INSTRUCTION MANUAL

TYPE 916-AL
RADIO-FREQUENCY
BRIDGE

Form 0916-0100-H
ID 1283
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GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

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SPECIFICATIONS

RANGES OF MEASUREMENT

Frequency: 50 kc/s to 5 Mc/s. Satisfactory operation for many measurements can be obtained at frequencies as low as 15 kc/s.

Reactance: ±11,000 Ω at 100 kc/s. This range varies inversely as the frequency; at other frequencies the dial readings must be divided by the frequency in hundreds of kc/s.

ΔX Dial: 100 Ω at 100 kc/s.

Resistance: 0 to 1000 Ω.

ACCURACY

Reactance: Below 3 Mc/s, $\pm(2\% + 0.2 \times \frac{100}{f_{kc}}\,\Omega + 3.5 f^2{}_{kc} R \times 10^{-10}\Omega)$, where R is the measured resistance in ohms and f_{kc} is the frequency in kc/s. The errors increase at frequencies above 3 Mc/s; at 5 Mc/s, the accuracy is $\pm(2\% + 0.01\Omega + 2.3R^{1.4} \times 10^{-3}\Omega)$.

Resistance: Below 5 Mc/s, $\pm(1\% + 0.1\Omega)$, subject to correction for residual parameters at low frequencies. The correction depends upon the frequency and upon the magnitude of the unknown reactance component.

GENERAL

Generator: External only (not supplied). TYPE 1330-A Bridge Oscillator, TYPE 1211-C Unit Oscillator, TYPE 1001-A Standard-Signal Generator recommended.

Detector: External only (not supplied). A heterodyne detector, the TYPE DNT-5, is recommended.

Accessories Supplied: 2 leads of different lengths to connect unknown impedance to bridge terminals; 2 input transformers, one to cover lower portion of frequency range, the other the higher portion; two TYPE 874-R22LA Patch Cords for connections to generator and detector.

MECHANICAL DATA Luggage-Type Cabinet, Shielded.

Width		*Height*		*Depth*		*Net Weight*		*Shipping Weight*	
in	*mm*	*in*	*mm*	*in*	*mm*	*lb*	*kg*	*lb*	*kg*
13½	345	17	435	11¼	290	34½	16	45	20.5

For a more detailed description, see *General Radio Experimenter*, March 1949.

U.S. Patent No. 2,548,457.

View of the Type 916-AL Radio-Frequency Bridge showing panel controls

Transformer removal.

TYPE 916-AL RADIO-FREQUENCY BRIDGE

1.0 DESCRIPTION

1.1 GENERAL DESCRIPTION

The Type 916-AL Radio-Frequency Bridge is a null instrument for use in measuring impedance at frequencies from 50 kc to 5 Mc. The low-frequency limit is mainly determined by sensitivity considerations and in most cases measurements can be made with slightly decreased accuracy at frequencies as low as 15 kc. Measurements can also be made at frequencies somewhat above the nominal upper limit with decreased accuracy and sensitivity.

The bridge is used with a series-substitution method for measuring an unknown impedance, Z_x, in terms of its series resistance component, R_x, and series reactance component, X_x. The resistance is read from a variable-capacitor dial directly calibrated in resistance (in ohms). The reactance is read from two variable-capacitor dials directly calibrated in reactance at 100 kc. The resistance dial reading is independent of frequency. The readings of the reactance dials increase linearly with frequency. For frequencies other than 100 kc the reactance dial readings must therefore be divided by the operating frequency in hundreds of kilocycles. The resistance dial reads from 0 to 1000Ω; the main reactance dial from 0 to 11,000Ω; and the incremental reactance dial from 0 to 100Ω at 100 kc.

1.2 BASIC CIRCUIT AND BALANCE CONDITIONS

The basic circuit used is shown in Figure 1.

A measurement is made by first balancing the bridge with the UNKNOWN terminals short-circuited, then rebalancing with the short-circuit removed and the unknown impedance connected to the UNKNOWN terminals.

When the UNKNOWN terminals are short-circuited, the bridge-balance conditions are:

$$R_P = R_B \frac{C_{A_1}}{C_N} \qquad (1)$$

$$\frac{1}{j\omega C_{P_1}} = \frac{R_B}{R_A} \frac{1}{j\omega C_N} \qquad (2)$$

When the short-circuit is replaced by the unknown impedance, $Z_x = R_x + jX_x$, the new balance equations are:

$$R_P + R_x = R_B \frac{C_{A2}}{C_N} \qquad (1a)$$

$$jX_x + \frac{1}{j\omega C_{P_2}} = \frac{R_B}{R_A} \frac{1}{j\omega C_N} \qquad (2a)$$

The unknown resistance, R_x, and reactance, X_x, are therefore related to the bridge parameters by the expressions:

$$R_x = \frac{R_B}{C_N} \left(C_{A_2} - C_{A_1}\right) \qquad (1b)$$

$$X_x = \frac{1}{\omega}\left(\frac{1}{C_{P_2}} - \frac{1}{C_{P_1}}\right) \qquad (2b)$$

The resistance, R_x, is seen to depend upon a change in capacitance C_A; the reactance, X_x, upon a change in capacitance C_P. The constant relating the resistance, R_x, to the change in capacitance, C_A, is determined by the fixed resistance, R_B, and fixed capacitance, C_N. The reactance, X_x, is equal to the change in reactance of the capacitor, C_P, and is opposite in sign.

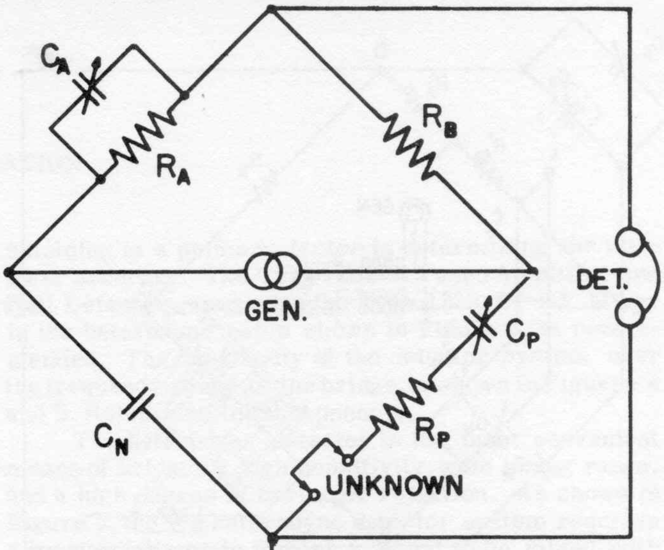

Figure 1. Basic circuit diagram of the Type 916-AL Radio-Frequency Bridge.

1.3 COMPLETE CIRCUIT

Figure 2 is a complete circuit diagram of the bridge.

Through the series-substitution method of measurement, simple relationships between the unknown resistance and reactance and increments of capacitance are obtained. In order to extend this simplicity of analysis to simplicity of operation, auxiliary controls not shown in the basic diagram of Figure 1 have been added. Their functions are most easily described when the resistance and reactance balances are considered separately.

The dial of the variable capacitor, C_A, that is used for resistance measurement, can be calibrated in resistive ohms, with any capacitance setting chosen as zero. For maximum resistance range, this setting is chosen at minimum capacitance. A small trimmer capacitance, C'_A, is then connected in parallel with the resistance capacitor, C_A, so that the initial resistance balance, with the UNKNOWN terminals short-circuited, can be made at zero dial setting, irrespective of slight changes in the bridge parameters with time or frequency.

The dial of the variable capacitor, C_P, used for the main reactance measurement, and the dial of the incremental reactance capacitor, C_P', can be calibrated in reactive ohms at any one frequency, again with any capacitance setting chosen as zero. For maximum reactance range and best scale distribution, this setting is chosen at maximum capacitance for both dials.

As shown in Equations (1), (1b), (2), and (2b) the resistance R_A affects only the initial reactance balance and has no effect on either the resistance or reactance dial calibrations. Therefore the resistor R_A can be made variable to allow the main reactance dial to be initially set at zero or at any other desired setting on the main reactance dial, irrespective of changes in the bridge parameters with time or frequency. Actually, R_A is used only as a coarse initial balance control, as it is a wire-wound rheostat, and the fine initial reactance balance is made with C_P'. With the zero position established at maximum capacitance, the dial scale reads inductive reactance directly; for measurements of capacitive reactance, the initial balance must be made at an up-scale reading so that the negative change in dial reading will remain on scale. In order to obtain maximum capacitive-reactance range and yet keep the range of the variable resistor, R_A, small to allow the maximum fineness of adjustment, a two-position switch that short-circuits a fixed resistor which is connected in series with the adjustable resistance is added. With the switch set in the L position, an initial balance can be obtained over the lower portion of the main reactance dial for measuring inductive reactances and small capacitive reactances; with it set in the C position, an initial balance can be obtained over the upper portion of the dial for measuring large capacitive reactances.

