DELTA ELECTRONICS

INSTRUCTION BOOK

for

MODEL OIB-3

OPERATING IMPEDANCE BRIDGE

WARNING: *Dangerous radio frequency voltages may be encountered when measuring high power active circuits. Exercise care in grounding the instrument before applying power.*

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TECHNICAL MANUAL FOR
MODEL OIB-3
OPERATING IMPEDANCE BRIDGE

I. GENERAL INFORMATION

1.1 General Description

The OIB-3 is an improved Operating Impedance Bridge designed specifically for measurement of AM broadcast antenna impedances. It permits measurements under power with a minimum of insertion effects on the circuit being measured. The bridge will handle a through power of up to 5,000 watts at moderate standing wave ratios. Resistance and reactance values may be read directly from two dials located on the front panel. An internal detector circuit is provided so that when the bridge is operating in a power circuit, no other instruments are required. An input adaptor and an external detector connector are provided so that it may be used with a well sheilded generator and receiver such as the Delta Electronics RG-1 or RG-3 Receiver Generators for low level impedance measurements.

The instrument's specifications are:

Frequency Range:	500 kHz - 2 mHz	Primary Range
	500 kHz - 5 mHz	Usefull Range

Maximum Through Power: 5 kw at VSWR≤3:1
10 kw intermittent duty below 2 mHz
Resistance Range: -1000 to +1000 ohms
Reactance Range: -900 to +900 ohms at 1 mHz
Resistance Accuracy: ±2% ±1 ohm
Reactance Accuracy: ±2% ±1 ohm

1.2 Operating Impedance

The term "operating impedance" is defined as the complex ratio of the voltage applied to a load to the current flowing in the load when it is operating under normal power and in its normal environment. In many cases, this impedance differs substantially from the "self-impedance" or "cold impedance" of the load. In antenna systems a radiator has a certain 'self-impedance' when operating alone. When it is combined in an array to form a directional antenna, its 'operating impedance' may differ substantially from its 'self-impedance' because of coupled impedance from other radiators of the array.

Many loads have an operating impedance which differs with applied power level. A 'dummy load', for example, may have an operating impedance which varies with applied power levels. Meaningful impedance measurements must, therefore, be made at normal power level.

1.3 Differences Between Bridges

The Delta Electronics, Inc. Model OIB-3 Operating Impedance Bridge differs from bridges based on classical design in that the bridge can handle a substantial power level and causes a minimum of insertion effects. This permits the direct measurement of operating impedance as defined above, the Model OIB-3 can be inserted directly in the circuit and the operating impedance of the load measured under normal power. Bridges of a classical design are ordinarily incapable of handling large amounts of power. They measure the "cold" impedance of the load. When the matching circuits are adjusted from these measurements, it is found that

