OPERATING INSTRUCTIONS

for

TYPE 1000-P7
BALANCED MODULATOR

GENERAL RADIO COMPANY

CAMBRIDGE 39 MASSACHUSETTS

NEW YORK CHICAGO LOS ANGELES

U. S. A.

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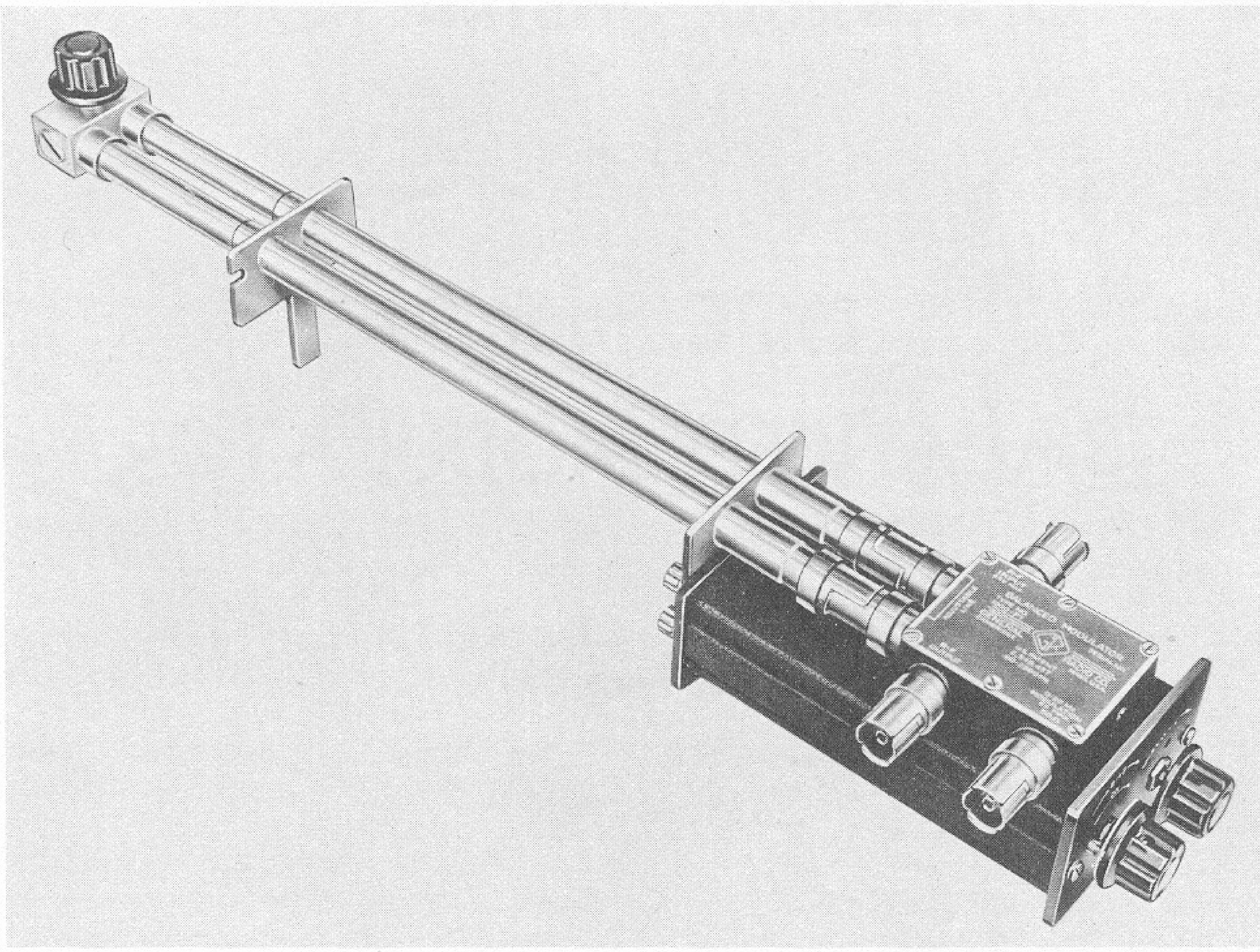


View of the Type 1000-P7 Balanced Modulator.

Specifications

Carrier-Frequency Range: The useful carrier-frequency range is 60 to 2500 megacycles.

Modulation-Frequency Range: The modulating frequency response is flat from 0 to 20 megacycles. For pulsing, the rise-time contribution is less than 20 millimicroseconds.

Impedance: The impedance looking into either input or output terminals is a function of the bias and modulating voltages. The source and load impedances should be 50 ohms. The impedance at the modulation input is 50 ohms $\pm 5\%$.

Modulation: Double-sideband-suppressed-carrier modulation, pulse modulation with 60-db carrier suppression between pulses, and 100% amplitude modulation can be obtained throughout the carrier frequency range. One volt peak at the modulation terminals is sufficient to produce full r-f output from a zero output initial condition.

R-F Output: A maximum output of 10 millivolts of radio frequency into a 50-ohm load can be obtained during pulses or at modulation peaks, with a source of 50 millivolts behind 50 ohms. At this level and lower input levels the modulation characteristics are independent of input voltage. However, somewhat higher input voltages and, consequently, higher output voltages are permissible if bias and balance readjustments are made for each change in level. The r-f source must not exceed 0.5 volt behind 50 ohms or the crystal diodes may be damaged.

Controls: The operating controls consist of an adjustable coaxial line, bias, and balance controls. The bias control also operates the bias battery switch.

Bias Supply: Bias is supplied by a self-contained battery consisting of readily available, inexpensive flashlight cells.

Terminals: The radio-frequency input and output terminals and the modulation input terminals are Type 874 Coaxial Connectors. The radio-frequency input terminal is of proper elevation to plug directly into the output connector of the Type 1021-A Signal Generator.

Crystal Diodes: Two Type IN21-B Crystal Diodes are used.

Accessories Supplied: One Type 1000-P7-28 40-cm Cable; one Type 1000-P7-28-2 80-cm Cable; one Type 874-C Cable Connector.