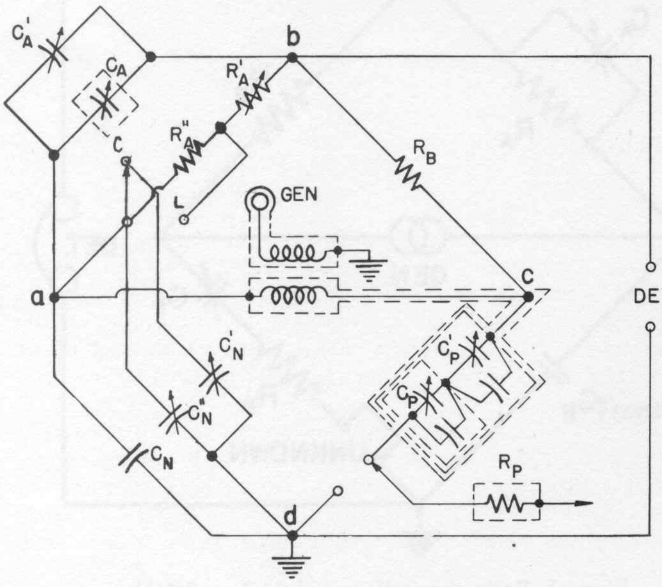

Figure 2. Circuit diagram of Type 916-AL.

The small variable capacitors, C_N' and C_N'' are used to equalize the capacitance from point "a" to ground in the two ratio-arm switch positions and to adjust the resistance dial calibration.

1.4 PANEL LAYOUT AND CONTROLS

The controls, plainly marked on the panel, are:

(1) The variable capacitor, C_P, used to measure reactance (X). The 4-inch dial of this capacitor is calibrated from 0 to 11,000Ω at a frequency of 100 kc. It is provided with a vernier knob for precise setting.

(2) The variable capacitor, C_P', used to measure incremental reactance (ΔX). The 2-3/4-inch dial of this capacitor is calibrated from 0 to 100Ω at 100 kc.

(3) The variable resistor, R_A, used to make the coarse initial reactance balance. The knob controlling this resistor is located below and to the right of the incremental REACTANCE dial.

(4) The two-position toggle switch used to establish the initial balance setting of the REACTANCE dial in the region about 0 or 11,000Ω. This switch is located immediately above the main REACTANCE dial. The two positions are marked L and C to indicate that the first is to be used when measuring inductive reactances and the second is to be used when measuring capacitive reactances. (See Paragraphs 2.6 and 2.71.)

(5) The variable capacitor, C_A, used to measure resistance (RESISTANCE). The 8-inch dial of this capacitor is calibrated from 0 to 1000Ω. It is provided with a slow-motion drive mechanism to facilitate precise setting.

(6) The trimmer capacitor, C_A', used to make the initial balance when the RESISTANCE dial is set at 0 ohms. The knob controlling this capacitor is located immediately below the RESISTANCE dial.

The two adjusting capacitors, C_N' and C_N'', are accessible through holes in the panel covered by snap buttons to the left of the RESISTANCE dial. They are set at the factory and should not be varied unless recalibration becomes necessary. (See Paragraph 3.1.)

The two coaxial terminals for making the input and output connections to the bridge are marked GEN and DET on the panel.

The binding post for making the ground connection to the unknown impedance is located on the panel to the left of the RESISTANCE dial. The other connection to the unknown impedance is made to the jack in the center of the circular window, at the left of the ground binding post, through one of the two special connecting leads supplied with the instrument. (See Paragraph 1.51.)

1.5 ACCESSORIES SUPPLIED

1.51 Connecting Leads: Two leads for connecting the unknown impedance to the bridge are supplied, one about five inches long, overall, and the other about twenty-seven inches. Each of these leads terminates at one end in a cylindrical metal probe, which houses a small fixed resistor and carries a plug to fit the jack provided on the bridge panel. The resistor is connected in series with the lead and is designated by Rp in Figures 1 and 2. Each lead terminates in a clip at the other end for convenience in connecting. One of the two leads supplied must always be used to connect to the unknown impedance since the bridge cannot be initially balanced without the resistor, R_p.

1.52 Shielded Transformers: Two transformers are supplied, one for use in the frequency range from 50 kc to 400 kc and the other from 400 kc to 5 Mc. The low-frequency transformer (Type 916-P1S1) is shipped in place. The high-frequency transformer (Type 916-P1) is held in a mounting affixed to the removable section of the instrument case.

NOTE

While markings on the Type 916-P1 indicate a range of 400 kc to 3 Mc, it performs effectively to 5 Mc.

1.53 Cables: Two Type 874-R22LA Patch Cords are supplied for connection to the generator and detector. These have a locking GR874 Connector on each end. If the generator or detector is fitted with other standard connectors, coaxial adaptors can be used for making the connection between the two types of connectors. Adaptors to several common types of connectors are available. For best results the detector should be fitted with a coaxial r-f input connector.*

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* It has been found that low-reactance connections between the outer condutors of the coaxial cables and the generator, bridge and detector panels are very important. Wherever possible, it is strongly recommended that coaxial terminals be used to complete the continuity of shielding.

2.0 OPERATION

2.1 GENERATOR

Any well shielded radio-frequency oscillator having an output voltage of the order of 1 to 30 volts and adequate frequency stability will serve as a generator. The Type 1330-A Bridge Oscillator is recommended.

2.2 DETECTOR.*

A sensitive, well-shielded detector system is a basic requirement. Detector sensitivity determines the resolution of bridge measurements and adequate shielding is a primary factor in determining the ultimate accuracy. The Type 1232-A Tuned Amplifier and Null Detector, used with the Type 1232-P1 RF Mixer in the heterodyne setup shown in Figure 3, is recommended. The sensitivity of the detector system over the frequency range of the bridge is shown in Figures 4 and 5. Refer also to the Appendix.

The heterodyne detector is the most convenient means of achieving high sensitivity, wide tuning range, and a high degree of harmonic rejection. As shown in Figure 3, the r-f heterodyne detector system requires a local oscillator to furnish a signal to be mixed with the rf output of the bridge. The Type 1232-A Null Detector functions as a sharply tuned i-f amplifier, with an adjustable gain of about 120 dB. Amplifier output is

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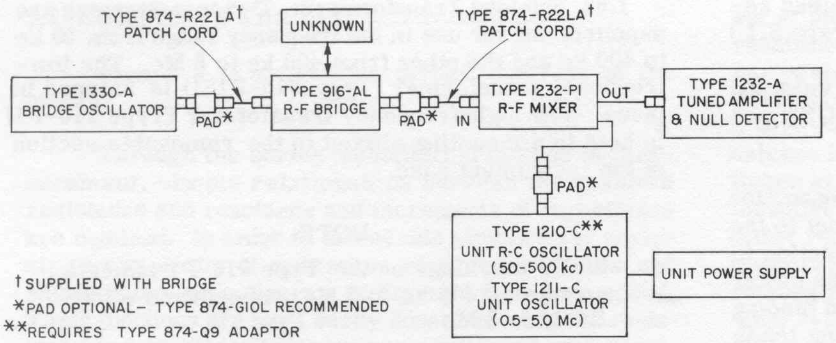
* For details, see the General Radio Experimenter, Vol 37, No. 12, Dec. 1963.



†SUPPLIED WITH BRIDGE
*PAD OPTIONAL– TYPE 874-G10L RECOMMENDED
**REQUIRES TYPE 874-Q9 ADAPTOR

Figure 3. Block diagram of the measurement system.

rectified and drives a wide-scale meter for excellent null resolution. At test frequencies below 500 kc, the switch-selectable mixer output is 20 kc, while at test frequencies above 500 kc, the mixer output is 100 kc (see Figure 4). Mixer crystal current, as indicated in Figures 4 and 5 for optimum detector sensitivity, can be set by adjustment of local-oscillator output and monitored by the meter mounted on the mixer.

A front-panel gain control on the Type 1232-A Null Detector permits continuous adjustment, over at least 85 dB of bridge output. This, plus a compression stage, keeps meter indications on-scale as the balance proceeds from a coarse initial setting to the deep null of the final setting. Thus, the detector system affords maximum utilization of the very fine resolution possible with the vernier adjustments on the RESISTANCE/REACTANCE controls of the bridge.

2.3 GROUNDING

The instrument should, in general, be grounded at a single point, through as low reactance a connection as possible. To facilitate making this connection a ground clamp is provided on the instrument case.

The ground lead should preferably be made with a short length of copper strip, say 1 inch wide. In laboratory set-ups a satisfactory "ground" can be obtained by covering the top of the bench with copper foil, even though the bench is physically far removed from ground. If the foil area is large enough, it will usually be found that a connection from it to ground, say through a steam radiator system, will make no appreciable difference in results*. In field set-ups the best "ground" is usually found to be some large metal structure, such as a relay rack.

If the grounding is not adequate, it will usually be found that the panel of the instrument is at a different potential from the hand of the operator and that the balance can be changed by touching the panel, and erroneous results will be obtained.

2.4 STRAY PICKUP

If the panel of the instrument is at ground potential but those of the detector and generator are not, it is

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* The foil area should be at least great enough so that the generator, bridge, and detector can all be placed upon it.

Figure 4. Sensitivity (open-circuit voltage from 50-ohm source, equivalent to noise level) and local-oscillator drive vs signal frequency.

