NEW R-F BRIDGE FEATURES SMALL SIZE AND ADDED OPERATING CONVENIENCE

Since its introduction in 1942, the General Radio TYPE 916-A Radio-Frequency Bridge[1] has been the radio industry's standard for measurements on antennas, lines, networks and components in the frequency range between 400 Kc and 60 Mc. The widespread acceptance accorded this bridge is due largely to two important characteristics — accuracy of measurement and simplicity of operation. A new and improved version of this bridge has recently been developed, the TYPE 1606-A Radio-Frequency Bridge, which retains the desirable features of the older bridge and incorporates several new ones that contribute to increased ease and convenience of operation.

As in the older bridge, the resistive and reactive components of the unknown impedance are directly indicated on separate dials when the bridge is balanced to a null. The direct-reading resistance range is from 0 to 1000 ohms, and the direct-reading reactance range is from 0 to $\pm$ $5000/f_{Mc}$ ohms, where f_{Mc} is the frequency in megacycles. Higher impedances can be measured indirectly. A modified Schering bridge circuit, shown in Figure 2, is used, in which both the resistive and reactive components of the unknown impedance are measured in terms of capacitance,

[1] Sinclair, D. B., "A New R-F Bridge for Use at Frequencies up to 60 Mc," *General Radio Experimenter*, XVII, 3, August, 1942.

and all balance adjustments are made by means of variable air capacitors.

Among the improvements in the new bridge are:

1. The volume occupied by the bridge has been halved.
2. A single bridge transformer replaces the two transformers used in the older bridge, thus eliminating the necessity of changing transformers at 3 megacycles.
3. New milled-plate variable air capacitors, which have very low losses, are used as reactance standards.
4. The resistor previously mounted in the lead used to connect the unknown to the bridge has been moved inside the bridge, which facilitates connections to the unknown.
5. The reactance dial is calibrated over a 330° arc rather than over a 165° arc, which permits more precise readings.
6. Teflon insulation is used to support the important bridge elements in order to keep losses low and to make operation possible over wide temperature ranges.
7. Dial locks are provided on the initial balance controls to prevent accidental movement.
8. A separate carrying case is made available as an accessory.

Bridge Transformer

Probably the most significant improvement in the bridge is the new broadband bridge transformer, which operates efficiently over the entire frequency range of the bridge. As shown in Figure 2, this transformer is the isolation network used to couple power from the generator into the bridge through junction points a and c.

The transformer must develop a voltage between points a and c which "floats" with respect to ground. That is, the relative potentials between point a and ground and between c and ground must be determined by the impedances in the bridge arms alone and not by stray couplings in the transformer. The transformer therefore should have only magnetic coupling between the primary and secondary, and all capacitive couplings between the windings themselves should be eliminated.

Figure 1. View of the Type 1606-A Radio-Frequency Bridge in its carrying case. Shielding is provided by the metal cabinet of the instrument, so that the bridge can be used either in or out of the carrying case.