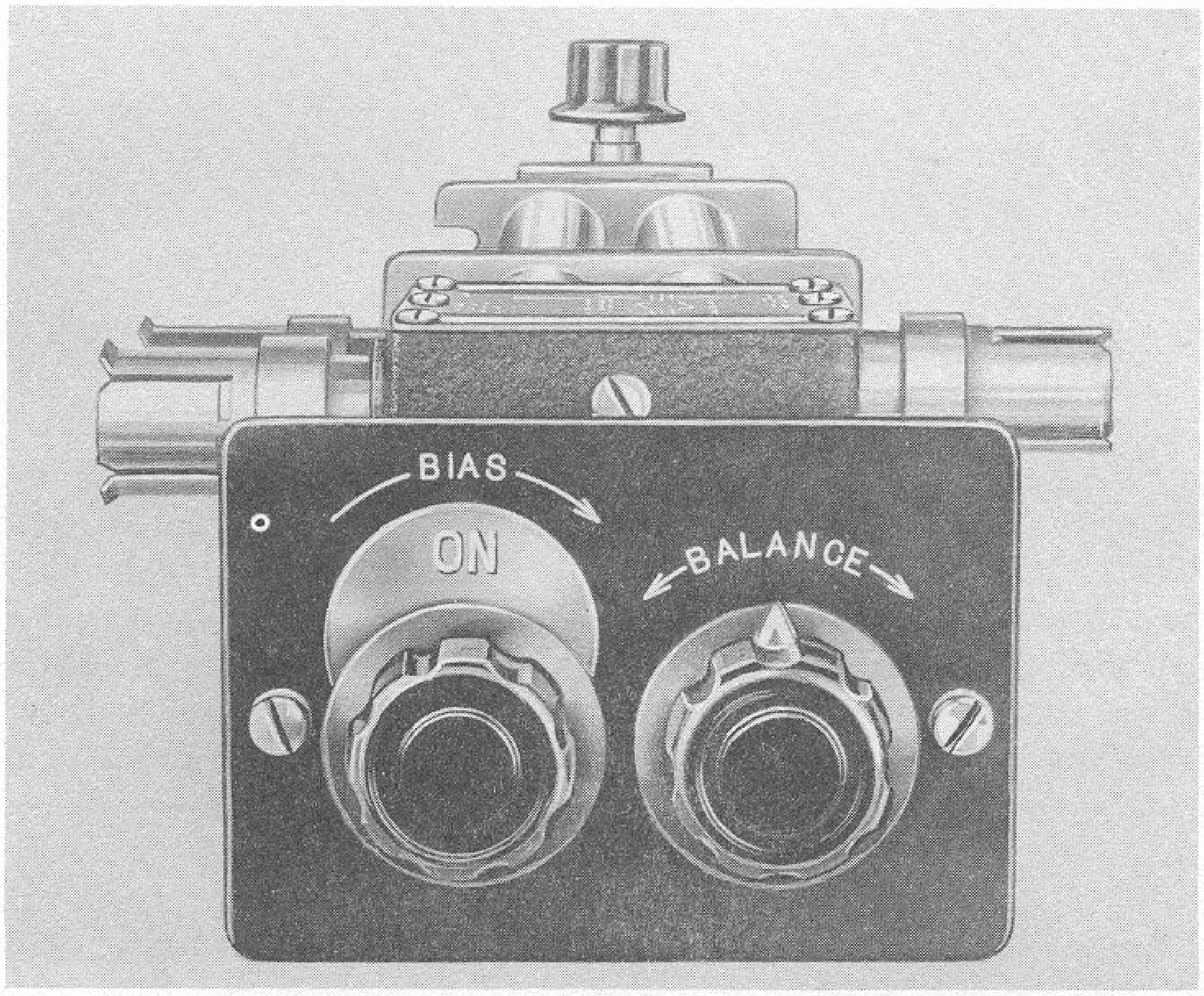
Other Accessories Required: Terminal adaptors, unless generator and load are equipped with Type 874 Coaxial Connectors; suitable coaxial cable for connecting modulation source.

Accessories Available: Type 874-GF Fixed Attenuator, 20 db; Type 874-GG Fixed Attenuator, 10 db; Type 1000-P5 V-H-F Transformer; Type 874-R20 Patch Cord; Type 874 Adaptor to Types N, BCN, C, and UHF Connectors and to Type 274 Binding Posts.

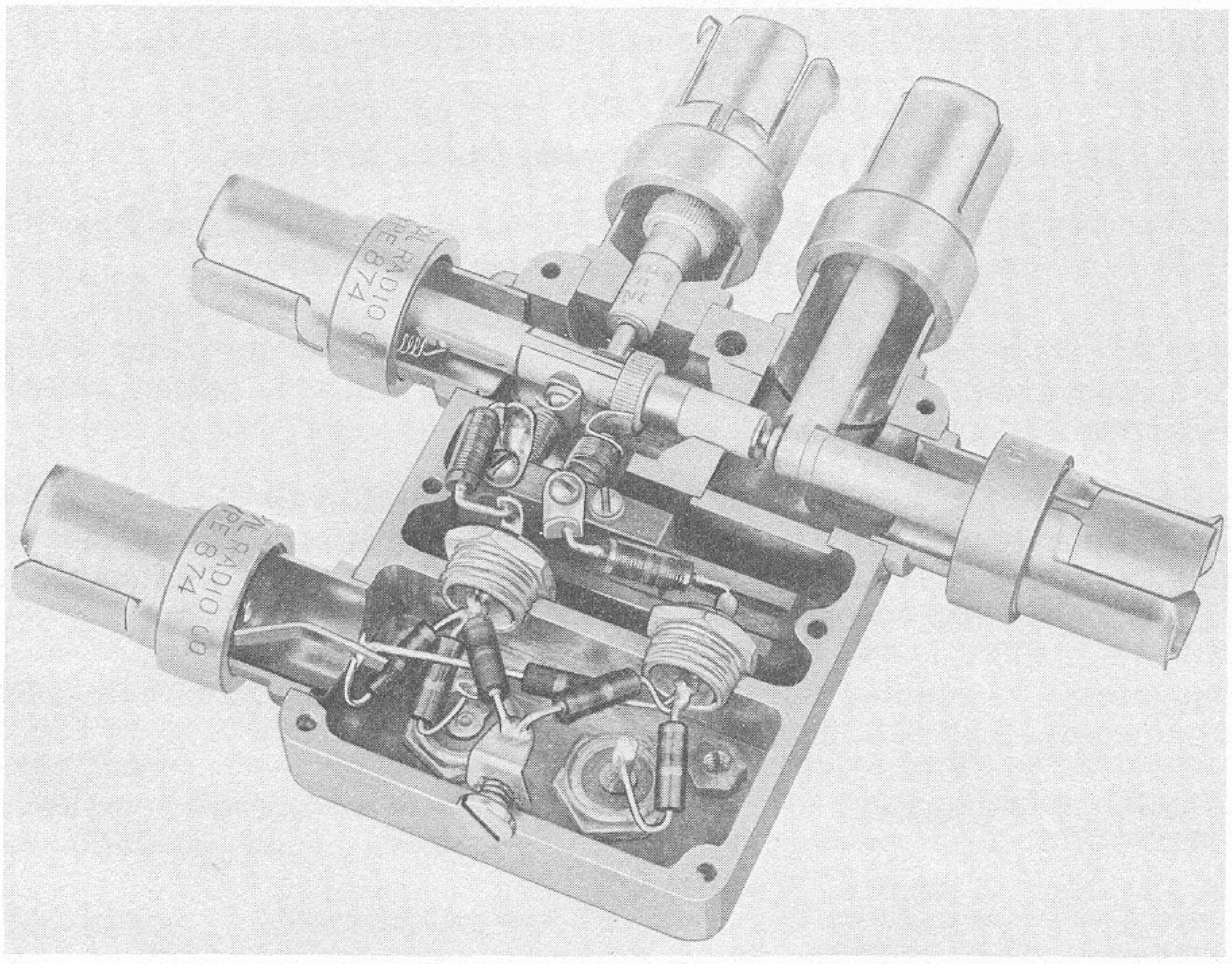
Dimensions: (Including fully extended adjustable line) 30 inches (width) x 3 inches (height) x 5 inches (depth) over-all.