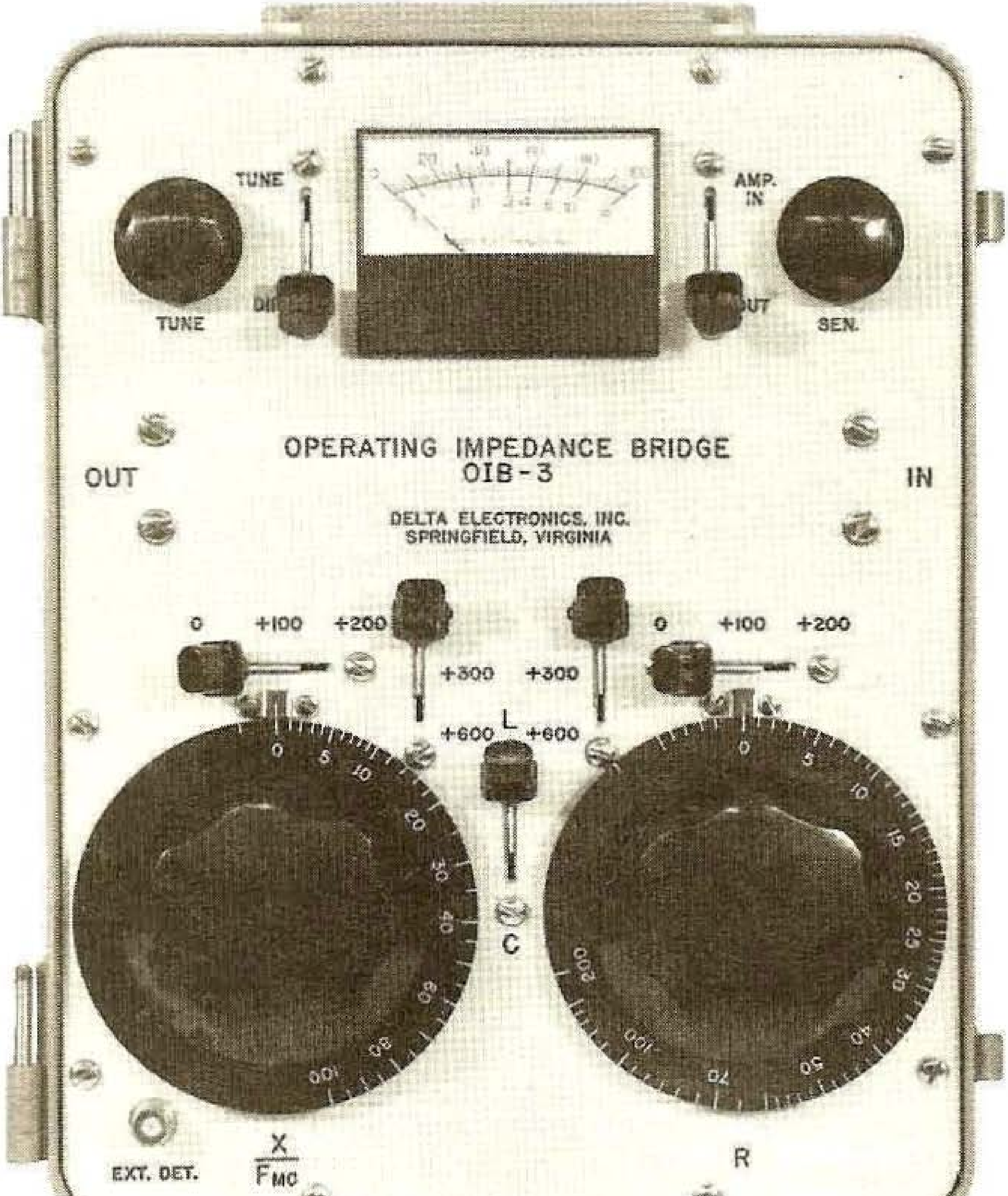


FIGURE I

OIB-3

OPERATING IMPEDANCE BRIDGE

II. OPERATING INSTRUCTIONS

2.1 Identification of Controls

Figure 1 is a photograph of the impedance bridge. A large UHF connector is mounted in the recess on each side of the case. The connectors are identified by markings directly above them on the front panel. The connector on the right is marked IN and the connector on the left is marked OUT. In normal operation, the power source or signal generator is connected to the IN connector, and the load is connected to the OUT connector.

The lower group of controls on the panel operate the internal variable standards. The right dial is calibrated directly in ohms resistance, this dial is marked R. The lever switches immediately above the dial are the resistance adder switches. When the adder switches are in the 0 position they are inactive. When the switches are in other positions the values indicated are added to the reading of the R dial to obtain the resistance of the load. The two adder switches may be used in any combination of settings to extend the resistance range of the bridge to 1000 ohms.

The left dial is calibrated in ohms of reactance at 1 mHz and marked X/FMC. The reactance adder switches are immediately above this dial. They can be used in combination to extend the reactance range (at 1 mHz) to ±900 ohms. When measurements are made at frequencies other than 1 mHz, the reactance reading must be corrected by multiplying the value read (including the adders) by the frequency in megahertz. For example, if measurements are made at 1.5 mHz and the total of the adder switch and the dial reads 250 ohms, the actual load reactance will be:

1.5 x 250 = 375 ohms

The switch marked L -C between the two dials in the center of the panel is for the selection of positive or negative reactance loads. If the load is inductive, the switch must be in the L position to obtain a null, and the reactance values read from the reactance dial are +j values. A bridge null can be obtained only when the switch is in the correct position.

Immediately to the right of the meter is a switch marked AMP. IN/OUT. When this switch is in the Out position the detector circuit is connected directly to the bridge and the sensitivity controls, marked SEN., controls the meter sensitivity. When it is in the AMP. IN position an integrated circuit RF Amplifier is inserted before the detector circuit. This amplifier increases the internal detector sensitivity for measurements in low power circuits.

Immediately to the left of the meter is the meter TUNE - DIR switch. In the DIR position the outpur of the bridge is connected directly to the meter circuit without tuning. In the TUNE position a resonant circuit is inserted between the bridge output and the meter for increased sensitivity. This circuit is tuned to the desired frequency by a variable capacitor operated by the TUNE knob to the far left of the meter.

To the far right of the indicating meter is a sensitivity control (SEN) which adjusts the sensitivity of the meter. The sensitivity is increased by turning this knob in a clockwise direction.