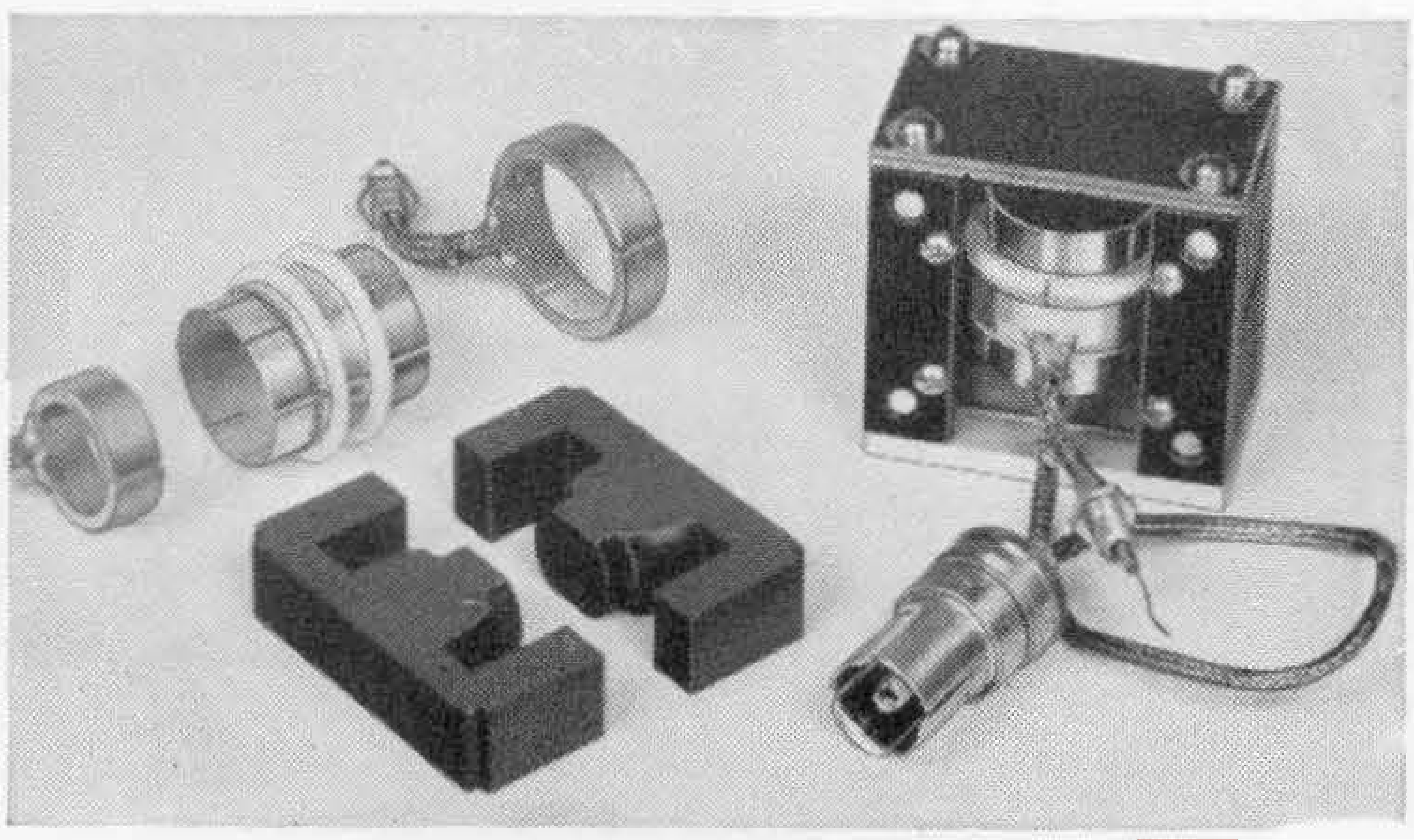
In order to keep the stray capacitance coupling negligible, the primary and secondary windings are completely shielded, and an additional shield is used between the shielded primary and secondary, as shown in Figure 3. The fixed capacitance between the middle shield and the secondary shield causes no error since it appears in parallel with the capacitive arm of the bridge and can be included as part of the capacitance C_N. The details of construction are shown in Figures 3 and 4. Note that the individual shields are not complete turns around the core but are slotted to avoid the formation of short-circuited turns.

The wide frequency range is obtained through the use of a high-permeability ferrite core ($\mu = 850$) which forms a complete magnetic path around the windings. The low-reluctance magnetic circuit results in a high degree of coupling between the primary and secondary, and, since only two turns are required on both windings to produce an adequate primary inductance for satisfactory performance at the lowest frequencies, it also results in a high self-resonant frequency for the transformer.

All connections to the windings are made by means of coaxial cables in order to minimize possible capacitance couplings.

The performance of this new transformer is completely satisfactory. It covers the entire frequency range of the bridge and does not require any

Figure 3. View of the bridge transformer with component parts shown at left.



