TYPE N AND ON CARRIER REPEATERS—REPEATERED HIGH-FREQUENCY LINE

DESCRIPTION—TYPE N1A LOW-HIGH TRANSISTORIZED REPEATER

J98703MB

CONTENTS PAGE

1. GENERAL

1.01 This section describes the physical and functional characteristics of the N1A low-high repeater used in the high-frequency line of Type N and ON carrier systems. It is one of two similar repeater circuits and is designated a low-high (L-H) transistorized repeater. Section 362-400-121 describes the N1A high-low repeater.

1.02 This section is reissued to include coverage of the new silicon diode modulators, which provide improved performance for transistorized repeaters. Arrows are used to indicate changes.

1.03 The N1A repeater is used on a 4-wire basis to transmit 12-channel N1 or N2 signals, 24-channel ON2 or N3 signals, or 20-channel ON1 signals. The input signals from the line are filtered by the imput filter to remove unwanted frequencies. The signals are then modulated by a 304-kHz carrier to change bands from the low group to the high group. The same oscillator is used to supply the 304-kHz carrier for both directions of transmission ▶as shown in Fig. 1.◀ The action whereby the repeater transmits a different frequency band than it receives is termed frequency frogging.

1.04 Frequency frogging is the basis for the repeater nomenclature low-high (L-H). 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 gain by a thermistor regulator to maintain an output power which is almost constant over the operating range of the input power.

1.05 Only a small amount of 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.

2. EQUIPMENT DESCRIPTION

A. Overall Repeater

2.01 The N1 Transistorized Low-High Repeater Circuit consists of three major parts, the E-W (east-west) subassembly, the W-E (west-east) subassembly, and the oscillator subassembly.◆Test jacks and the slope adjust switches are mounted on the repeater faceplate for easy access. The subassemblies are enclosed in an aluminum housing which plugs into an N1A mounting shelf, as shown in Fig. 2.◆

B. E-W and W-E Subassemblies

2.02 The E-W and W-E subassemblies are identical. They consist of:

(1) A modulator with input and output filters plus associated transformers.

(2) A 3-stage transistor amplifier with regulating thermistor, slope adjustment, and flat-gain adjustment.

(3) A voltage regulating diode power supply.

C. Oscillator Subassembly

2.03 The oscillator subassembly consists of:

(1) A 1-transistor crystal-controlled oscillator with an output level adjustment plus a 1-transistor buffer amplifier and ◆for those units equipped with copper-oxide varistors in the modulator circuits,◆ a second harmonic rejection filter.

(2) A bias adjustment for the E-W and W-E amplifiers.

(3) A current adjustment for the heaters of the two thermistors.

3. FUNCTIONAL DESCRIPTION

A. Repeater Input Coil

3.01 The repeater input coil (T1) serves to match the impedance of the incoming line to that of the 3000-ohm filters. 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 an adequate longitudinal balance to the line to suppress longitudinal noise.

B. Modulator Filter

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

3.03 The modulator input filter FL1 passes signals of the incoming low-group frequencies onto the modulator and rejects the unwanted high-group signals that are present at the repeater input due to crosstalk between the cable pairs. This filter is a low-pass filter with a configuration and characteristic (measured between 3000-ohm resistance), as shown in Fig. 3.

C. Modulator Pad

3.04 A 4-dB pad is used between the modulator output coil and the modulator output filter. This pad improves the impedance match between the filter and modulator, materially improves the transmission characteristic, and stabilizes the changes with temperature.

D. Modulator

3.05 The modulator receives the low-frequency group and modulates it with the group carrier (304 kHz) to produce the high-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, ◆or silicon diode quad CR1, which is connected between two repeating coils T2 and T3.◆

3.06 The modulator output filters FL2, FL3, and FL4 (Fig. 4) select the lower sideband created by the modulator for transmission to the amplifier and reject the upper sideband, all other

