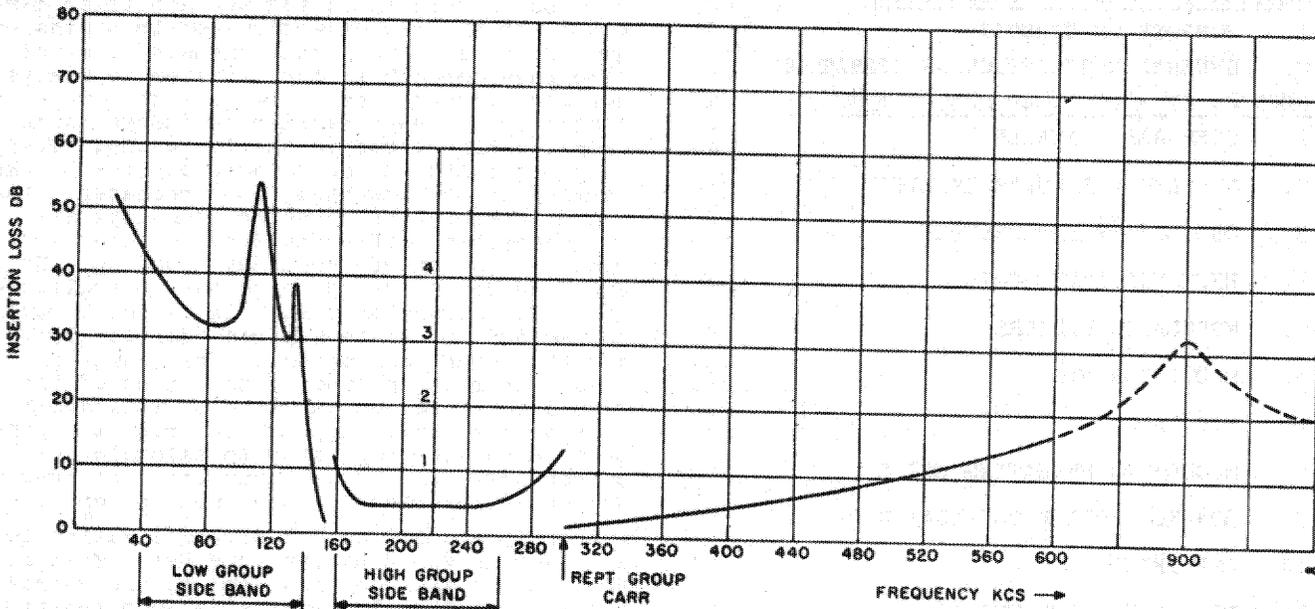
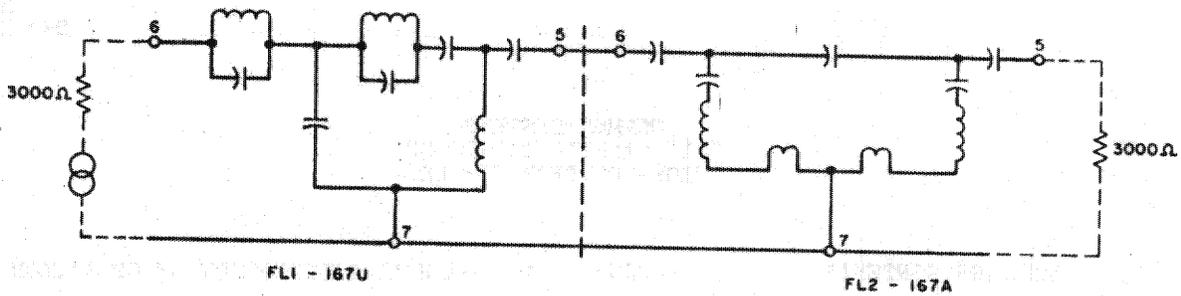


