the GENERAL RADIO Experimenter

INDEX

TO

GENERAL RADIO EXPERIMENTER

Volumes XXIV and XXV

JUNE, 1949 to JUNE, 1951

GENERAL RADIO COMPANY
CAMBRIDGE MASSACHUSETTS
U. S. A.

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GENERAL RADIO EXPERIMENTER

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THE General Radio EXPERIMENTER

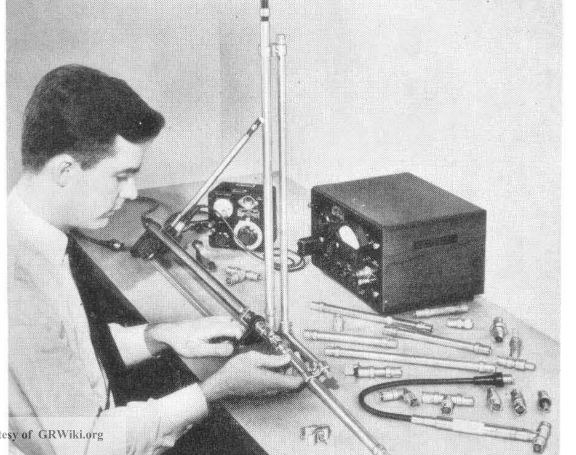
VOLUME XXIV No. 8 JANUARY, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

SIMPLE, COMPLETE COAXIAL MEASURING EQUIPMENT FOR THE U-H-F RANGE

● **NOW COMMERCIALLY AVAILABLE** for the first time is a complete set of measuring equipment for the 300-Mc to 3,000-Mc frequency range. It will measure, rapidly and accurately, impedance, standing-wave ratio, power, voltage, attenuation, and many other quantities. The set consists of a number of inexpensive coaxial elements, each one simple in itself, that can be plugged together to make many different measurement setups easily and quickly. Thus a relatively small investment in these versatile parts provides the necessary equipment for most measurement problems encountered in a high-frequency laboratory. In the proposed u-h-f television band, 475 Mc to 890 Mc, coaxial elements can be used for checking everything from antennas to components.

The fundamental measuring tools are a slotted line for impedance and standing-wave ratio measurements, bolometer elements and a bolometer bridge for power measurements, and a crystal rectifier and indicator for voltage measurements. These devices are supplemented by all the necessary accessory parts, such as tuning stubs, a "line-stretcher," a tee, an ell, line sections of various lengths, a matching resistance termination, fixed and adjustable attenuators, low-pass filters, and other specialized devices.



With Type 874 Coaxial Elements, any required measurement setup can be assembled quickly and easily, as shown here.

The keystone of this group of coaxial elements is the TYPE 874 Coaxial Connector.[1] This unique connector, any two of which, though identical, can be plugged together, is ideally suited for use on coaxial measuring equipment and was specifically designed for this purpose. Its quick-connect-and-disconnect feature simplifies the assembly of coaxial elements into complete measurement setups, and its low reflections at ultra-high frequencies can be neglected except in very accurate work.

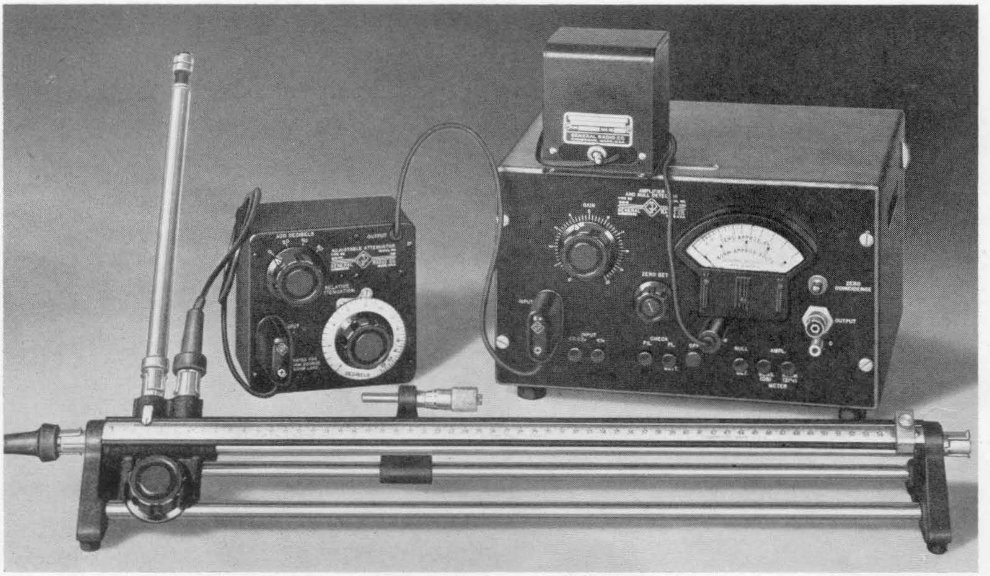
Although the equipment was designed primarily to cover the frequency range from 300 Mc to 3,000 Mc, many of the coaxial elements can be used equally well at much lower frequencies (some at dc), and others perform well up to 5,000 Mc and beyond. The first higher-order transmission mode appears at about 9,000 Mc. A characteristic impedance of 50 ohms is used wherever possible throughout. The various transmission-line sections have air dielectric, and the inner conductors are supported at their ends by the thin, polystyrene beads in the connectors. The outside diameter of the outer conductor tubes is in most cases ⅝ inch.

Applications for this new equipment are numerous. It is ideal for college laboratories, where experimental setups are continually being assembled, taken apart, and changed, and where the versatility of the coaxial elements will permit the same elements to be combined in many different ways for various experiments. Furthermore, the relatively low cost means that more equipment can be obtained within a given budget, so that it becomes practical to have more setups with fewer students per setup, thereby increasing the effectiveness of the laboratory work.

The sturdiness and light weight of TYPE 874 equipment make it convenient for field use. The TYPE 874-LB Slotted Line, for example, has been found to be very satisfactory for making antenna measurements at the top of antenna towers.

[1] W. R. Thurston, "A Radically New Coaxial Connector for the Laboratory," *General Radio Experimenter*, Vol. XXIII, No. 5, October, 1948.

View of complete equipment for standing-wave measurements, consisting of Type 874-LB Slotted Line with Type 874-LV Micrometer Vernier, Type 1231-P4 Adjustable Attenuator, Type 1231-B Amplifier with Type 1231-P2 Tuned Circuit, and Type 874-R32 Patch Cord.



Certain research and development laboratories have devised a clever method of taking full advantage of the quick-assembly feature of the coaxial elements. A "tea wagon," fitted out with a complete assortment of the equipment and using spring clips to hold the smaller elements, can be wheeled out of the instrument room to any desired location in the department whenever any high-frequency measurements are to be made. The appropriate combination of coaxial elements can then be assembled from the group stored on the "tea wagon" and after the measurements are completed can be replaced ready for the next person. The short time required to assemble the equipment makes the use of several, permanent, single-purpose setups unnecessary.

— W. R. Thurston

1. EQUIPMENT FOR STANDING-WAVE MEASUREMENTS

Type 874-LB Slotted Line

An air-dielectric, coaxial transmission line with a longitudinal slot in the outer conductor. An electrostatic pickup probe, mounted on a sliding carriage, projects through the slot and samples the electric field within the line. The depth of probe penetration is fully adjustable, and the probe travel distance is 50 cms., which is a half wavelength at 300 Mc. The line inner conductor is supported at its ends by two Type 874 Connectors. The first higher-order mode of transmission can exist only above about 9000 Mc.