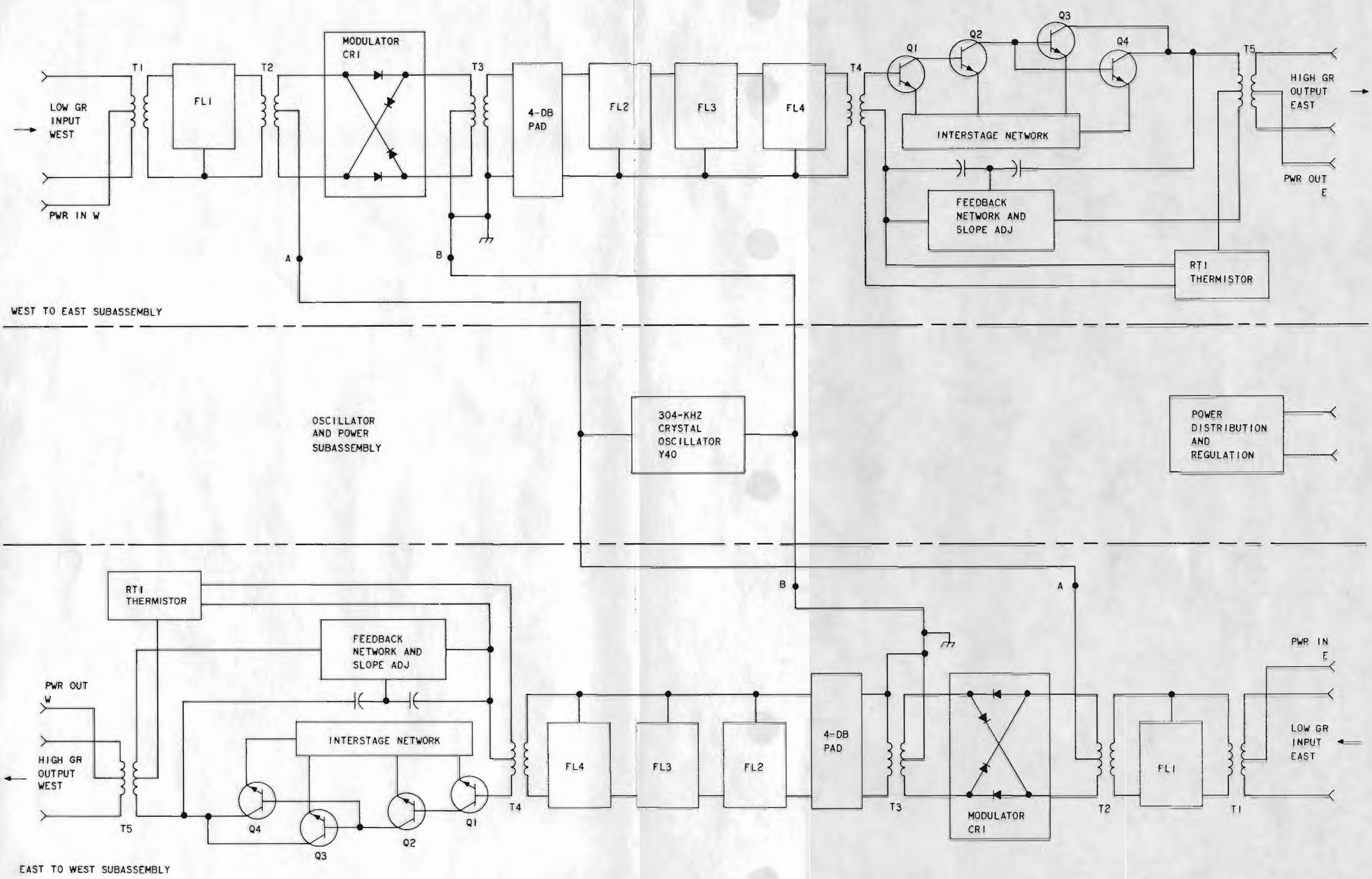

Fig. 1—Type N1A Repeater—Block Schematic

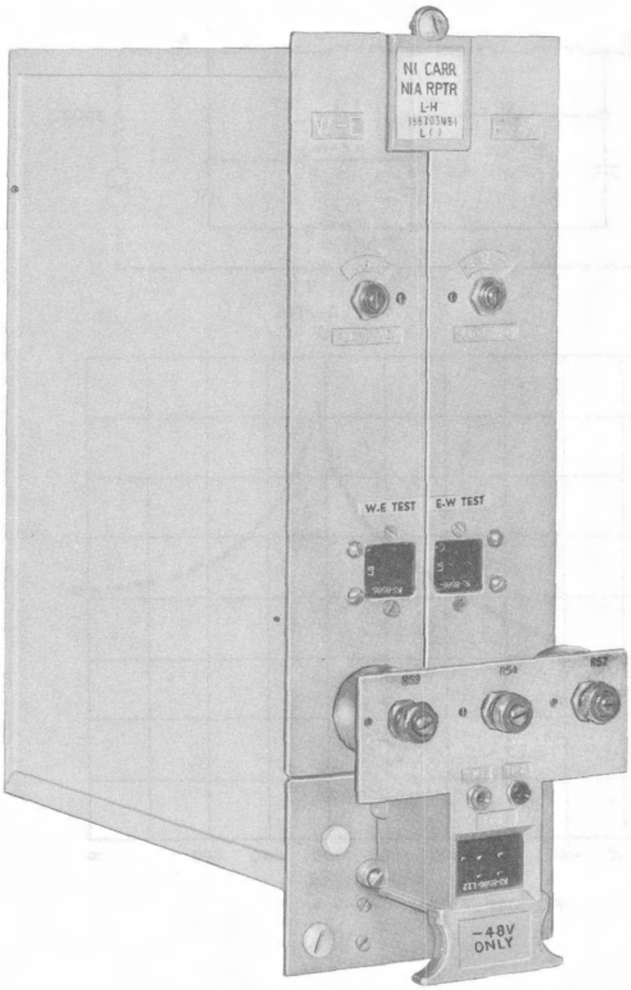

Fig. 2—N1A L-H Repeater Unit, J98703MB-1

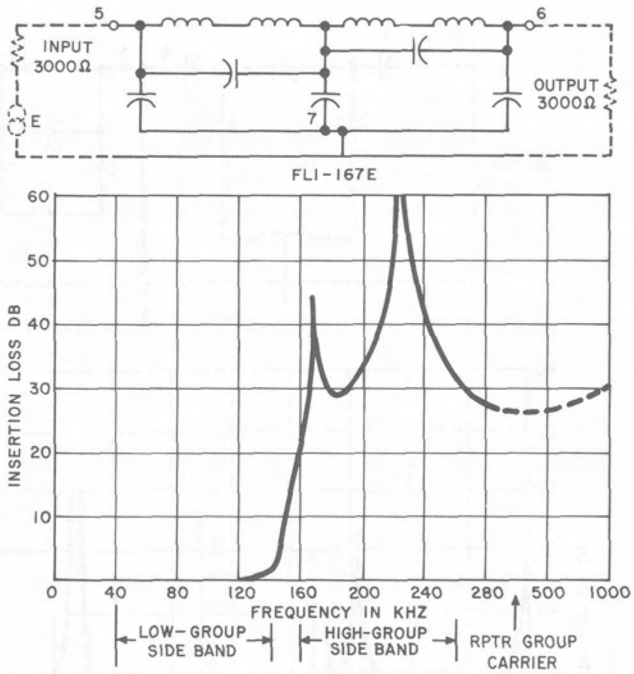

Fig. 3—Schematic and Insertion Loss Characteristic of FL1 Filter

modulation products, and the signals of the frequency group applied at the input of the modulator. This output filter also includes a peak section to reject the 304-kHz carrier that is present due to imperfect modulator balance.

3.07 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 2 and 3. When the carrier voltage is positive at A and negative at B 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 the 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.

3.08 This double-pole, double-throw 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-kHz 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 integers. Of these modulation products only