COMMON SYSTEMS
"N1" CARRIER TELEPHONE
HIGH-LOW REPEATER CKT

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<u>SECTION I - GENERAL DESCRIPTION</u>		
1. PURPOSE OF CIRCUIT		
1.1 This circuit is used as a repeater in the low-frequency line of an N1-type carrier system. It is one of two similar repeater circuits and is designated a high-low (H-L) repeater.		
		2. GENERAL DESCRIPTION OF OPERATION
		2.1 The signals are handled on a 4-wire basis throughout and the amplifier circuits for the two directions of transmission are identical. The input signals from the line pass through an input filter to remove unwanted frequencies. They are then modulated by a 304-kc carrier to change bands from the high group to the low group. The same oscillator is used to supply the 304-kc carrier in the low-high (L-H) repeater. The action whereby the repeater transmits a frequency band different from the one received is termed frequency frogging. It is also the basis for the repeater nomenclature H-L. The modulator output is passed through the 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 repeater gain by a thermistor regulator to maintain an output power which is almost constant over the operating range of the input power.
		2.2 Only a small amount of equalization is accomplished by the repeater. Most of the equalization depends upon having approximately equal cable lengths between repeater and the use of frequency frogging at each repeater. The residual slope equalization is adjusted by the control SLOPE ADJ in the amplifier.
		<u>SECTION II - DETAILED DESCRIPTION</u>
		1. OVER-ALL REPEATER
		1.1 The N1 high-low repeater circuit consists of three major parts, the east-west (E-W) subassembly, the west-east (W-E) subassembly, and the oscillator subassembly.
		2. E-W AND W-E SUBASSEMBLIES
		2.1 The E-W and W-E subassemblies, which are identical, consist of:
		(a) A modulator with input and output filters plus associated transformers.
		(b) A 2-stage amplifier with regulating thermistor, slope adjustment, and flat-gain adjustment.
		3. OSCILLATOR SUBASSEMBLY
		3.1 The oscillator subassembly consists of:
		(a) A crystal-controlled oscillator and second harmonic rejection filter.



CD Fig. 1(A) - Schematic and Insertion Loss Characteristic of (FL1 & FL2) Filters

- (b) A current adjustment, VR CUR, for the VR tube V41.
- (c) A current adjustment, FIL CUR, for the heaters of the tubes.

4. REPEATER INPUT COIL

4.1 Repeater input coil T1 serves to match the impedance of the incoming 130-ohm line to that of the 3000-ohm filters. Capacitor C2 is shunted across the coil to improve the transmission characteristic. This input coil provides the simplex connection to the line for the purpose of obtaining or supplying power over the line. It also aids in maintaining at adequate longitudinal balance to the line to suppress longitudinal noise.

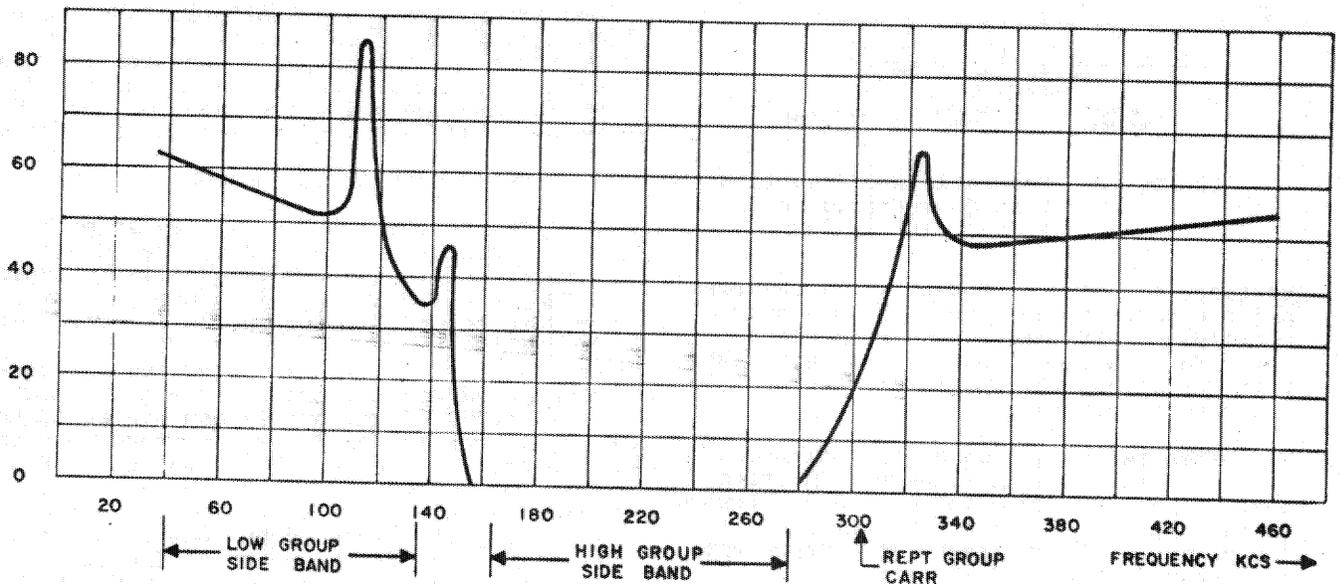
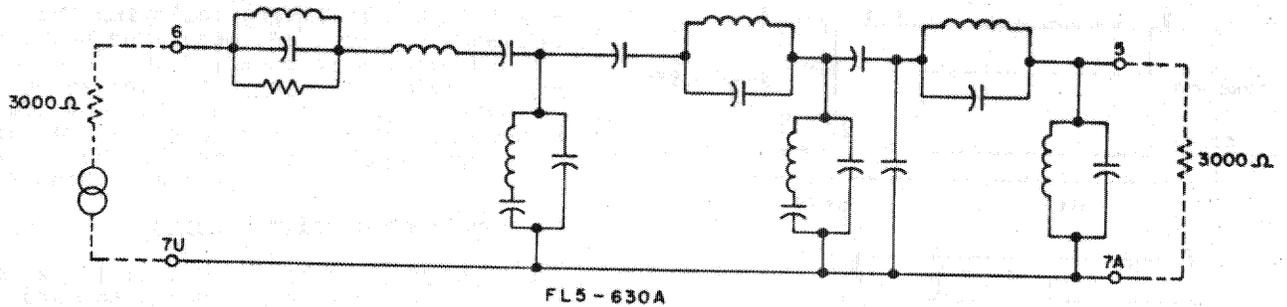
5. MODULATOR FILTERS

