THE General Radio EXPERIMENTER

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ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

Also IN THIS ISSUE

A GENERAL PURPOSE WAVEMETER

● ONE OF THE INDISPENSABLE TOOLS OF THE RADIO ENGINEER is the ordinary wavemeter. While precise frequency measurements are often necessary, there are many uses in the laboratory for an instrument that gives an answer within a few per cent quickly and conveniently. Among these are checking the frequency ranges of oscillator coils, setting and determining oscillator frequencies, and finding the frequencies of parasitic oscillations in r-f amplifiers For experimental work the low accuracy of the wavemeter, as compared to precise crystal frequency standards, is more than offset by the speed and convenience of measurement.

The two inexpensive, general-purpose wavemeters formerly carried in our catalog (Type 574 and Type 358) have now been replaced by a single instrument, Type 566-A, which combines, in an improved design, wide range, small size, good accuracy, and low price.

Figure 1. View of the Type 566-A Wavemeter showing how coils are stored when not in use.

FIGURE 2. View of the wavemeter dial showing the frequency scales. The outer scale is engraved in red, the other two in black.

This new wavemeter is direct reading in frequency between 0.5 and 150 Mc. Only three frequency scales are used, as shown in Figure 2, although there are five plug-in coils. The outer scale is used with two coils, 0.5 to 1.6 Mc and 5 to 16 Mc. The middle scale covers the ranges 1.6 to 5 Mc and 16 to 50 Mc. The inside scale is used for the highest frequency coil, 50 to 150 Mc. These scales are accurate to ±2% up to 16 Mc, and to ±3% between 16 and 150 Mc.

FIGURE 3. View of the TYPE 566-A Wavemeter in use. The coil can be rotated to secure optimum coupling to the source whose frequency is being measured.

The resonance indicator is an incandescent lamp. With low-power oscillators the reaction of the wavemeter on the oscillator tube currents can be observed.

Figure 3 gives an idea of the size of the wavemeter, and shows one of the features, that all coils except the highest frequency one can be rotated to secure the desired coupling. When not in use, coils are stored in the rack on the side of the instrument, as shown in Figure 1.

The slow-motion drive provided on the dial makes possible a fine adjustment of the condenser. The condenser itself is similar in construction to the TYPE 568, but has a longer stack. Figure 4 is an inside view of the instrument showing this condenser.

Four of the coils are wound on phenolic forms which enclose and protect the winding. The highest frequency coil, as shown at the left in Figure 3, is a straight bar.

The small size, accuracy, and low price of this wavemeter make it a particularly desirable instrument for the radio laboratory. Because all our facilities are devoted to war projects, this instrument is, at present, available only for war work. — E. KARPLUS

SPECIFICATIONS

Frequency Range: 0.5 to 150 Mc (600 to 2 meters) using the five plug-in inductors furnished with the instrument. The condenser dial is direct reading in frequency. The precision with which the dial can be read is 2% or better.

Accuracy: The accuracy of dial indication is ±2%, 0.5 to 16 Mc; and ±3%, 16 to 150 Mc.

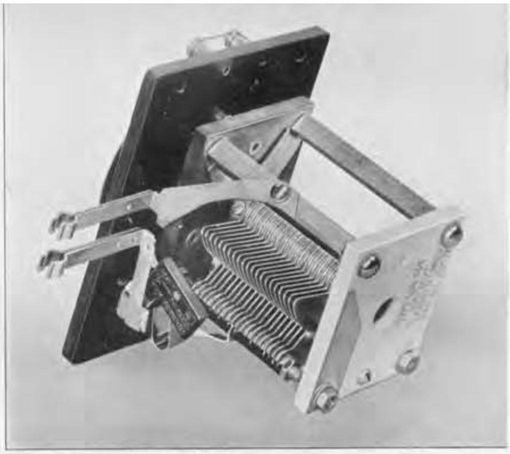


FIGURE 4. Interior view of the TYPE 566-A Wavemeter, showing the construction of the condenser.

Accessories Supplied: Two spare indicator lamps.

Dimensions: 4¾ x 5⅞ x 5¾ inches, over-all.

Net Weight: 3 pounds.