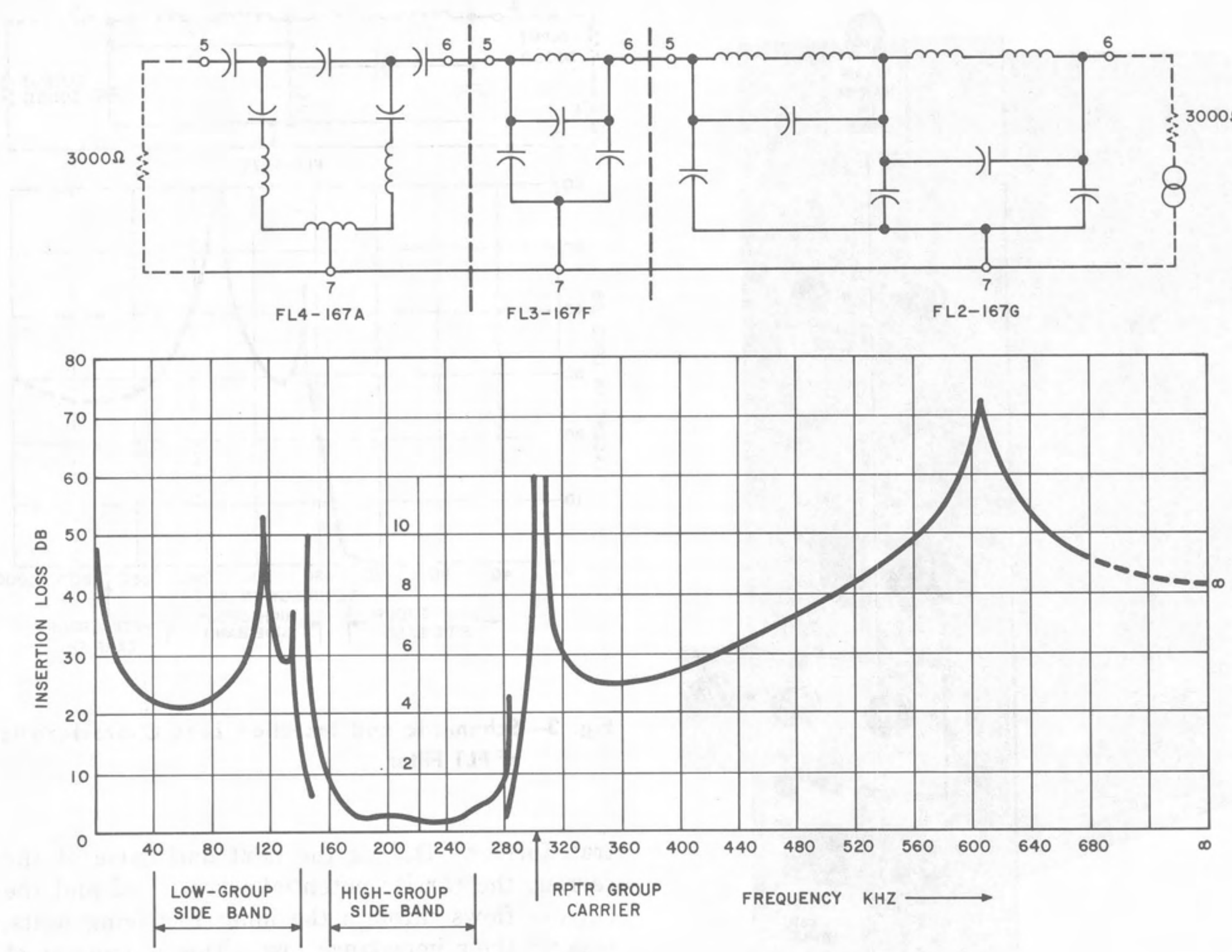

Fig. 4—Schematic and Insertion Loss Characteristic of FL2, FL3, and FL4 Filters

the odd order set, $n_oc \pm n_ov$, 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.

$$304-(36\leftarrow\rightarrow 140) = (164\leftarrow\rightarrow 268).$$

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 energy is composed principally of the input signals *v,* which are suppressed about 20 dB, and the 304-kHz carrier *c,* which is suppressed about 40 dB.

E. Modulator Repeating Coil

3.09 A low-group sideband coil T2 is used at the input to the modulator and a high-group sideband coil T3 at the output of the modulator. These coils have an impedance ratio of 3000:130 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, ac ground connection is made at T3.

F. 304-kHz Carrier Oscillator

3.10 The carrier frequency used at each repeater is supplied by the 304-kHz crystal oscillator. This oscillator employs a transistor and a quartz crystal to form the oscillating circuit. A buffer amplifier consisting of one transistor drives the two modulator circuits in parallel. This amplifier is necessary in order to obtain sufficient carrier power; it also serves to isolate the oscillator from the nonlinear modulator load. ➧A rejection filter, for use only with the copper-oxide varistor modulator, suppresses the second harmonic of 304 kHz. The filter is not in the circuit when the silicon diode quad is used in place of the copper oxide varistor. The nonlinear characteristic of the silicon creates a squaring effect on the driving signal, which results in rejection of all even harmonics of the 304-kHz signal so that the second harmonic at the modulator output is comparable in level to that of the copper-oxide varistor modulator. A resistor at the output of the oscillator circuit is connected in parallel with the silicon diode load so that the combined terminating impedance becomes more resistive. The addition of this resistor enables the carrier oscillators to function in all repeaters upon application of power.◀

3.11 The frequency of oscillation is stabilized by crystal Y40 to 304 kHz with a maximum deviation of approximately ±20 Hz over a temperature range of −40°C to +60°C. The output voltage is 0.55 volts ±0.2 volts and the second harmonic level is at least 55 dB below the fundamental.

G. Amplifier

3.12 A high-group amplifier is used in the L-H repeater. The amplifier uses three transistor stages with hybrid feedback connections at both the input and the output. The amplifier contains a thermistor-regulated output, a flat-gain adjustment, and a slope control adjustment.

3.13 The input to the amplifier is coupled to the modulator output filter by a hybrid transformer T4. The input impedance of the first transistor Q1 ▶in conjunction with the feedback provides the proper termination for T4, thereby assuring◀ that the input impedance of the transformer is 3000 ohms, which matches the modulator output filter.

3.14 The amplifier output is coupled to the line by a hybrid transformer T5. The output impedance of the last stage ▶Q3 and Q4 in conjunction with the feedback provides the proper termination for T5, thereby assuring◀ that the output impedance of the transformer is 125 ohms, which matches the line impedance.

3.15 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 utilizing diodes so that the temperature effects of diodes and transistors tend to cancel. The emitter voltages of the two transistors in the last stage Q3 and Q4 are the most critical points in the circuit because these voltages set the current in the transistors and therefore set the clipping level. The emitter voltage of transistor Q3 is factory set to 3.0 volts by adjusting the potentiometer in the collector of the second stage. After this voltage is factory set, it becomes a good indication of the condition of all transistors and diodes.

