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ELECTRICAL COMMUNICATIONS TECHNIQUE
AND ITS APPLICATIONS IN ALLIED FIELDS

A UNIVERSAL BRIDGE

THERE has been a marked increase in recent years in the use of bridge methods for the measurement of impedances of all kinds. This increase has come from the greater number of quantities to be measured, from the greater range of their numerical values, and from the greater range of frequency at which the measurements must be made. The values of the magnitude range and frequency range over which measurements are desired are impressive; resistance from a microhm to a megamegohm, inductance from a millimicrohenry to a kilohenry, capacitance from a millimicromicrofarad to a millifarad; not all perhaps, but some of these at frequencies ranging from a cycle per second to a hectomegacycle per second.

A bridge is merely an instrument with which two impedances, known and unknown, may be compared. The known standard is not inherent in the bridge itself. It must be separately provided. The number and variety of these standards is large; for a single standard can rarely cover a range of a thousand to one in either direction from its own value, and that only at low frequency and low accuracy. As these rise the range of ratio drops, approaching unity for an accuracy of .01% and at a frequency of 100 kilocycles per second.

An obvious way by which the number of standards may be decreased and the accuracy of measurement increased is by the use of the various bridges in which unlike impedances may be compared, as for example, resistance and self and mutual inductance in terms of capacitance, capacitance in terms of resistance and frequency, frequency in terms of inductance and capacitance.

The TYPE 293-A Universal Bridge has been designed with considerations of this sort in mind. It provides the essentials of a bridge, variable ratio arms and a standard resistance which may be used as an added resistance to satisfy one of the conditions of balance, in such a form that all types of bridges may be constructed. These three resistances are mounted on the panel of the bridge as shown in Figure 1, with their terminals and those of an added

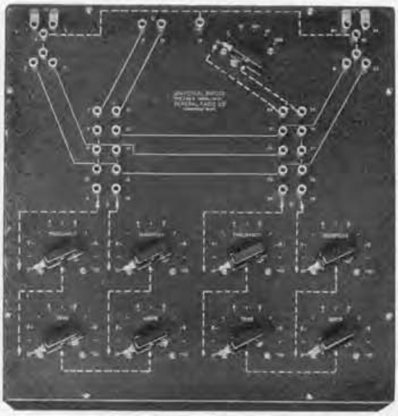


FIGURE 1. Panel view of a TYPE 293-A Universal Bridge. Dotted lines were drawn in after the photograph was taken

impedance symmetrically disposed. These four pairs of terminals may be connected to each other and to the input and output terminals placed at the upper corners of the panel through six pairs of intermediate binding posts, the actual connections being made by links which plug into the various jack-top binding posts.

The principle on which this terminal board is arranged is shown diagrammatically in Figure 2, in which the full lines represent the permanent connections. The three variable resistances together with the added impedance form the four arms of a simple Wheatstone bridge when the ten links indicated by the dotted lines are plugged in. For this four-impedance network the arrangement of the connecting links is symmetrical.

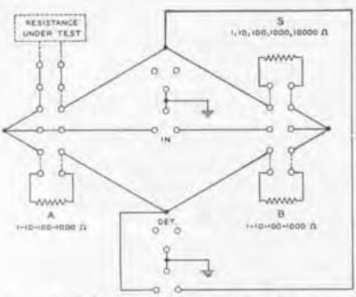


FIGURE 2. Schematic diagram for the measurement of resistance by the Wheatstone Bridge

The three kinds of bridge networks shown in Figure 3 cover practically all of the bridges used for the comparison of like and unlike impedances. The names of these bridges, together with the kinds of impedances compared on them, are given in the table. All of these bridges may be set up on the

TABLE I

Common Bridges Showing the Type of Network and the Kind of Known and Unknown Elements

Bridge	Network[1]	U[2]	S[2]
Impedance	*a*	*R* *L* *C*	*R* *L&R* *C&R*
Grover	*a*	*C* *C*	*C&R* *C&R*
Schering	*a*	*C*	*C&R*
Maxwell	*a*	*L*	*C&R*
Owen	*a*	*L*	*C&R*
Hay	*a*	*L*	*C, R&f*
Resonance	*a*	*L* *f*	*C&f* *L&C*
Wien	*a*	*C* *L* *f*	*R&f* *R&L* *C&R*
Anderson	*b*	*L*	*C&R*
Anderson-Hay	*b*	*C*	*C&R*
Campbell	*c*	*L*	*M&R*
Carey Foster	*c*	*C* *M*	*M&R* *C&R*

[1]Letters refer to the networks of Figure 3.
[2]*U* represents the unknown quantity that can be measured when the corresponding quantities in the *S* column are known. *L, M, R, C, and f* represent respectively self-inductance, mutual inductance, resistance, capacitance, and frequency.

