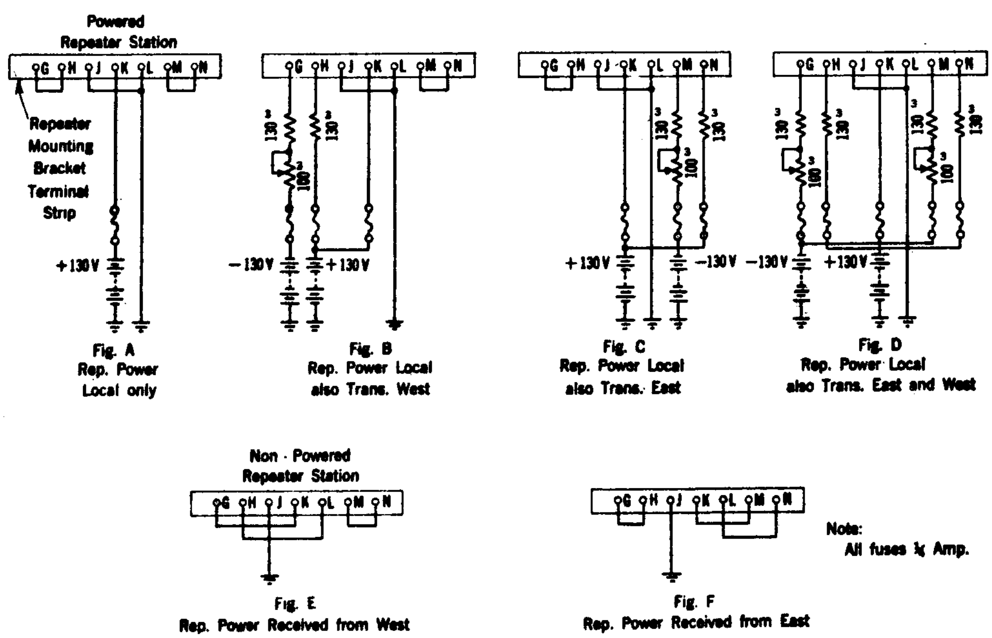


Fig. 17 - Repeater Power Cross-Connections

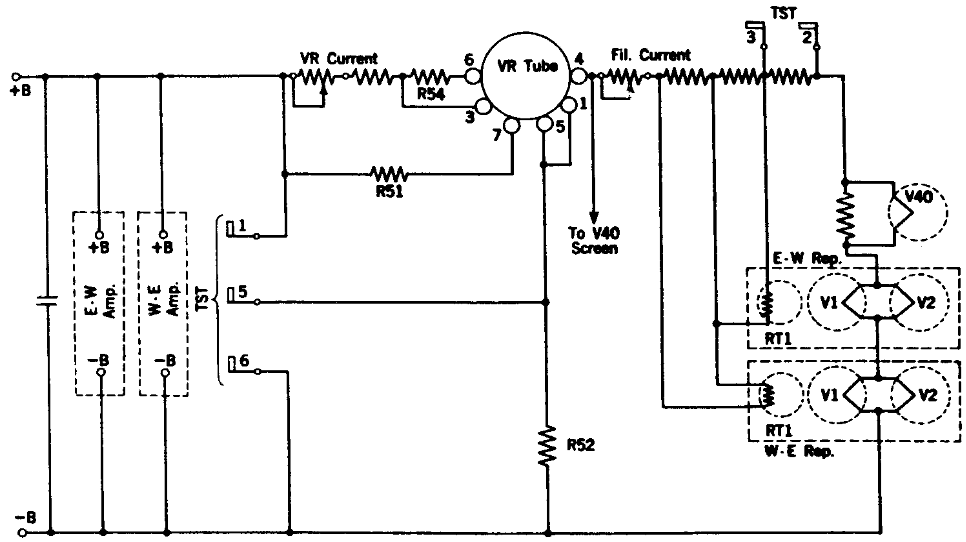


Fig. 18 - Power Regulator-Distributor Circuit

(E) Voltage Regulator Circuit

7.08 The regulator-distributor circuit is shown in Fig. 18. This unit supplies both non-regulated and regulated power to the repeater. The non-regulated voltage is supplied to the plates of the vacuum tubes directly as it is received by the repeater. The regulated voltage is supplied to the heaters of the vacuum tubes and the thermistors as a series string and to the screen of the 304 kc oscillator. The regulated voltage is required by the heaters of the tubes to give good life, by the thermistors to control their thermostated temperature and by the 304 kc oscillator to provide frequency stability. The heaters of the tubes are used two in parallel and these pairs in series. This arrangement gives an approximation of the desired condition of constant heater power which is preferred rather than either constant current or constant voltage heater operation.