H. Flat-Gain Adjustments

3.16 The gain of the amplifier is determined by the loss in the feedback network and thermistor RT1 situated between the input and output hybrid taps of transformers T4 and T5. The slope-adjust network includes 1-dB gain adjustment steps for use in manufacture to compensate for the accumulated variations due to all the circuit components.

3.17 When the repeater is used as an alternate repeater in the transistorized repeater switching set, a fixed gain without regulation is desired. This condition is obtained by using the 20,000-ohm resistor in place of the thermistor regulator. This resistor provides 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 is normally replaced by the thermistor for field installation.

I. Repeater Gain and Regulation

3.18 The repeater gain is controlled by the loss of the feedback circuit. The fixed gain condition is provided by use of the fixed resistor. The regulated gain condition is provided by the thermistor regulator RT1, which holds 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 ▶11.5 dBm,◀ and the thermistor holds this output power to within ±1 dB for a change in input level of ±8 dB. This regulation performance is shown in Fig. 5.

3.19 The thermistor regulator reaction time is plotted in Fig. 6 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

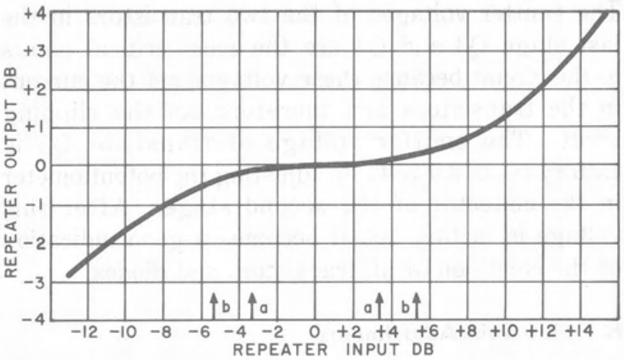

Fig. 5—Regulation Characteristic of Low-High Transistorized Repeater

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. 7 in terms of stabilization within 1/4 dB and also 1/10 dB. 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 a 6-minute wait. Accuracy within 1/10 dB requires a wait of 15 to 20 minutes.

3.20 The thermistor unit RT1 consists of a thermistor pellet and the associated ambient temperature control for this pellet. The thermistor pellet is a negative temperature coefficient resistance unit which normally varies from about 1000 ohms to about 20,000 ohms. Under abnormal transmission conditions, it may vary from a few hundred ohms to 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.

3.21 Because the thermistor changes its resistance with temperature, changes in the ambient temperature would affect the resistance values. Hence a heater is built around the pellet and the pellet is maintained at a temperature above normal ambients. The temperature at which it is held by the heat from this ambient compensation heater is adjusted in manufacture so that with +11.5 dBm output from the repeater, the pellet resistance is 9000 ohms. This thermostat-controlled temperature is between 135°F and 185°F. This temperature

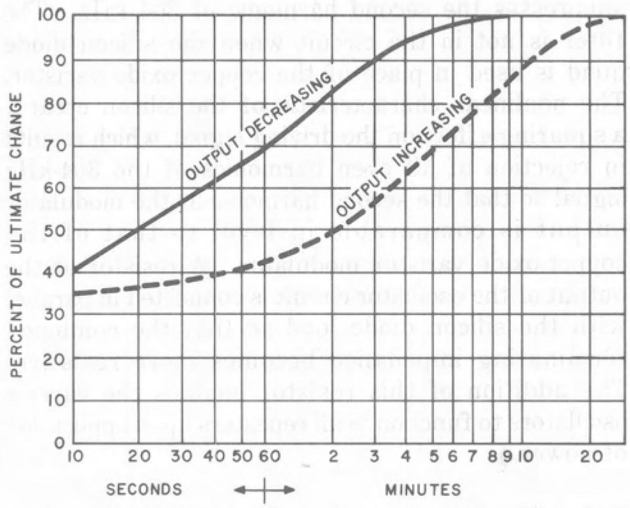

Fig. 6—Thermistor Regulator Reaction Time

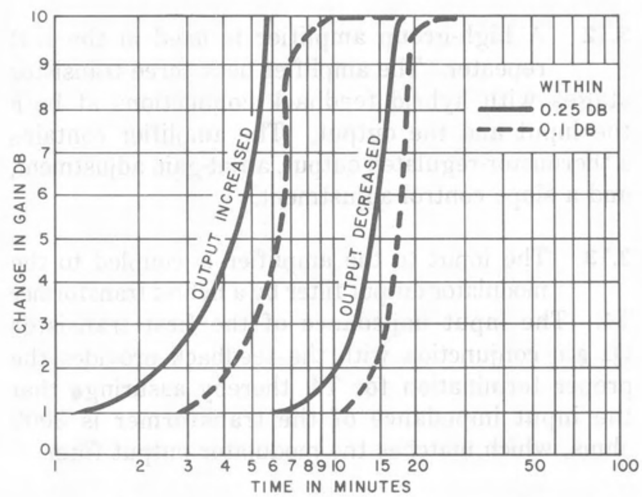

Fig. 7—Stabilization Time (Within 0.25 DB and 0.1 DB of Final Value)