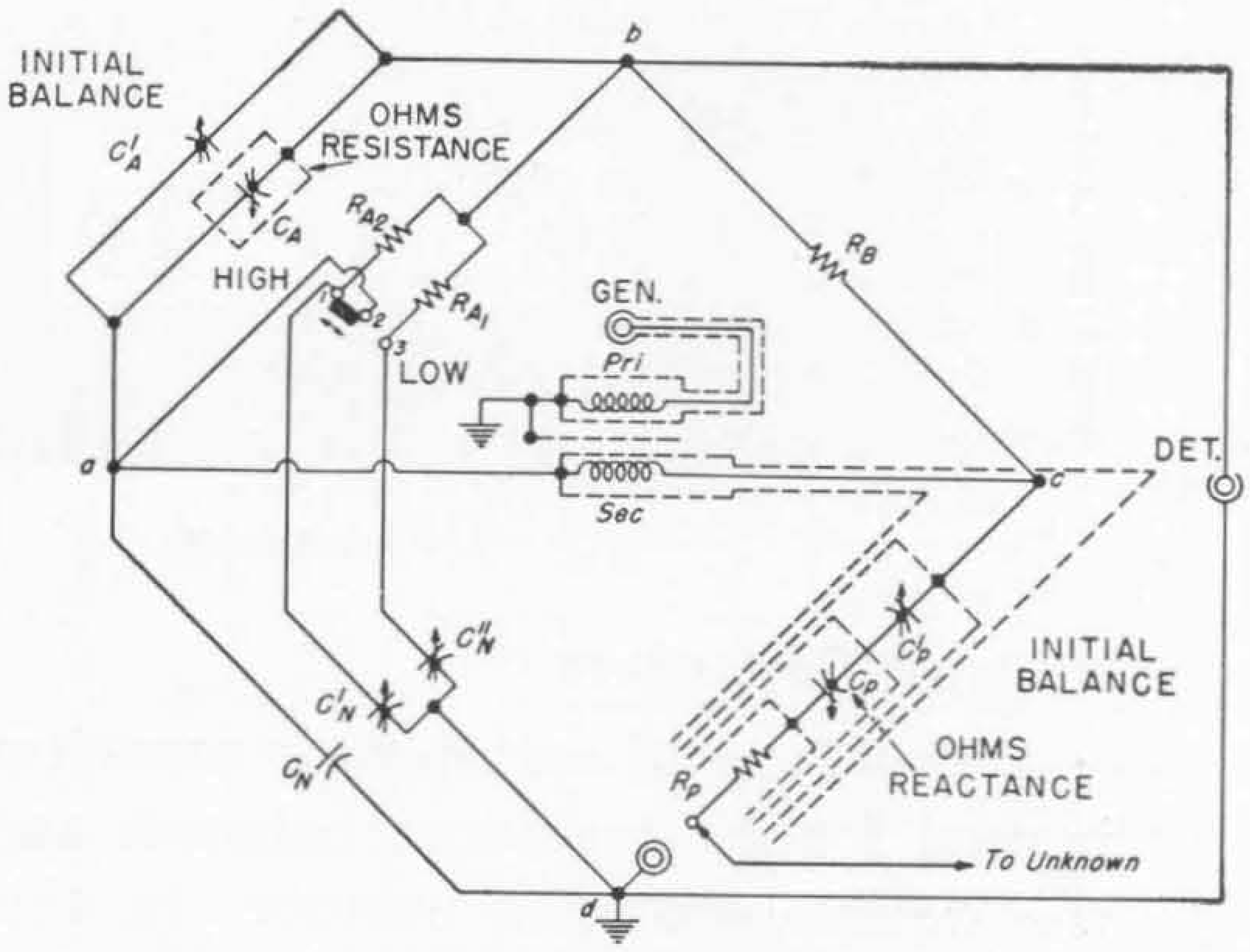