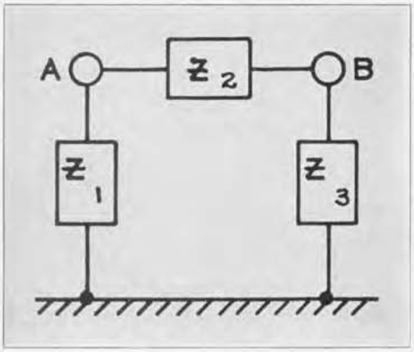
Type		*Code Word*	*Price*
566-A	Wavemeter	WAGON	$45.00

MEASURING BALANCED IMPEDANCES WITH THE R-F BRIDGE

INTRODUCTION

● **BECAUSE OF THE SPECIALIZED NATURE OF BALANCED IMPEDANCES**, equipment for their measurement has not received as much attention as has equipment for the measurement of impedances with one side grounded, and it is not as generally available. Consequently, the problem of measuring balanced impedances with equipment for measuring grounded impedances is often encountered. Measurements at radio frequencies of open-wire transmission lines and dipole antennas probably present the most common examples. Two methods by which these measurements can be accomplished are described here because of their particular usefulness with the TYPE 916-A and TYPE 516-C Radio-Frequency Bridges, and the TYPE 821-A Twin-T Impedance Measuring Circuit.

FIGURE 1. Equivalent circuit of a balanced line.



METHOD I

The first method[1] is similar to the well-known method of measuring the interelectrode capacitance of a triode by three capacitance measurements. The input impedance of the line is represented by the equivalent circuit of Figure 1. The measurement procedure is as follows:

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

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[1] D. B. Sinclair, "Impedance Measurements on Broadcast Antennas," Part II. *Communications;* July, 1939.

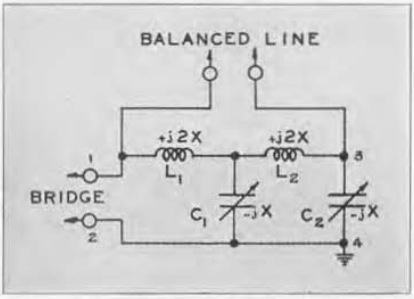

FIGURE 2. Circuit diagram of auxiliary network.

$$Z' = \frac{Z_2 Z_3}{Z_2 + Z_3} \qquad (1)$$

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

$$Z'' = \frac{Z_3 Z_1}{Z_3 + Z_1} \qquad (2)$$

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

$$Z''' = \frac{Z_1 Z_2}{Z_1 + Z_2} \qquad (3)$$

Combining Equations (1), (2), and (3) gives:

$$\begin{aligned} Z_1 &= \frac{2Z'Z''Z'''}{Z'Z'' - Z''Z''' + Z'''Z'} \\ &= \frac{2}{-\frac{1}{Z'} + \frac{1}{Z''} + \frac{1}{Z'''}} \qquad (4) \end{aligned}$$

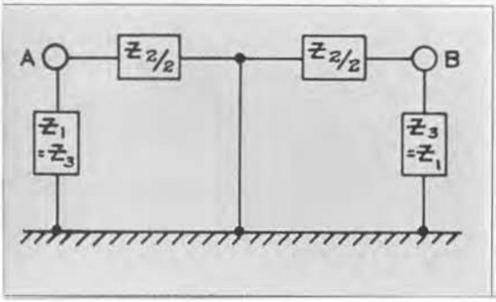

FIGURE 3. Optional equivalent circuit of balanced line for balanced excitation voltages.

$$\begin{aligned} Z_2 &= \frac{2Z'Z''Z'''}{Z'Z'' + Z''Z''' - Z'''Z'} \\ &= \frac{2}{\frac{1}{Z'} - \frac{1}{Z''} + \frac{1}{Z'''}} \qquad (5) \end{aligned}$$

$$\begin{aligned} Z_3 &= \frac{2Z'Z''Z'''}{-Z'Z'' + Z''Z''' + Z'''Z'} \\ &= \frac{2}{\frac{1}{Z'} + \frac{1}{Z''} - \frac{1}{Z'''}} \qquad (6) \end{aligned}$$

Equations (4), (5), and (6) give each component of impedance, from which both the line impedance Z_{AB} and the unbalance can be found.

When the line is truly balanced, $Z_1 = Z_3$, $Z' = Z'''$, and

$$Z_1 = Z_3 = 2Z'' \qquad (4a)$$

$$Z_2 = \frac{2Z'Z''}{2Z'' - Z'} = \frac{1}{\frac{1}{Z'} - \frac{1}{2Z''}} \qquad (5a)$$

$$Z_{AB} = \frac{2Z_1 Z_2}{2Z_1 + Z_2} = \frac{4Z'Z''}{4Z'' - Z'} \qquad (7)$$

This method, while highly accurate, is rather time consuming and is most useful when unbalance of the line is of particular importance.

METHOD II

A more rapid and direct method, suggested by Mr. John F. Byrne of Harvard University, is very useful when line balance is reasonably well maintained. It requires the use of the auxiliary network of Figure 2, which is a lumped-circuit single-frequency equivalent of a half-wave transmission line.