2.2 In-Line Impedance Measurement Under Power

The simplest measurement that can be made with the bridge is the impedance level at a point along a coaxial transmission line. For this measurement, the line is interrupted; the end of the line coming from the source is connected to the IN connector and the end of the line towards the load is connected to the OUT connector. A power level of up to 5,000 watts can be applied to the bridge with such connections. The controls are then adjusted, as follows: Meter switch in DIR position; AMP. IN/OUT switch in the OUT position; SEN control at minimum (full counterclockwise); R dial at zero; X dial at zero; L-C switch in L position and all adder switches to 0. Power is then applied to the circuit and the gain control is advanced until an upscale indication on the meter is obtained. The R and X dials are then adjusted for a minimum reading on the meter.

If the reading on the meter is decreased when the X dial is advanced from zero, the load is inductive and a null can be obtained. If the reading is increased when the X dial is advanced from zero, the load is capacitive and the L-C switch must be changed to the C position. After a minimum has been obtained on the meter, the gain control is further advanced and further adjustments are made on the R and X dials unitl a deep, sharp null is obtained. The R and X readings are noted and the X reading is corrected for frequency, as described above.

If either the R or X dial is advanced to its maximum value before a null is obtained it will be necessary to switch in one or both of the adder switches. When a null of obtained by the use of these switches, the values marked on the adder switches are added to the reading on the dials to obtain the load impedance.

Since the bridge will usually not be inserted directly into a line equipped with the proper connectors, a set of heavy clip leads is supplied for connecting the bridge into the antenna or matching network circuit. Both of the clip ground leads should be grounded when these leads are used.

2.3 Increased Detector Sensitivity with "TUNE" and "AMP." Circuits.

When the power level is not high, it may be desirable to increase the sensitivity of the indicating meter in order to obtain a more accurate null. This can be done with the TUNE circuit, as follows: The meter switch now is set to TUNE. The TUNE knob is rotated for a maximum meter deflection. Measurements are then made as before with increased meter sensitivity.

Additional sensitivity can be obtained by switching the AMP. IN/OUT switch to the AMP. IN position.

2.4 Operating With External Detector

At very low power levels, the meter sensitivity may not be high enough even when using the tuned circuit and amplifier circuit. For this circumstance, an external detector connector is provided at the bottom left of the panel. A well shielded communications receiver, or the receiver portion of Delta Electronics RG-1 or RG-3 Receiver Generator, can be connected by a well shielded coaxial cable to this connector and used as an external null detector. Impedance measurements are then made, as described above, using the meter on the receiver, or by nulling an audible tone. For this mode of operation, a signal generator, or the generator portion of an RG-1 or RG-3, can be used as a power source and the OIB-3 used as a normal impedance bridge.

In this mode of operation, the OIB-3 is somewhat more sensitive to stray coupling than a conventional bridge. The varible standards are necessarily isolated from the primary terminals of the bridge to permit high power operation. Thus, direct coupling by induction or leakage to the generator or receiver from the antenna under measurement can cause false nulls. To test for this condition, the receiver cable is disconnected from the EXT. Det. connector and held against it so the cable shield circuit is made but not the inner conductor circuit. The receiver output should be quite low. The cable is then connected normally and the R dial moved from the null position just sufficiently to duplicate the receiver output observed above. The magnitude of the R dial deviation is then a good estimate of the error caused by the leakage.

The Delta Electronics RG-1 and RG-3 receiver generator sets are specifically designed for such use. There is over 120 dB of isolation between the generator and receiver portions and double shielded coaxial cables are provided with the units for connection to the OIB-3.

2.5 Improving Precision by Substitution Method

Occasionally, it will be found that accuracies better than the accuracy of the bridge are desired. More accurate impedance measurements can be made by installing the bridge and adjusting for a null, as described above. The bridge is then removed from the circuit without disturbing the setting of the controls. A signal generator (tuned to the same frequency) is connected to the IN terminal and a communications receiver connected to the external detector jack. A variable composition resistor, such as a CTC RV4NAYSD 102 is connected to the OUT connector. A null is then established by adjusting the X dial (which should adjust to approximately zero), and by rotating the variable resistor. The resistor is then disconnected, and its value measured measured on an accurate ohmmeter or a wheatstone bridge. Very accurate power determinations can be made in this fashion. Accurate reactance measurements may also be made using a variable capacitor across the output connector. In this case, a null is re-established by adjusting the R control on the bridge and by varying the capacitor. When the actual load is inductive, an initial balance is obtained on the L position of the L-C switch. It will be necessary to change this switch to the C position to re-establish the null with a variable capacitor. In this case, the reactance of the cpapcitor after the null is re-established will equal the inductive reactance of the load.