5.1 The modulator filters used at the input and output of the modulator select the desired frequency groups. These filters are designated FL1, FL2, FL3, FL4, and FL5.

(a) Modulator input filters FL1 and FL2 pass signals of the incoming high-group frequencies to the modulator and reject the unwanted low-group signals that are present at the repeater input due to cross-talk between the cable pairs. This filter is a high-pass filter with a configuration and characteristic (measured between 3000-ohm resistances), as shown in CD Fig. 1(A).

(b) Modulator input filter FL5 in addition to (a) also rejects the image band which is present as a modulation product of the previous repeater and is transmitted on with little attenuation. The image band, if allowed to pass through the modulator, produces interference, which has been termed beats, in the outgoing low-group frequency band. The bandpass characteristic of this filter attenuates the image band and eliminates this source of beats. The filter configuration and characteristic (measured between 3000-ohm resistances) is shown in CD Fig. 1(B).

5.2 Modulator output filters FL3 and FL4, CD Fig. 2, are low-pass filters which



CD Fig. 1(B) - Schematic and Insertion Loss Characteristic of 630A Filter

select the lower sideband created by the modulator for transmission to the amplifier and reject the upper sideband. All other modulation products and the signals of the frequency group applied at the input of the modulator are rejected. This output filter also includes a peak section to reject the 304-kc carrier that is present due to imperfect modulator balance.

the 304-kc carrier to produce the low-frequency group. Of the modulation products produced by the modulator, only the lower sideband is desired. The modulator is of the double balanced type (input signal and carrier both balanced from the output). It consists of a copper-oxide varistor CR1 connected between two repeating coils T2 and T5.

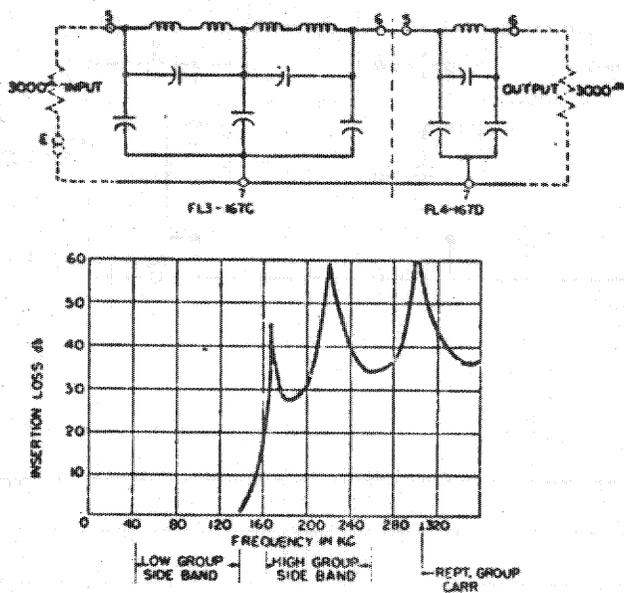
6. MODULATOR PAD

6.1 A 4-db pad (R1, R2, and R3) is used between the modulator input filter and the modulator input coil. This pad improves the impedance match between the filter and modulator and materially improves the transmission characteristic and stabilizes the changes with temperature.