Either a crystal rectifier or a receiver can be used as a detector. The probe carriage incorporates a built-in crystal mount, and a Type 1N21-B silicon crystal is supplied with the line. When a receiver is used as a detector, the energy picked up by the probe is fed to the receiver by a flexible coaxial cable, such as the Type 874-R20 Patch Cord described on page 11. When the crystal is used as a detector, it is tuned to the operating frequency by a Type 874-D20 Adjustable Stub, available separately and described on page 7, which plugs into a connector on the probe carriage. The u-h-f generator should be amplitude modulated, so that the crystal output is an audio-frequency voltage that can be amplified and indicated by the Type 1231-B Amplifier and Null Detector. The stub will tune the crystal over the frequency range from 300 Mc to above 5000 Mc. The probe carriage has two Type 874 Connectors, one for the crystal output and the other for the tuning stub or for a patch cord to a receiver.

Characteristic Impedance: 50 ohms.

Frequency Range: 300 to 5000 Mc.

Dielectric: Air.

Accuracy: Constancy of probe penetration—±2½% or better.

Voltage Standing-Wave Ratio of Terminal Connectors — Less than 1.02 at 1000 Mc. Less than 1.07 at 4000 Mc.

Accuracy of Characteristic Impedance — ±1% or better.

Dimensions: 26 x 4½ x 3½ inches, overall.

Net Weight: 8 pounds.

Type 874-LV Micrometer Vernier Attachment for Slotted Line

For measurement of high standing-wave ratios by the width-of-minimum method. Consists of a micrometer caliper head, calibrated in centimeters, mounted on an arm that can be attached to the rear base rod of the slotted line. One turn of the micrometer barrel advances the head by one millimeter. Maximum range is 2 cms.

Type		*Code Word*	*Price*
874-LB	**Slotted Line**	COAXRUNNER	**$220.00**
874-LV	**Micrometer Vernier Attachment**	COAXREADER	**30.00**

Type 1231-B Amplifier[2] (Standing-Wave Indicator)

Amplifies and indicates slotted-line crystal detector output in decibels. Consists of a high-gain audio amplifier and an output meter. Full-scale meter deflection is produced by an input voltage of less than 100 μv at full gain. The output meter has an approximate calibration in decibels for rough measurements of standing-wave ratios up to about 6 db. The instrument is normally furnished with internal batteries for power supply, but the Type 1261-A Power Supply, which fits into the battery compartment of the Type 1231-B Amplifier, is available separately if operation from a-c lines is preferred. With the a-c power supply, a line-voltage regulator may be needed if line voltage is not reasonably constant. If the modulation frequency is either 400 cycles or 1000 cycles, the Type 1231-P2 Tuned Circuit can be used to eliminate the slight fluctuations of the Type 1231-B output meter caused by amplifier noise. For details of Type 1231-B Amplifier, see current General Radio catalog.

[2] W. R. Thurston, "An Improved Amplifier and Null Detector," *General Radio Experimenter*, February, 1948.

Type 1231-P4 Adjustable Attenuator

For increasing the range and accuracy of standing-wave measurements with the Type 1231-B Amplifier. Is a high-impedance, resistance-type attenuator for use between the output of the slotted-line crystal detector and the input of the amplifier. Has three 20-db steps and a 20-db potentiometer to cover the range between steps.

Source Impedance: 30 kΩ — approximately equal to output impedance of crystal detector in slotted line at low voltage levels.

Initial Insertion Loss: Approximately 3 db.

Attenuation Range: 80 db; dial can be read to nearest tenth db.

Accuracy of Attenuation Increments: ±0.3 db or better when operated between rated source and load impedances. Additional errors caused by source impedance between 15 kΩ and 60 kΩ are less than ±0.3 db.

Frequency Error: Negligible below 2 kc.

Maximum Input Power: ½ watt.

Terminals: Input, Type 938-W Binding Posts; Output, shielded cable with Type 274-ND Shielded Plug to fit amplifier input terminals.

Circuit: Modified voltage divider.

Mounting: Metal cabinet.

Over-all Dimensions: 5½ x 5½ x 4½ inches, overall.

Net Weight: 2 pounds, 11 ounces.

Type		*Code Word*	*Price*
1231-B	**Amplifier**	VALID	**$210.00**
1231-P2	**Tuned Circuit**	AMBLE	**20.00**
1231-P4	**Adjustable Attenuator**	ANNEX	**52.50**

Connections between the crystal output connector of the Type 874-LB Slotted Line and the input of the Type 1231-B Amplifier or Type 1231-P4 Adjustable Attenuator can be made by the Type 874-R32 Patch Cord described on page 11.

2. EQUIPMENT FOR POWER MEASUREMENTS

Type 1651-A Bolometer Bridge

For conveniently measuring h-f power by either d-c substitution or direct-reading method with the three bolometer units described below. This new instrument will be described more fully in a forthcoming issue of the *Experimenter*, since specifications are not yet available.

Type 874-H25 Thermistor Unit (25 mw.)

Consists of a thermistor mounted in a coaxial holder with a disc-type by-pass capacitor. Binding posts are provided for connections to bolometer bridge. Can be used for power measurements over the frequency range from 5 Mc to several thousand megacycles. A d-c path is required in the r-f source. Complete with thermistor.

By-Pass Capacitance: Approximately 2000 $\mu\mu$f.

Physical Length Overall: 3⅝ inches.

Maximum Total Power: 25 mw.

Type 874-H100 Thermistor Unit (100 mw.)

Similar to Type 874-H25, with maximum power rating of 100 mw. Complete with thermistor.

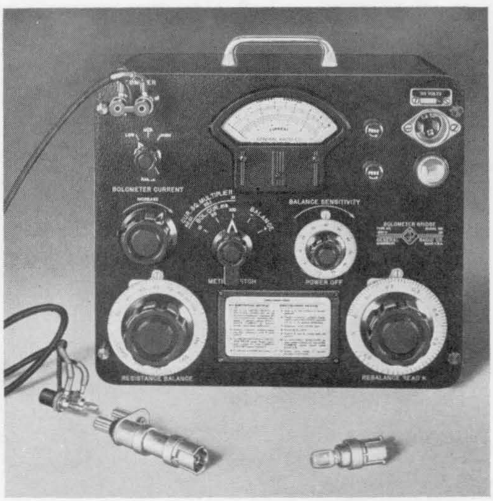
Physical Length Overall: 3¾ inches.

Type 874-HF Fuse Bolometer Holder

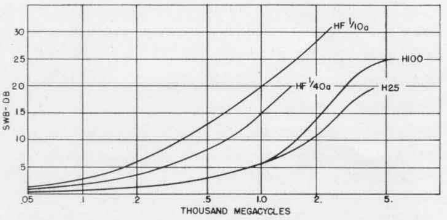
A coaxial holder for fuse bolometers 1 inch long by ¼ inch diameter (8AG size). Otherwise similar to the thermistor units described above. Supplied with one Type 874-HF-P1 Fuse Assortment.

By-Pass Capacitance: Approximately 2000 $\mu\mu$f.

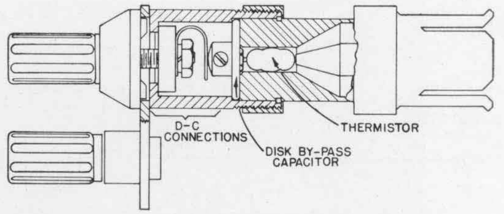
Physical Length Overall: 4 inches.



Typical assembly of equipment for power measurements, consisting of the Bolometer Bridge, with Thermistor Unit and Lamp Termination in the foreground. Patch cord is Type 274-NC.



Standing-wave ratio as a function of frequency for the Thermistor Units and Fuse Bolometer.



Cross section of the Thermistor Unit.

Type 874-HF-P1 Fuse Assortment

Replacement fuses for Type 874-HF. Includes five 1/10-amp. fuses (Buss AGX 1/10) and five 1/40-amp. fuses (Buss MJB 1/40). Maximum total power is 25 mw. for the 1/40-amp. fuses and 700 mw. for the 1/10 amp. fuses.

Connections

Between the bolometer bridge and the bolometer units can be made by the Type 274-NC Shielded Connector.