Net Weight: 6 pounds.

U.S. Pat. No.: 2,125,816, 2,548,457.



View of Panel Controls of Type 1000-P7 Balanced Modulator


Cutaway View of the Type 1000-P7 Balanced Modulator

Operating Instructions

for

TYPE 1000-P7 BALANCED MODULATOR

Introduction

The Type 1000-P7 Balanced Modulator is an insertion-loss modulator designed for use at the output of a radio-frequency generator in the 60- to 2500-megacycle range. A balanced-modulator circuit permits high percentages of modulation to be obtained well up into the u-h-f range. The principal uses are for pulse modulation where a high degree of carrier suppression is required with good rise time characteristics, or where full 100% linear amplitude modulation is required.

Section 1.0 Principles of Operation

As can be seen from the elementary schematic diagram, the Type 1000-P7 Balanced Modulator consists of two crystal diodes in two separate signal paths between the input and output, a phasing line set to an odd multiple of one-half wave-length at the carrier frequency in one of the signal paths, a simple high-pass filter in the output, and modulation and bias feed circuits to the two crystal diodes.

For small r-f signals, each diode can be considered an impedance which can be controlled by varying the applied forward bias current. The incremental resistance of the Type IN21-B Crystal Diode used can be varied over the range from several thousand ohms down to 50 or 60 ohms.

At high radio frequencies, the series impedance of the crystal diode drops to a low value, due principally to the shunt capacitance of the unit. A balanced-modulator circuit permits the residual diode shunting impedances to be nuetralized up to high radio frequencies where a single diode unit is useless as a modulator.

The phasing line shown in the elementary schematic diagram is set to provide two sources of equal voltages at the carrier frequency, which are 180° out of phase. Each source is connected to the common output terminal via a crystal diode. By suitably biasing the diodes their impedances may be made equal, with the result that the carrier voltage at the common output can be balanced to zero. The diodes are oppositely poled so that an in-phase modulation signal, simultaneously applied to both, increases the impedance of one and decreases the impedance of the other. This results in a degree of unbalance and, consequently, of r-f output. Such an arrangement permits the use of a single-ended or grounded modulation source. The bias supply has a differential bias control which provides the d-c BALANCE adjustment. The magnitude of the BIAS is adjustable, which permits selecting the best operating point on the diode characteristics for linearity.

For pulsing, the adjustable phasing line and the d-c BALANCE control are set to give zero output with no modulation applied. The application of pulses of either polarity will then produce pulses of r-f output.

For linear amplitude modulation, the output is balanced out, as above; then the d-c BALANCE control is offset to give the desired carrier level before applying modulation. With suitable BIAS and BALANCE adjustment, 100% linear amplitude modulation can be obtained throughout the carrier-frequency range.

Application of modulation without offsetting the BALANCE adjustment results in double-sideband suppressed carrier operation.

Section 2.0 Operation

2.1 GENERAL

The radio-frequency source should have a 50-ohm output resistance and the load should be 50 ohms. It is recommended that 10- or 20-db pads, such as the Types 874-GG or 874-GF Fixed Attenuators, be used at the input and output of the Balanced Modulator, whenever the attenuation can be tolerated, to ensure proper terminal conditions. If this modulator is to be used with the General Radio Type 1021-A Signal Generator, the input terminal can be plugged in directly since it is at the same elevation as the output connector of the signal generator. Figure 1 shows the Type 1000-P7 Balanced Modulator set up with the Type 1021-A Signal Generator and Type 1217-A Unit Pulser.

A Type 874-R20 Patch Cord can be used with signal sources provided with Type 874 output connectors. If the source has another type of output connector, a suitable adaptor to Type 874 must be used. Adaptors are available for Types N, BNC, C, and UHF Connectors. The load can be connected by a Type 874-R20 Patch Cord if it is provided with an 874 connector or suitable adaptor to Type 874. The modulation source can be connected with a Type 874-R20 Patch Cord, using an adaptor if required. A Type 874-Q2 adaptor with banana plugs is used to connect a Type 874-R20 Patch Cord to the binding posts of the Type 1217-A Unit Pulser to supply the modulation in the setup shown in Figure 1. A Type 874-C Cable Connector is supplied which may be attached to an existing coaxial cable or wire leads for connecting the modulation source if desired.