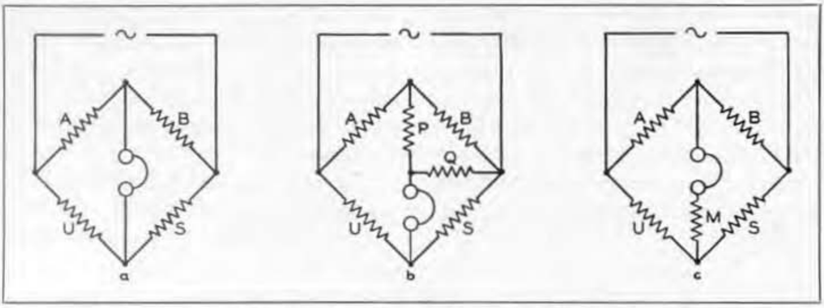


FIGURE 3. Practically all bridge networks are elaborations of these three basic circuits. The letters *a*, *b* and *c* refer to the second column of Table I

TYPE 293-A Universal Bridge by suitably placing the known and unknown impedances and the interconnecting links. The determination of their positions is facilitated by the procedure illustrated in Figure 4.

Owen's bridge, in which the inductance and resistance of an unknown inductor are measured in terms of two added capacitances and the variable resistances, has been chosen as an example. The schematic diagram of the bridge is made and the four arms lettered cyclically *A-B-S-U* in such a manner that the three variable resistors are used to best advantage. The position of the connecting links may then be drawn on the terminal board diagram, together with the places for connecting the external impedances. Such figures for all the bridges mentioned in Table I are given in the instruction book furnished with each TYPE 293-A Universal Bridge. Blank diagrams for other bridges are also provided.

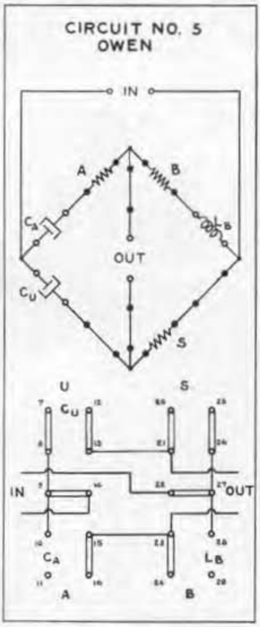


FIGURE 4

The TYPE 293-A Universal Bridge set up as an Owen Bridge

The resistors used in this bridge are the new TYPE 510 Decade-Resistance Units, having the switch contacts below the panel. The three variable resistors are shielded from each other and the whole bridge is placed in a copper-lined cabinet. Double pairs of input and output terminals are provided so that shielded transformers may be used.

The accessories required for the operation of the bridge include a power supply, null detector, and standards of impedance. Suitable instruments for these purposes are described in Catalog F. The TYPE 508-A Oscillator and the TYPE 514-A Amplifier used in conjunction with head telephones or the Type 488-DM Alternating-Current Meter are particularly recommended as power supply and null detector. The Type 293-P1 and Type 293-P2 Transformers are shielded transformers for isolating electrostatically the power supply from the bridge. The Type 293-P3 Slide-Wire Resistor provides a continuously variable resistance which bridges the lowest resistance steps in the bridge. It is particularly useful in the measurement of small reactances.

The price of the Type 293-A Universal Bridge is $140.00.

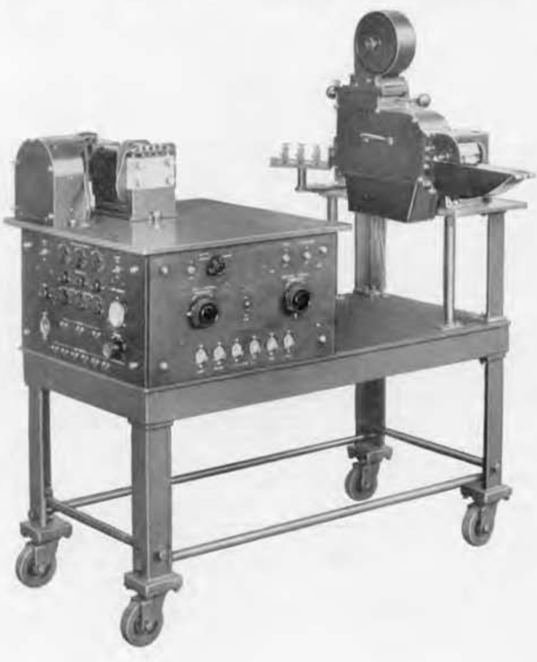
— Robert F. Field

A SELF-DEVELOPING CAMERA OSCILLOGRAPH

As an illustration of one of the many types of special equipment built by the General Radio Company, we are showing a photograph of a new self-developing string oscillograph.