7.09 The heater string includes a variable resistance Fil.Cur. for adjusting the circuit current to the desired 98 milliamperes and has test jacks TST 2 and 3 to measure it.

7.10 The regulated voltage of 100 volts is obtained by means of a 427A voltage regulator tube. This tube produces a large change in current through it (3 to 40 milliamperes) for a small change in applied voltage (100 to 101.5 volts). This large change in gas tube current produces an increment of line current which flows through the line resistance and produces a voltage drop to compensate for a change in the applied voltage. The degree to which this balancing action is obtained is indicated by the regulation characteristics shown in Fig. 19. Changes in gas tube current are plotted against changes in applied battery voltage, line resistance and electron tube space currents.

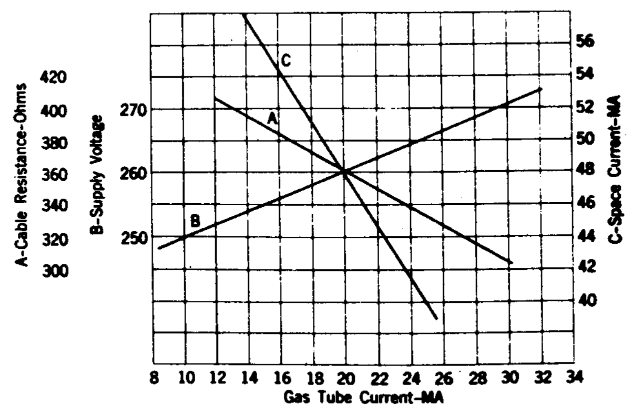


Fig. 19 - Voltage Regulation Characteristic

7.11 The V.R. tube current is adjusted, by the variable resistance VR CUR, for differences in tubes and applied line voltages to a nominal value of 20 milliamperes. With this adjustment there is sufficient regulation range available to accommodate for the changes in line resistance with temperature and for applied battery voltages of about ± 10 volts from the nominal 260 volt value.

7.12 The V.R. tube requires an applied voltage of 130 volts or more on the trigger electrode to make the tube conducting and to start egulation action. To obtain this the trigger lectrode is connected by means of resistance 51 to the power supply ahead of the adjusting esistances to obtain the full applied voltage. The tube has a small resistance R52 connected in series with its cathode to provide test voltage for adjusting purposes. This tube is wired internally so that it serves as a switch to connect as well as to regulate the voltage applied to the thermistor and vacuum tube heaters.

7.13 At a locally powered repeater station the applied repeater voltage is obtained directly from a regulated battery source. Thus a voltage regulator is not required and a 377A shorting plug is used in place of the voltage regulator tube. This shorting plug serves as a switch to connect the heater and thermistor circuit to the power source as did the V.R. tube. It also has a connection to short out part of the regulator circuit control resistance to compensate for the nominal applied voltage of 130 volts instead of the 140 volts used at a non-battery repeater.

## 8. TRANSMISSION PERFORMANCE

### (A) Sideband and Carrier Powers

8.01 The output power at which the two types of repeaters operate is substantially different. For mean circuit conditions the H-L repeater operates with a total output power of about +3 dbm and the L-H repeater with about +12 dbm. These values may vary by ± 1.5 db over the normal range of system regulation. Under abnormal circuit operation greater departure from normal output results. The output power is composed of the twelve channel carriers and their associated sidebands. The carriers have a slope over the band of 7 db for each repeater. For the H-L repeater the channel 1 carrier, 136 kc, is -5 dbm, the channel 12 carrier, 48 kc is -12 dbm and the other channel carriers uniformly spaced between. For the L-H repeater the channel 1 carrier, 168 kc is -3 dbm, the channel 12 carrier, 256 kc is +4 dbm and the other channels distributed between them as in the H-L repeater. A plot of the carrier powers for both repeaters is shown on Fig. 20. The sideband energy associated with each of these channel carriers is composed of the 3700 cycle signalling tone or the speech energy. The signalling tone adds about 0.25 db to the carrier power. The speech energy is considerably weaker than the carriers except for instantaneous peaks of voice energy so that, as measured, the power contributed by them is unimportant.