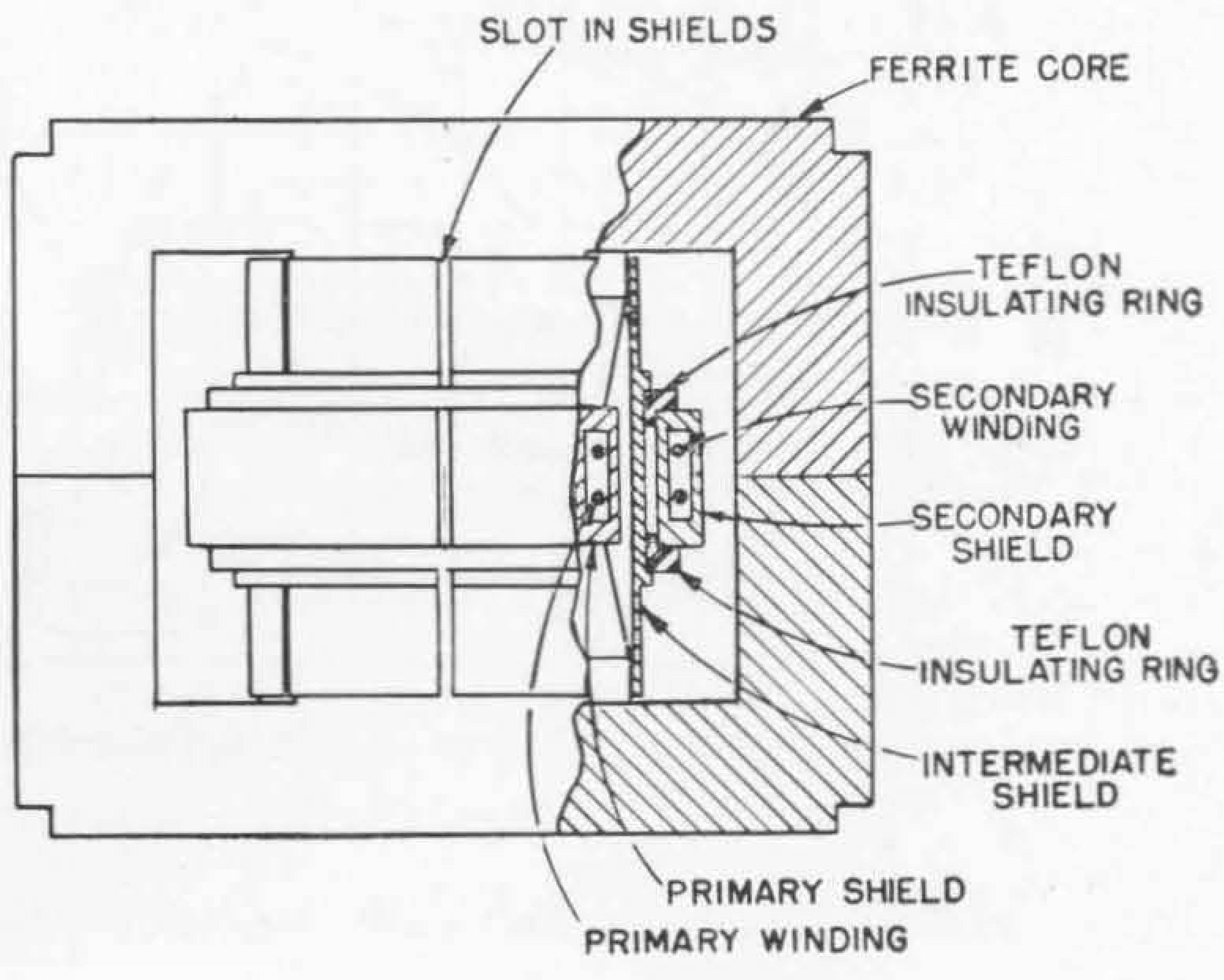