Type 874-WL Lamp Termination

For rough indications of power in the 50 mw. to 100 mw. range. Useful for making preliminary tests on experimental oscillators. Consists of a flashlight bulb in a screw-type, miniature socket on the rear of a connector. Bulb has a straight-wire filament and is rated at 1.35 volts. Either Type 874-MA Loop or Type 874-MB Probe can be used for coupling to power source. Can be used with a photoelectric cell and meter (such as a photographic exposure meter) in a d-c substitution method for more accurate measurements.

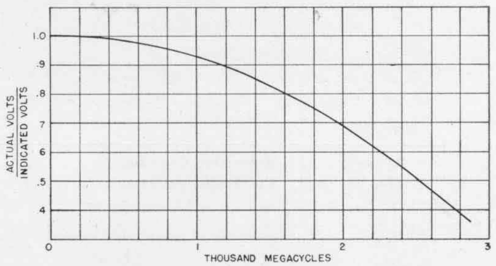
Type		*Code Word*	*Price*
874-H25	**Thermistor Unit**	COAXWARMER	**$40.00**
874-HP25	**Replacement Thermistor for Type 874-H25**	THERM	**9.00**
874-H100	**Thermistor Unit**	COAXHEATER	**40.00**
874-HP100	**Replacement Thermistor for Type 874-H100**	CALDO	**9.00**
874-HF	**Fuse Bolometer Holder**	COAXHOLDER	**34.00**
874-HF-P1	**Fuse Assortment**	FUSOR	**2.50**
874-WL	**Lamp Termination**	COAXLAMPER	**5.00**
274-NC	**Patch Cord**	STANPARZOO	**2.75**

3. EQUIPMENT FOR VOLTAGE MEASUREMENTS

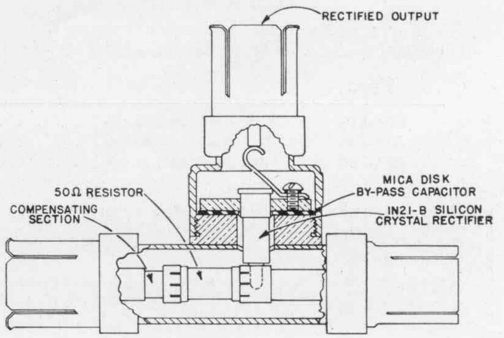
Type 874-VR Voltmeter Rectifier

Consists of a short coaxial line with a crystal rectifier mounted between inner and outer conductors and with a 50-ohm cylindrical resistor in series with the line inner conductor at one end. A by-pass capacitor is incorporated in the crystal mount. The crystal rectifies the high-frequency voltage across the line, and the rectified output is brought out to a coaxial connector. Placed in a coaxial system, the voltmeter rectifier can be used to monitor voltage levels. The 50-ohm resistor provides an effective termination for a 50-ohm cable or line extension connected to the resistor end of the unit, so that at the far end of the cable or line extension the open-circuit voltage equals the voltage at the crystal, less attenuation, and the effective source impedance is 50 ohms.[3] The resistor can be replaced by a suitable metal tube if no termination is desired, however. The voltmeter

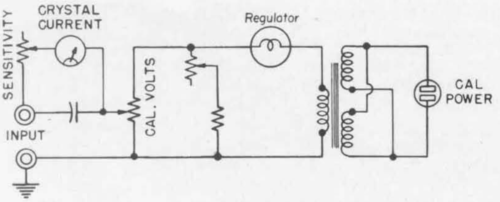
[3]Arnold Peterson, "Output Systems of Signal Generators," *General Radio Experimenter*, XXI, 1, June, 1946.



Correction factor for resonance in the Type 874-VR Voltmeter Rectifier.



Cross section of the Voltmeter Rectifier.



Schematic circuit diagram of the Type 874-VI Voltmeter Indicator.

rectifier can also be used as a general-purpose detector in conjunction with a high-gain amplifier such as the General Radio Type 1231-B.

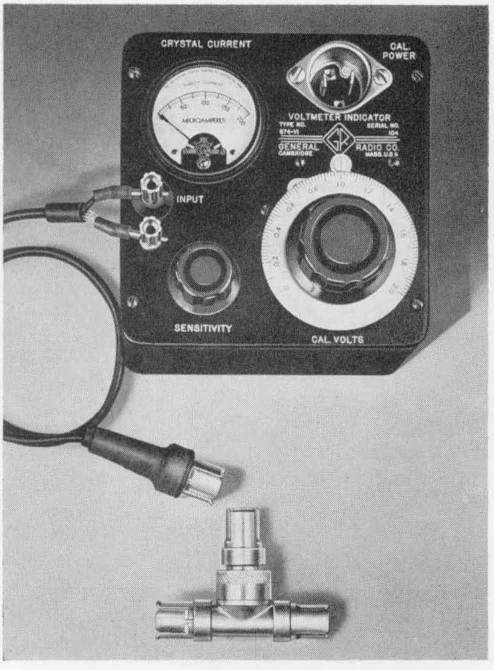
Resonant Frequency: Approximately 3600 Mc.

Maximum Voltage: 2 volts.

By-Pass Capacitance: Approximately 300 $\mu\mu$f.

Frequency Range for Voltage Measurements: Approximately 15 Mc to 2500 Mc, subject to resonance correction above 1000 Mc.

Frequency range for voltage *indications* extends to both lower and higher frequencies.



Type 874-VI Voltmeter Indicator

Includes a meter and a sensitivity control for indicating rectified d-c output of the Type 874-VR Voltmeter Rectifier. A 60-cycle circuit is also included for calibrating the crystal of the voltmeter rectifier at any desired level between 0.1 volt and 2 volts, so that errors due to gradual changes in crystal rectifier characteristics are eliminated. The 60-cycle calibrating voltage is regulated against line-voltage fluctuations.

Accuracy of Calibrating Voltage: $\pm$0.05 volt.

Crystal Current for Full-Scale Indication: 200 μa.

Dimensions: 5½ x 5½ x 4½ inches, overall.

Net Weight: 3 pounds, 1 ounce.

Connections

Connections between the Type 874-VR Voltmeter Rectifier and the Type 874-VI Voltmeter Indicator can be made by the Type 874-R31 Patch Cord. For completely shielded connections between the voltmeter rectifier and more sensitive indicating instruments, the Type 874-R32 or 874-R20 Patch Cords can be used. These patch cords are described on page 11.

Equipment for voltage measurement, consisting of Type 874-VR Voltmeter Rectifier, Type 874-VI Voltmeter Indicator, and Type 874-R31 Patch Cord.

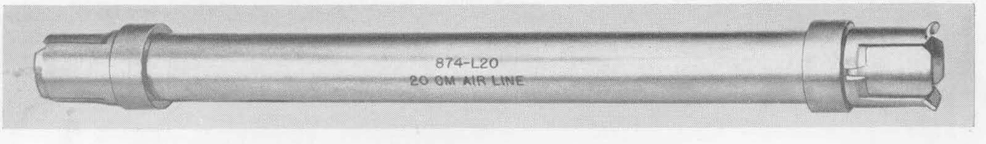
Type		*Code Word*	*Price*
874-VR	**Voltmeter Rectifier**	COAXRECTOR	**$25.00**
874-VI	**Voltmeter Indicator**	COAXVOLTER	**65.00**

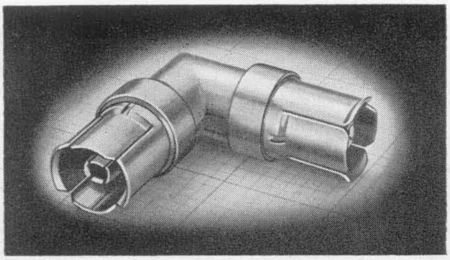
4. FIXED LINE ELEMENTS

50-Ohm Air Lines

For spacing stubs or other elements of a coaxial system. Each air line consists of a length of 50-ohm, air-dielectric, coaxial line with a connector at each end. The electrical lengths are 10 cms., 20 cms., and 30 cms., respectively.