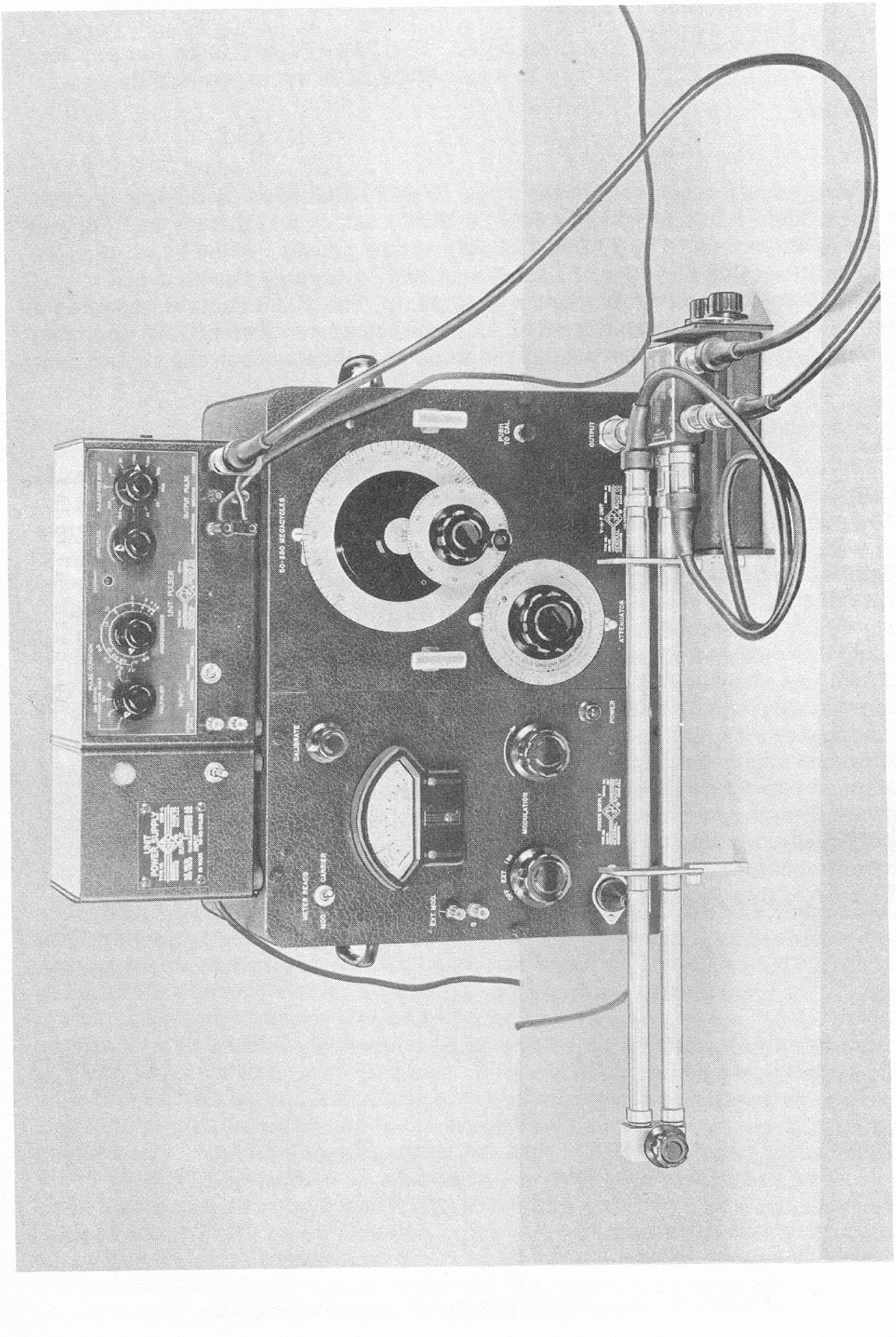


Figure 1. Type 1000-P7 Balanced Modulator set up with the Type 1217-A Unit Pulser to pulse-modulate the Type 1021-A Signal Generator.

2.2 BATTERY INSTALLATION

The battery is not shipped installed. See Paragraph 2.10 on Battery Replacement and install the battery in accordance with the procedure described therein.

2.3 OPERATING CONTROLS

The operating controls of the Type 1000-P7 Balanced Modulator consist of a Type 1000-P7LA Adjustable Line, a BIAS control and battery switch, and a BALANCE control. The 1000-P7LA Adjustable Line is varied by sliding the telescoping section for coarse adjustment and by turning the knob at the end of the telescoping section for fine adjustment. The BIAS control operates a battery switch as it is rotated from an extreme counterclockwise (OFF) position. A red indicator rises from behind the knob to indicate when the instrument is ON.

2.4 BALANCING ADJUSTMENTS

In order to adjust the Balanced Modulator properly, it is almost essential that means be provided for viewing the modulation envelope. This can be best accomplished by heterodyning the carrier frequency down to the range of an available cathode-ray oscilloscope. A satisfactory arrangement is to tap into the output of the intermediate-frequency amplifier of a radio receiver, tuned to the carrier frequency, at the output of the modulator. It will usually be necessary to heterodyne the intermediate frequency down to bring it within the range of most oscilloscope amplifiers. It is also possible that sufficient i-f output can be provided to be applied directly to the defection plates of the oscilloscope, but use of a converter at the output is more universally applicable. For example, a typical receiver might have a 30- to 60-megacycle i-f. An oscilloscope may be available with a 5-megacycle vertical amplifier. By means of a simple one-tube converter, the intermediate frequency can be heterodyned to, say, 2.5 megacycles and sufficient bandwidth provided so that the frequency instability of even the higher frequency receivers and signal generators can be accommodated. A frequency converter circuit is given in Figure 2 using a 6X8 tube, which is satisfactory for this use.

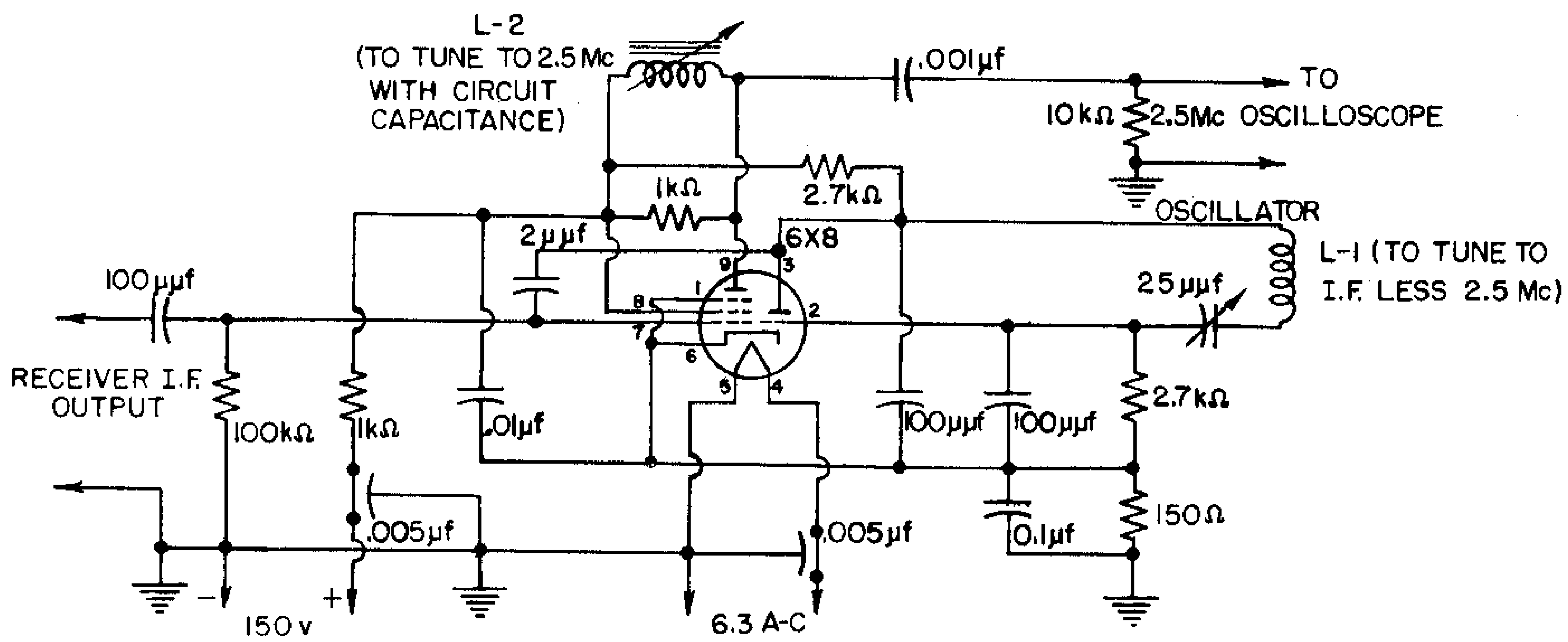


Figure 2. Frequency converter circuit diagram.