The open-circuit output voltage appearing across points 3 and 4 is equal in magnitude and 180° out of phase with the input voltage across points 1 and 2. The short-circuit impedance looking back from points 3 and 4 is zero. Thévenin's theorem therefore shows that, whatever the loading, the voltages between points 1 and 2 and between points 3 and 4 will be equal and 180° out of phase.

A balanced line connected between points 1 and 3 will, as a consequence, be excited with balanced voltages. Under this condition, the equivalent circuit of Figure 1 can be redrawn as shown in Figure 3 with the midpoint of the architrave impedance grounded.

When a balanced line is connected between terminals 1 and 3, it is therefore equivalent to connecting an impedance equal to Z_1 in parallel with $Z_2/2$ across the input terminals 1 and 2, and another identical impedance across the output terminals 3 and 4. Since the network simulates a half-wave line, the input impedance is equal to the terminating impedance. The effective input impedance, Z, is therefore

$$Z = \frac{1}{2}\,\frac{Z_1Z_2/2}{Z_1 + Z_2/2}$$

$$= \frac{1}{4}\,\frac{2Z_1Z_2}{2Z_1 + Z_2} = \frac{Z_{AB}}{4} \qquad (8)$$

The experimental procedure in adjusting the circuit of Figure 2 is very simple. The two coils, L_1 and L_2, should be identical and should have a reactance at the operating frequency of the same order of magnitude as the impedance to be measured. The variable condensers, C_1 and C_2, should be of such size that their reactance can be set to half the coil reactances. The output terminals, 3 and 4, are first short-circuited and condenser C_1 adjusted to series resonance. This condition can be found by observing the input impedance on the bridge and setting to zero reactance. The output terminals are then open-circuited and condenser C_2 adjusted to parallel resonance. This is most easily observed by balancing the bridge with a capacitance across the UNKNOWN terminals and adjusting to make the change in reactance setting zero when the input impedance is connected in parallel. Losses in the condensers and coils used in the network will cause a small measurement error. By proper choice of circuit elements, however, these can ordinarily be made negligible. Substantial unbalance of the line will also cause error. Whenever suspicion arises that errors from these causes are significant, a measurement by Method I can be used for verification.

— D. B. Sinclair

TAKING THE PULSE OF TURBINES

● **AN EXCELLENT ILLUSTRATION** of the ever-increasing utility of electronic technique and equipment in the field of mechanical research is the method used by General Electric engineers for the study of vibration of high-speed-turbine buckets.

Figure 1. Type 713-B Beat-Frequency Oscillator mounted in assembly with power amplifier.

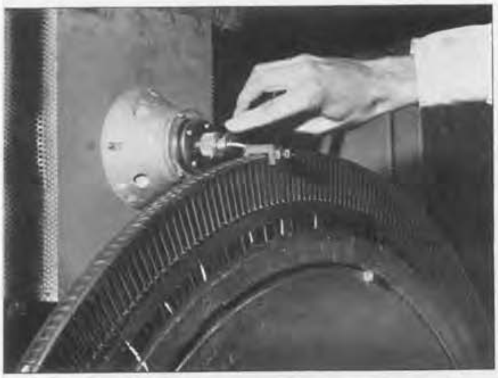

FIGURE 2. The oscillator supplies power to vibrate the turbine buckets through a power amplifier and an electro-mechanical transducer shown above.

FIGURE 3 (*above*). Engineers move the crystal pickup along the bucket tips. The pickup output is fed to the cathode-ray oscillograph shown below.

FIGURE 4 (*below*). Points of peak vibration are noted on the oscillograph as the pickup is moved along the buckets.

One of the problems confronting the designers of turbine wheels is that of obtaining a quantitative knowledge of the frequency and amplitude of resonant or other vibrations set up in the wheels, particularly in the buckets at the periphery (which may travel at speeds approaching a thousand miles per hour). In wheels designed for the high speeds prevalent in modern practice, the vibrations that occur are likely to be of high frequency and relatively small amplitude. Conventional mechanical means of reproducing and studying these conditions, while satisfactory with the larger structures and lower frequencies common at lower speeds, become practically useless. In the flexibility and versatility of modern electronic practice, however, a satisfactory solution has been found.