Type		*Code Word*	*Price*
874-L10	**50-Ω Air Line (10 cm.)**	COAXDECKER	**$10.00**
874-L20	**50-Ω Air Line (20 cm.)**	COAXVENTER	**11.00**
874-L30	**50-Ω Air Line (30 cm.)**	COAXTRIPLY	**12.00**





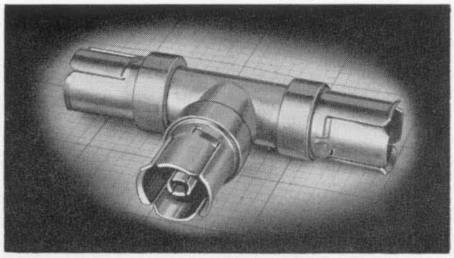
Type 874-EL 90° Ell

For making a right-angle bend in a coaxial system.

Characteristic Impedance: 50 ohms.

Electrical Length: Approximately 7 cms.

Type		*Code Word*	*Price*
874-EL	**90° Ell . . . . .**	COAXANGLER	**$6.50**



Type 874-T Tee

Used for connecting stubs and other elements in shunt with a coaxial line.

Note: All cross-section backgrounds shown in photos are 1/8-inch squares.

Type		*Code Word*	*Price*
874-T	**Tee . . . . . .**	COAXTOGGER	**$8.50**

5. ADJUSTABLE LINE ELEMENTS

Adjustable Stubs

For matching or tuning, and use as reactive elements. Can be used with indicator and scale as reaction-type wavemeters. Stubs consist of a coaxial line with a sliding short circuit of the multiple-spring-finger type. The short circuit is moved by a bakelite tube having a sliding reference marker to facilitate use as a wavemeter.

Characteristic Impedance: 50 ohms.

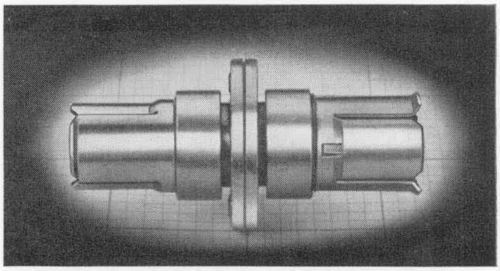
Maximum Travel of Short Circuit:
20 cms. for 874-D20
50 cms. for 874-D50.

Type 874-LA Adjustable Line (Line-Stretcher)

An air-dielectric, coaxial line that can be telescoped to change its length. Used in matching networks. Contacts are made by multiple spring fingers.

Length Change: 25 cms.

Characteristic Impedance: Not constant — approximately 50 ohms when fully collapsed. Approximately 57 ohms when fully extended.

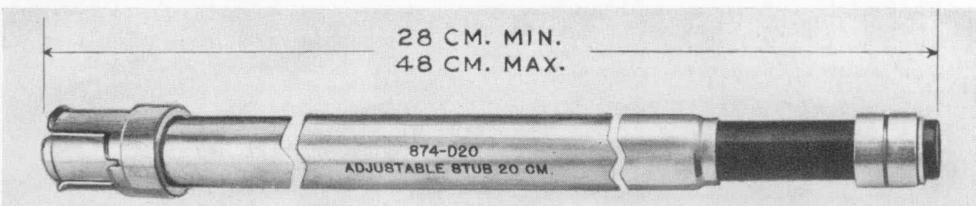


Type 874-JR Rotary Joint

Used when one part of a system must be rotated with respect to another part, as when measuring antenna patterns or when changing the coupling of a loop.

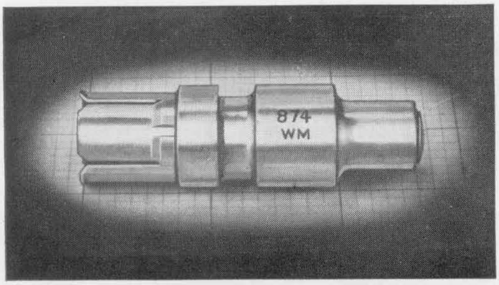
Type		*Code Word*	*Price*
874-JR	**Rotary Joint . . .**	COAXJOINER	**$8.50**

Type		*Code Word*	*Price*
874-D20	**Adjustable Stub (20 cm.) . . . .**	COAXTUBBER	**$15.00**
874-D50	**Adjustable Stub (50 cm.) . . . .**	COAXBIGGER	**16.00**
874-LA	**Adjustable Line . . . .**	COAXLAPPER	**18.00**



6. TERMINATIONS

Type 874-WM 50-Ohm Termination



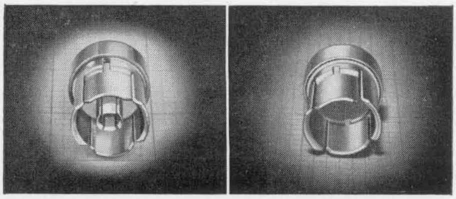
Provides a good impedance match for 50-ohm coaxial systems from dc to several thousand megacycles. Useful for establishing reference conditions, for terminating filters and attenuators, and for many other purposes. Consists of a 50-ohm cylindrical resistor mounted in a tapered coaxial holder.

D-C Resistance: 50 ohms ±1%.

Maximum Power: ½ watt.

Type 874-WN Short-Circuit Termination
Type 874-WO Open-Circuit Termination

Useful for establishing reference conditions on coaxial lines. Can be used in substitution measurements when the unknown is to be replaced by a short circuit or an open circuit. The short-circuit termination consists of a fixed shorting strap mounted in a connector. The effective position of the electrical short-circuit is fixed. The open-circuit termination is a shielding cap for open-circuited lines. Because of unavoidable end capacitance, the effective position of the electrical open-circuit varies with frequency over a distance range of 2 mm. On the average, it is 2 mm. from the effective position of the electrical short-circuit produced by the short-circuit termination.



Left, Short-Circuit Termination and, *Right*, Open-Circuit Termination.

Type		*Code Word*	*Price*
874-WM	**50-Ohm Termination**	COAXMEETER	**$8.00**
874-WN	**Short-Circuit Termination**	COAXNULLER	**3.50**
874-WO	**Open-Circuit Termination**	COAXOPENER	**3.00**

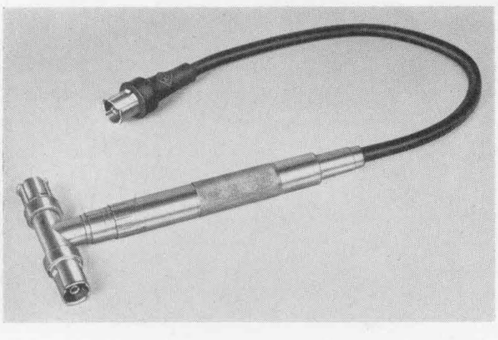
7. ATTENUATORS

Type 874-GA Adjustable Attenuator

A mutual-inductance (waveguide-below-cut-off) type attenuator useful for producing known voltage ratios, for measuring attenuation, and for adjusting voltage magnitude. Consists of a loop that can be positioned longitudinally within a hollow tube by rotating an outside sleeve. One turn of the sleeve produces a 20 db change in attenuation. The sleeve advances when it is turned, so that complete turns are indicated by engraved lines on the tube. Sleeve and tube are calibrated directly in decibels, and unit is read like micrometer calipers. The input system is a short coaxial line with a connector at each end, one end for connection to the power source and the other for connection to a 50-ohm termination, an adjustable stub, or any desired load. The hollow tube of the attenuator joins the input line at right angles and is excited through a hole in the outer conductor by the inner-conductor current. Calibration holds when the loop is within the hollow tube, but higher, uncalibrated output can be obtained by moving the loop beyond the mouth of the tube and into the input line. The output of the loop is brought out through three feet of double-shielded flexible cable, which is approximately matched at the loop end by a 50-ohm resistor between the low side of the loop and ground.

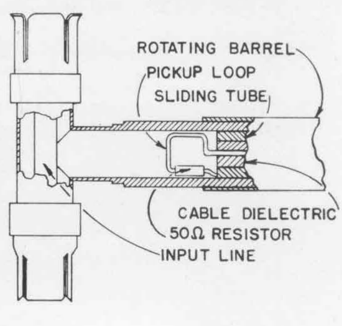
Calibrated Range: 120 db — usable range depends upon shielding between input and output.