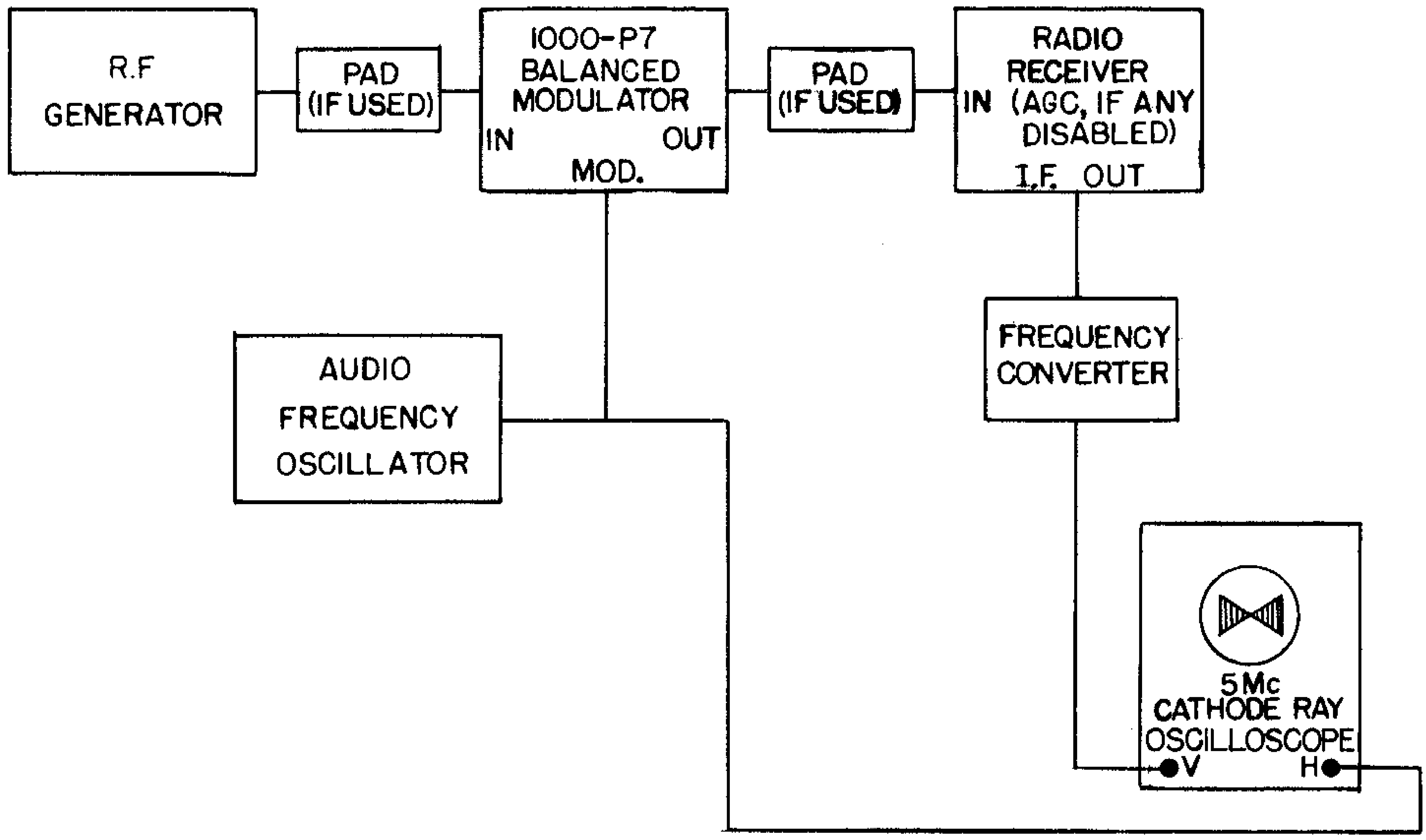


Figure 3. Block diagram of balancing and adjusting setup.

The block diagram in Figure 3 shows the setup for balancing and adjusting the modulator. An audio signal is applied to the MODULATION connector of the Type 1000-P7 and to the horizontal input of the oscilloscope. The heterodyned output of the receiver is applied to the vertical input of the oscilloscope. One volt r-m-s is sufficient at the MODULATION connector of the Type 1000-P7 for full modulation, so a series resistance of 550 ohms can be used if the audio oscillator will supply 12 volts r-m-s into 600 ohms. A check of system linearity at the desired r-f level should be made by varying the signal generator attenuator and seeing that the indicated amplitude on the oscilloscope varies accordingly. The receiver AGC, if any, must be disabled for all measurements. If a non-linearity is indicated, the receiver probably is overloading and its gain should be reduced.

The ADJUSTABLE LINE, the BIAS, and the BALANCE should be adjusted until a symmetrical "butterfly" pattern is obtained with the envelope going to zero in the center of the screen. It will be found that the ADJUSTABLE LINE permits the envelope to be brought to zero at some point along the X-axis of the oscilloscope, that the BIAS adjustment changes the shape of the envelope on either side of the null point, and that the BALANCE adjustment sets the position of the null along the X-axis. There is some interaction between these adjustments. If the BALANCE adjustment is correct, the pattern will decrease in size to a point in the center of the screen as the output of the audio oscillator is gradually reduced to zero. Final ADJUSTMENT LINE and BALANCE adjustment should be made with maximum receiver gain available and minimum audio signal applied. The ADJUSTABLE LINE is provided with a small trimmer adjustment, controlled by the knob at the end of the movable section, which is useful for the final adjustment, particularly at the higher carrier frequencies. The optimum BIAS adjustment is the one that gives maximum envelope height with the most linear rise either side of the null point.