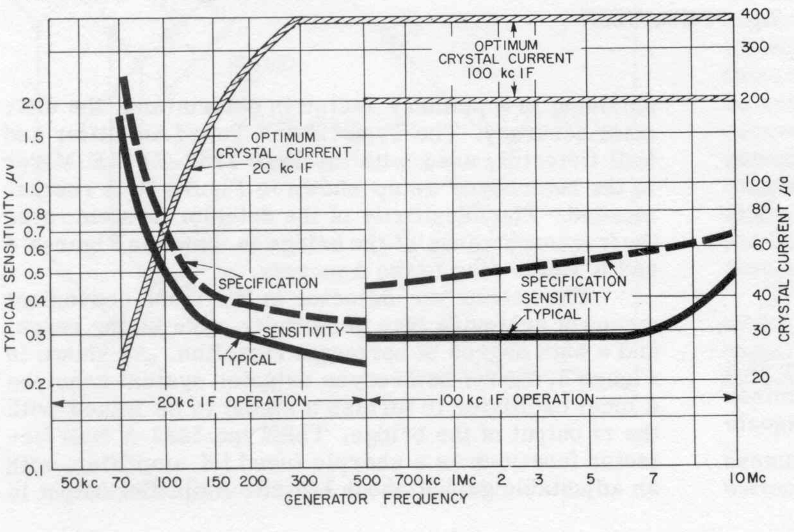
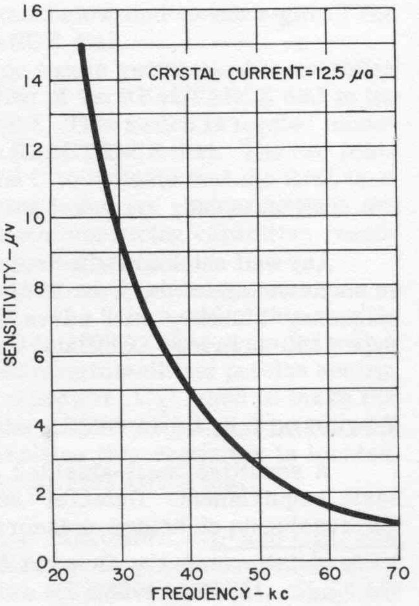


Figure 5. Typical sensitivity below 70 kc of Type 1232-A/-P1 detector system.



usually an indication of excessive reactance in the connections from the outer conductors of the coaxial leads to those panels. The use of Type 874 Coaxial Connectors, will generally eliminate these differences of potential. A further test for the existance of this condition can be made by removing the detector cable from the panel jack of the bridge. The detector pickup should be negligibly small if the generator is adequately shielded. If the outer shell of the Type 874 Connector can then be touched to the ground post of the bridge without significantly increasing the detector output, no excessive reactance exists.

If the detector, when disconnected from the bridge, shows considerable pickup, it is usually an indication of poor shielding in the generator or of energy transfer from the generator to detector through the power line.

It is sometimes found, in field setups where grounding conditions cannot be carefully controlled, that individual ground connections from the panels of the generator, bridge, and detector to a common ground point will give less pickup and more consistent results than a single common ground to the bridge alone. The use of coaxial connectors at both generator and detector is particularly recommended for these field setups to avoid, as much as possible, the necessity for such multiple ground connections.

2.5 TRANSFORMER INSTALLATION

The Type 916-P1S1 low-frequency transformer (50-400 kc) is shipped in place. To remove it, first remove the rectangular access section of the instrument case that is held in place by four Dzus fasteners. The Type 916-P1 high-frequency transformer (400 kc-5 Mc) is mounted on the inside of this removable section. Release the Allen-head screw in the side of the hexagonal lock nut at the GEN terminal and pull the Type 874 connector out of the terminal. With a 1 1/16-inch wrench, release the lock nut, support the transformer with one hand and unscrew the nut with the other. Disconnect the chrome plug appended to the transformer and remove the assembly through the case opening. (See the frontispiece photo.)

CAUTION

Do not force the assembly in this procedure as too much stress can damage the transformer.

In installation, the transformer slides into position as the coaxial terminal is plugged into the internal shielding assembly, and the lock nut of the terminal is screwed on from the front of the panel to secure the assembly. Care should be taken to see that the locating pin on the transformer is seated in the panel receptacle before the shell of the coaxial terminal is tightened.

The transformer that is not in use must be mounted on the removable section of the instrument case and the section secured in place by the Dzus fasteners whenever the instrument is operated. If the spare transformer is not mounted within the instrument the value of the capacitance C_N will differ from the value for which the resistance calibration was made and inaccuracy of resistance readings will result.

In order that the transformer in circuit may be identified easily, a pin is made to engage either of two holes in the panel. When Type 916-P1 Transformer is connected, the pin can be seen in hole engraved P1, and when the pin appears in P1S1 hole, the Type 916-P1S1 Transformer is in circuit.

2.6 INITIAL BALANCE

To place the instrument in operation, install the proper transformer for the frequency at which measurements are to be made, connect the generator and detector with the cables provided in the cover, and ground the instrument as described in Paragraph 2.3. Plug one of the two connecting leads into the panel jack and clip the free end to the ground binding post. If the circuit to be measured is known to have an inductive reactance, set the toggle switch to the L position, the RESISTANCE and main REACTANCE, X, dials to zero, and the incremental REACTANCE, ΔX, dial to 50. Roughly balance to a null by adjusting the two INITIAL BALANCE knobs. For a fine balance, use the incremental REACTANCE dial and the righthand INITIAL BALANCE knob, which is the initial resistance balance control. The initial reactance balance control is not suited for a fine balance as it is a wire-wound variable resistor and hence the resistance varies in steps as the slider moves from one wire to the next. If the circuit to be measured has a large capacitive reactance component, set the toggle switch in the C position, the RESISTANCE dial at zero, the main REACTANCE dial at 11,000, and the incremental REACTANCE dial at 50, and proceed in the same manner as outlined previously.

Since reactance is measured by the substitution method, the REACTANCE dials can be set initially at any desired point. In measuring many circuits it is advantageous to initially set the main REACTANCE dial at some point other than at 0 or 11,000. For instance, if the sign of the unknown reactance is undetermined, it is usually advisable to initially set the REACTANCE dial at some point above zero so the dial can be moved in either direction. In the general case a setting of about 5000 ohms with the toggle switch set in the C position is the most advantageous. This reactance setting permits a change in scale reading of 6000 ohms inductive or 5000 ohms capacitive. If the detector sensitivity control is turned down, this variable reactance range is sufficient to indicate the direction in which the dial must be turned for reactive balance and a new initial balance can be established accordingly. With the toggle switch in the L position, an initial balance can be obtained over the range from zero to about 3000 ohms. With the toggle switch in the C position, an initial balance can be obtained over the range from about 2000 to 11,000 ohms.

2.7 MEASUREMENT OF UNKNOWN IMPEDANCE

2.71 Impedance Components within Direct-Reading Ranges of Bridge: Connect the ground terminal of the unknown impedance to the ground binding post on the bridge panel with as short a lead as possible,* and arrange the setup so that the ungrounded terminal of the unknown impedance can be reached with one of the two connecting leads supplied, preferably the short one. Clip the connecting lead to the ground terminal of the unknown impedance† and establish an initial balance as described in Paragraph 2.6. Remove the connecting lead clip from the grounded terminal of the unknown impedance, clip to the ungrounded terminal, and rebalance with the RESISTANCE and main REACTANCE controls alone or with the help of the incremental REACTANCE control. If the incremental REACTANCE dial is used, set the main REACTANCE dial to the calibrated point nearest the null and make the final adjustment with the incremental REACTANCE control. For small reactances the incremental REACTANCE dial only should be used. In shifting the clip from the grounded to the ungrounded terminal, the location of the connecting lead should be altered as little as possible to minimize the change in the effective inductance of the lead between the two balances.

The unknown resistance is read directly from the RESISTANCE dial; the unknown reactance is equal to the algebraic sum of the changes in the settings of the main and incremental REACTANCE dials divided by the frequency in hundreds of kilocycles.

When the capacitive reactance is small, the precision of measurement may be low if the REACTANCE dial is initially set at 11,000 due to the cramping of the scale at the high-reactance end. When a measurement is made and this is found to be the case, the accuracy can be improved greatly by remeasuring the circuit with the initial setting of the REACTANCE dial changed to a reading slightly greater than the difference in the dial readings obtained in the first measurement. In this manner the maximum accuracy of the bridge can be utilized.

Another method of achieving the same result is to set the RESISTANCE dial to R_x, the main REACTANCE dial to zero, the incremental REACTANCE dial to 50, and clip the connecting lead to the ungrounded terminal of the unknown impedance. First attempt to obtain an initial balance as previously outlined with the toggle switch set in the L position. If no balance is obtainable, try setting the toggle switch in the C position. After an initial balance is obtained, clip the connecting lead to the grounded terminal and rebalance with the RESISTANCE and REACTANCE dials. The REACTANCE dials will then read up-scale for capacitive reactance and the precision of reading will then be the same as for inductive reactance. This method of reading capacitive reactance has the disadvantage of requiring four balances, one pair to determine the resistive component and the other to determine the reactive component.

2.72 Impedance Components outside Direct-Reading Ranges of Bridge: If the resistance or reactance component of the unknown impedance falls outside the direct-reading range of the bridge, indirect measurements can be made through the use of an auxiliary parallel capacitor.

When a pure reactance, jX_a, is connected in parallel with the unknown impedance, $Z_x = R_x + jX_x$, the effective input impedance, $Z_e = R_e + jX_e$, becomes:

$$R_e = \frac{R_x X_a^2}{R_x^2 + (X_x + X_a)^2} \tag{3}$$

$$X_e = \frac{X_a \left[R_x^2 + X_x(X_x + X_a)\right]}{R_x^2 + (X_x + X_a)^2} \tag{4}$$

As X_a is made smaller, these equations approach zero, in the limit, according to the relations

$$R_e = X_a^2 \frac{R_x}{R_x^2 + X_x^2} \tag{3a}$$

$$X_e \cong X_a \tag{4a}$$

"Shunting down" a high impedance with a parallel capacitor will, accordingly, bring either or both the resistance and reactance components within the measurement range of the bridge.