2.6 Measuring Negative Impedances

Quite often, in complex antenna systems, it is found that one or more of the elements has a negative operating impedance; that is, the total of the coupled impedance from all other elements exceeds the self-impedance of that element, and the element actually returns power to the transmitter. It is necessary to know the magnitude of this negative impedance in order to match the feed system of the element, and to determine the total power in all of the elements. This can be measured by simply reversing the connections to the bridge; that is, the source is connected to the OUT connector, and the load to the IN connector. The bridge is operated in the normal manner and the impedance read from the dials of the bridge. The actual impedance of the load for this case is the negative of the impedance indicated.

The R dial of the OIB-3 is calibrated below zero to about -5 ohms. This facilitates measurement of operating resistance values near zero without the reversing technique described above.

III. OPERATING PRINCIPLES AND CIRCUIT DESCRIPTION

3.1 Theory of Operation

Figure 2A is a simplified schematic, illustrating the operating principles. The circuit between the generator , G, and the load, Z_L is, interrupted by a short length of transmission line having a characteristic impedance of Z_{01}. To this short length of transmission line is lightly coupled a second section of transmission line having a characteristic impedance of Z_{02}. The coupling coefficient between the two lines is k. Across the secondary line nearest the load is a meter circuit. Across the end of the secondary nearest the generator is a variable standard resistance and a variable standard reactance. The combination of these standards is identified as Z_s.

There will be two waves on the main transmission line: one direct wave carrying energy from the generator to the load, identified as W, and a reflected wave identified as Γ_L W. Quantity ΓL is the reflection coefficient of the load impedance Z_L for the characteristic impedance of Z_{01}. Because of the coupling, k, these two waves induce waves in the secondary line. One wave is induced traveling toward Z_s, of magnitude kW, and another wave is induced traveling toward the meter of magnitude k Γ_LW. If the load impedance, Z_s, is not equal to Z_{02}, a third wave will exist on the line of magnitude, k Γ_sW. The direction of travel of this wave will be toward the meter. Γ_s is, of course, the reflection coefficient of the impedance Z_s for the characteristic impedance Z_{02}.