Figure 2. Schematic diagram of the bridge circuit.

adjustment in order to balance out undesired couplings. Figure 5 is a graph showing the relative voltage developed across the bridge at balance as a function of frequency. The performance of the two transformers used in the older Type 916-A R-F Bridge is also shown. As is evident, the new transformer produces a substantially larger voltage across the bridge at practically all frequencies than do the older units.

As a matter of interest, the characteristics of the transformer alone working between a 50-ohm source and a 50-ohm load were measured and are plotted in Figure 6. As can be seen, the insertion loss is reasonably low over a very wide frequency range in spite of the large physical spacing necessitated by the shielding between the primary and secondary windings.

Figure 4. Cross section drawing of the bridge transformer.



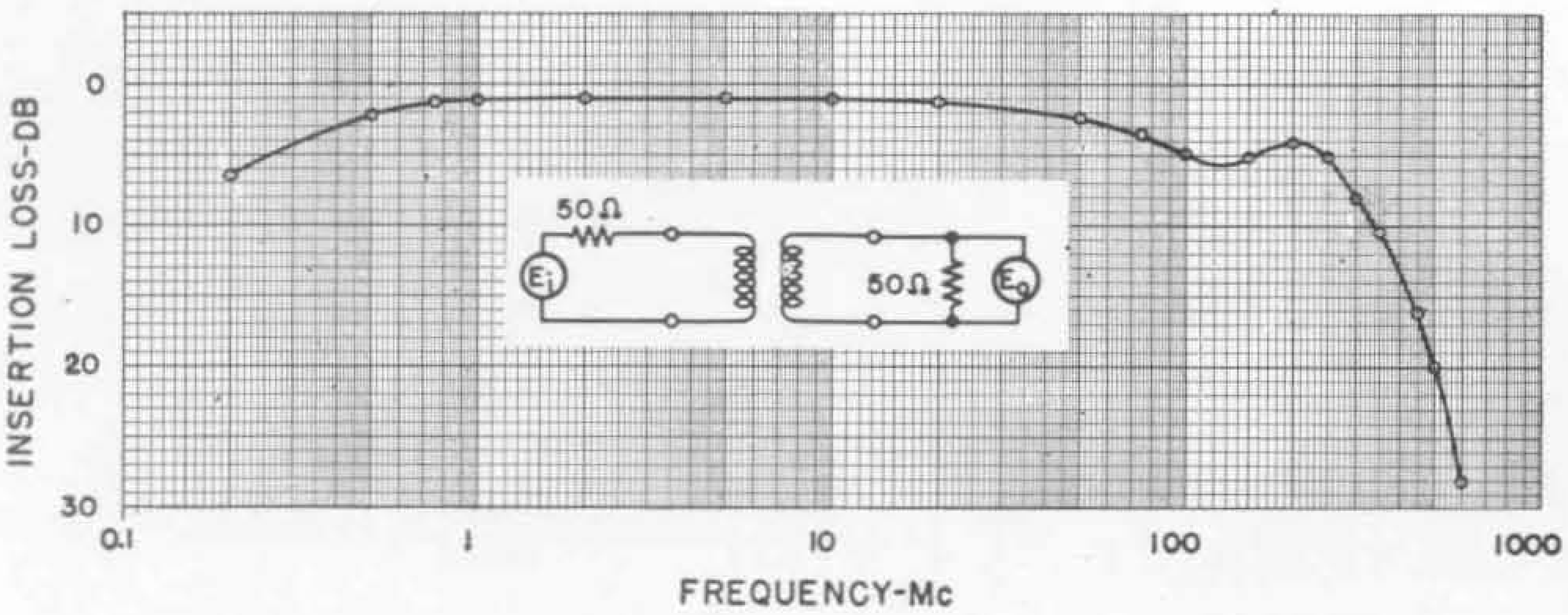


Figure 6. Insertion loss of the bridge transformer as a function of frequency, working between 50-ohm impedances.

Variable Capacitors

A new type of variable air capacitor is used for the reactance balances and the initial resistance balance. In this capacitor the complete rotor and stator sections are milled out of solid blocks of aluminum, a construction which avoids the losses at the joints between plates and spacers found in many conventional designs. Ball bearings mounted in high-temperature polystyrene-disk insulators support the glass-fiber shaft to which the rotor is clamped. Because their over-all losses are very low, capacitors of this type are excellent components for use in the bridge. Figure 7 is a view of a 220 $\mu\mu$f variable capacitor of the type used in the instrument.

Unknown Lead

In the older bridge the resistor, *Rp*, shown in Figure 2, used to make possible the initial resistance balance, is mounted external to the bridge in the lead used to connect the unknown to the circuit under test. As a result, special leads with the resistor mounted in them had to be used or an initial balance could not be obtained. In the new bridge the resistor is mounted inside the bridge, which permits much greater flexibility in the selection of connecting leads. In fact, components can often be most satisfactorily measured at high frequencies when connected directly across the unknown terminals by means of their own leads.

Carrying Case

The bridge is mounted in a sturdy aluminum cabinet, the inside of which is actually part of the bridge circuit. In field applications where some additional protection is desired, or in cases in which the instrument is transported frequently, a separate luggage-type case, shown in Figure 1, can be obtained as an accessory. The instrument can be operated while inside the case if desired.

Figure 5. Relative voltage developed across the bridge at balance as a function of frequency. Data for the older Type 916-A model are shown for comparison.