Insertion Loss at Beginning of Calibrated Range: Approximately inversely proportional to fre-



At left, view of the adjustable attenuator.

At right, cross section of the coupling system.



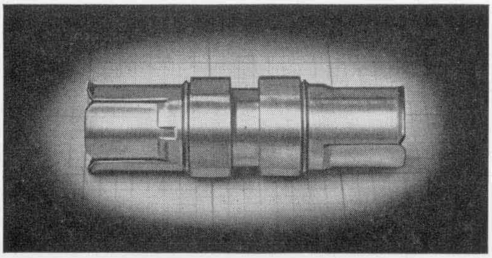
quency up to 1000 Mc; approximately 20 db at 1000 Mc with tuned input; approximately 33 db with input line terminated in 50 ohms.

Minimum Insertion Loss (Outside of Calibrated Range): Approximately inversely proportional to frequency; approximately 18 db at 1000 Mc.

Waveguide Mode: $TE_{1,1}$; cutoff frequency: 12,300 Mc.

Accuracy of Attenuation: ±0.5 db when corrected; correction chart supplied.

Frequency Range: 100 Mc to 3000 Mc.



View of the Type 874-GF Fixed Attenuator.

Type 874-GF, GG Fixed Attenuators

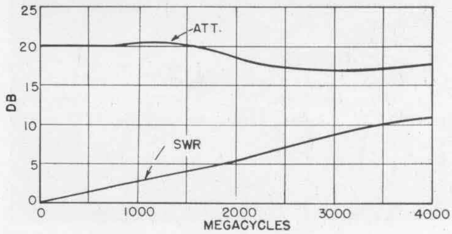
A single-section, π-type resistance attenuator useful over the frequency range from dc to several thousand megacycles. Consists of two disc resistors and one cylindrical resistor as the shunt and series elements respectively.

Impedance: 50 ohms.

Maximum Power Input: ½ watt.

Physical Length Overall: 2½ inches.

Low-Frequency Accuracy: ±0.5 db.



Attenuation and standing-wave ratio of the Type 874-GF Fixed Attenuator as a function of frequency.

Type		*Code Word*	*Price*
874-GA	**Adjustable Attenuator**	COAXLOSSER	**$55.00**
874-GF	**Fixed Attenuator (20 db)**	COAXNEPPER	**18.00**
874-GG	**Fixed Attenuator (10 db)**	COAXBELLER	**18.00**

8. FILTERS

Type 874-F500, F1000 Low-Pass Filters

Reduction of harmonics from an u-h-f generator by filters such as these is usually necessary for best measurement results, particularly if a system contains peak-reading voltmeters or sections that might resonate at a harmonic frequency, or if high standing-wave ratios are to be measured using a slotted line. These filters are of the Tschebyscheff type, in which very sharp cutoff is obtained at some sacrifice of uniformity in the pass band. The alternately large and small diameter sections of the inner conductor form the equivalent of shunt capacitances and series inductances respectively. Unequal section lengths reduce the likelihood of spurious pass bands above cutoff.

Insertion Loss: In pass band, varies as a function of frequency between 0 and 4 db; beyond cutoff, 20 db at 10% above cutoff, 40 db at 30% above cutoff.

Cutoff Frequencies:

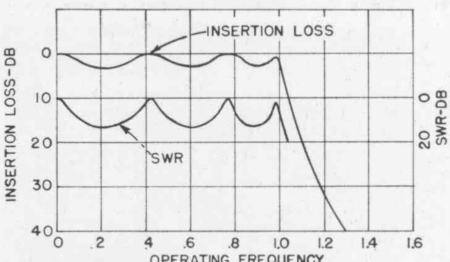
TYPE 874-F500, 500 Mc $\left\{ \begin{matrix} -0 \\ +10 \end{matrix} \right\}$ %;

TYPE 874-F1000, 1000 Mc $\left\{ \begin{matrix} -0 \\ +10 \end{matrix} \right\}$ %.

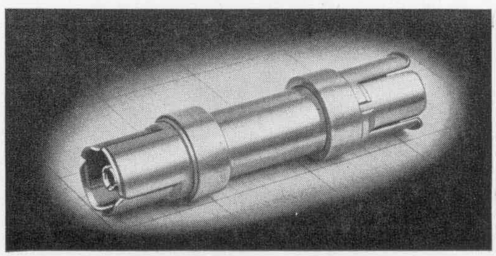
Physical Length Overall:

TYPE 874-F500, 10$\frac{3}{16}$ inches;
TYPE 874-F1000, 7⅛ inches.

View of the Type 874-F1000 Low-Pass Filter.



Insertion loss and standing-wave ratio of the Type 874-F1000 Low-Pass Filter.



View of Type 874-K Coupling Capacitor, described on next page.

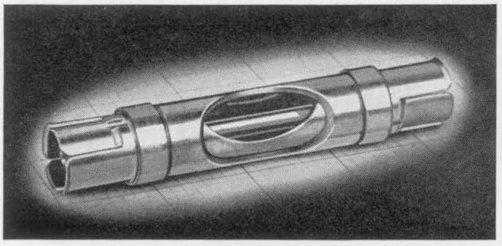
Type 874-K Coupling Capacitor

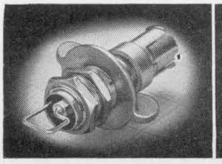
Consists of a short length of coaxial line having a cylindrical capacitor in series with the inner conductor. High frequencies are transmitted with small reflections, but dc and low audio frequencies are blocked. This unit is often necessary for separating d-c paths in systems including two or more crystal rectifiers, as in measurements of insertion loss.

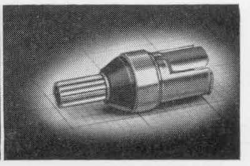
Coupling Capacitance: Approximately 5000 $\mu\mu$f.

Type		*Code Word*	*Price*
874-F500	**500-Mc Low-Pass Filter**	COAXDIPPER	**$22.50**
874-F1000	**1000-Mc Low-Pass Filter**	COAXMEGGER	**22.50**
874-K	**Coupling Capacitor**	COAXKICKER	**12.00**

9. EXTERNAL COUPLING ELEMENTS







At left, Type 874-LR Radiating Line; *above, left*, Type 874-MA Adjustable Coupling Loop; *above, right*, Type 874-MB Coupling Probe.

Type 874-LR Radiating Line

Allows coupling an external wavemeter or heterodyne frequency meter to the fields within a coaxial system. Consists of short coaxial line with hole in outer conductor that can be partially or completely covered by a rotatable sleeve.

Type 874-MA Adjustable Coupling Loop

A general-purpose coupling loop. Consists of short coaxial line with a one-turn loop at one end and a connector at the other. A collet is supplied for panel mounting. The loop can be adjusted for desired degree of coupling and clamped in that position by the collet.

Physical Length Overall: 3 inches.

Maximum Diameter: 1⅞ inches.

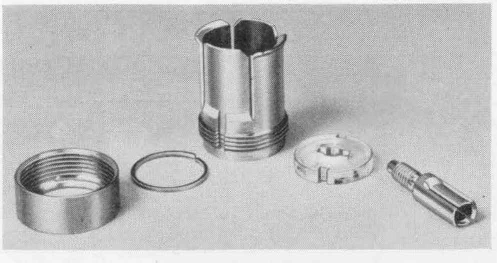
Type 874-MB Coupling Probe

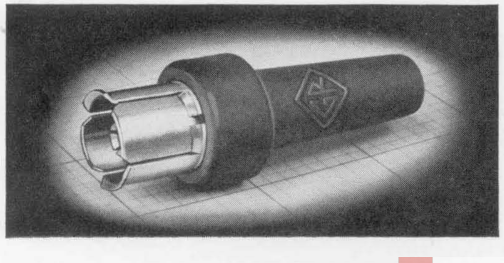
A general-purpose electrostatic probe consisting of a binding post, acting as a probe, mounted on a connector.