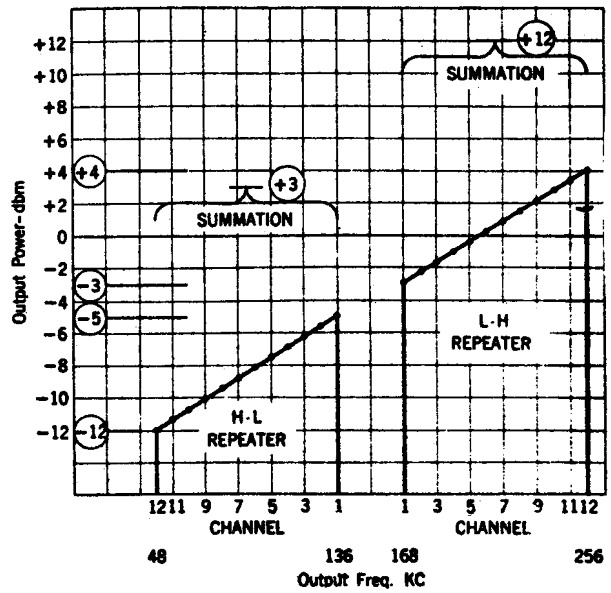


Fig. 20 - Repeater Output - Channel Carrier Powers

### (B) Load Capacity

8.02 The maximum single frequency load rating of the two types of repeater is about +23 dbm. This characteristic is shown by Fig. 21. The maximum output for each repeater is about the same even though there is a difference in output transformer impedances. The output transformer for the L-H repeater presents a load impedance to the vacuum tube of approximately 18,000 ohms. This value varies slightly as the thermistor resistance changes over its range. This value of load impedance is a little above the optimum but provides increased gain with sufficient power to handle the required load. The output transformer for the H-L repeater presents a nominal load impedance of 6100 ohms to the tube. This value of load impedance is materially lower than that of the L-H repeater. It is dictated by the regulating level used with this repeater and the

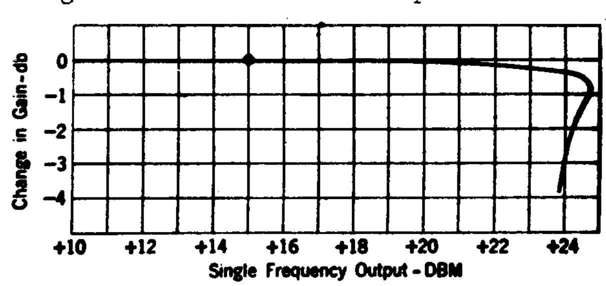


Fig. 21 - Gain-Load Characteristic of High-Low and Low-High Repeaters

power required to operate the thermistor regulator. This value of 6100 ohms is realized when the thermistor resistance is 2500 ohms. As the thermistor resistance increases or decreases from this value the transformer load impedance is influenced in the same manner as in the L-H repeater but to a considerably greater extent. The effect of this change is apparent in the unwanted modulation products formed in the amplifier.

(C) Unwanted Modulation Products and Repeater Noise

8.03 The unwanted modulation products formed in the repeater may be due to either the amplifier or the modulator sections. Typical characteristics are given by Fig. 22 and Fig. 23 for a representative case of both second and third order products for the L-H and H-L repeaters respectively.

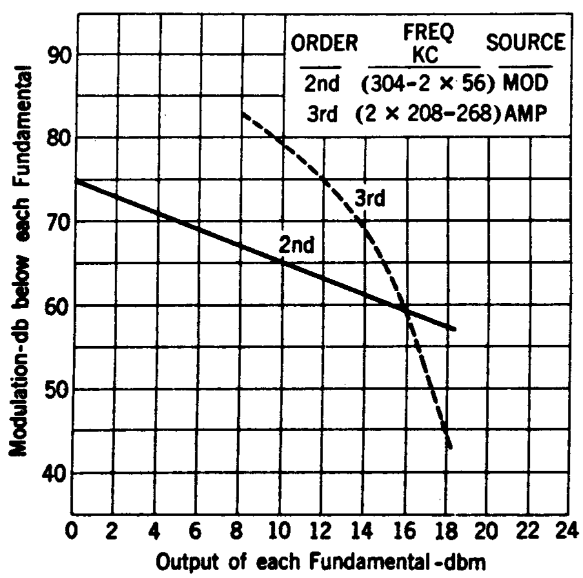


Fig. 22 - Low-High Repeater Modulation (Typical Characteristic)

8.04 In the L-H repeater the predominating second order products that occur within the transmitted band are due to the modulator. The predominating third order modulation products that are transmitted are formed in the amplifier. These modulation products for both orders follow closely the customary performance of 2 db increase in 2nd order and 3 db increase in 3rd order products for each db increase in fundamental power. At a given output the modulation products vary inversely as the repeater gain changes with regulation.