7.2 The modulator action may be considered as a double-pole double-throw switch inserted in the signal path between the input and output coils. This switch action is activated by the plus and minus voltages of the carrier applied longitudinally through the transformers T2 and T5. When the carrier voltage is positive at JE9 and negative at JE10, the carrier current flows through the two outer rectifying elements. Their impedance is then made low. A signal present in the input will then flow directly through the modulator to the output transformer. During the next half cycle of

7. MODULATOR

7.1 The modulator receives the high-frequency group and modulates it with



CD Fig. 2 - Schematic and Insertion Loss Characteristic of FL3 and FL4 Filters

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.

7.3 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 modulation products only the odd order set, $n_o c \pm n_o v$ appears at the output terminals of the modulator; all the other sets of modulation products are theoretically balanced out. Of the odd order set, the simple difference (c-v) is the modulation product desired

$$304 - (164 \leftrightarrow 264) = (140 \leftrightarrow 40)$$

The other components of this order are

rejected by the filters following the modulator. As perfect modulator balance is not achieved, some energy from the other sets of modulation products does appear at the output terminals. This is composed principally of the input signals (v) which are suppressed about 20 db and the 304-kc carrier (c) which is suppressed about 40 db.

8. MODULATOR REPEATING COILS

8.1 A high-group sideband coil T2 is used at the input to the modulator and a low-group sideband coil T5 is used at the output of the modulator. These coils have an impedance ratio of 3000 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 ac ground connection to this modulator circuit be at T5, as indicated. These same two coils are used for the L-H repeater but in reverse circuit positions.

9. 304-KC CARRIER OSCILLATOR

9.1 The carrier frequency used at each repeater is supplied by the 304-kc crystal oscillator. 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 steps down the impedance of the oscillator to match that of the two modulator circuits in parallel. By use of an electron coupled oscillator, 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 by capacitor C47 to provide discrimination against harmonics of 304 kc. Between the output transformer and the variators, there is a rejection filter composed of components L40, C49, and C50 to further suppress all frequencies in this circuit above 304 kc. This filter has a peak suppression at 608 kc.

9.2 The frequency of the oscillation is controlled by the crystal Y40 and is 304,000 cycles \pm about 10 cycles within the range of operating temperatures expected.

9.3 The screen voltage for the oscillator tube is obtained from the repeater regulated voltage supply to provide as stable a voltage as possible. This stabilization is not necessary for the plate excitation which comes from the nonregulated voltage used for the amplifier tubes. The cathode of this oscillator is maintained 20 volts above -B voltage by resistors R41 and R42 to keep the cathode and heater potentials within about 40 volts of each other. Resistor R42 provides a voltage drop

for measuring the V40 vacuum tube current. Resistors R43 and R44 with capacitor C44 provide filtering in the regulated power supply to the oscillator. Capacitor C43 provides the screen load impedance for the oscillator circuit. The oscillator feedback voltage from the screen to the grid is provided by capacitor C40 and crystal Y40. The grid circuit load impedance is provided by capacitor C41 with resistor R40 providing the grid bias resistance. Resistor R46 is a high-frequency antising resistor.

10. AMPLIFIER

10.1 A low-group amplifier is used in the H-L repeater. The amplifier uses two 408A pentode tubes stabilized by feedback and is transformer coupled at both input and output. It has a thermistor flat-gain adjustment and a slope control adjustment incorporated into the feedback circuit. The feedback circuit is connected as series feedback at the input and bridge-type high-side hybrid feedback at the output.

10.2 The input to the amplifier is coupled from the modulator output filter by the amplifier input transformer T3. It has a 3000-ohm low-side impedance to match the impedance of the modulator output filter and a 20,000-ohm high-side impedance, which gives as much gain as is practical for the bandwidth and frequencies used. The impedance values of the transformer are stabilized in the circuit by the 20,000-ohm resistance termination R6 on the high side. This transformer also serves to provide dc separation of the grounded filter circuit from the amplifier circuit which is operated at 70 volts from dc ground when power is received over the cable.

10.3 The interstage network is a simple impedance coupled circuit consisting of an inductor L2 in the plate circuit, a 330,000-ohm grid leak resistor R19 and a coupling capacitor C8 between them. The inductance is antiresonant with the tube and circuit capacitances in the low-group frequency range.