The Type 1000-P7LA Adjustable Line is arranged either to be connected directly to the Adjustable Line connectors of the basic 1000-P7 Balanced Modulator, or to be rotated forward and one of its connectors plugged into the ADJUSTABLE LINE connector nearest the r-f input. A thumb screw, for locking the ADJUSTABLE LINE in either position, and a two-position supporting foot are provided. The second position permits the addition of flexible line extensions which are required below a carrier frequency of 350 megacycles. Two line extensions of 40 and 80 cm electrical length are provided, which are used individually or in combination. For operation in the vicinity of 60 megacycles, a Type 874-R20 Patch Cord is used in place of the regular line extensions. Table I lists the proper line extensions to be used in the carrier-frequency range of 60 to 600 megacycles. The table is intended only as a rough guide. There may be some deviation from the table in the actual frequency range covered by a particular line extension depending on the individual modulator unit but sufficient overlap is provided for full frequency coverage. Above 600 megacycles the adjustment will fall well within the range of the Type 1000-P7LA alone. More than one balance point will be found at the higher frequencies where the line can be adjusted through a range of several wavelengths.

TABLE I

Carrier Frequency Range	Line Extension
58 - 68	874-R20
62 - 74	40 cm + 80 cm
74 - 96	80 cm
91 - 122	40 cm
117 - 184	None
182 - 222	40 cm + 80 cm
215 - 270	80 cm
260 - 378	40 cm
350 - 580	None
450 - 625	40 cm
585 - 2500	None

NOTE: By use of the trimmer on the Type 1000-P7LA, it is usually possible to get overlap at 580 mc so that no line extension is required above 350 megacycles. It is usually also possible to reach 60 mc with 40 cm + 80 cm extension with this trimmer set near maximum.

The balance adjustments must be repeated with each change in carrier frequency, the principal change being required in the ADJUSTABLE LINE to bring it to an odd multiple of one-half wavelength. There is some interaction between the adjustments, so that being able to view the r-f envelope while making adjustments speeds the operation greatly, shows at once the modulation characteristic, and permits making adjustment for the desired characteristic.

It is possible to make the required adjustments without being able to see the shape of the modulation characteristic. This can be accomplished by essentially static measurements where ADJUSTABLE LINE and BALANCE adjustments are made for a minimum carrier output, as indicated by a carrier meter on a receiver. The null is sometimes hard to find with this method, and if the modulation linearity is important, static measurement of r-f output vs. d-c modulation voltage must be made.

2.5 PULSE MODULATION

Pulse modulation can be applied after completion of the balance adjustments described in Paragraph 2.4. The zero level of the pulser must be at zero d-c level or the BALANCE control must be readjusted to give minimum carrier between pulses with modulation applied. Pulses of either polarity can be used. If the General Radio Type 1217-A Unit Pulser is used as a pulse source, the positive pulse output should be used since this output gives pulses with zero level at ground potential. Other pulse sources should be arranged to deliver one volt peak into the 50-ohm MODULATION input. Do not exceed 5 volts peak positive or negative, or the crystals may be damaged. For pulsing, modulation linearity usually is not important, so that completing the adjustment for a carrier null before applying modulation usually is all the adjustment that is required.

2.6 AMPLITUDE MODULATION

For conventional amplitude modulation, the balance adjustments are completed as described in Paragraph 2.4, and then the BALANCE control is offset to provide the desired carrier level. The carrier level can be set to one half the amplitude of the linear portion of the envelope, and 100% linear amplitude modulation can be obtained. The operating conditions are best established while viewing the envelope with the setup described in Paragraph 2.4. Applied modulation voltage, BIAS, and BALANCE adjustments can then be made to give a triangular pattern with straight edges indicating 100% linear modulation, or any other percentage of modulation can be set by adjusting for the required trapezoidal pattern. The percentage modulation is given by the relationship

$$M = \frac{B - A}{B + A} \times 100 \text{ percent} ,$$

where M is the percentage of modulation, B is the height of the large end of the trapezoid, and A is the height of the small end of the trapezoid.

Any carrier level can be set, of course, for asymmetrical modulation. The modulation signal can include a d-c component to establish the carrier level, if desired, since the modulation input is d-c coupled. Television video signals, including d-c insertion, can therefore be accommodated. The resulting signal, however, will have double sidebands, so that if it is desired to simulate exactly a standard television signal a suitable filter must be provided at the output to secure vestigial-sideband operation.

Either polarity sense of modulation can be chosen by offsetting the d-c BALANCE in the proper direction.

One volt peak-to-peak at the MODULATION input will produce full modulation. Do not exceed 5 volts peak, positive or negative, or the crystal diodes may be damaged.

The 50-ohm MODULATION input impedance can be padded to a higher value if adequate modulation voltage is available. For example, an oscillator that provides 12 volts, peak-to-peak, into 600 ohms can be connected to the MODULATION input with a series 550-ohm resistor and give full modulation.

2.7 DOUBLE-SIDEBAND SUPPRESSED CARRIER

The Type 1000-P7 is a balanced modulator and, of course, can be used for any application requiring such operation. The output of a balanced modulator with a modulation signal applied is two sidebands with the carrier suppressed. For each component of frequency in the modulation signal there is generated a pair of sideband frequencies which are equal in frequency to the carrier frequency plus and minus the frequency of the modulation component. The amplitudes of the sidebands are proportional to the amplitude of the modulating signal component.

2.8 DETERMINING MODULATOR OUTPUT LEVEL

If a signal generator with a calibrated output system is used as the carrier source, a substitution measurement can be made to determine the magnitude of the r-f output voltage from the modulator. Since the value of r-f load impedance usually is not accurately known, the r-f output of a high-frequency signal generator is frequently expressed as a voltage in series with a specified resistance. General Radio high-frequency signal generators have output systems which indicate the voltage supplied in series with 50 ohms. In the description that follows it is assumed that this type of signal generator is used. In order to provide an equivalent source when using the Type 1000-P7 Balanced Modulator, a 50-ohm pad of at least 10-db attenuation, such as the Type 874-GG, must be used between the output of the modulator and the load. A 10-db pad limits the available r-f voltage to about 6 millivolts behind 50 ohms but provides a known source impedance. With pulse modulation, the setup described in Paragraph 2.4 for viewing the modulation envelope can be used to display a given reference level of r-f pulses out of the modulator. Pulses of sufficient length to fall within the bandwidth capabilities of the observing system must be used to establish the reference level. After the reference level is established, a c-w signal can be applied directly from the signal generator to the input of the receiver and the output voltage adjusted to obtain an indicated r-f level equal to the reference level. The output of the signal generator is then equal to the r-f pulse voltage behind 50 ohms.

In order to establish a given level, the procedure described above is reversed. First establish the required level with a c-w signal output of the signal generator, then insert the Type 1000-P7 Balanced Modulator and pad, and match the tops of the r-f pulses to the reference level. For these measurements the receiver gain must be the same with pulses and c-w so any AGC must be disabled.