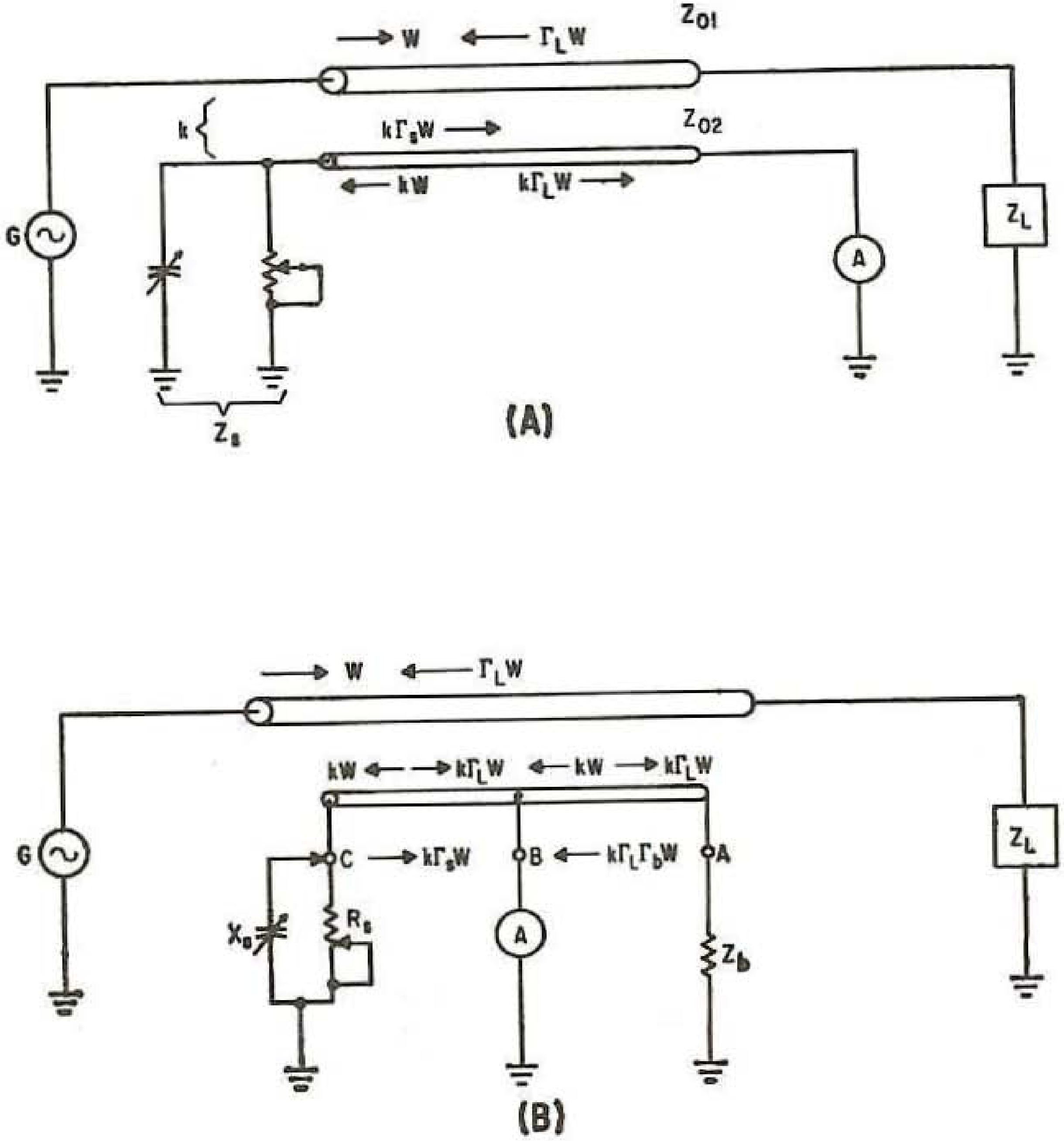


Figure 2
Simplified Schematic

Therefore, two waves arrive at the meter circuit. They are $k\Gamma_S W$ and $k\Gamma_L W$. If these two waves are of equal magnitude and opposite time phase, the meter indication will be zero. The null condition of the bridge will be:

$$k\Gamma_L W = -k\Gamma_s W \tag{1}$$

Or,

$$\Gamma_L = -\Gamma_s \tag{2}$$

The reflection coefficients Γ_L and Γ_s are:

$$\Gamma_L = \frac{Z_L - Z_{01}}{Z_L + Z_{01}} \; ; \quad \Gamma_s = \frac{Z_s - Z_{02}}{Z_s + Z_{02}} \tag{3}$$

Replacing Γ_L and Γ_s in Eq. 2 with these definitions and solving for Z_L

$$Z_L = \frac{Z_{01} \; Z_{02}}{Z_s} \tag{4}$$

Or,

$$Z_L = Y_s \; (Z_{01} \; Z_{02}) = Y_s C \tag{5}$$

The load impedance is directly proportional to the shunt admittance of the standard circuit. The constant of proportionality C is the product of the characteristic impedance of the main transmission line and the auxiliary transmission line. This constant has first-order independence of frequency. A standard circuit, using a parallel-connected variable resistance and variable reactance, can be calibrated directly in the series equivalent load impedance.

When these reflection coefficients are replaced by their defining impedance ratios, and the resulting equation is solved for Z_L, then