10.4 The coupling from the amplifier output to the line is obtained by the amplifier output transformer T4. This transformer is a hybrid coil and also provides coupling to the feedback circuit. The output transformer has impedance transformation ratios from 6100 ohms at the plate to 4200 ohms at the feedback circuit and 135 ohms at the output. These impedance values are chosen to provide the desired level of the regulated output signal. The nominal value of 135 ohms closely matches the cable impedance over the frequency range of the low group. The vacuum tube does not terminate the output transformer by its correct resistance, but the feedback and the value of resistor R21 do produce the desired output impedance of

135 ohms to match that of the cable pair.

11. FLAT-GAIN ADJUSTMENTS

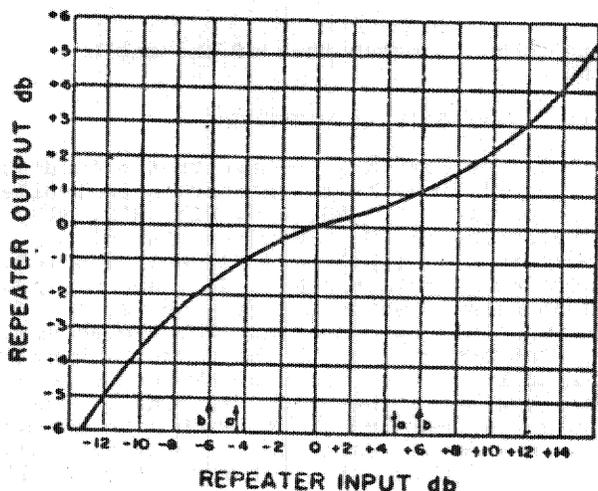
11.1 The feedback voltage to the input tube V1 from the thermistor is controlled by resistors R7, R9, R10, R11, R12, R13, and capacitor C5. Resistors R9 and R13 with resistors R10, R11, and R12 act as a voltage divider. Resistors R10, R11, and R12 provide 1-db gain adjustment steps for use in manufacture to compensate for the accumulated variations due to all the circuit components. Capacitor C5 and resistor R7 form a dc block and bypass so that the grid bias on the tube will not be altered with gain adjustment changes. Capacitor C4 provides the ac ground connection for the entire amplifier circuit.

11.2 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 20,000-ohm resistor R24 in place of the thermistor regulator. This resistor provides about 6 db more repeater gain than that provided by the thermistor at its mean operating value. The resistor is also used for manufacturing and repair testing. It will normally be replaced by the thermistor for field installation.

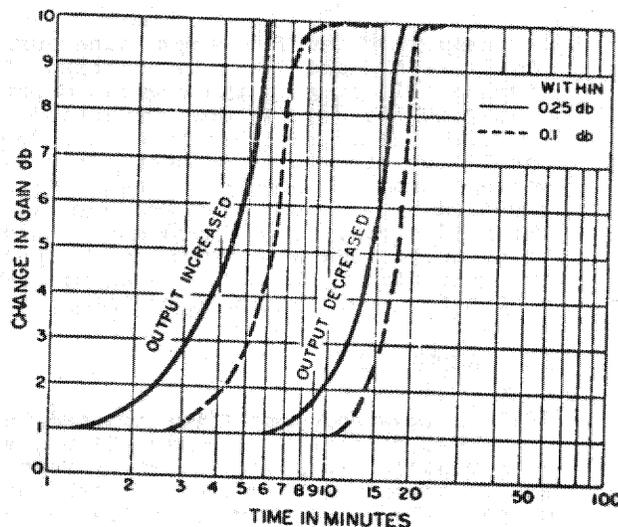
12. REPEATER GAIN AND REGULATION

12.1 The repeater gain is controlled by the loss of the feedback circuit. The fixed gain condition is provided by use of the fixed resistor R24. The regulated gain condition is provided by use of the thermistor regulator RT1 which functions to hold the repeater output nearly constant for a considerable range of inputs. This regulated gain is essentially flat with frequency. The thermistor is activated in proportion to the total power at the output of the repeater. This power is nominally +3 dbm and the thermistor holds this output power to within ± 1.5 db for a change in input level of ± 10 db. This regulation performance in terms of change of output from a mean condition versus change in input is shown in CD Fig. 3. The thermistor pellet is protected from dc voltages between it and the thermistor heater by the capacitors C11 and C12.

12.2 The thermistor regulator reaction time is plotted in CD Fig. 4 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 decreases output 3 to 5 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.