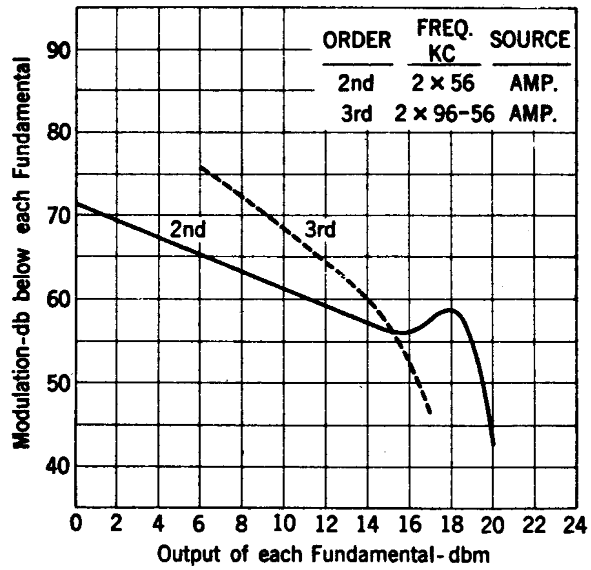


Fig. 23 - High-Low Repeater Modulation (Typical Characteristic)

8.05 In the H-L repeater all the modulation products are due principally to the amplifier. However, these products do not follow the same performance with changes in repeater gain as observed in the L-H repeater in that the modulation level remains nearly constant as the repeater gain is varied. This effect is more pronounced in the second order but the underlying cause is present for all products. This effect results from a balancing action between the modulation products formed in the tube and the suppression of them caused by the circuit feedback.

8.06 The noise generated in the repeater is due primarily to the amplifier. This noise is equivalent to about 15 db above thermal at the repeater input, which for the frequency band width of one channel is about -73 dbm at the output of a nominal 48 db gain repeater. This value is somewhat lower than other sources of noise in the system and thus is not controlling.

9. EQUIPMENT ARRANGEMENTS

9.01 A plug-in unit method of construction is employed for the N1 repeaters. A complete two-way repeater is made up of three subassemblies in a single unit. The external connections of each unit terminate in a 20 point plug which is plugged into a jack in the repeater mounting bracket. This method permits the testing of the units without jack fields and