$$Z_L = \frac{C}{2} Y_s - \frac{C}{2} Y_b \quad (7)$$

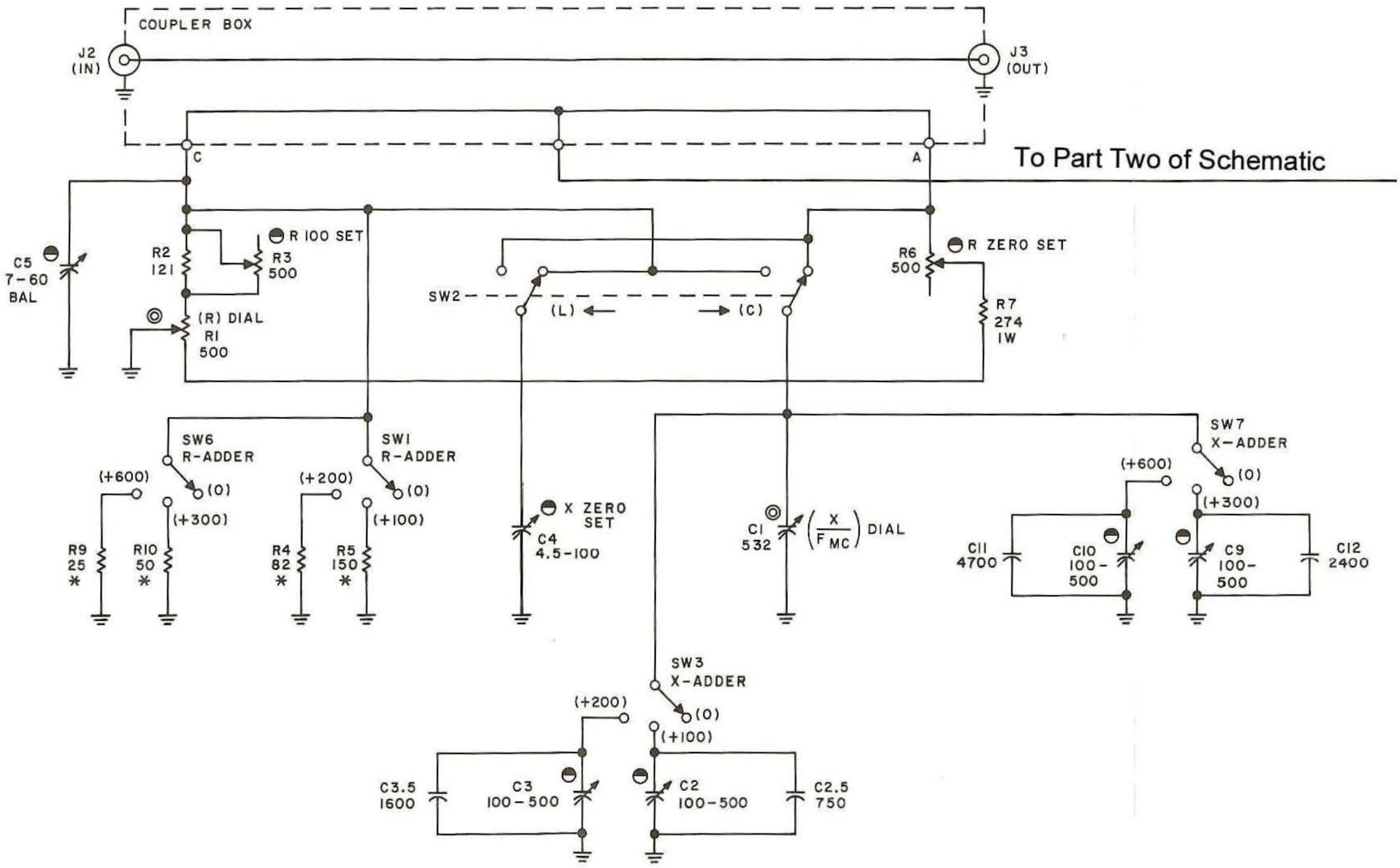
This result is obtained, assuming an exact centertap of the secondary line. Other tap ratios may be used, but they will modify this equation. Equation 7 is similar to Eq. 5, except that a negative term has been added. This means that the negative of the bias admittance Y_b is effectively in parallel with the admittance of the standard Y_s. The two limitations of the circuit in Figure 2A are now circumvented, and the requirement for an infinite resistance standard no longer exists. When Z_L is zero, it is only necessary that Y_s and Y_b be equal. Neither is required to be zero. It is not necessary to have a variable inductor for capacitive loads. The variable capacitor standard can be switched from terminal C to terminal A. Equation 7 shows that this has the effect of reversing the sign of the susceptance of this standard.