This oscillograph automatically develops its own photographic records and, accordingly, is of unusual value in commercial research or in adjustment of control circuits where the results of any change must be seen at once.

The sensitized paper is fed into a constantly revolving cylinder, carried past the shutter, and then on through



A three-element camera oscillograph with the self-developing feature both developing and fixing solutions, so that the record is available within a few seconds of the time of exposure. A wide range of operating speed is available and satisfactory oscillograms can be made with paper speeds up to about 15 inches per second.

The action is controlled by a two-position lever which feeds the paper in the first position, and cuts and stops the paper in the second. A three-string harp is standard, and the camera, driving motor, light source, timing units, and controls are all mounted on a portable table.

We have available at the present time two extra oscillographs of this type, designed for operation from 110 volts, d-c. They are priced at $3000.00 each, subject to prior sale.

— H. H. Scott

A FREQUENCY DEVIATION INDICATOR FOR TRANSMITTERS

General Order No. 116 of the Federal Radio Commission, which requires radio broadcasting stations to hold their transmitter frequencies to within ±50 cycles per second of the assigned channels, places on the station frequency monitoring equipment more rigid requirements than have heretofore been necessary.

A highly stable piezo-electric oscillator for use as a monitoring standard of frequency was described by James K. Clapp in the last issue of the *Experimenter*.

While the frequency standard is the most important element of the monitoring system, General Order No. 116 requires, by implication, that an accurate means be available for comparing the frequency of the transmitter with that of the monitoring standard. Under the old 500-cycle tolerance, a zero audible beat or any audible beat note below 500 cycles was sufficient, while under the new order, the beat-frequency indicator should be accurate to within a few cycles per second.

The design of a frequency meter to operate from zero to 50 or 100 cycles per second is extremely difficult since it involves the measurement of both audio and sub-audio frequencies, and, if it actually operates down to zero, it must cover an infinite frequency range. Even if it operates only between one and 50 cycles per second, the frequency

Figure 1. The frequency monitor consisting of a Type 575-D Piezo-Electric Oscillator and a Type 581-A Frequency Deviation Meter

range covered has a ratio of 50 to 1. In general, an accurate frequency meter can cover only a narrow range of frequency; and, as the range becomes smaller, the accuracy increases accordingly.

Since the problem of measuring the deviation of a radio transmitter from a known standard is concerned with the actual deviation in cycles rather than the percentage deviation, it is immaterial what actual value of beat frequency corresponds to zero deviation as long as the variations above and below this value can be measured. A practical answer, then, is to move the normal operating point up in the audio-frequency spectrum until 50-cycle deviations on either side correspond to smaller percentage changes in the audio frequency. This can be realized by using as a monitoring standard a crystal whose frequency differs from the assigned broadcast channel by, say, 1000 cycles per second. The frequency meter can then be designed to read 50 cycles per second above and below 1000. The 1000-cycle difference need not appear on the frequency indicator which can be arranged to read zero at 1000 cycles per second.

General Radio Type 581-A Frequency Deviation Meter is specifically designed to meet these requirements. It consists of a 1000-cycle frequency meter, preceded by a detector and a two-stage audio amplifier.

Voltages derived from the unmodulated master oscillator of the transmitter and from the monitoring standard are impressed on the detector and the resulting audio-frequency beat is amplified and applied to the frequency meter. The frequency indicator is a large pointer-type meter reading zero at 1000 cycles per second and indicating deviations of 100 cycles above and below this value. The scale is sufficiently open to indicate changes of one cycle per second.

The frequency meter itself is a tuned circuit arrangement, as are nearly all

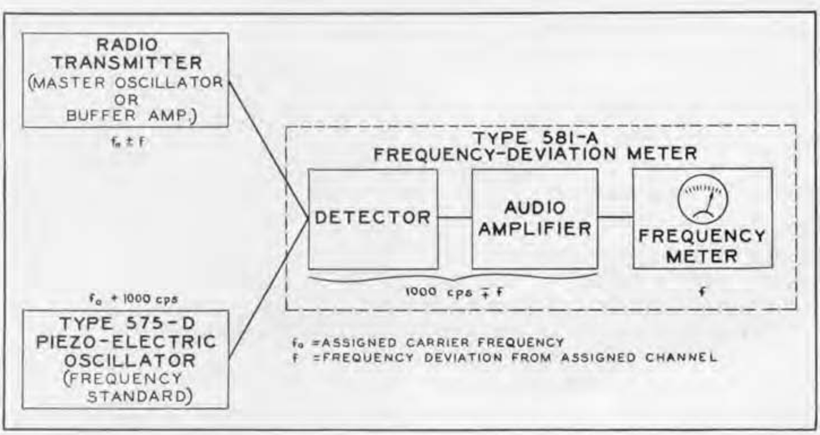


Figure 2. Schematic diagram for the frequency monitor. The "frequency standard" is operating at a frequency 1000 cps above that of the carrier. When operating 1000 cps below the carrier the beat frequency involved in the deviation meter is $(1000 \pm f)$

such instruments which cover narrow frequency ranges.