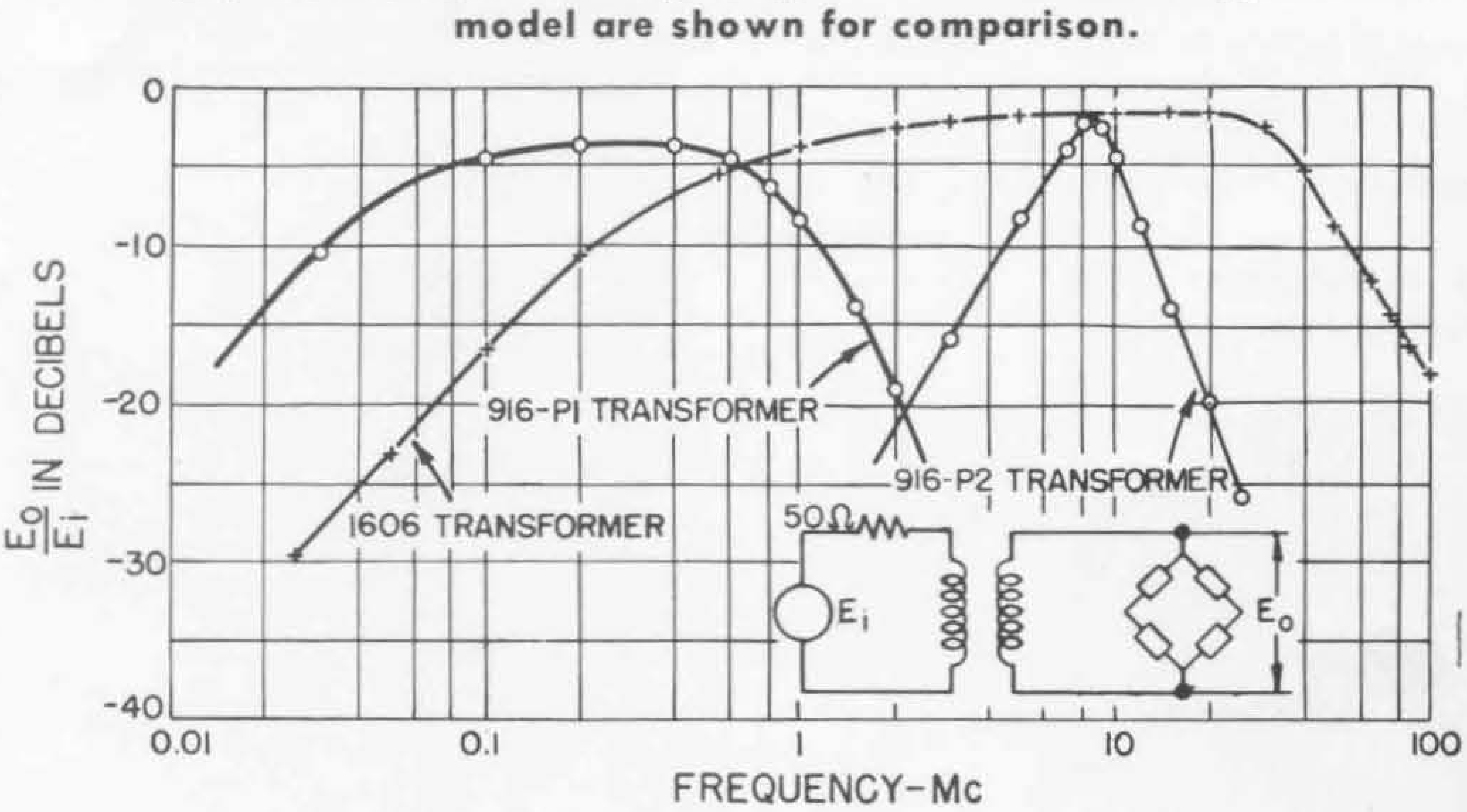
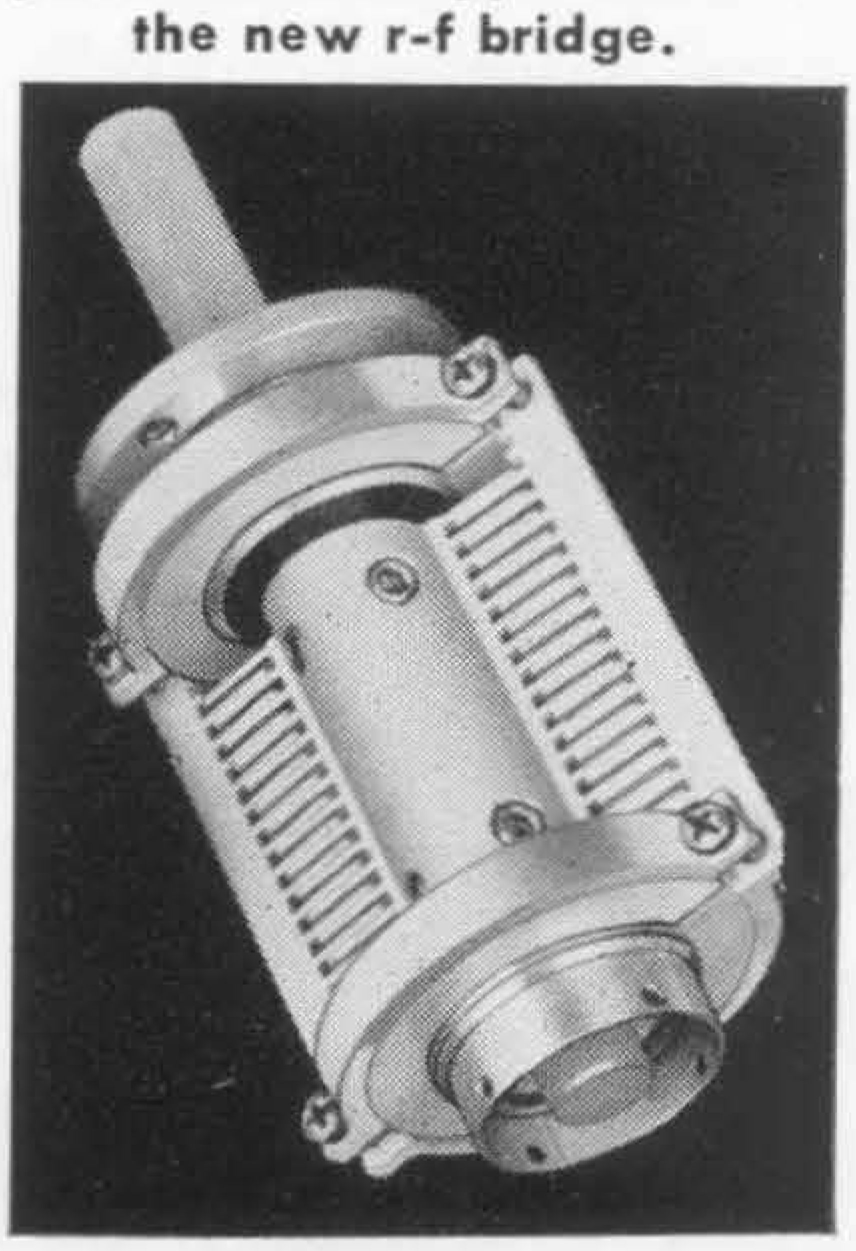