Physical Length Overall: 2⅛ inches.

Type		*Code Word*	*Price*
874-LR	**Radiating Line**	COAXMITTER	**$12.00**
874-MA	**Adjustable Coupling Loop**	COAXLOOPER	**7.50**
874-MB	**Coupling Probe**	COAXPROBER	**5.00**

10. FOUNDATION ELEMENTS





Connectors

All Type 874 Connectors are supplied unassembled with complete assembly instructions. No special tools are needed.

Type 874-B Basic Connector

For use on rigid, 50-ohm, air-dielectric, coaxial lines. Consists of inner and outer conductors, insulating bead, coupling nut, and retaining ring. Fits lines made from ⅝″ O.D., 9/16″ I.D. tubing, and 0.244″ D rod. The inner conductor is to be screwed into an 8-32 tapping in the end of the rod, and the retaining ring for the coupling nut is to be snapped into a 1/64″ deep, 0.035″-wide groove cut in the ⅝″ tubing.

Type 874-C Cable Connector

For use on Type 874-A2 Polyethylene Cable. Consists of the basic connector parts plus inner and outer transition pieces, a soft copper ferrule, and a rubber guard. The transition pieces are tapered so as to maintain the 50-ohm characteristic impedance of the connector and cable throughout the change in diameters. The cable inner conductor is to be soldered to the inner transition piece, and the cable braid is attached to the outer transition piece by crimping the ferrule. The rubber guard provides strain relief and a protective handle.

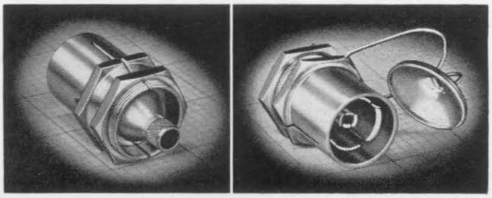
Type 874-C8 Cable Connector

For use on Army-Navy Type RG-8/U Cable. Same as TYPE 874-C, except outer transition piece fits R-8/U Cable.

PANEL CONNECTORS

Type 874-P Panel Connector

For use on panels. Rear end fits TYPE 874-A2 Cable. Is similar to the cable connector, except a panel adaptor and nut are supplied in place of rubber guard. The panel adaptor fits into a $1\frac{5}{16}''$ D hole in panels from $\frac{1}{16}''$ to $\frac{1}{4}''$ thick and is designed to clamp the connector in any desired orientation.



Left, Panel Connector; *right*, Panel Connector with Cap.

Type 874-P8 Panel Connector

Same as TYPE 874-P, except rear end fits Army-Navy Type RG-8/U Cable.

Type 874-PC Panel Connector with Cap

For use on panels. Same as TYPE 874-P, with addition of a spring-hinged cap to shield the connector when not in use. Rear end fits TYPE 874-A2 Cable.

Type 874-PC8 Panel Connector with Cap

Same as TYPE 874-PC, except rear end fits Army-Navy Type RG-8/U Cable.

ADAPTORS

Type 874-Q1 Adaptor to Type N

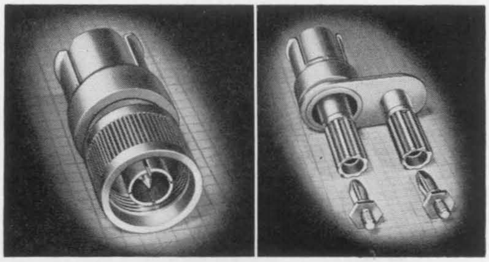
Plugs into Army-Navy Type UG-22/U and similar jack-type connectors.

Type 874-Q2 Adaptor to Type 274

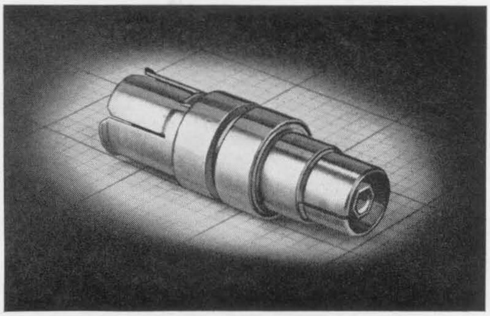
Makes output of a coaxial system available at a pair of $\frac{3}{4}$-inch-spaced binding posts or banana plugs.

Type 874-Q7 Adaptor to Type 774

Plugs into any General Radio TYPE 774 Connector.



Above, left, Type 874-Q1; *right*, Type 874-Q2; *below*, Type 874-Q7.



PATCH CORDS

Type 874-R20 Patch Cord

For making shielded connections. Consists of three feet of TYPE 874-A2 Polyethylene Cable with a TYPE 874-C Connector on each end.

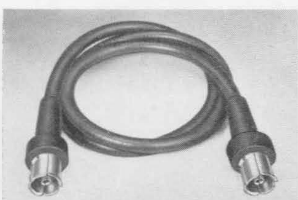
Type 874-R31 Patch Cord

Makes output of a coaxial system available at a pair of phone tips. Useful as a test probe with clips or prods on phone tips. Consists of three feet of rubber-dielectric, flexible coaxial cable with a TYPE 874 Connector on one end and phone tips on the other.

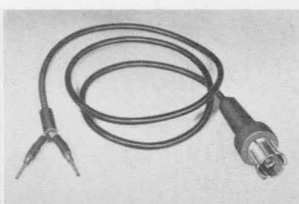
Type 874-R32 Patch Cord

Similar to TYPE 874-R31, with a TYPE 274-ND Shielded Plug in place of phone tips. Makes output of a coaxial system available at a pair of shielded, $\frac{3}{4}$-inch-spaced, banana plugs.

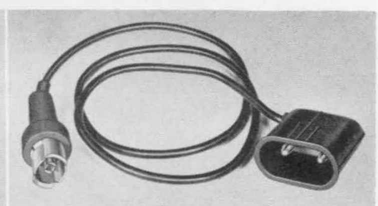
Type 874-R20.



Type 874-R31.



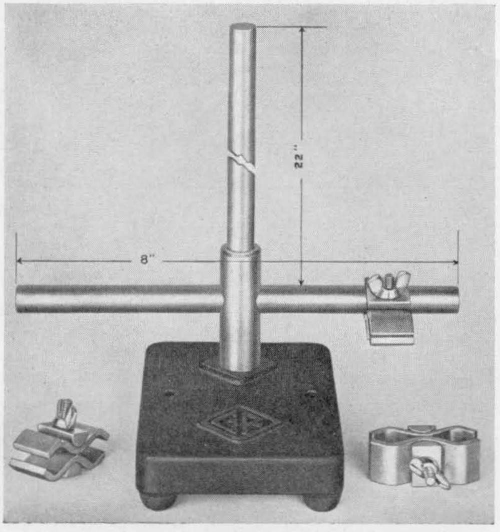
Type 874-R32.



Type 874-A2 Polyethylene Cable

Bulk cable for permanent or semipermanent installations and for making long patch cords. Characteristic impedance is 50 ohms ±5%. Cable is double-shielded and has good mechanical flexibility. Nominal capacitance is 32 $\mu\mu$f per foot. Attenuation at 100 Mc is about 2.6 db per 100 feet, and at 1000 Mc about 10.5 db per 100 feet. Consists of a No. 14 stranded inner conductor, separated from the two, braided, tinned-copper shields by 0.244″ OD Polyethylene insulation, and an outer gray Plastex jacket 0.365″ OD.

Type 874-Z Stand



Provides firm support for the parts of a wide variety of coaxial systems. Consists of a heavy bronze base with rubber feet, 22-inch and 8-inch brass rods, and three universal clamps. Will not rust or corrode. The vertical rod can be used to hold long tuning stubs. The horizontal rod can be moved longitudinally or interchanged with the vertical rod to provide support where needed. Two bases can be used with one 22-inch rod between them to support a long horizontal run of coaxial parts. Clamps will fit a range of diameters and will hold between two rods of different diameters. Any desired arrangement can be set up quickly. Base can be screwed down to table top for permanent setups.