The buckets are vibrated by means of an electro-mechanical transducer, driven by a 1000-watt amplifier. A General Radio TYPE 713-B Beat-Frequency Oscillator was selected to drive the power amplifier. The relatively high-power output (1 watt), the low distortion, and the fine frequency control of the TYPE 713-B make it particularly suitable for this application. With the oscillator and power amplifier, the buckets can be driven at any frequency in the range from 30 cycles to 20,000 cycles.*

The resulting vibration of the driven buckets is picked up by a piezo-electric vibration pickup applied to the bucket tips, and applied to an amplifier feeding a cathode-ray oscillograph. The vibrations, amplified in magnitude approximately 100,000 times, can then conveniently be observed and measured. The resulting information assists in the design of wheels that are free from destructive resonances at normal speeds.

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*The range of the TYPE 713-B is 20 cycles to 40,000 cycles, the power amplifier and driving system limiting the range to that given above.

DISCONTINUED INSTRUMENTS

● **IN ORDER TO PRODUCE CRITICAL WAR GOODS** at maximum efficiency, it is necessary for the manufacturer of specialties to eliminate from his line those items for which there is little demand, which can be easily produced by others, or which essentially duplicate other items in the line. In this way, production facilities, materials, and man power are conserved for the manufacture of more urgently needed items.

We have listed from time to time in the *Experimenter** instruments that are discontinued for the duration of the war. To those previously listed the following items have now been added:

Type 419-A Wavemeter
Type 714-A Amplifier
Type 672-A Power Supply
Type 673-A Power Supply
Type 755-A Condenser
Type 588-AM Meter

Except for frequencies between 150 Mc and 300 Mc, the Type 419-A Wavemeter can be replaced by the new Type 566-A described in this issue of the *Experimenter*. For frequencies above 150 Mc, the Type 758-A Wavemeter can be used.

The amplifier and the two power supplies can, for most uses, be duplicated easily in the laboratory or by other manufacturers.

The Type 588-AM Meter, formerly carried in our catalog for use with Type 493 Thermocouple, is no longer needed since this thermocouple was discontinued some time ago.†

**Experimenter*, Sept., 1941, Feb., 1942.
†*Experimenter*, Dec., 1941.

USING A POLARIZING VOLTAGE WITH THE CAPACITANCE TEST BRIDGE

● **FOR MEASUREMENTS** of the capacitance and the power factor of electrolytic condensers with the Type 740-B Capacitance Test Bridge, it is usually desirable to apply a d-c polarizing voltage to the condenser under test, in order to simulate operating conditions.

Formerly, terminals for applying the polarizing voltage with this bridge were available on special order only, at an extra charge. Because of the growing de-

Figure 1. Schematic circuit diagram of the Type 740-B Capacitance Test Bridge.

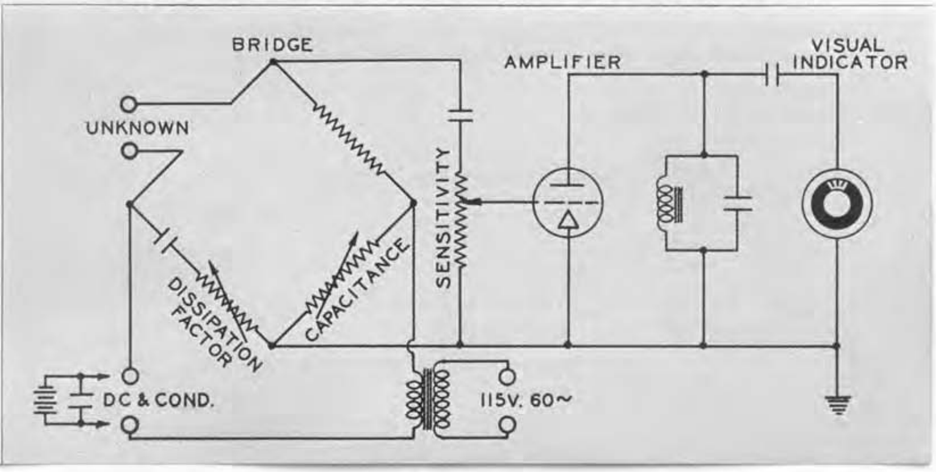

FIGURE 2. Panel view of the TYPE 740-B Capacitance Test Bridge. The polarizing voltage terminals are at the top of the panel.

mand for this feature, it is now included in the stock model of the bridge, at no increase in price.

Figure 1 is a schematic circuit diagram, and Figure 2 shows the position of the terminals on the panel.

The polarizing voltage is applied in series with the 60-cycle bridge supply. The condenser shown across the polarizing battery is usually necessary to avoid a reduction in bridge supply voltage resulting from the impedance of the battery in series with the supply. A rectifier-filter combination with a high-capacitance condenser in the filter output will obviate the need for the condenser as will also a storage battery, which usually has a high equivalent capacitance. The condenser should always be used with dry batteries.

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