3.2 Circuit Description

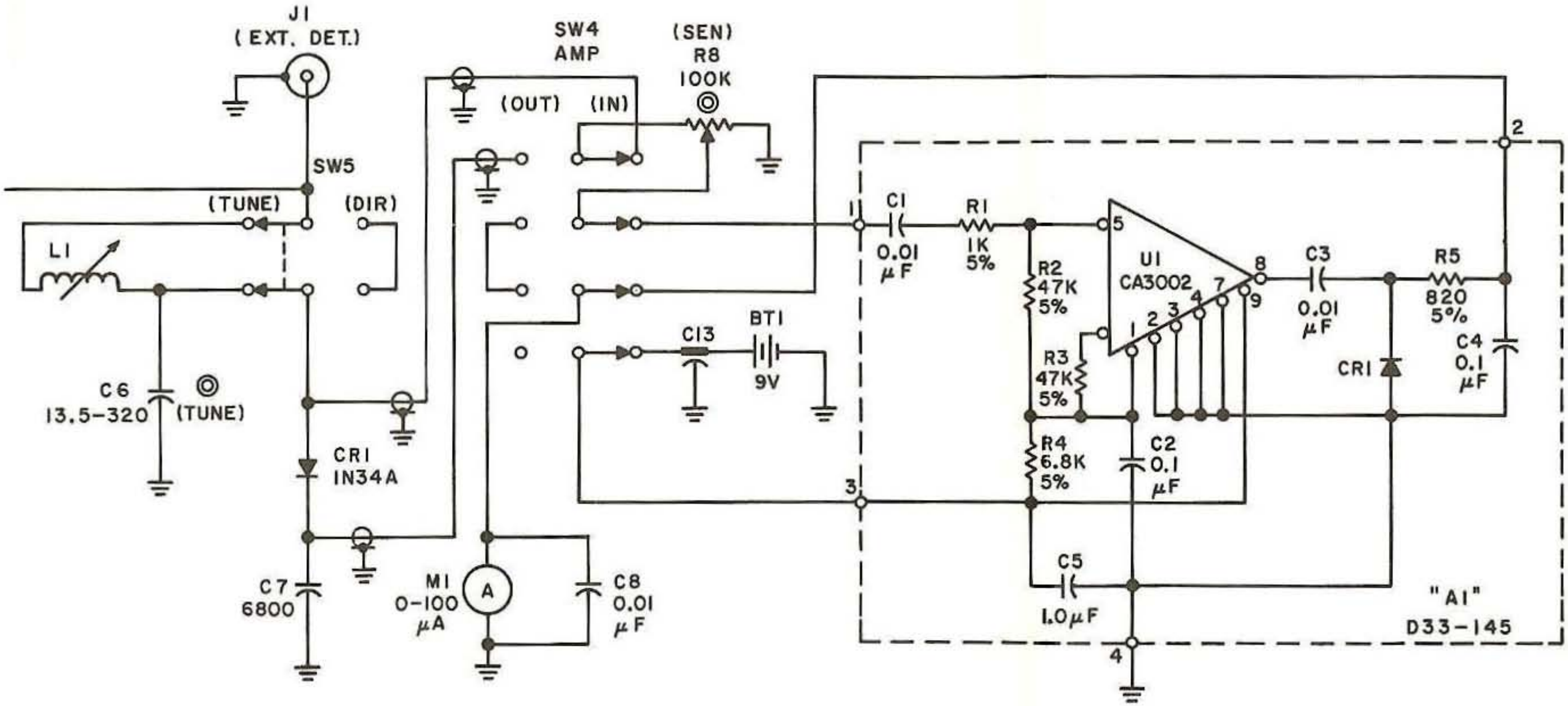
Figure 3 is the schematic diagram for the bridge measuring circuit. The Coupler Box consists of a heavy rod suspended directly between the IN and OUT connector. This center conductor along with the shielding box forms the primary line and has a characteristic impedance of approximately 150 ohms. The secondary line is formed by a small rod mounted from the cover of the shielding box by three shielded teflon feed-through terminals, these terminals are the A, B, and C points shown in Figure 2B. The shielding box should never be opened in the field since this will affect the primary calibration of the bridge.

The components in the Standards Circuit are selected for both their RF characteristics and long term stability. The variable R dial resistor (R1) is a special precision, low noise, ceramet potentiometer. The resistance adder resistor (R4 and R5) are high stability metal film units of values individually selected to calibrate each bridge.

The Meter Circuit is a straight forward R.F. detector circuit using an "L" matching section for increased sensitivity in the TUNE position and an RF amplifier for further sensitivity improvement.



To Part Two of Schematic



NOTES:

1. UNLESS OTHERWISE SPECIFIED:
   - A ALL RESISTORS ARE IN OHMS (± 1% - FIXED)
   - B ALL CAPACITORS ARE IN PICOFARADS
2. ◎ INDICATES FRONT PANEL CONTROL
3. ◒ INDICATES SCREWDRIVER ADJUSTMENT, SEAL AFTER CALIBRATION
4. ( ) INDICATES FRONT PANEL MARKING
5. ✱ INDICATES SELECTED VALUE
6. ⊖ INDICATES SCREWDRIVER ADJUSTMENT

FIGURE 3

SCHEMATIC DIAGRAM
OPERATING IMPEDANCE
BRIDGE

IV. MAINTENANCE

Due to the complexity of the RF distributed circuit and the interaction of all controls it is recommended that field maintenance not be attempted on this unit. If the unit is damaged or ceases to function, it should be returned to the factory for maintenance and calibration.

Note: A precision ceramet potentiometer is used as a variable standard resistance in this bridge. A relatively high contact resistance is a characteristic of precision potentiometers. For this reason, the user may notice an apparent "noise" when obtaining a deep null with an external detector. This is normal and does not affect the rated accuracy of the instrument.

DO NOT attempt to break the seal on the potentiometer for cleaning purposes.

The amplifier battery may be replaced by removing the two screws securing the small panel on the rear of the bridge case. Unplug the 9V transistor radio battery and replace it with a new one being carefull to orient it for correct polarity. A Mallory MN1604 Alcaline battery or equivalent is recommended.

APPENDIX I.

Because of a light interaction between the resistance and reactance measuring components, a correction must be made to the resistance measurement of a high Q circuit (low resistance and high reactance). The correction factor C_R can be computed from the following equation:

$$C_R = xf\ (.009 - .00014R)$$

Where: X is dial reactance before frequency correction.