Figure 7. A variable air capacitor of the type used in the new r-f bridge.



Performance

The bridge is well suited to the accurate measurement of components, antennas, and other circuits having relatively low impedances over a frequency range from below 400 kc to 60 Mc. Figure 9 shows the results of a series of measurements made over a frequency range from 100 kc to 60 Mc on a length of transmission line terminated in a resistor and a capacitor connected in series.

At very low frequencies, that is below about 400 Kc, the resistance balance becomes progressively less sensitive than the reactance balance and as a result it becomes more difficult to measure very small resistances accurately. Since the reactance range is inversely proportional to frequency, it also becomes increasingly more difficult to measure very small reactances as the difference in dial settings for a given reactance is also inversely proportional to frequency, and in extreme cases the resolving power of the dial is approached or exceeded.

The improvements outlined in the previous paragraphs will make this bridge even more useful than was the previous model. The broadcast engineer measuring antennas and the research worker in the field will both find new features which will simplify their work.

— R. A. SODERMAN

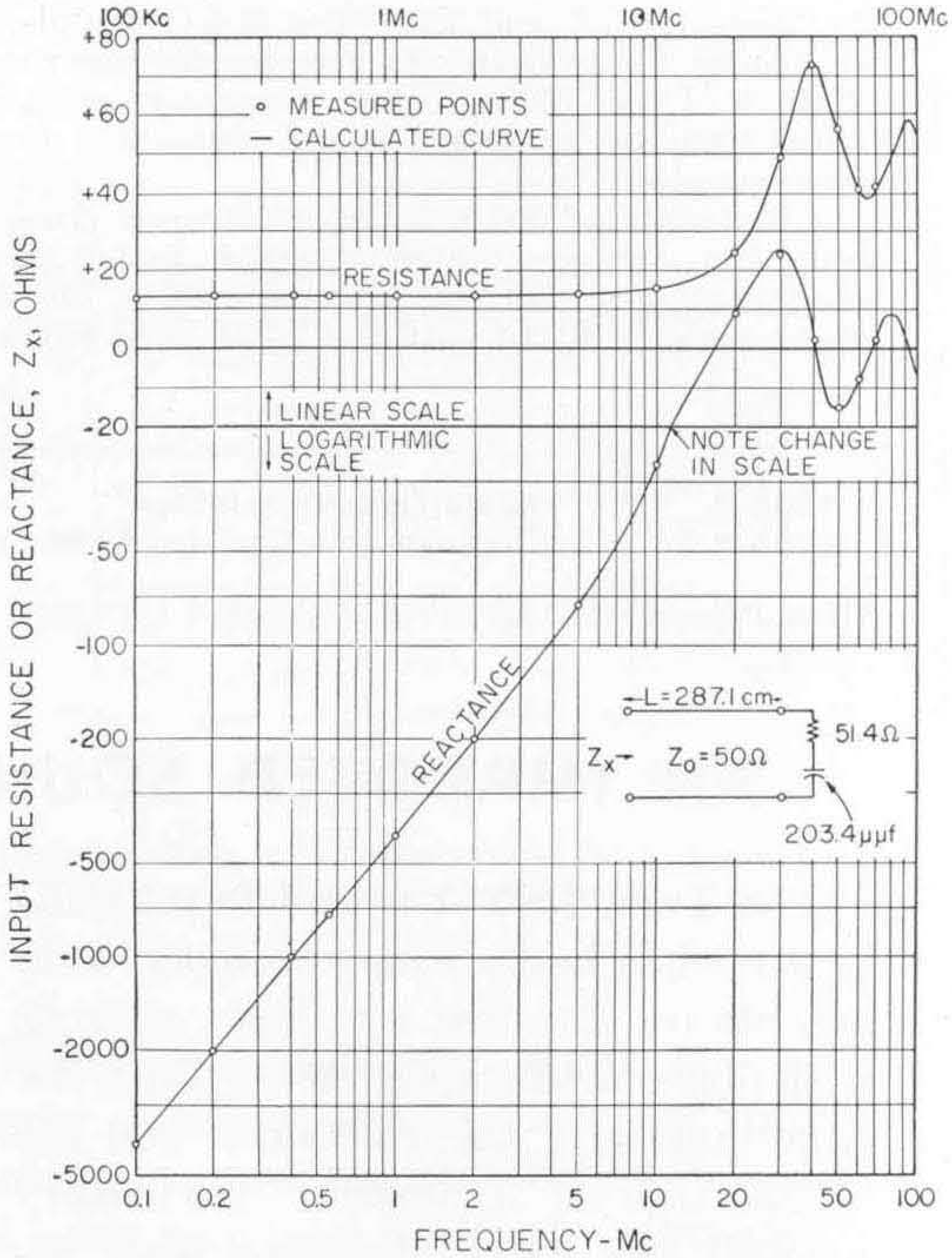


Figure 8. Resistance and reactance of a loaded transmission line as measured on the bridge (circles) and as calculated (curve).

SPECIFICATIONS

Frequency Range: 400 Kc to 60 Mc.

Reactance Range: ±5000Ω at 1 Mc. This range varies inversely as the frequency; and at other frequencies the dial reading must be divided by the frequency in megacycles.

Resistance Range: 0 to 1000Ω.

Accuracy: For reactance at frequencies up to 50 Mc, ± (2% + 1Ω + 0.0008 x R x f), where R is the measured resistance in ohms and f is the frequency in Mc.

For resistance, at frequencies up to 50 Mc,

$$\pm \left[1\% + 0.0024 f^2 \left(1 + \frac{R}{1000}\right) \% \pm \frac{10^{-4} X}{f} \Omega + 0.1\Omega \right]$$