If a d-c voltage equal to the peak amplitude of the applied modulating pulses is substituted for the pulse modulation source, an intercomparison of carrier level out of the modulator and the signal generator can be made on a carrier meter of a receiver. This gives a fairly accurate indication of the pulsed r-f level without using the more complicated setup.

For amplitude modulation, where all that is required is to check the r-f carrier level, the receiver carrier meter intercomparison described above is a satisfactory method.

2.9 CRYSTAL REPLACEMENT

To replace the crystal diodes, the adjustable line must first be removed from the basic Balanced Modulator unit. The two IN21-B Crystal Diodes are accessible by removing the appropriate coaxial connector. One crystal diode is attached to the center conductor of the ADJUSTABLE LINE connector nearest the r-f output, and the other is attached to the center conductor extension of the r-f output connector. To remove a connector, turn the ring, on which are imprinted the words "General Radio Co. Type 874," clockwise until it drops free of the threads. The ADJUSTABLE LINE connector nearest the r-f output must be removed first. After the threaded ring is free of threads, pull the outer sleeve and the connector will come off carrying the crystal diode on the center conductor. A knurled thumb nut holds the crystal unit in place and is removed by rotating counterclockwise, as viewed from the tip of the crystal.

The second crystal diode can now be removed by removing the r-f output connector. Do not attempt to do so before the other diode has been removed. The outer shell of the r-f output connector will usually come off without carrying the center conductor with it. Grasp the exposed center conductor and pull gently. Use caution, gently rocking the connector until the long center conductor extension can be withdrawn. There are projecting contact springs on this element, which may be damaged if excessive force is used. The crystal diode is held in place at the end of the center conductor with a knurled nut in the same manner as the other diode. Grasp the center conductor between the small coil and the crystal diode to prevent damage to the coil while removing the diode. To replace the diodes, reverse the procedure just described, replacing the r-f output connector assembly first.

Most IN21-B Crystal Diode units will function in the modulator, but the two diodes should be reasonably matched. There are wide deviations between the characteristics of individual crystal units, but the range of BIAS adjustment is sufficient for setting good modulation characteristics. As a rough guide, replacement crystals should have a matched d-c forward resistance of less than 300 ohms with 0.25 volt applied, and a back resistance of over 10,000 ohms with 1.5 volts applied.

Crystals should not require replacement unless excessive r-f or modulation voltage has been applied.

2.10 BATTERY REPLACEMENT

The battery consists of four easily obtained 1-1/2-volt, size D flashlight cells (Eveready 950 or equivalent).

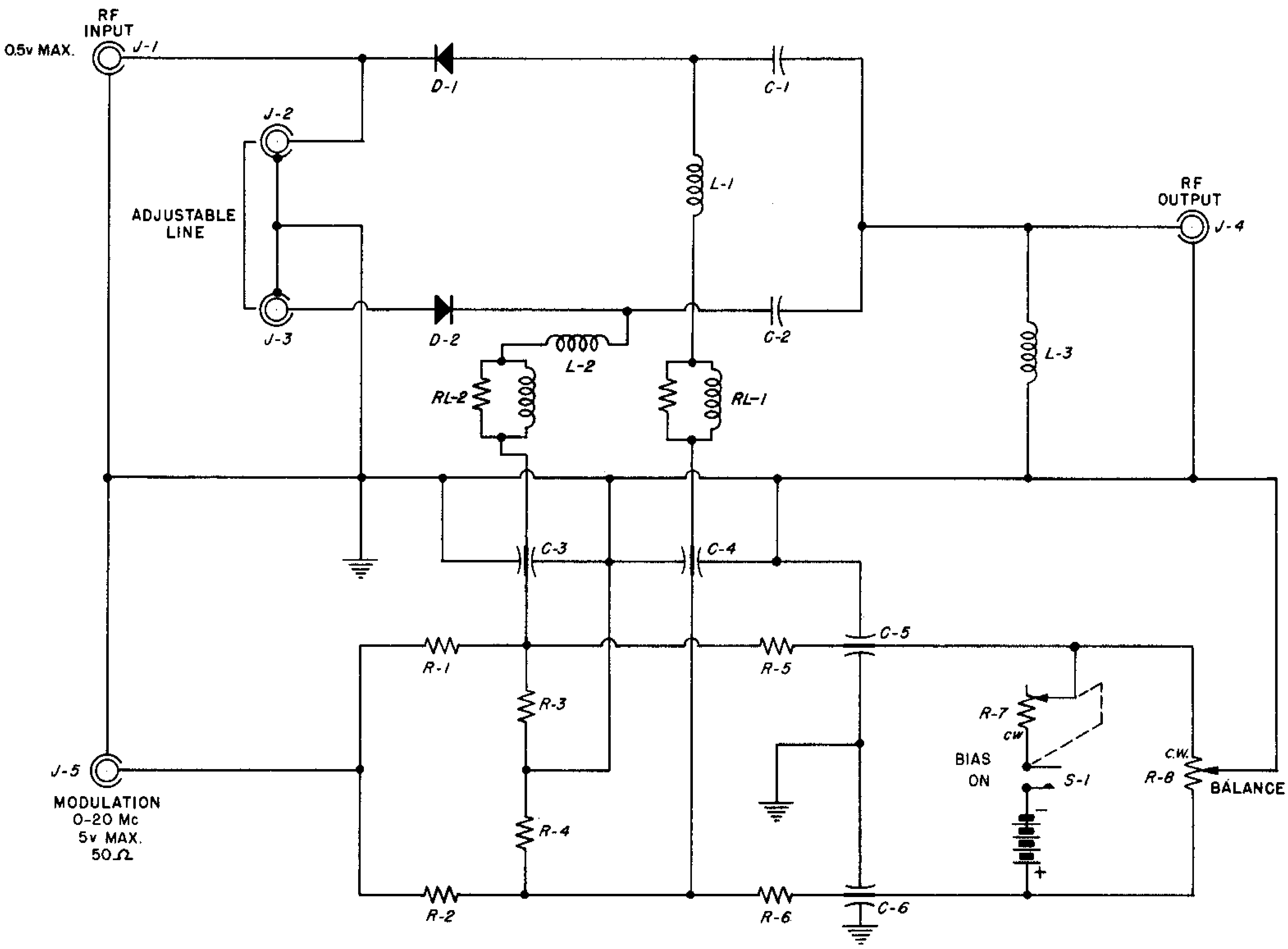
The ADJUSTABLE LINE must be removed from the basic Balanced Modulator unit in order to make the battery cover plate accessible. Remove the two thumb screws holding the cover in place. The cells can then be removed. Replace the cells in such a manner that the center or positive post of the first cell on the right-hand side contacts the spring marked +6 v (right-hand side looking into the battery compartment), and the case or negative connection of the first cell on the left-hand side contacts the spring marked -6 v. Each of the other two cells is placed facing the same direction as the cell immediately below it. Looking into the battery compartment, the cells on the left-hand side should have their center posts facing toward the observer and those on the right-hand side should have their center posts facing away.