To measure a high impedance by this method, connect one lead of the auxiliary capacitor to the ground terminal of the unknown impedance and locate the other lead near the ungrounded terminal of the unknown impedance. Establish an initial balance as described in Paragraph 2.6 and measure the capacitive reactance, X_a, of the auxiliary capacitor as described in Paragraph 2.71. Connect the ungrounded lead of the auxiliary capacitor to the ungrounded terminal of the unknown impedance, using as nearly as possible the same auxiliary-capacitor lead length as was used in making the reactance measurement, and measure the effective impedance, $Z_e = R_e + jX_e$, of the parallel combination. The unknown impedance can then be found from the relations

$$R_x = \frac{R_e (X_a)^2}{(R_e)^2 + (X_e - X_a)^2} \tag{5}$$

$$X_x = -\frac{X_a \left[(R_e)^2 + X_e(X_e - X_a)\right]}{(R_e)^2 + (X_e - X_a)^2} \tag{6}$$

It should be noted that, since the auxiliary reactance, X_a, is capacitive, the number to be inserted for X_a in Equations (5) and (6) will be negative. The sign

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* For an inherently grounded impedance, for instance an antenna, this ground connection can be dispensed with since the bridge is already grounded through a low-reactance connection.

† For an inherently grounded impedance, the connecting lead can be clipped to the ground binding post on the bridge panel.

of the number for the effective reactance, X_e, will be positive or negative accordingly as the measured value is inductive or capacitive.

The value of the auxiliary capacitance to use is easily found by experiment. It should be kept reasonably small so that the impedances to be measured are not reduced so far that precision of dial readings is lost, but it will not ordinarily be found critical. A value between 160 $\mu\mu$f and 1000 $\mu\mu$f will usually be found adequate. The resistance, R_a, of the auxiliary capacitor is generally negligible but can be corrected for, when necessary, by subtracting from the effective resistance, R_e, of the parallel combination, a resistance,

$$R = R_a \frac{X_e^2 + R_e^2}{X_a^2} \qquad (7)$$

The corrected value of R_e can then be substituted in Equations (5) and (6).

2.73 Lead Corrections: In common with other types of impedance-measuring equipment, the bridge can only measure impedance at its own terminals. The residual impedances of the leads used to connect the unknown impedance to these terminals, however, often causes this impedance to differ from the impedance appearing at the terminals of the device under test. Under some circumstances the difference can be ignored and the measured impedance taken as the impedance of the device under test, including the leads. In most cases, however, the device will not be used with the same leads used to connect it to the measuring instrument and it is necessary to compensate for the effect of these leads to obtain the desired impedance. An exact correction for the effect of the leads requires analysis as a transmission line and is laborious and cumbersome. For specific measurements, however, approximate corrections will yield satisfactory accuracy.

In the procedure outlined in Paragraphs 2.6 and 2.71 for measuring impedance components within the direct-reading ranges of the bridge it is noted that the length and location of connecting leads to the unknown impedance should be altered as little as possible when the clip is shifted for initial and final balances. This precaution assures that the inductive reactance of the leads is very nearly equal under the two conditions and that it therefore cancels out in the series-substitution process. The capacitance to ground of a connecting lead, however, will cause errors in measurement that increase as the frequency is raised.

Since the capacitance of a connecting lead to ground has the same effect as a capacitance deliberately placed in parallel with the unknown impedance, the corrections for its effect can be obtained directly from Equations (5) and (6), where $Z_e = R_e + jX_e$ is the observed impedance, and X_a the reactance of the lead capacitance. The reactance, X_a, however, is usually very high compared to both R_x and X_x and the equations can be written in the simple, approximate form

$$R_x = R_e \left[1 + 2\frac{X_e}{X_a} + 3\,{\frac{X_e}{X_a}}^{2} - {\frac{R_e}{X_a}}^{2}\right] \qquad (5a)$$

$$X_x = X_e + \frac{X_e^2 - R_e^2}{X_a} + \frac{X_e}{X_a}\left(\frac{X_e^2 - 3R_e^2}{X_a}\right) \qquad (6a)$$

Equations (5a) and (6a) contain both first and second order correction terms; however, in many cases the second order terms are negligibly small and can be neglected.

It should be noted that, since X_a is capacitive, the number to be inserted for X_a in Equations (5a) and (6a) is negative. If the connecting leads are kept at a reasonable distance from metal objects, say an inch or more at the closest point, their capacitances to ground are, approximately:

Short connecting lead (916-P3) - 3.2 $\mu\mu$f
Long connecting lead (916-P4) - 8.5 $\mu\mu$f*

For convenience in making corrections, the reactances corresponding to these capacitances are plotted in Figure 6.

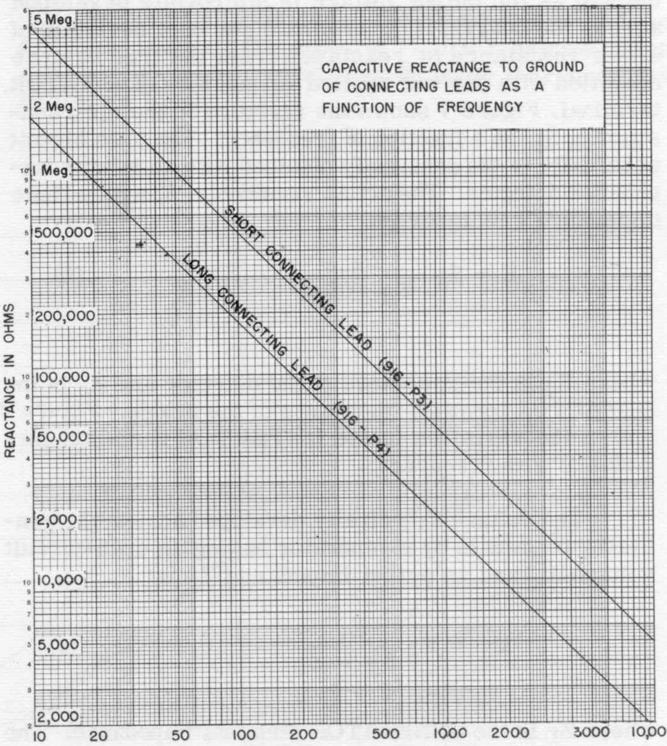

Figure 6.

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*This capacitance was measured with lead held about 6 inches away from the panel, on the average. It will depend more upon the position of the lead than will the capacitance of the short lead.

When measurements are made of impedance components beyond the direct-reading ranges of the bridge, no lead corrections are necessary. Precaution in keeping the length and position of the connecting lead as nearly the same as possible insures constant inductance, which cancels out in the series-substitution process; the reactance of the connecting-lead capacitance to ground is included in the measured reactance, X_a, of the parallel capacitor.

It should be emphasized that the above treatment of lead corrections is approximate. If, for instance, the inductive reactance of the connecting lead is comparable to the unknown impedance, the voltage to ground will vary along the lead and the effective capacitance to ground will not be the same as it is when the inductive reactance of the lead is small compared to the unknown impedance. When the unknown impedance is zero, in fact, the effective capacitance to ground of a connecting lead will be only one third the static value. In compensation, it should be noted that the lower the unknown impedance, the less the effect of lead capacitance. Obviously, the shorter the connecting lead, the smaller will be the lead corrections and the more nearly exact Equations (5a) and (6a). The short connecting lead (916-P3) should therefore be used wherever possible, especially at the higher frequencies. To aid in estimating the inductive reactance of the leads relative to the unknown impedance, approximate inductance values are given below:

Short lead (916-P3) - 0.05 μh
Long lead (916-P4) - 0.6 μh

2.74 Sensitivity: The sensitivity, S, of the bridge is defined as the output voltage in microvolts developed across the DETECTOR terminals per ohm deviation of either resistance or reactance from the true balance condition with one volt applied across the GENERATOR. terminal. Figure 7 shows the variation in the open sensitivity, S_o, as a function of frequency. The open circuit sensitivity is the sensitivity obtained with an infinite impedance detector. The actual sensitivity, S, with a finite impedance generator is:

$$S = S_o \frac{Z_d}{Z_d + Z_o} \tag{8}$$

where Z_d is the impedance of the detector and Z_o is the DETECTOR terminal impedance of the bridge. Figure 8 shows the variation in the DETECTOR terminal impedance with frequency.

The voltage E_i actually developed across the generator terminals by a generator having an open-circuit voltage E_g and an output impedance Z_g is:

$$E_i = E_g \frac{Z_i}{Z_g + Z_i} \tag{9}$$

where Z_i is the GENERATOR terminal impedance. The GENERATOR terminal impedance is plotted as a function of frequency in Figure 9.