compensation is obtained by a disc thermistor in the heater network which varies the power dissipated in the pellet heater with the ambient temperature. 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 and so in general is not vital to operating performance.

J. Slope Adjustment

3.22 The amplifier has a manual slope control for adjusting the amplifier frequency characteristic in order to obtain the desired slope across the band. The slope changes are produced by varying the amplifier feedback as shown in Fig. 8. The adjustment is in three steps designated A, B, and C, providing slopes of about +2 dB, 0 dB, and −2 dB of gain, respectively, for channel 12 with respect to channel 1 ➧and channel 13 with respect to channel 2.➧ These adjustments are so arranged that for each setting the repeater has the same power output. Thus a 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. In position A the shunt consists of a series resonant circuit C20, L3, and R26 in parallel with the series combination of resistors R27 and R29. In position B the shunt consists of resistors R27 and R28 and does not provide shaping. In position C the network consists of a parallel resonant circuit C20, L3, and R28 in series with resistor R27. The networks associated with positions A and C are designed to give the proper inband slope while having a negligible effect on the out-of-band feedback. This feedback ensures amplifier stability for all slope positions.

K. Power Arrangement

3.23 The power connections to the cable pairs are made at the center tap of the appropriate repeater input and output transformers.

3.24 The power used by a repeater is applied at jacks PA9 and PA11 and is distributed to the several components as shown in Fig. 9. The voltage applied to the amplifiers, oscillator, and thermistor heater circuit is regulated by two 22-volt regulation diodes CR2, W-E and CR2, E-W. The W-E diode controls the oscillator and W-E amplifier, while the E-W diode controls the thermistor heater circuit and the E-W amplifier. Capacitor 26 is a power supply filter which prevents crosstalk and 304-KHz carrier leak.

3.25 The two thermistor heaters are powered in series through potentiometer R54 and resistor R55. The current through the thermistor heaters is factory set to 18 mA by adjusting potentiometer R54 and setting the voltage across resistor R55 to 3 volts. The voltage across each thermistor heater is controlled by an internal 8.2-volt diode.

3.26 The oscillator circuit is supplied through a decoupling network consisting of resistor R50 and capacitor C48. This network is necessary to reduce the 304-kHz carrier leak.

3.27 The voltage at the base of the first stage Q1 of each amplifier is regulated to about 3.0 volts. The voltage regulating network for the W-E amplifer consists of components CR40, R51, R52, R30, W-E; ➧RV16, W-E and in the later models RV17, W-E.➧ A capacitor C24, together with this network provides decoupling from the power supply to prevent crosstalk and 304-kHz carrier leak. The diodes CR40 ➧and varistors RV16 and RV17➧ are also used to enhance the temperature stability. The voltage regulating network for the E-W amplifier consists of components RT1, E-W; R30, E-W; ➧RV16, E-W; and in later models, RV17, E-W. The internal diode in RT1, E-W performs the same function as CR40. The collector supplies of all three stages are taken directly from the 22-volt diode without additional decoupling. The collector of the second stage is supplied through potentiometer R53 for the W-E amplifier and R57 for the E-W amplifier. These potentiometers are used to factory adjust the emitter of transistor Q3 to 3.0 volts in each amplifier.➧

L. Lightning Protection

3.28 The repeater is partially protected from lightning surges induced in the transmission lines by carbon lightning protection blocks external to the repeater. These blocks, placed from each conductor to ground at both the input and output of the repeater, limit surge voltages to approximately 500 volts. If the blocks break down at the far side of the repeater from a lightning surge, large