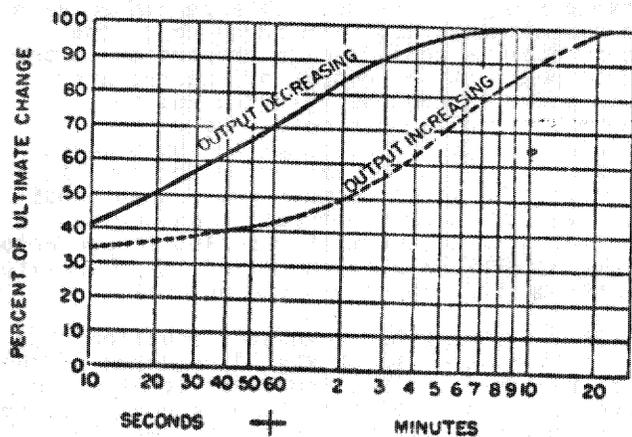
CD Fig. 3 - Regulation Characteristic of High-Low Repeater



CD Fig. 5 - Stabilization Time (Within 0.25 db and 0.1 db of Final Value)

This waiting period is plotted in CD Fig. 5 in terms of stabilization within 1/4 db and also 1/10 db measuring accuracy. The output increased curves apply for changes which have increased the output above normal and which the regulator restores to normal by decreasing the repeater gain while the output decreased curves apply for decreased changes in output which the regulator restores to normal by increasing the repeater gain. Thus, an increase in input of 2 db would require a wait of about 4 minutes for

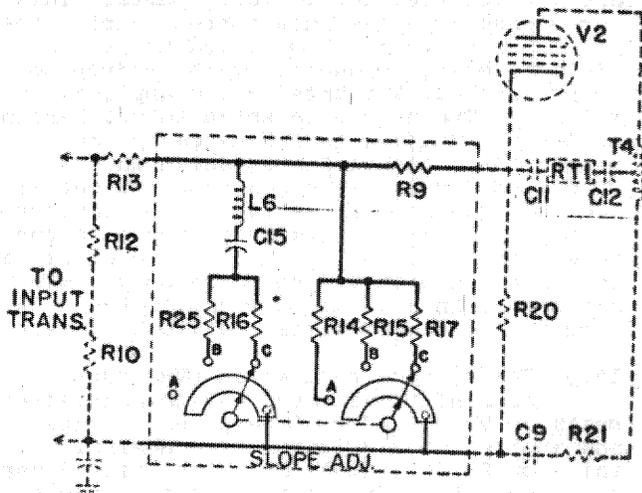
1/10-db measuring accuracy, whereas a decrease in input of 2 db would require a wait of about 14 minutes. A cold repeater when inserted is at high gain and for a normal input will have a high output; so to obtain 1/4-db accuracy of stabilization output requires about 6 minutes wait. Accuracy within 1/10 db requires a wait of 15 to 20 minutes.



CD Fig. 4 - Thermistor Regulating Time

12.3 The thermistor unit RTL consists of a thermistor pellet and the associated ambient temperature control for this pellet. The thermistor pellet is a negative temperature coefficient resistance unit that normally varies from about 1000 ohms to about 20,000 ohms. Under abnormal transmission conditions, it may vary from a few hundred ohms to upwards of 40,000 ohms. For a repeater having the nominal gain, the thermistor resistance will be about 9000 ohms. This value is referred to as the design value.

12.4 Because the thermistor changes its resistance with temperature, changes in ambient temperature would affect the resistance value. Hence, a heater is built around the pellet to maintain it at a temperature above normal ambient. The temperature at which it is held by the heat from this ambient compensation heater is adjusted in manufacture so that with +3 dbm output from the repeater, the pellet resistance is 9000 ohms. This controlled temperature in general is between 135° 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