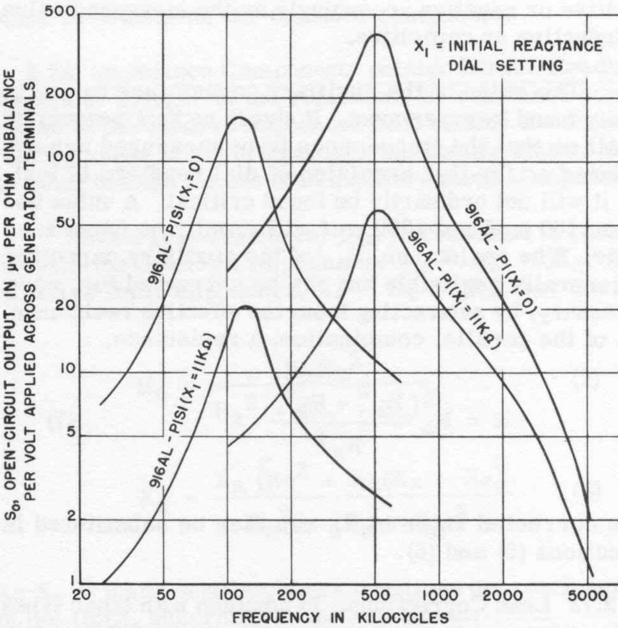


Figure 7. Open-circuit sensitivity of signal bridge

The actual voltage E_o developed across the DETECTOR terminals per ohm of unbalance is then:

$$E_o = SE_i \tag{10}$$

In measuring antennas and other types of circuits, in many cases a great deal of noise and other extraneous signals are picked up by the circuit under test and tend to obscure the null, thus effectively decreasing the sensitivity. Of course, the increasing generator voltage is one method of overcoming this effect. However, the use of a null detector with sufficiently narrow bandwidth is also helpful, and in many cases a considerable improvement can be obtained by reversing the generator and detector connections; that is, connecting the signal generator to the DETECTOR terminals and the detector to the GENERATOR terminals.

2.75 Corrections for Residual Parameters: Frequency limits for accurate operation of radio-frequency impedance-measuring equipment are nearly always determined by residual parameters, in the wiring and in the impedance elements, that are not accounted for in the basic theory of operation. While these have been made extremely small in the bridge, they are still large enough to affect performance at the lowest and at the highest frequencies and to set the respective limits of operation at about 50 kc and 5 Mc.

The low-frequency limitation arises from dielectric loss in the REACTANCE capacitor, Cp. This loss causes an effective series resistance that varies with the dial setting and the frequency as shown in Figure 10. Since the resistance changes with the setting of the REACTANCE capacitor, incorrect measurements of the

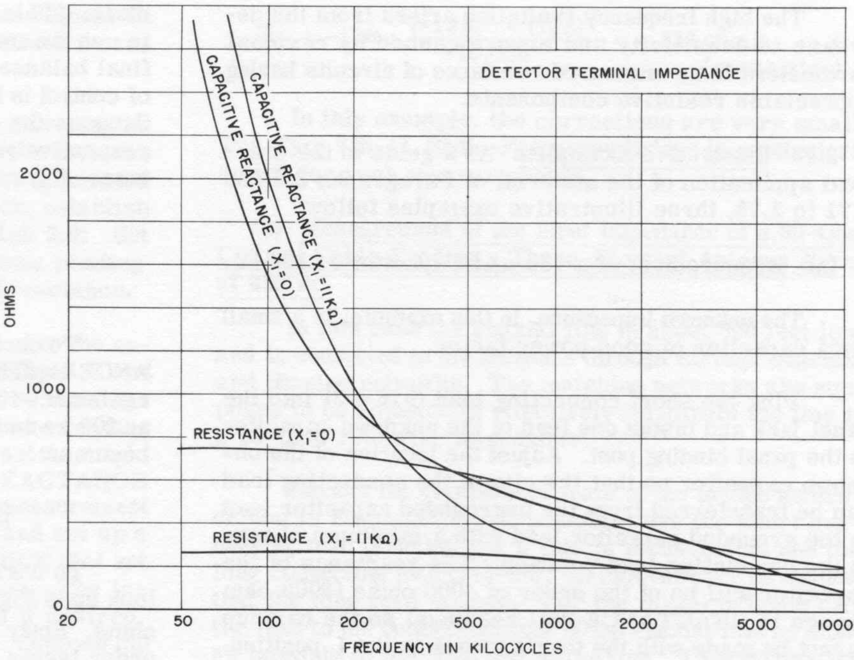


Figure 8. Detector terminal impedance

resistive components of impedances with substantial reactive components will occur unless corrections are made. The change of resistance is such that resistance associated with capacitive reactance will appear too low, resistance with inductive reactance too high. From the curves it is evident that reactance measurements should be made at the low-reading end of the **REACTANCE** dial whenever possible in order to minimize corrections for dielectric loss. In some cases when a very low-loss capacitor is measured, the indicated resistance will be negative before correction for the dielectric loss in the **REACTANCE** capacitor. In order to bring the resistance reading on-scale, the **RESISTANCE** dial can be initially set upscale or the initial balance can be made with the **RESISTANCE** dial set at zero and the clip lead connected to the ungrounded terminal, as described at the end of Paragraph 2.71. In the latter case, a negative measured resistance will read upscale.

In spite of the effect of dielectric losses and the decrease in sensitivity noted in Figure 7, in most cases satisfactory measurements can be made at frequencies as low as 15 kc.

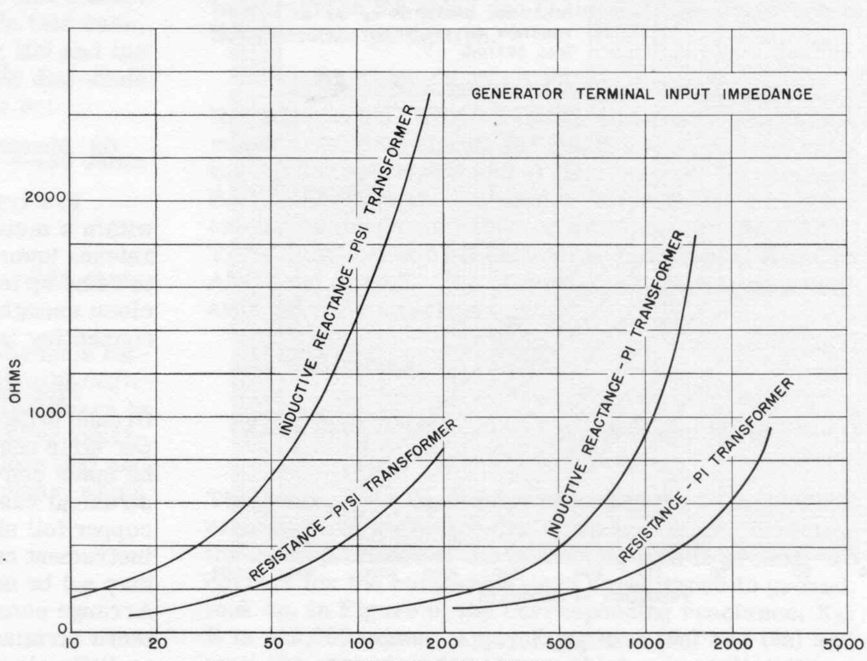


Figure 9. Generator terminal input impedance.

The high frequency limitation arises from the decrease in sensitivity and errors caused by residual parameters in the measured reactance of circuits having appreciable resistive components.

2.76 Illustrative Examples: As a guide to the practical application of the material of Paragraphs 2.6 and 2.71 to 2.75, three illustrative examples follow:

(a) Measurement of a 185 $\mu\mu$f Capacitor at 200 kc.

The unknown impedance, in this example, is a small mica capacitor of good power factor.

Plug the short connecting lead (916-P3) into the panel jack and fasten one lead of the unknown capacitor to the panel binding post. Adjust the location of the unknown capacitor so that the clip of the connecting lead can be transferred from the ungrounded capacitor lead to the grounded capacitor lead with a minimum change in the connecting lead position. The reactance of the capacitor will be of the order of 4000 ohms (8000 ohm change in REACTANCE dial readings) so the balance cannot be made with the toggle switch in the L position.

With the switch set in the C position, set the main REACTANCE dial to 9000 ohms to obtain the maximum dial reading accuracy, the incremental REACTANCE dial to 50, and set up the initial balance as described in Paragraph 2.6.

Then transfer the clip of the connecting lead to the ungrounded lead of the unknown capacitor and rebalance with the RESISTANCE and main REACTANCE dials. (This reactance is so large it is not necessary to use the incremental REACTANCE dial in making the final balance. However, it can be used if the fineness of control is found desirable for making the final balance.) Suppose the final dial readings are 3.1 and 560 ohms respectively. Before corrections, the observed resistance, R_e, and reactance, X_e, are:

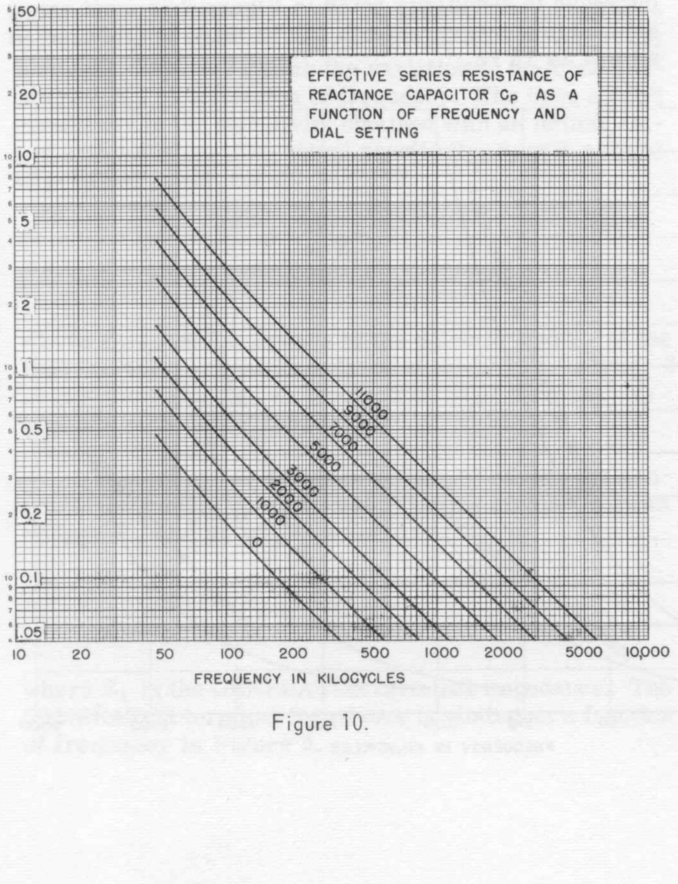


Figure 10.

$$R_e = 3.1 \text{ ohms}$$

$$X_e = \frac{560-9000}{2} = -4220 \text{ ohms}$$

To correct for dielectric loss in the main REACTANCE capacitor, look up the effective reactance capacitor resistance for dial settings of 9000 ohms and 560 ohms at 200 kc in Figure 10. The corrected value of kc then becomes:

$$R_e' = 3.1 + 1.0 - 0.1 = 4.0 \text{ ohms}$$

To correct for the connecting-lead capacitance, look up in Figure 6 its reactance at 200 kc. It is -250,000 ohms. Apply Equations (5a) and (6a) and omit the second-order terms as they are negligible in this case:

$$R_x = 4.0 \left[1 + 2\left(\frac{-4220}{-250,000}\right)\right] = 4.1 \text{ ohms}$$

$$X_x = -4220 + \frac{(-4220)^2}{-250,000}$$

$$= -4291 \text{ ohms (capacitive)}$$

From these measurements, the capacitance, C_x, and the dissipation factor, $D_x = \frac{R_x}{X_x}$, are:

$$C_x = \frac{10^{12}}{2\pi \times 0.2 \times 10^6 \times 4291} = 185\ \mu\mu f$$

$$D_x = \frac{4.1}{4291} = 0.00096 = 0.096\%$$

(b) Measurement of a Broadcast Antenna at 1170 kc.

In a typical case, the antenna terminal is located within a metal rack in a small house at the foot of the antenna tower. The bridge can be set up on packing boxes to come up to the front of the rack but cannot be brought close enough to the antenna terminal to use the short connecting lead (916-P3).

Plug long connecting lead (916-P4) into panel jack. Ground bridge to rack with short lead, preferably of copper strip one inch or so wide. If this connection cannot be made conveniently to the clamp provided on the instrument case the panel can be loosened and a piece of copper foil slid onto the crack between the panel and the instrument case. Do not ground to panel screws as they may not be making contact to the panel because of paint. Arrange connecting lead so that it can be clipped to antenna terminal or to nearest ground point on rack with as little change in physical location as possible. The lead should be kept as far away from metal objects as possible throughout its length by any convenient means such as suspending it with string.

Suppose the antenna to be about 0.6 wavelengths long with an impedance having a capacitive reactance component. With the toggle switch set in the C position and the connecting lead grounded to the rack, establish an initial balance as described in Paragraph 2.6. Set the main REACTANCE dial to 11,000 ohms pending further knowledge of the magnitude of the reactance.

Transfer the clip of the connecting lead to the antenna terminal and rebalance with the RESISTANCE and REACTANCE dials. Suppose the respective readings are 193 ohms and 9500 ohms. The resistance reading is adequate but the reactance reading is not as might be desired because of crowding of the REACTANCE scale. To obtain a more precise reactance measurement throw the toggle switch to the L position, and set up a new initial balance with the main REACTANCE dial set at 1700 ohms. Then remeasure the antenna. The incremental REACTANCE dial can be used if desired, but it is probably not necessary in this case. Suppose the incremental REACTANCE dial is not used and the final RESISTANCE and REACTANCE dial readings are 193 and 180 respectively. Before corrections, the observed resistance, R_e, and reactance, X_e, are:

$$R_e = 193 \text{ ohms}$$

$$X_e = \frac{-1620}{11.7} = -138 \text{ ohms}$$

If the incremental REACTANCE dial is used for the fine balance and its initial setting was 54, the main REACTANCE dial should be set to the multiple of 100 ohms nearest the apparent null before the incremental REACTANCE dial is touched. Then make the fine balance with the incremental REACTANCE dial. In this case, the main REACTANCE dial would be set at 200 and the final reading of the incremental REACTANCE dial would be 34. The observed reactance would then be:

$$X_e = \frac{(200 - 1800) + (34 - 54)}{11.7} = \frac{-1620}{11.7} = -138 \text{ ohms}$$

or

$$X_e = \frac{(200 + 34) - (1800 + 54)}{11.7} = \frac{-1620}{11.7} = -138 \text{ ohms}$$

The corrections for dielectric loss in the main REACTANCE capacitor are seen from Figure 10 to be negligible. To correct for the connecting-lead capacitance to ground, look up, in Figure 6, the corresponding reactance, X_a. It is -16,000 ohms. Apply Equations (5a) and (6a) and omit the second-order correction terms, which are negligible:

$$R_x = 193 \left[1 + 2\left(\frac{-138}{-16{,}000}\right)\right] = 196 \text{ ohms}$$

$$X_x = -138 + \frac{(-138)^2 - (193)^2}{-16{,}000} = -137 \text{ ohms} \quad \text{(capacitive)}$$

In this example, the corrections are very small. The Type 916-AL Radio-Frequency Bridge is particularly suited for such measurements.

(c) <u>Measurement of the Input Impedance of a 50-Ohm Coaxial Cable Feeding a Three-Element Antenna Array at 850 kc.</u>

In this case the coaxial line is about 500 feet long and is connected to the antennas through various matching and phasing networks. The matching networks are supposed to be adjusted to effectively terminate the line in a 50-ohm resistive impedance.

Connect the ground terminals of the bridge as described in Example (b). If possible, use the short connecting lead (916-P3) but if this is inconvenient use the long connecting lead (916-P4). In this case let us assume that the long lead is used. For the initial balance clip the lead to the outer conductor of the coaxial line as close as possible to the open end of the line. This throws the inductance of the ground connections into the initial balance where they have no effect on the measurements. Make sure that the lead can be clipped on to the center conductor of the coaxial line with as small a change in the position of the lead as possible. If desired, the lead can be left clipped on the center conductor and the short circuit for the initial balance made by shorting the end of the coaxial line with a low inductance strap or sheet.

In this case, the measured reactance should be small, but its sign is unknown. Therefore, for the initial balance set the toggle switch in the L position, the main REACTANCE dial at 100 and the incremental REACTANCE dial at 50. Set up the initial balance as described in Paragraph 2.6 using one of the methods described in the previous paragraph.

Suppose after the initial balance has been obtained, the incremental REACTANCE dial reads 49. Then, remove the short circuit and obtain a final balance using the RESISTANCE dial and at first only the incremental REACTANCE dial. Suppose it is found that a balance can be obtained under these conditions with the RESISTANCE dial set at 51 ohms and the incremental REACTANCE set at 45.2. The observed resistance and reactance before corrections are:

$$R_e = 51 \text{ ohms}$$

$$X_e = \frac{45.2 - 49.0}{8.5} = -0.45 \text{ ohms (capacitive)}$$

The corrections for dielectric loss in the REACTANCE capacitor are negligible, but there is a small correction for the capacitance of the connecting lead to ground. To correct for the connecting-lead capacitance to ground, look up, in Figure 6, the corresponding reactance, X_a. It is -22,000 ohms. Apply Equations (5a) and (6a) and omit the second-order terms which are negligible:

$$R_x \cong R_e = 51.0 \text{ ohms}$$

$$X_x = -0.45 + \frac{(-0.45)^2 - (51)^2}{-22{,}000} = -0.45 + 0.12 = -0.33 \text{ ohms}$$

2.77 Balanced Lines and Antennas: The measurement of three-terminal devices, such as balanced lines and antennas, can be made with the bridge, although the computations involved are quite laborious.