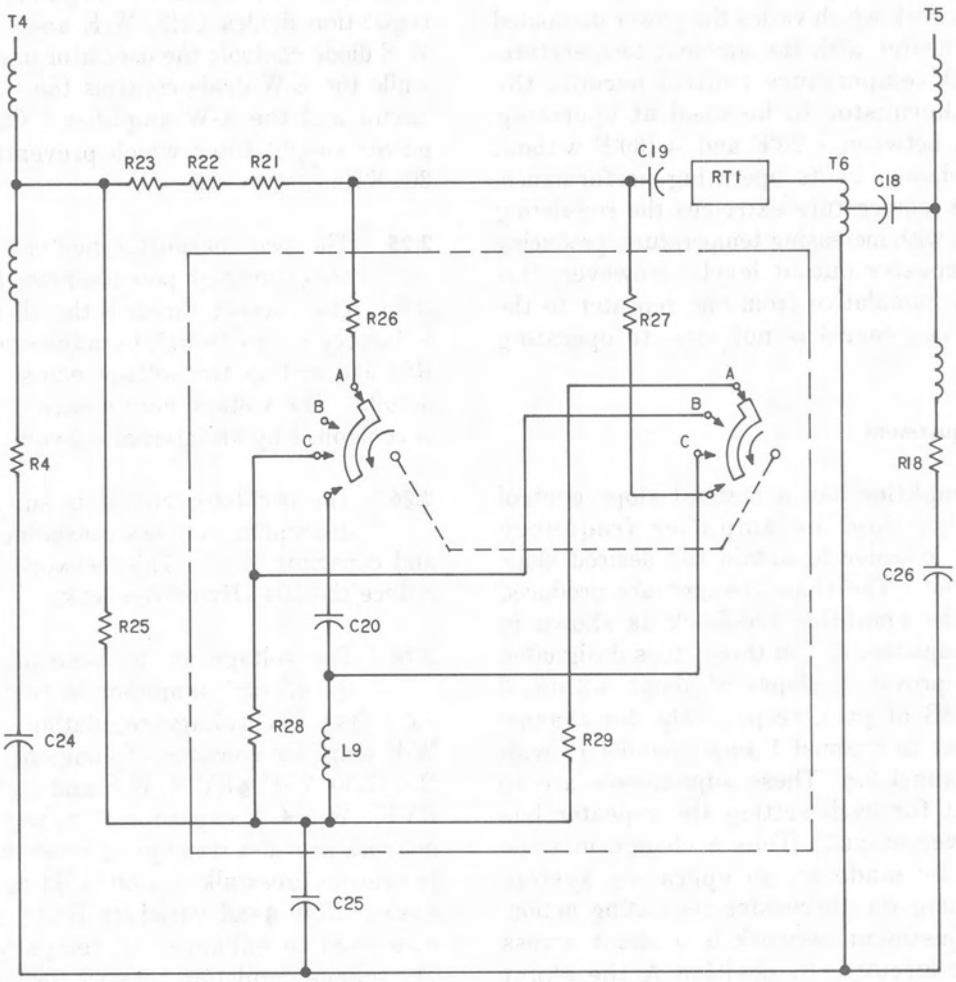

Fig. 8—Low-High Transistorized Repeater Slope Adjustment Network

longitudinal currents may flow through the power supply diodes CR2, W-E and CR2, E-W. Resistor R48 limits the current to a safe value. If the blocks at the near side of the repeater breakdown, transverse currents may flow through the input transformers. The input of the repeater is protected from transverse surges by the band limiting filters and the modulator. The output of the repeater is protected from transverse surges by diodes which shunt the output transformer T5.

M. Testing Facilites

3.29 In order to facilitate the in-service detection of component variations, test points are provided on each subassembly. In the E-W and W-E subassemblies, the test points are located at the emitters of Q1, Q3, and Q4 and at circuit ground. The test points in the oscillator subassembly are located at the emitter of Q40 in the emitter circuit of Q41 at both terminals of each 22-volt diode (one of which is the oscillator circuit ground), at true ground, and on both sides of resistor R55 in the thermistor heater circuit. The voltage measured from an emitter test point to the appropriate circuit ground effectively measures the emitter current of that transistor. Any change in an emitter current indicates a change in current gain of that transistor or a change in other biasing component values because of aging or temperature change. The voltage from the emitter of Q3 to amplifier circuit ground is especially sensitive to component degradation in the amplifier circuit. 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