subject to correction for residual parameters. R is the measured resistance in ohms, X is the measured reactance in ohms, and f is the frequency in Mc. At high frequencies, the correction depends upon the frequency and magnitude of the unknown resistance component. A chart from which the correction can be determined is given in the instruction book supplied with the bridge.

Satisfactory operation can be obtained at frequencies as low as 100 Kc and somewhat above 60 Mc with not quite as good accuracy as indicated above. The f^2 term is important only at frequencies above 10 Mc. The $1/f$ term is important only at very low frequencies when the resistance of a high-reactance, low-loss capacitor is measured.

Accessories Supplied: Two leads of different lengths for connecting the unknown impedance to the bridge terminals, two TYPE 874-R22 Coaxial Cables for connecting the generator and detector, and one TYPE 874-PB58 Panel Connector.

Other Accessories Required: Radio-frequency generator and detector. The TYPE 1330-A Bridge Oscillator and the TYPE 1211-A Unit Oscillator are satisfactory generators, as are the TYPE 1001-A and the TYPE 805-C Standard-Signal Generators. At frequencies above 50Mc a TYPE 1215-A Unit Oscillator or a TYPE 1021-AV Standard-Signal Generator is recommended.

A well-shielded communication receiver covering the desired frequency range makes a satisfactory detector. It is recommended that the receiver be fitted with the TYPE 874-PB58 Panel Connector or other coaxial connector to avoid leakage at the input connection.

Mounting: Welded aluminum cabinet supplied. A luggage-type carrying case is available separately and is recommended if the bridge is to be used as a portable field instrument.

Dimensions: 12½ x 9½ x 10¼ inches, over-all.

Net Weight: 23 pounds without carrying case; 29 pounds with carrying case.

Type		*Code Word*	*Price*
1606-A	**Radio Frequency Bridge***	CIGAR	**$535.00**
1606-P 1	**Luggage-type Carrying Case**	BILLY	**$15.00**

*U. S. Patents Nos. 2,125,816; 2,548,457; and 2,376,394