Several new features are involved which permit high accuracy to be achieved at low cost, a factor which is important if the meter is to be commercially acceptable. Another advantage lies in the fact that it indicates continuously the direction, as well as the magnitude of the frequency deviation. A glance at the meter tells the operator what adjustments he must make to bring the station to the proper frequency.

Type 581-A Frequency Deviation Meter is intended for use with the Type 575-D Piezo-Electric Oscillator. An assembly of the two instruments is shown in Figure 1.

A functional block diagram of the frequency meter assembly is shown at the right of Figure 2. A schematic diagram of the frequency meter itself is given in Figure 3. It consists of two tuned circuits, and two rectifiers connected in opposing directions. The difference of the currents from these rectifiers is indicated by a meter which is calibrated directly in cycles per second.

Figure 2 is a block diagram of the entire monitoring system. In this diagram, f_o is the assigned channel frequency and f is the deviation of the

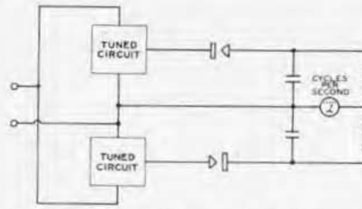


Figure 3. Schematic diagram for the frequency indicating element of the deviation meter

transmitter from that frequency. The transmitter frequency is accordingly $f_o \pm f$. The crystal oscillator operates at a frequency 1000 cycles per second above the assigned channel and its frequency may be expressed as $f_o + 1000$.

When the crystal oscillator and transmitter voltages are impressed on the detector, the resulting audio-frequency beat tone is 1000 cycles $\mp$f.*

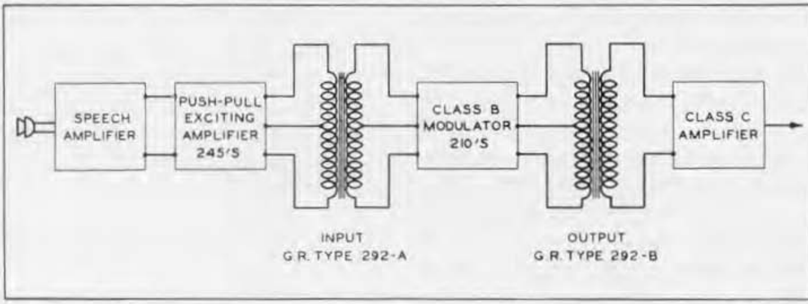
If f is zero, that is, if the transmitter is on frequency, the beat is 1000 cycles per second and the indicator is at zero. An increase in transmitter frequency produces a deflection to the right; a decrease one to the left. The scale is 200 cycles wide, that is, deviations of 100 cycles either side of zero can be read on the meter.

*The crystal frequency can, of course, be either above or below the channel frequency. The sign of the deviation indication can be reversed by reversing the leads to the frequency indicator.

THE "CLASS B" MODULATOR FOR AMATEUR PHONE TRANSMITTERS

By means of "the so-called Class B" type of amplifier, the power output from an amplifier using standard types of tubes may be greatly increased over that possible in the conventional amplifier system.

The circuit arrangement is that known as a push-pull amplifier. The



Schematic diagram for a low-power amateur phone transmitter utilizing General Radio Type 292 Transformers in a "Class B" Modulator

gain in power is obtained by a shift in the operating point of the tube on its characteristic so that grid current is taken. The plate current cuts off entirely in each tube during one-half of the cycle. The current in the B lead is therefore not constant, as is the case with the standard push-pull amplifier, but varies cyclically. This difference is of importance in considering power-supply design.

One of the most interesting applications of the "Class B" amplifier is in radio-phone transmitters of moderate power. By means of this circuit, tubes of the 210-type can be made to produce sufficient power for 100% modulation of 50-watt tubes.

The circuit is shown above. Two new General Radio transformers are announced for use in this circuit. One is used as an input push-pull transformer between two 245 and 210 stages and the other is used as the output transformer, coupling the "Class B" modulating amplifier to the radio-frequency amplifier.

The new transformers are: Type 292-A Input Transformer, price $7.00. Type 292-B Output Transformer, price $10.00.

THE GENERAL RADIO COMPANY mails the Experimenter, without charge, each month to engineers, scientists, and others interested in communication-frequency measurement and control problems. Please send requests for subscriptions and address-change notices to the

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