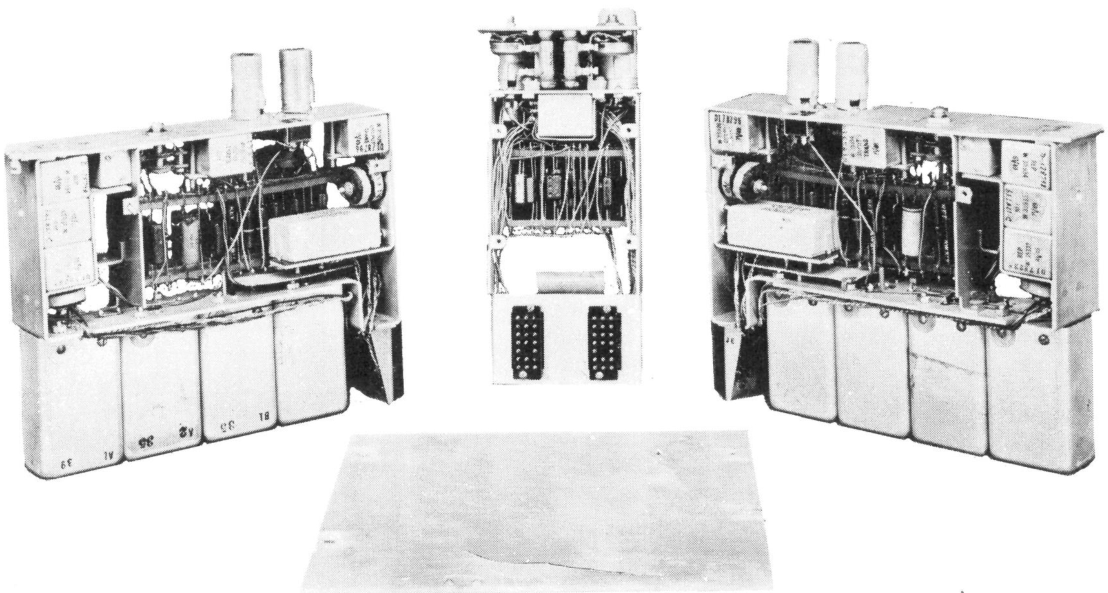


Fig. 24 - N1 Repeater Subassemblies

allows replacement by a spare repeater and the removal of a repeater in trouble to a convenient location for maintenance. Access for wiring maintenance is required only at the front of the rack which permits back-to-back relay rack mounting or mounting in a cabinet or against a wall.

9.02 Each of the two basic types of repeater unit, the H-L and the L-H, is made up of three subassemblies, as shown by Fig. 24. Two of these subassemblies are identical in function and mirror images in structure. They are the E-W modulator and amplifier subassembly and the W-E modulator and amplifier subassembly. These are plugged into a common subassembly containing the 304 kc oscillator and the voltage regulator, all under a common cover. In the L-H repeater the E-W and W-E subassemblies are similar to those on the H-L repeater except for low-to-high instead of high-to-low frequency conversion. The common subassembly is identical in all repeaters and carries the plug which connects to the repeater jack in the repeater mounting bracket. When the cover is removed from the unit and the subassemblies are separated all apparatus and wiring is accessible for maintenance. Pigtail apparatus, so far as electrical requirements permit, is mounted on two parallel thermoplastic strips by setting their terminal wires into the edges of the strips. An individual component can be removed readily by applying heat to its leads with a soldering iron.

9.03 Four repeaters are mounted on one shelf on a 19 inch relay rack and occupy a vertical space of approximately 14 inches as indicated in Fig. 25. A repeater top support is required to support any group of repeaters not having a repeater mounting shelf above them. Each repeater plugs into a jack on a repeater mounting bracket which is secured to the shelf. Span adjustment pads, when required, also mount on this bracket. There are three jacks on the bracket, one to receive the repeater and two repeater switching jacks for testing and in-service replacement of the repeater. The outside cable pairs and the repeater input and output connections terminate in the repeater switching jacks J2 and J3, which are multipled. The repeater is connected to the cable pairs by inserting the repeater connector plug in either of these jacks. Means are also provided on the bracket for terminating the external wiring.

9.04 The repeaters may be mounted in a pole-type cabinet at non-power-supply points as shown in Fig. 26. The capacity of the cabinet

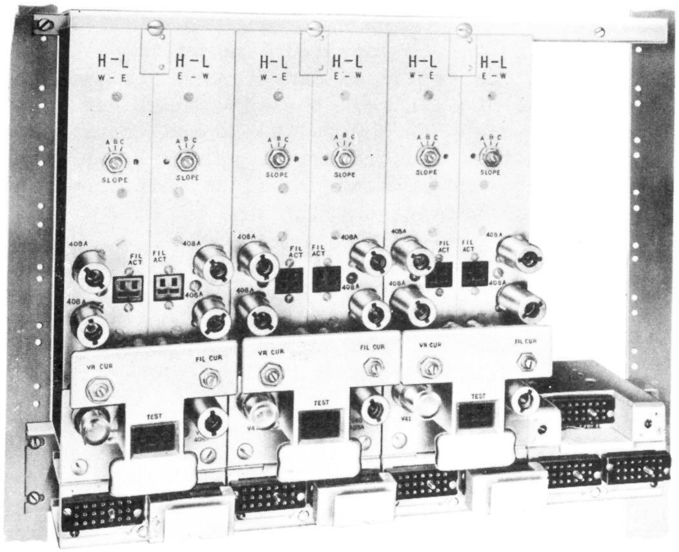


Fig. 25 - Relay Rack Mounting of Type N1 Repeaters

is twelve repeaters a d the associated 52 pair cable terminal and the required order wire equipment. Fig. 26 shows the cable terminal mounted at the top of the cabinet. Arrangements are also available for mounting it at the bottom.