For normal BIAS settings, the battery drain is low, giving a battery life of 1000 hours or better.

2.11 CONNECTORS

The terminals used on the Type 1000-P7 Balanced Modulator are General Radio Type 874 Coaxial Connectors. This universal-type connector has been designed especially for use in v-h-f and u-h-f measuring equipment. Its low standing-wave ratio makes it suitable for use over the entire u-h-f range. For use as accessories with the Type 1000-P7 Balanced Modulator, and other General Radio equipment, a complete line of coaxial elements is available, including tees, ells, rigid lines, patch cords, attenuators, adjustable lines, filters, and many others. Consult the latest General Radio Catalog for details, or write for literature.

TYPE 1000-P7 BALANCED MODULATOR



WIRING DIAGRAM FOR THE TYPE 1000-P7 BALANCED MODULATOR.
(60 TO 2500 MEGACYCLES)

PARTS LIST

RESISTORS

R-1	=	82 Ω	± 5%	REC-20BF
R-2	=	82 Ω	± 5%	REC-20BF
R-3	=	22 Ω	± 5%	REC-20BF
R-4	=	22 Ω	± 5%	REC-20BF
R-5	=	82 Ω	± 5%	REC-20BF
R-6	=	82 Ω	± 5%	REC-20BF
R-7	=	5 kΩ	±10%	POSC-19
R-8	=	500 Ω	±10%	POSC-7

CAPACITORS

C-1	=	25 to 28 μμf matched within 1/2 μμf		
C-2	=			
C-3	=	300 μμf	±10%	COU-8-2
C-4	=	300 μμf	±10%	COU-8-2
C-5	=	300 μμf	±10%	COU-8-2
C-6	=	300 μμf	±10%	COU-8-2

DIODES

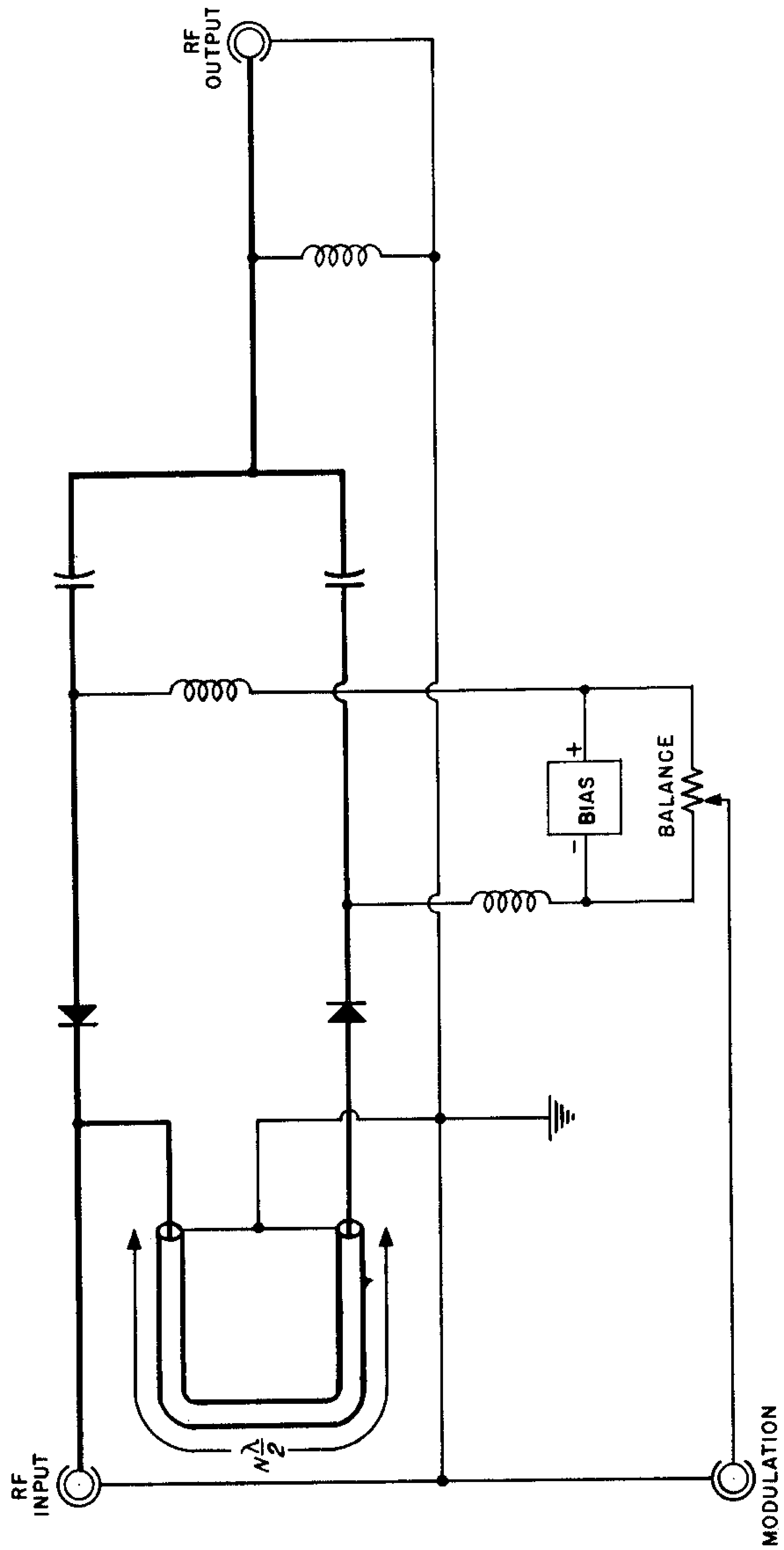
D-1	=	IN-21-B
D-2	=	IN-21-B

CHOKES

L-1	=	0.5 μh	1000-P7-26
L-2	=	0.5 μh	1000-P7-27
L-3	=	0.1 μh	1000-P7-86
RL-1	=	200Ω/1μh ±5%	1000-P7-29
RL-2	=	200Ω/1μh ±5%	1000-P7-29

MISCELLANEOUS

J-1, J-2, J-3, J-4, J-5	=	874
S-1	=	Part of R-7
B-1	=	6v (4x1-1/2v Burgess #2 or Eveready #950)



Elementary Schematic Diagram for the Type 1000-P7 Balanced Modulator.