CD Fig. 6 - High-Low Repeater Slope Circuit

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. However, this change

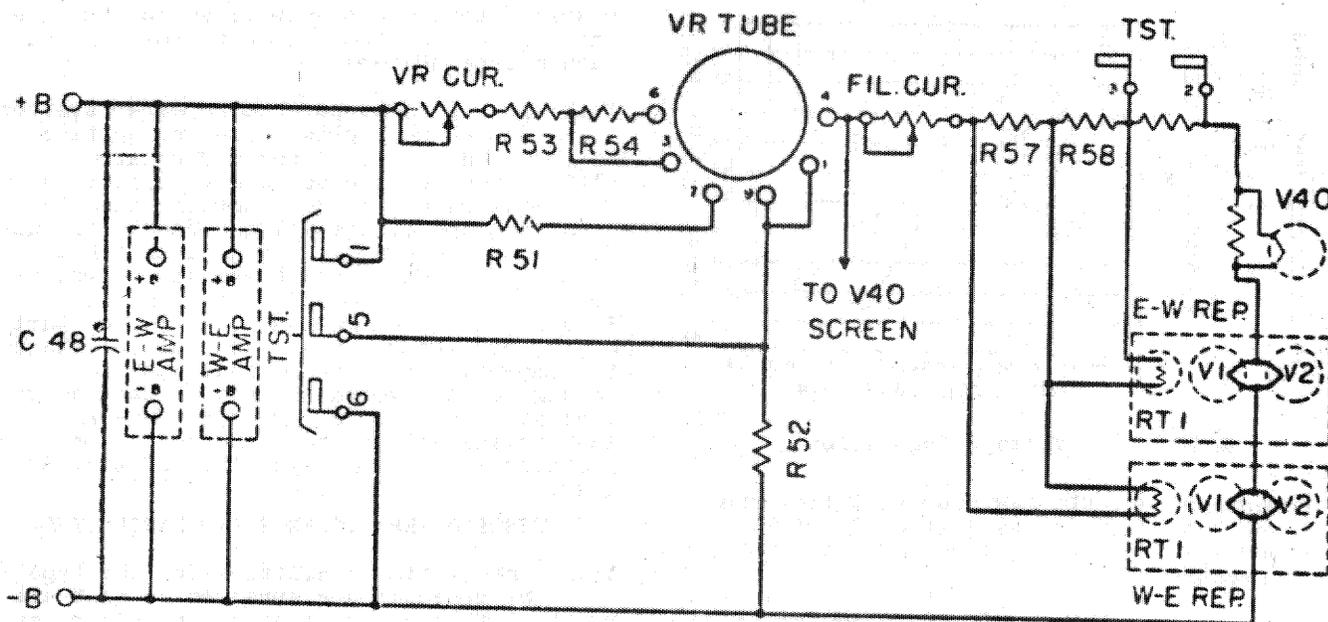
is not cumulative from one repeater to the next, so in general is not vital to operating performance.

13. SLOPE ADJUSTMENT

13.1 The amplifier slope adjustment provides the manual control of the amplifier frequency characteristic to obtain the desired slope across the band. The slope changes are produced by varying the amplifier feedback as shown in CD Fig. 6. The adjustment is in three steps designated A, B, and C, respectively, providing slopes of about 0 db, -2 db, and -4 db gain for channel 12 with respect to channel 1. These adjustments are so arranged that for each setting the repeater has the same power output. Thus, change in slope setting may be made on an operating system without affecting the thermistor regulating action. The slope adjustment network is a shunt across the feedback circuit. The shunt consists of two parts, a series resonant circuit L6 and C15 with Q varied by resistors R16 and R25; and varied resistors R14, R15, and R17 which position the gain of the repeater so that the integrated power of the usual 12-channel carriers remain at the same value.

14. POWER ARRANGEMENTS

14.1 The power connections to the cable pairs are made at the center tap of the appropriate repeater input and output coils through the choke coils L1 and L5.

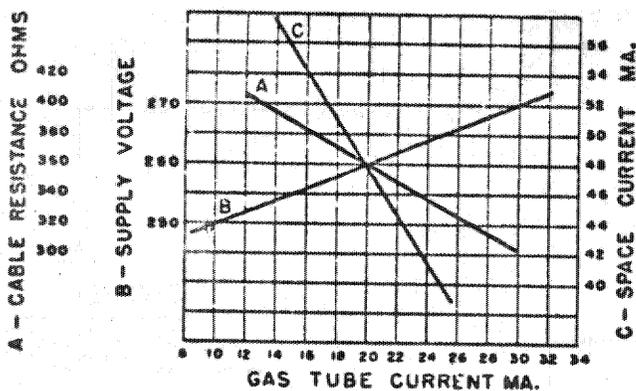


CD Fig. 7 - Power Regulator-Distributor Circuit

Capacitors C42 and C51 with choke coils L1 provide power supply filtering.

14.2 The power used by a repeater is applied to the repeater at jacks PA9 and PA11, and is distributed to the several components as shown in CD Fig. 7. The power to the amplifier vacuum tube plates is supplied with only noise filtering, whereas the power to the heaters of the vacuum tubes, the screen of the 304-kc oscillator tube, and the thermistor ambient temperature control is regulated as well as filtered. The main power supply is filtered by capacitor C48 across the battery leads. This filtering is supplemented for the amplifiers by resistors R22 and R23 with capacitor C13 and further by resistor R18 and inductor L4. Inductor L4 also serves to prevent the power supply to the output transformer from being a low-impedance connection across the output impedance control resistor R21. Capacitor C48 is supplemented by resistor R45 with capacitors C45 and C46 to provide filtering for the 304-kc oscillator. The regulated voltage is required by the heaters of the tubes to give good life, by the 304-kc oscillator to provide frequency stability, and by the thermistors to control their controlled temperature.