9.05 For office installations the same mounting brackets and shelves are used for 19 inch wide relay racks, either duct or channel type. Where the office is also a power supply point, a power distribution panel is required for each four systems. The power distribution panel contains the power resistors, fuses and fuse alarms. Each panel will provide power t• four local repeaters and, when required, to the four adjacent repeaters in each direction.

9.06 The deviation equalizer panel contains two equalizers, one for each direction of transmission of one system. The equipment arrangement for this panel provides for office installation only.

9.07 The size of units and panels as well as typical bay layouts are as follows:

| | Width | Height in 1-3/4" Mounting Plates |
|---|---|---|
| Group of 4 Repeaters on Shelf | 19" | 8 |
| Repeater Top Support | 19" | 1 |
| 40A Cable Terminal | 19" | 4 |
| Power Distribution Panel | 19" | 5 |
| Deviation Equalizer Panel | 19" | 1 |

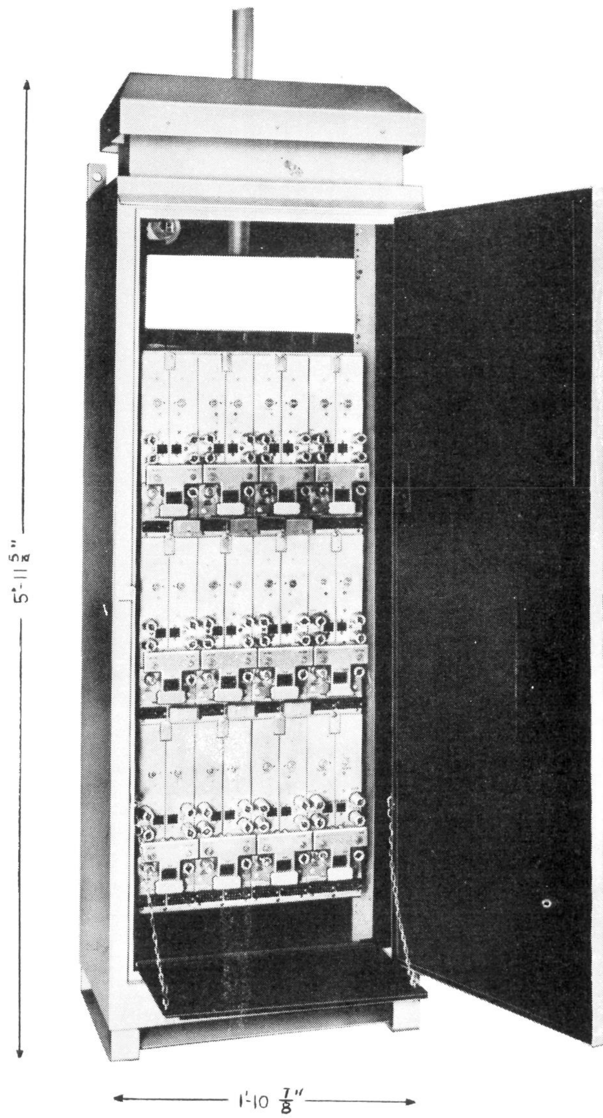


Fig. 26 - Type Nl Repeaters-In Pole Mounted Cabinet

9.08 A typical 11'-6" relay rack layout at a power supply point, with deviation equalizers for each direction of transmission in all repeaters, will provide for 16 repeaters. When deviation equalizers are not required, a total of 20 repeaters may be accommodated. This arrangement assumes that a protector frame is available in the office.

9.09 A typical 11'-6" relay rack layout at a non-power supply point, without deviation equalizers, may provide for as many as 32 repeaters. With deviation equalizers space is available for 24 repeaters.

9.10 The installation requirements for these repeaters vary widely and include many small differences due to bay height and pole mounting arrangements, power source, provision for deviation equalizers, etc. To accommodate easily these situations and provide the desired flexibility of equipment mounting arrangements there are no shop wired bays involved.