Bridge Dial Readings

Example: 10 -j100 at 680 kc (.68 mHz)

$$\begin{aligned} C_R &= -100f\ [.009 - .00014\ (10)] \\ &= -100f\ [.009 - .0014] \\ &= -100f\ [.0076] = -.76\ f \end{aligned}$$

Correcting for frequency

$$-.76\ (.68) = -.52$$

True Resistance: 10 -.52 = 9.48

Note that the correction is negative for capacitor loads and positive for inductor loads.

The correction equation has been plotted for reactances reading up to 200 in Figure 4. The correction can be read directly from this figure. The example above is illustrated by the dotted lines on the graph. The correction read from the graph must be multiplied by the frequency in mHz. These corrections are usually not significant for resistances above about 50 ohms.

CORRECTION FACTOR

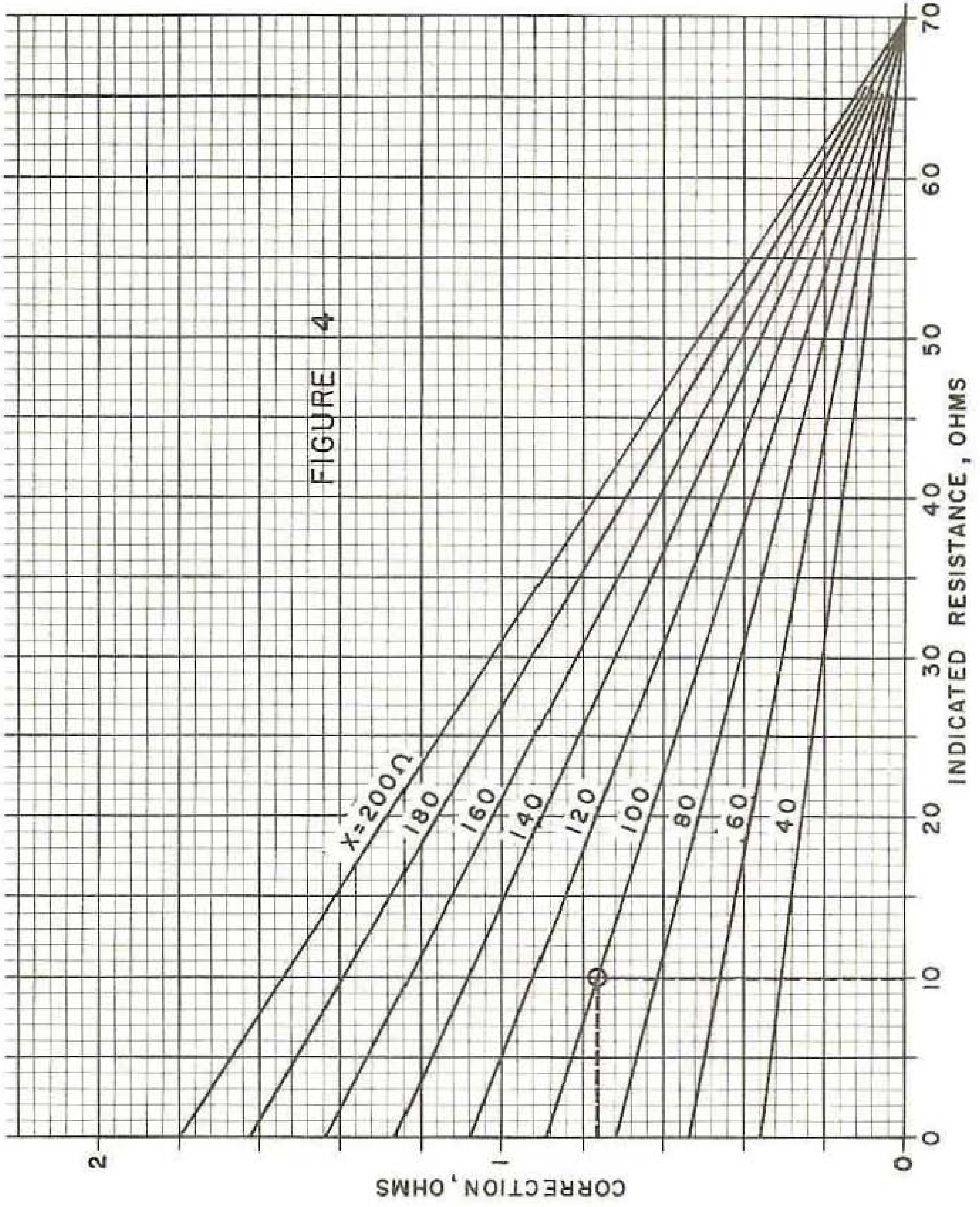


FIGURE 4