14.3 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. The heater string includes a



CD Fig. 8 - Voltage Regulation

potentiometer, FIL CUR, for adjusting the circuit current to the desired 98 milliamperes and has test jacks TST 2 and TST 3 to measure it.

14.4 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 varies the 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 CD Fig. 8. Changes in gas tube current are plotted against changes in applied battery voltage B, line resistance A, and electron tube space currents C. Each curve expresses the change due to one variable only. The net effect on gas tube current is the summation of the several individual effects.

14.5 The voltage regulation (VR) tube current is adjusted, by the variable resistor 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.

14.6 The VR tube requires an applied voltage of 130 volts or more on the trigger electrode to make the tube conducting and to start regulation action. To obtain this, the trigger electrode number 7 is connected by means of resistor R51 to the power supply ahead of the adjusting resistances to obtain the full applied voltage. The tube has a small resistor 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.

14.7 At a locally powered repeater station where the applied repeater voltage is obtained directly from a regulated battery source, the voltage regulator is not required and a 337A 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 VR 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 nonpowered repeater. Where a 136- or 152-volt battery is used, a 16A resistor lamp is used in place of the 337A plug.

15. TESTING ARRANGEMENTS AND FACILITIES

15.1 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:

- (a) The customary electron tube activity tests.

- (b) Adjustments of the current for the heater string.
- (c) Adjustment of the voltage regulator tube current.

These tests can be performed with the 2P tube test set or its equivalent.

15.2 Jacks FIL ACT and TST provide the necessary access points in the circuits for the tube tests and adjustments. The tube activity test is made at jack FIL ACT with the 2P tube test set in the usual manner by observing the change in tube space current for a 10 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 change in heater current is obtained by connecting an adjustable resistance to provide the desired change. The tube space currents are measured by jack connections across the cathode resistors R8 and R20. Resistor R8 is bypassed by capacitor C6 to prevent cathode feedback around the first stage. Resistor R20 has no bypass capacitor and this cathode resistor introduces about 5-db local feedback around the second stage. The screen of tube V1 is bypassed to its cathode by capacitor C7 and V2 by C9.

15.3 The measurement and adjustment of the currents in the vacuum 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 milli-amperes. 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 milli-amperes required in the voltage regulator tube also necessitates individual adjustment to compensate for the variations among VR 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.

SECTION III - REFERENCE DATA

1. WORKING LIMITS

- 1.1 Temperature: -40 F to +140 F.
- 1.2 Input Level: -44 dbm ±8 db.

2. FUNCTIONS

2.1 This repeater receives signals at high-group frequencies (164 kc to 268 kc) from the line, translates them to low-group frequencies (36 kc to 140 kc), and then suitably amplifies and regulates them for transmission at the desired output level. This repeater is used alternately along the cable with another repeater designated L-H repeater.

2.2 The repeater provides a transmission slope across the band adjustable to about 0, -2, or -4 db.

2.3 Wiring adjustment is provided to obtain a fixed repeater gain in place of the regulated gain to be used when the repeater is used for testing or in the repeater switching set.

2.4 The repeater provides means, when required, to transmit power over the cable in either or both directions to another repeater and to receive power in a like manner from another repeater.

2.5 The repeater provides means for making filament activity tests and for measuring space currents, filament current, and the regulated voltage for the tubes.

3. CONNECTING CIRCUITS

3.1 "N1" Carrier Telephone - Application Schematic for Repeater - SD-95124-01

SECTION IV - REASONS FOR REISSUE

CHANGES

B. CHANGES IN APPARATUS

B.1 Superseded Superseded by

In Fig. 1

2 - Filters FL1 and FL2 167A and 167U	1 - Filter FL5 630A
--	------------------------

In Fig. 2

2 - Filters FL1 and FL2 167A and 167U	1 - Filter FL5 630A
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D. DESCRIPTION OF CIRCUIT CHANGES

D.1 The "C" and "D" options were added to cover B.1 above. The "C"

option was previously shown but not rated "Mfr Disc."

All other headings under Changes, no change.

BELL TELEPHONE LABORATORIES, INCORPORATED

DEPT 2169-LES-DDS