## 10. TESTING ARRANGEMENTS AND FACILITIES

10.01 The testing facilities for the type N1 repeater are arranged so that all routine tests may be made on an in-service basis. The tests include (1) the customary electron tube activity tests, (2) measurements and adjustments for each individual repeater of the current for the heater string and for the voltage regulator tube, (3) measurement of the total power at the output of a repeater to check on proper repeater operation, (4) means of switching a standby repeater into the circuit without service interruption to make the regular repeater available for out-of-service maintenance or adjustment. The tests can be performed with three test sets peculiar to this system, the 2J Repeater Test Set, the 2M Repeater Switching Set and the 2P Tube Test Set.

10.02 The Fil. Act. and Test jacks, shown in Fig. 24, provide the necessary access points in the circuits for the tube tests and adjustments. The tube activity test is made with the 2P Tube Test Set in the usual manner by observing the change in tube space current for a ten per cent. reduction in the heater current. As all of the tubes in the repeater are in one string this test can be made for the whole repeater at once. The tube space currents are measured by jack connections across the cathode resistors and the change in heater current is obtained by connecting an adjustable resistance to provide the desired change.

10.03 The measurement and adjustment of the currents in the electron tube heater string and the voltage regulator tube, and the measurement of the line voltage applied to the repeater are also made with the 2P Tube Test Set. The current requirement for the electron tube heater string is 98 milliamperes. The current requires individual adjustment each time a tube is replaced to compensate for varying heater resistances or variations in voltage provided by the voltage regulator tubes. The current of 20 milliamperes required in the voltage regulator tube also necessitates individual adjustment to compensate for the variations among V.R. tubes with the same applied voltage and to compensate for variations that may exist in the applied line voltage. The applied line voltage measurement is made to check and to control the adjustment of the nominal value of 140 volts to the repeater. Although this measurement is primarily an installation adjustment procedure, it provides a good maintenance check.

10.04 The measurement of repeater output power is made with the 2J Repeater Test Set. This test is made by bridging the meter across the repeater output circuit at one of the Repeater Switching Jacks. The meter measures the total power present which for normal repeater operation is about +12 dbm for the L-H repeater and about +3 dbm for the H-L repeater. This power is the summation of the twelve channel carriers plus a small augmentation by the signal powers. In case of system failure in which the power of the channel carriers is absent, the repeaters endeavor to increase their gain until the noise output is enough to provide the normal output power. To prevent such noise power from being mistaken for the normal power of the channel carriers the test set includes a receiver which permits the output power to be monitored audibly. The normal carrier power will be heard as an 8000 cycle tone in the absence of which the system can be assumed to be in trouble. The noise power present in faulty repeater operation will, when loud enough to be audible at all, be heard as irregular noise. By use of this meter, a quick check can be made along a line to determine proper system operation or to locate a circuit failure.

10.05 When the replacement of a repeater is indicated it may be accomplished without interruption of service on the system by use of the 2M Repeater Switching Set. This switching set plugs into the vacant repeater switching jack and provides the necessary switches and gain adjustment so that a standby repeater may be switched into the circuit in place of the regular repeater. The regular repeater may then be removed for out-of-service repair or replacement. The standby repeater is a component of the switching set and may be either a L-H or H-L as the location requires. It is a standard repeater with the flat gain regulating thermistor replaced by the 20,000 ohm resistance, R24 in Fig. 1, to provide a fixed gain. This repeater plugs into the Repeater Switching Set and becomes an integral part of it. The power for this set is derived from the regular office battery at a repeater power point and at a non-powered repeater point from the simplex of the order wire and the alarm circuit pairs.

11. DRAWINGS (Not Attached)

(A) SD Drawings

SD-95122-01 H-L Repeater Unit Circuit
SD-95123-01 L-H Repeater Unit Circuit
SD-95124-01 Repeater Application Schematic

(B) ED Drawings

ED-92293-01 Span Adjustment Pads
ED-92308-01 Repeater Power Supply Unit
ED-92309-01 Repeater and Group Connectors
ED-92310-01 Repeater Mounting Bracket
ED-92315-01 Pole Type Cabinet Equipment
ED-92334-01 Repeater Bay Arrangements
ED-92335-01 Deviation Equalizer Equipment
ED-95070-01 H-L Repeater Unit
ED-95071-01 H-L Repeater W-E Subassembly
ED-95072-01 H-L Repeater E-W Subassembly
ED-95073-01 H-L and L-H Repeaters, Oscillator and Power Adjustment Subassembly
ED-95074-01 L-H Repeater Unit
ED-95075-01 L-H Repeater W-E Subassembly
ED-95076-01 L-H Repeater E-W Subassembly