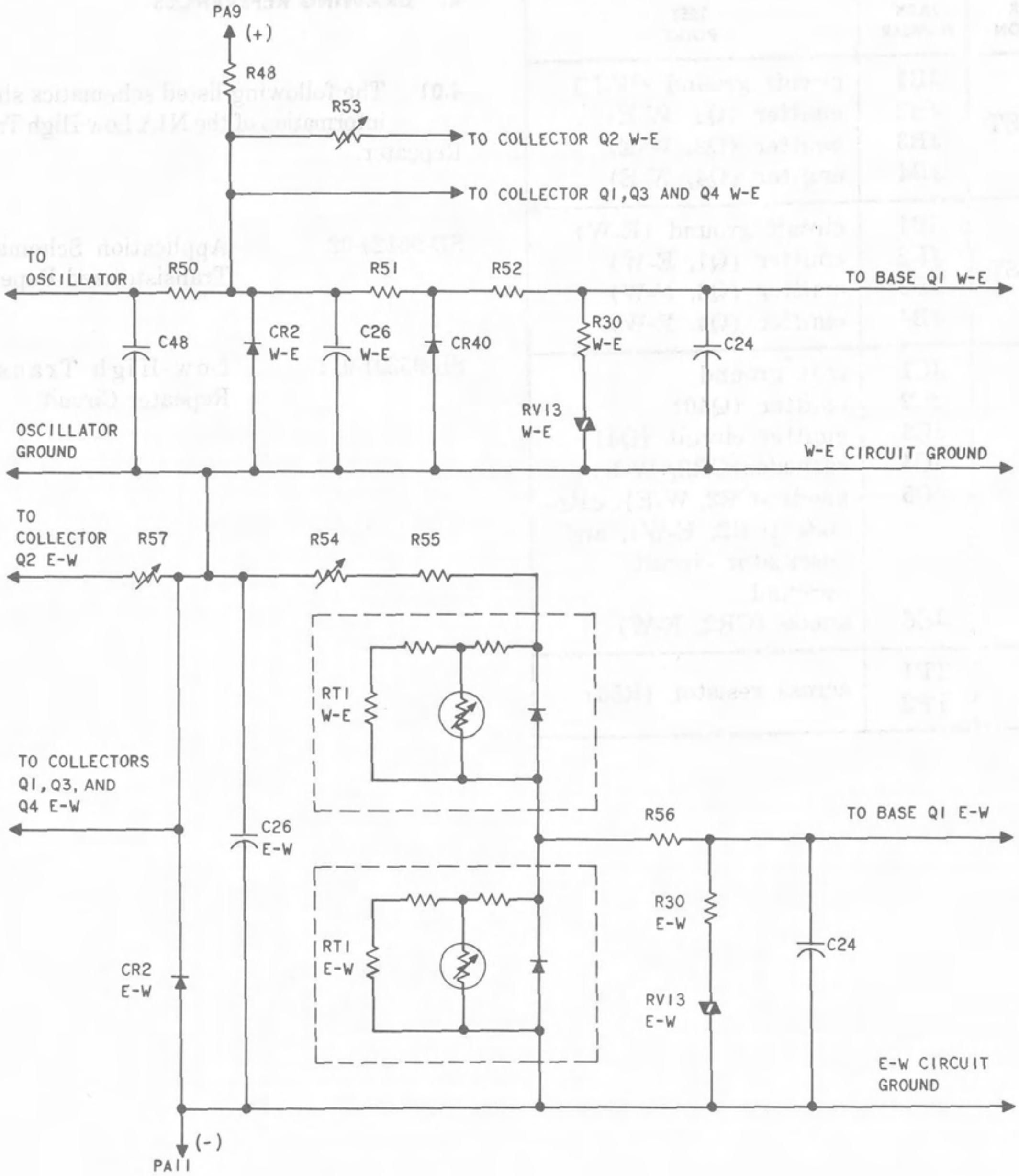

Fig. 9—Power Distribution Low-High Transistorized Repeater

component degradation, repeater temperature, and cable temperature. The voltage across the 22-volt diodes indicates the condition of the diode and the dc current in the cable. If this voltage drops below 20 volts, a trouble condition exists. The voltage across resistor R55 indicates the current in the heater circuit. If this voltage drops below 2.2 volts, a trouble condition exists. All these voltages may be measured with a 20,000-ohms-per-volt meter while the repeater is in service. These voltages are intended to indicate a trouble condition, not to specify the defective component.

3.30 The test points are tabulated below:

TEST JACK DESIGNATION	JACK NUMBER	TEST POINT
W-E TEST	JB1 JB2 JB3 JB4	circuit ground (W-E) emitter (Q1, W-E) emitter (Q3, W-E) emitter (Q4, W-E)
E-W TEST	JB1 JB2 JB3 JB4	circuit ground (E-W) emitter (Q1, E-W) emitter (Q3, E-W) emitter (Q4, E-W)
TEST	JC1 JC2 JC3 JC4 JC5 JC6	true ground emitter (Q40) emitter circuit (Q41) cathode (CR2, W-E) anode (CR2, W-E), cathode (CR2, E-W), and oscillator circuit ground anode (CR2, E-W)
Red Black	TP1 TP2	across resistor (R55)

4. DRAWING REFERENCES

4.01 The following listed schematics show detailed information of the N1A Low-High Transistorized Repeater.

SD-95124-02	Application Schematic for N1 Transistorized Repeater
SD-95291-011	Low-High Transistorized Repeater Circuit