Type		*Code Word*	*Price*
874-Z	**Stand**	COAXHELPER	**$12.50**

CREDITS

Development of the Type 874 Coaxial Elements was directed by Eduard Karplus. Electrical and mechanical engineers on the project were, respectively, William R. Thurston and Harold M. Wilson.

Type		*Code Word*	*Price*
874-B	**Basic Connector**	COAXBRIDGE	**$1.50**
874-C	**Cable Connector**	COAXCABLER	**2.00**
874-C8	**Cable Connector**	COAXCORDER	**2.00**
874-P	**Panel Connector**	COAXPEGGER	**2.25**
874-P8	**Panel Connector**	COAXPUTTER	**2.25**
874-PC	**Panel Connector with Cap**	COAXCAPPER	**2.75**
874-PC8	**Panel Connector with Cap**	COAXTOPPER	**2.75**
874-Q1	**Adaptor to Type N**	COAXNUTTER	**6.00**
874-Q2	**Adaptor to General Radio Type 274**	COAXTIPPER	**5.00**
874-Q7	**Adaptor to General Radio Type 774**	COAXPASSER	**5.00**
874-A2	**Polyethylene Cable**	COAXCUTTER	**.50/foot** **27.00/100 feet**
874-R20	**Patch Cord**	COAXHATTER	**8.00**
874-R31	**Patch Cord**	COAXFLEXOR	**4.50**
874-R32	**Patch Cord**	COAXFITTER	**5.25**

Type 874 Coaxial Connectors are licensed under U. S. Patent 2,125,816. Also patent applied for.

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PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXIV No. 9 FEBRUARY, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A NEW BRIDGE FOR THE MEASUREMENT OF IMPEDANCE BETWEEN 10 AND 165 MC

Also IN THIS ISSUE

● **WITH** the increasing use of higher and higher frequencies in radio and electronics has come a demand for a bridge for the measurement of impedances of antennas, lines, networks, and components with the accuracy and ease of operation that characterize the TYPE 916-A R-F Bridge[1], so widely used at lower frequencies. To meet this demand a new instrument, the TYPE 1601-A V-H-F Bridge, has been developed, which extends the range of conventional bridge techniques up to about 165 Mc. It can be used at frequencies at least as low as 10 Mc. This bridge is particularly well adapted to the measurement of coaxial-line circuits as well as lumped parameter circuits.

THE TYPE 1601-A V-H-F Bridge is designed for the direct measurement of relatively low impedances, but will measure high impedances indirectly. The resistive and reactive components of the unknown im-

[1]Sinclair, D. B., "A New R-F Bridge for Use at Frequencies up to 60 Mc," *General Radio Experimenter*, Vol. XVII, No. 3, August, 1942.

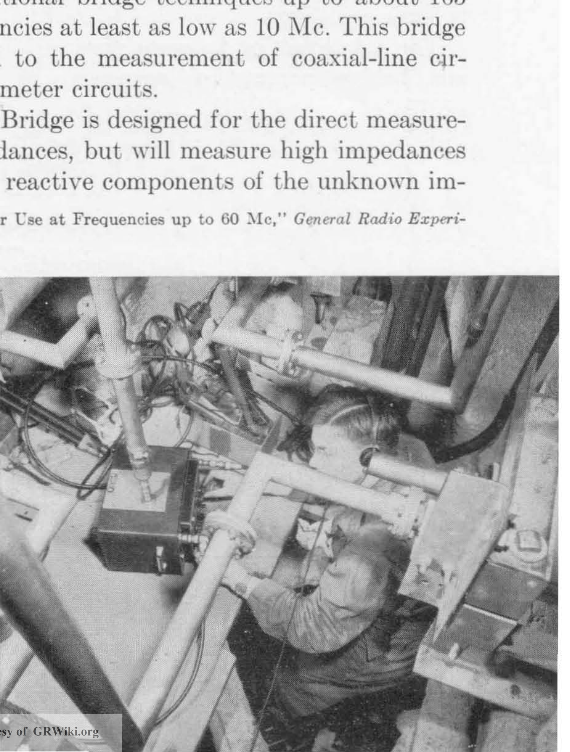


Figure 1. Ogden Prestholdt, CBS engineer, using the V-H-F Bridge to measure the new antenna of WCBS-TV, on the Chrysler Building. Some of the results of the measurement are shown in Figures 7 and 8, page 5.

pedance are measured in terms of incremental capacitances and are indicated on separate dials. The direct-reading resistance range is from 0 to 200 ohms and is independent of frequency except for small corrections. The direct-reading reactance range is from 0 to 230 ohms at 100 Mc and is inversely proportional to frequency. To insure a high accuracy of measurement on coaxial line circuits, a coaxial connector can be mounted directly on the bridge terminals so that errors due to connections between the bridge and line are kept small. For measurements on other types of circuits, a pair of terminals (one grounded) or a single terminal and a ground plane are provided.

BRIDGE CIRCUIT

The basic bridge circuit is shown in Figure 2 and is the same as that of the lower frequency Type 916-A Bridge. A complete analysis of this circuit has been published in previous articles[2] and it will suffice to indicate here only the basic balance equations.

The relationships between the various bridge parameters necessary to obtain an initial balance with the unknown short-circuited are given by the expressions:

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

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

After the final balance has been made with the circuit under test connected to the unknown terminals, the expressions for the unknown impedance in terms of the bridge parameters are:

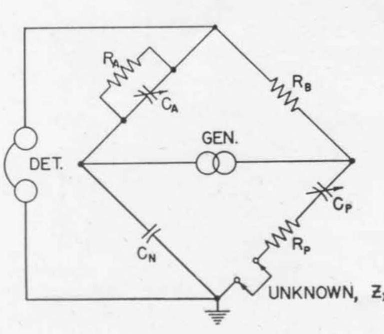
$$R_X = \frac{R_B}{C_N} (C_{A_2} - C_{A_1}) \qquad (3)$$

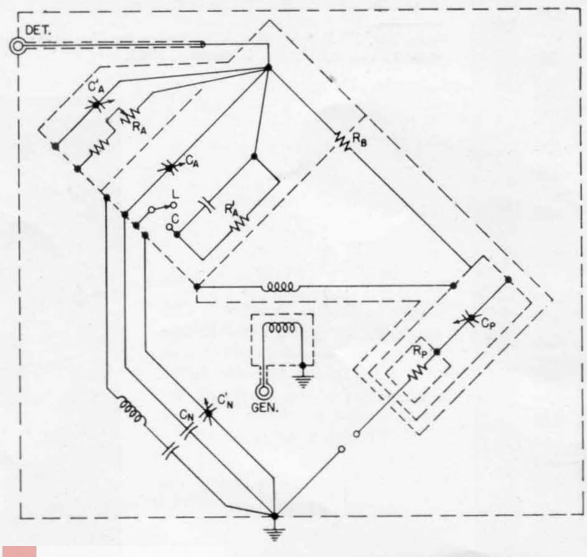
$$X_X = \frac{1}{\omega} \left(\frac{1}{C_{P_2}} - \frac{1}{C_{P_1}} \right) \qquad (4)$$

As can be seen from Equations (3) and (4), the unknown resistance, R_X, is proportional to the change in capacitance of C_A, and the unknown reactance, X_X, is equal to the change in reactance of C_P and has the opposite sign. In this series-substitution bridge, the C_A dial can be calibrated directly in resistive ohms, with the calibration independent of frequency, and the C_P dial can be calibrated in reactive ohms at one frequency, with the calibration inversely proportional to frequency.

[2]Sinclair, D. B., "A Radio Frequency Bridge for Impedance Measurements from 400 kc to 60 Mc," Proc. I.R.E., Vol. 28, No. 11, pp. 497-503, November, 1940.

(*Below*) Figure 2. Basic bridge circuit.
(*Right*) Figure 3. Complete schematic circuit.