The method depends upon the analysis of the unknown impedance in terms of the equivalent circuit of Figure 11 and requires three separate measurements, as follows:

(1) Short-circuit impedance Z_1 by grounding line A at point of measurement, and measure impedance Z' from line B to ground.

$$Z' = \frac{Z_2 Z_3}{Z_2 + Z_3} \qquad (11)$$

(2) Short-circuit impedance Z_2 by connecting line A to line B at point of measurement, and measure impedance Z'' from the junction to ground.

$$Z'' = \frac{Z_3 Z_1}{Z_3 + Z_1} \qquad (12)$$

(3) Short-circuit impedance Z_3 by grounding line B at point of measurement, and measure impedance Z''' from line A to ground.

$$Z''' = \frac{Z_1 Z_2}{Z_1 + Z_2} \qquad (13)$$

Combining Equations (11), (12), and (13) gives:

$$Z_1 = \frac{2Z'Z''Z'''}{Z'Z'' - Z''Z''' + Z'''Z'}$$

$$= \frac{2}{-\frac{1}{Z'} + \frac{1}{Z''} + \frac{1}{Z'''}} \qquad (14)$$

$$Z_2 = \frac{2Z'Z''Z'''}{Z'Z'' + Z''Z''' - Z'''Z'}$$

$$= \frac{2}{\frac{1}{Z'} - \frac{1}{Z''} + \frac{1}{Z'''}} \qquad (15)$$

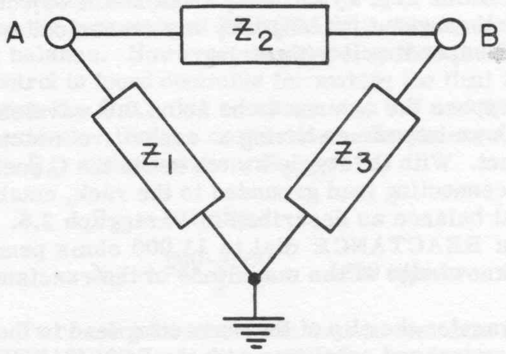


Figure 11. Equivalent circuit of a balanced line.

$$Z_3 = \frac{2Z'Z''Z'''}{-Z'Z'' + Z''Z''' + Z'''Z'}$$

$$= \frac{2}{\frac{1}{Z'} + \frac{1}{Z''} - \frac{1}{Z'''}} \qquad (16)$$

This method gives each component of impedance, detecting any unbalance. At perfect balance, $Z_1 = Z_3$, $Z' = Z'''$.

$$Z_1 = Z_3 = 2Z'' \qquad (14a)$$

$$Z_2 = \frac{2Z'Z''}{2Z'' - Z'} = \frac{1}{\frac{1}{Z'} - \frac{1}{2Z''}} \qquad (15a)$$

When the balanced line is fed from a balanced source, the effective input impedance is given by

$$Z_{AB} = \frac{2Z_1 Z_2}{2Z_1 + Z_2} = \frac{4Z'Z''}{4Z'' - Z'} \qquad (17)$$

Z_{AB} is the input impedance seen from the source. It should be measured once with the far end of the line open and once with it closed if it is desired to compute the characteristic impedance and propagation constant by the usual method. No grounds should be made to the line at any point other than the input when making measurements.

In Equations (14) to (17) the component impedances must, of course, be written in their complex forms.

3.0 CHECKS AND ADJUSTMENTS

3.1 RESISTANCE CALIBRATION

If the calibration of the RESISTANCE dial changes slightly, with time or rough usage, it can be restored by adjusting the trimmer capacitors C_N' and C_N'' (see Figure 2), which are mounted behind snap buttons on the panel. C_N', mounted behind the left-hand snap button, adjusts the RESISTANCE dial span with the toggle switch set to the L position; C_N'', mounted behind the right-hand snap button, adjusts the RESISTANCE dial span with the toggle switch set to the C position.

To check the calibration, measure at 100 kc the resistance of a good radio-frequency resistor, preferably a carbon or metal-film type. The measured resistance should check the d-c value within 1%. If it does not, adjust C_N' and C_N''. First adjust C_N'' with the toggle switch in the C position and then C_N' with the toggle switch in the L position. Turning these capacitors clockwise decreases the dial reading for a given resistance and vice versa.

Similar trimmer capacitors are mounted on the two transformers. If measurements of the same resistor at 400 kc made with the two transformers are not the same, the trimmer capacitor on the high-frequency transformer (400 kc - 5 Mc) can be adjusted to bring them into agreement. Unless the transformers are subjected to abuse these capacitors should not require adjustment.

3.2 CORRECTION FOR DIELECTRIC LOSS IN REACTANCE CAPACITOR

The dielectric loss described in Paragraph 2.75 is subject to some variation among different instruments because of variations in the ceramic insulation, and the curves of Figure 10 may not be sufficiently accurate for the most refined work. An independent check of the resistance of this capacitor at any frequency can be made by measuring the resistance of a 1000 $\mu\mu$f capacitor at the frequency in question as follows:

First measure the resistance of the capacitor with an initial REACTANCE dial setting of 11,000 ohms (switch in C position). Say the reading is:

$$R_{e_1} = +0.10 \text{ ohms}$$

If a very low-loss capacitor is measured, R_e may be negative. In this case, set the RESISTANCE dial initially up-scale by the amount necessary to bring the final reading on scale or use the method described at the end of Paragraph 2.75 with the RESISTANCE dial initially set at zero. In either case, do not forget to indicate the sign of the measured resistance.

Now reset the REACTANCE dial to 1592 ohms, the switch in the L position, and obtain a new initial balance. Then measure the resistance of the 1000 $\mu\mu$f capacitor again. Say this reading is:

$$R_{e_2} = +0.55 \text{ohms}$$

Then take the algebraic difference, ΔR, between R_{e2} and R_{e1}, which in this case is 0.45 ohms, and find the effective series resistance of the REACTANCE capacitor at any desired setting from Figure 12. This is, of course, the effective series resistance at the frequency, at which the measurement was made. If the capacitor measured is not exactly 1000 $\mu\mu$f, multiply the resistance obtained from the chart by the ratio of the actual capacitance to 1000 $\mu\mu$f.

Another method of checking the effective series resistance of the REACTANCE capacitor is to measure a capacitor whose effective series resistance is known to be small compared to that of the REACTANCE capacitor in the bridge; or, if the resistance is not small, its value is known accurately. The algebraic difference between actual series resistance and the measured series resistance is equal to the difference between the effective series resistance of the REACTANCE capacitor at its initial and final settings. The actual series resistance of the REACTANCE capacitor can then be determined from Figure 9 by finding the value of ΔR from the chart which gives the same <u>difference</u> in the effective resistance of the REACTANCE capacitor for the initial and final settings of the REACTANCE dial. The effective resistance at any other dial setting can then be read from the chart. For maximum accuracy a capacitance of the order of 160 $\mu\mu$f should be used.

CAUTION

If for any reason the bridge needs to be removed from its case, remove the screws on the edges of the panel, set both initial balance controls so the pointers on the knobs point to the right, and lift the bottom edge of the panel by means of the knobs. Keep the top edge of the panel securely pressed against the top side of the cabinet when raising the bottom edge to prevent damage to the variable resistor and capacitor located beneath the bottom edge of the panel. Reverse the same procedure when replacing the bridge in its cabinet.

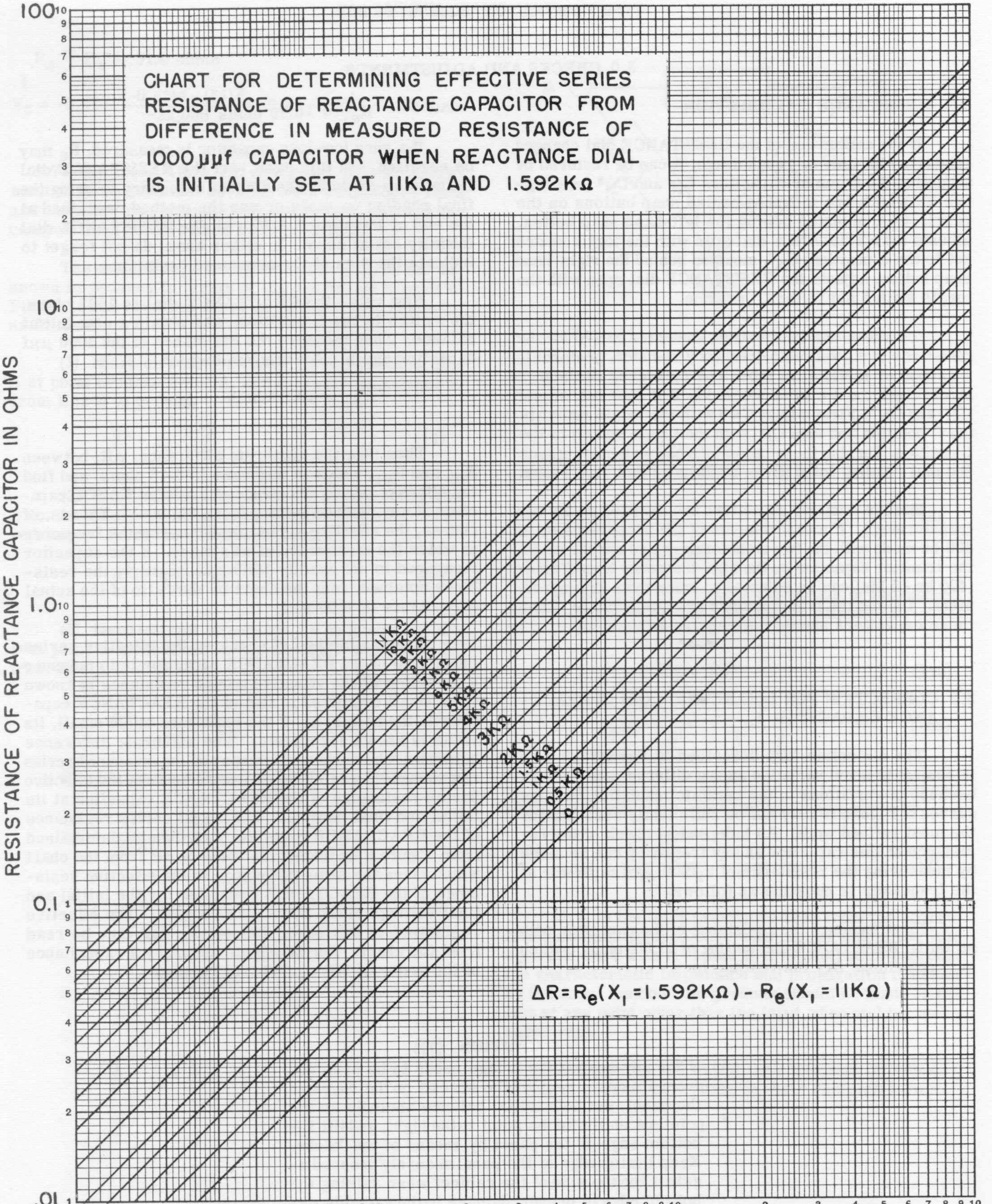


CHART FOR DETERMINING EFFECTIVE SERIES RESISTANCE OF REACTANCE CAPACITOR FROM DIFFERENCE IN MEASURED RESISTANCE OF 1000 μμf CAPACITOR WHEN REACTANCE DIAL IS INITIALLY SET AT 11KΩ AND 1.592KΩ

$\Delta R = R_e(X_1 = 1.592K\Omega) - R_e(X_1 = 11K\Omega)$

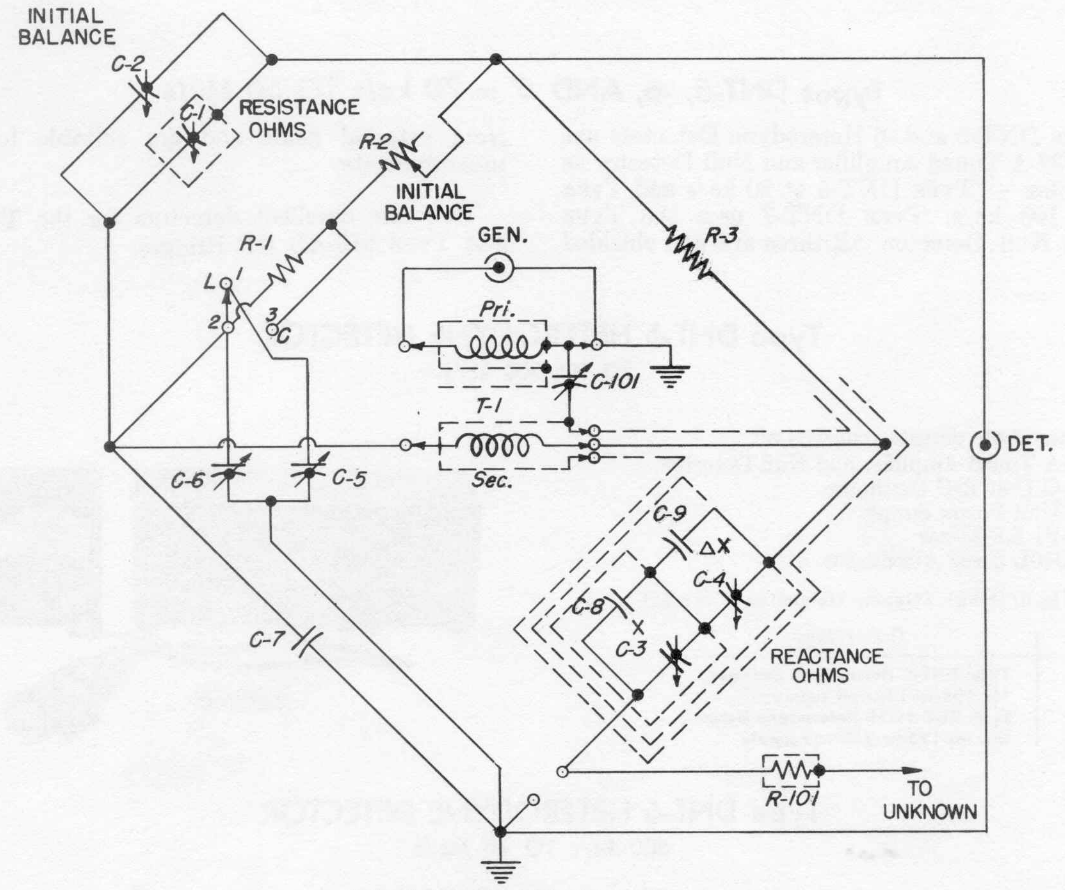


Figure 13.

WIRING DIAGRAM OF 916AL R.F. BRIDGE

PARTS LIST

Ref. No.	*Description*	*Part No.*
R1	Resistor, Film 750 Ω ±5%	6130-0750
R2	Resistor, Potentiometer, Wire-wound 1 kΩ ±10%	0410-4140
R3	Resistor, Wire-wound 2.250 kΩ ±1/2%	0916-3240
R101	Resistor Assembly, 916-P3 (2" lead) 240 - 260 Ω 916-P4 (24" lead) 240 - 260 Ω	0916-0030 0916-0040
C1	Precision Variable Capacitor Assembly	0916-3000
C2	Micro-Capacitor (variable) 15 pF	0368-4150
C3	Capacitor, Variable 360 pF	0568-4072
C4	Capacitor, Variable 360 pF	0568-4082
C5	Capacitor, Trimmer 1 - 10 pF	4910-2001
C6	Capacitor, Trimmer 1 - 10 pF	4910-2001
C7	Capacitor, Mica 500 pF ±1%	0916-4200
C8	Capacitor, Mica 78 pF ±2 pF	4690-1100
C9	Capacitor, Mica 1850 pF ±2%	4750-0800
C101	Capacitor, Air 2 - 12 pF	0916-3500
T1	Transformer, 916-P1S1 Low Frequency	0916-0020
T1	Transformer, 916-P1 High Frequency	0916-0010

Mech
Par

APPENDIX—ACCESSORY EQUIPMENT

Types DNT-5, -6, AND -7 — 70 kc/s TO 50 Mc/s

The Types DNT-5 and -6 Heterodyne Detectors use the Type 1232-A Tuned Amplifier and Null Detector as the i-f amplifier — Type DNT-5 at 20 kc/s and Type DNT-6 at 100 kc/s. Type DNT-7 uses the Type 1212-A Unit Null Detector. All three are well shielded from external fields and are suitable for low-level measurements.

They are excellent detectors for the Type 1606-A and Type 916-AL RF Bridges.

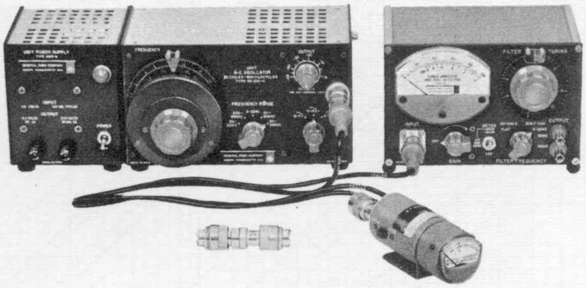
Type DNT-5 HETERODYNE DETECTOR

70 TO 500 kc/s

Complete heterodyne detector consists of:
1 Type 1232-A Tuned Amplifier and Null Detector
1 Type 1210-C Unit R-C Oscillator
1 Type 1203 Unit Power Supply
1 Type 1232-P1 RF Mixer
1 Type 874-G10L Fixed Attenuator

Net Weight: 17½ lb (8 kg). **Shipping Weight:** 24 lb (11 kg).

Catalog No.	*Description*
1235-9605	**Type DNT-5 Heterodyne Detector, for 105-to-125-volt supply**
1235-9795	**Type DNT-5Q18 Heterodyne Detector, for 195-to-250-volt supply**



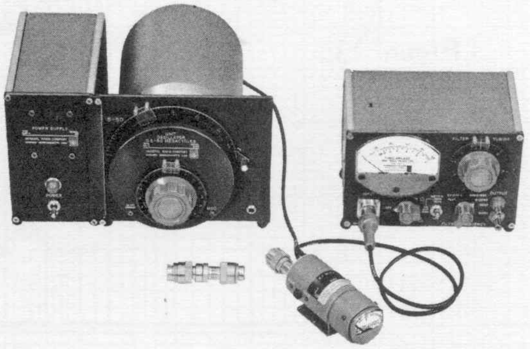
Type DNT-6 HETERODYNE DETECTOR

500 kc/s TO 10 Mc/s

Complete heterodyne detector consists of:
1 Type 1232-A Tuned Amplifier and Null Detector
1 Type 1211-C Unit Oscillator
1 Type 1269-A Unit Power Supply
1 Type 1232-P1 RF Mixer
1 Type 874-G10L Fixed Attenuator

Net Weight: 24½ lb (11.5 kg). **Shipping Weight:** 33 lb (15 kg).

Catalog No.	*Description*
1235-9606	**Type DNT-6 Heterodyne Detector, for 105-to-125-, 195-to-235-, or 210-to-250-volt supply**



Type DNT-7 HETERODYNE DETECTOR

3 TO 50 Mc/s

Complete heterodyne detector consists of:
1 Type 1212-A Unit Null Detector
1 Type 1212-P3 RF Mixer
1 Type 1211-C Unit Oscillator
1 Type 1269-A Unit Power Supply
1 Type 1203 Unit Power Supply
1 Type 874-G10L Fixed Attenuator

Net Weight: 28½ lb (13 kg). **Shipping Weight:** 39 lb (18 kg).

Catalog No.	*Description*
1235-9607	**Type DNT-7 Heterodyne Detector, for 105-to-125-volt line**
1235-9797	**Type DNT-7Q18 Heterodyne Detector, for 195-to-250-volt supply**