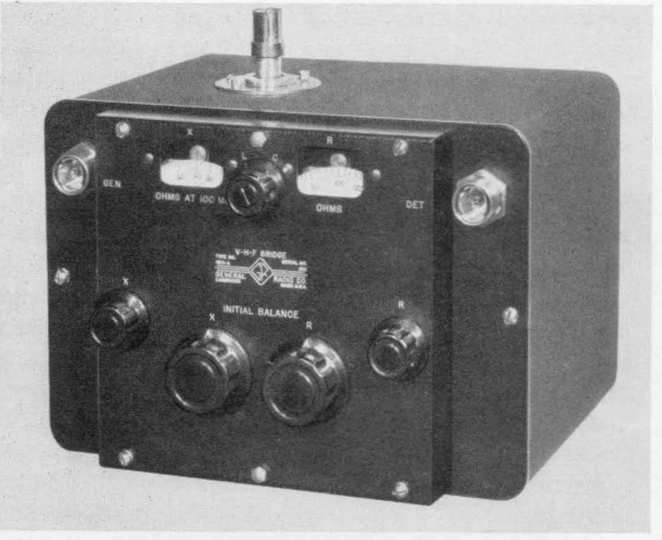


Figure 4. View of the engineering model of the V-H-F Bridge with coaxial adapter installed on the unknown terminal at the top of the cabinet. Panel size is approximately 11 x 9 inches. Production model has a larger ground plate around the unknown terminal and is equipped with carrying handles.

Although the basic circuit is similar, the method of obtaining the initial reactance balance in the V-H-F bridge differs from that of the Type 916-A Bridge. As shown in the complete circuit diagram in Figure 3, the initial reactance balance is made by means of the carbon rheostat R_A. The resistor R_A controls the reactance balance as can be seen from Equation (2), but has no effect on the dial calibrations as long as the value of R_A is not changed between the initial and final balances. The *L-C* switch indicated in the schematic is used to provide maximum fineness of control over a very wide range of resistance values by allowing a small resistor to be shunted across the variable resistor. The initial resistance balance is made by means of a small variable capacitor connected in parallel with C_A.

DESIGN CONSIDERATIONS

The actual bridge circuit is more complex than is indicated in either Figure 2 or 3, owing to the presence of various stray inductances and capacitances. In general, these residual parameters cause errors in the bridge readings, and the most difficult problem in the design of the bridge was to keep these errors within acceptable limits by minimizing the residual parameters or placing them in parts of the circuit where they cannot cause errors.

A complete discussion of the bridge design is too lengthy to incorporate in this article, but a few of the more important considerations will be mentioned.

Standard Resistor

The standard resistor, R_B, must be so designed that it inserts a practically pure resistance between the top and right bridge junctions in Figure 3. Any reactance present causes an error in reactance which is proportional to the magnitude of the measured resistance. Of course, every resistor has some capacitance and inductance which cannot be eliminated, but if the inductance and capacitance are so proportioned that the square root of their ratio is equal to the resistance, the resistor will have a very small effective reactance at frequencies up to an appreciable fraction of the resonant frequency. For best compensation, therefore, the inductance and capacitance should have this relationship, and they should both be as small as possible in order to keep the resonant frequency high. In the V-H-F bridge the standard resistor is a cylindrical palladium-palladium oxide film resistor fitted with threaded end caps to eliminate the need for high inductance wire leads. In the circuit the total capacitance across the resistor is 0.31 $\mu\mu f$, and the inductance is about 0.019 μh which gives a very low reactance over the operating frequency range of the bridge when the resistance is 250 ohms.

Resistance Capacitor

Another serious residual parameter is the series inductance in the capacitor C_A used to measure resistance.

Equation (3) indicates that the measured resistance is proportional to the change in the effective capacitance of this capacitor. At high frequencies, the effective capacitance differs from the low frequency capacitance due to inductance in the capacitor, and the bridge tends to read low in resistance at high frequencies. In a conventional capacitor it is impossible to reduce the inductance to a negligible value; therefore, in order to minimize the magnitude of this effect, a compensating circuit consisting of an inductance and capacitance in series is connected across the capacitor C_N. The compensation is not perfect, but the magnitude of the corrections is appreciably reduced.

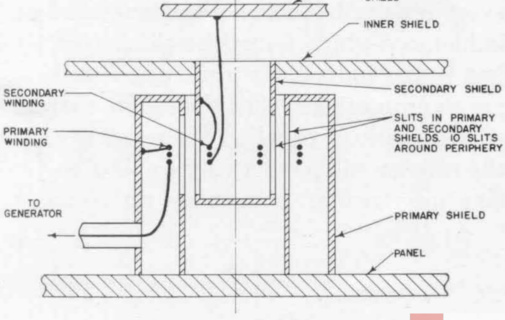
Transformer

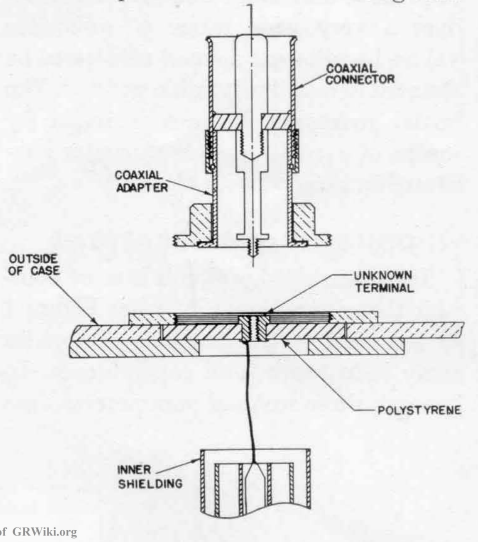
The heart of the bridge is the transformer. The coupling between the primary and secondary windings must be almost purely magnetic, since any electrostatic coupling between the windings effectively places a reactance in parallel with C_N and the unknown arm, which may cause serious errors. As shown in Figure 3, the primary and secondary windings are separately shielded, with the primary shield connected to the instrument case. Figure 5 is a cross-sectional view of the transformer used in the bridge. Magnetic coupling between the primary and secondary windings is obtained through a series of slots in the adjacent walls of the two shields. The direct capacitance between shields is part of C_N. Although the coefficient of coupling is small, adequate sensitivity is obtained and the electrostatic shielding is excellent.

Unknown Terminal

In any bridge, terminals of some type must be provided for connecting the

(*Below*) Figure 5. Cross section of bridge transformer.
(*Right*) Figure 6. Cross section of unknown terminal and coaxial adapter.





unknown circuit to be measured. At high frequencies the design of these terminals is important, because stray inductances and capacitances will seriously affect the measured impedance. The ultimate terminal design would be one in which the terminals produce no transformation of the unknown impedance. The terminal arrangement used in the V-H-F bridge, shown in Figure 6, has been designed to approach the ideal. One actual terminal is provided, and the instrument case acts as the other terminal.

For measurements using the terminals directly, a short-circuiting cap is provided for setting up the initial balance. The cap screws into the instrument case and contacts the high unknown terminal, thus providing a very low inductance short circuit. After the initial balance is made, the cap is removed, and the circuit to be measured is connected between the high unknown terminal and the instrument case. A small residual capacitance of 1 $\mu\mu$f between the unknown terminal and the instrument case appears in parallel with the unknown circuit. In some cases this capacitance has an appreciable effect on the measured impedance, and the impedance indicated by the bridge must be corrected for it in order to obtain the true impedance. A chart, provided in the instruction book, greatly simplifies the task of making this correction.

For measurements on coaxial systems, a coaxial adapter is supplied, which eliminates errors from connecting leads and from the residual terminal capacitance. This adapter, shown in Figure 6, is a short section of 50-ohm coaxial line, with a Type 874 Coaxial Connector on one end and fittings to mount it on the bridge at the other end.

Terminal capacitance compensation is provided by adding series inductance in the center lead, so that the terminal capacitance and the inductance form a 50-ohm artificial line whose only effect is to increase slightly the electrical length of the adapter. This series inductance is obtained by increasing the characteristic impedance of a short section of the adapter line. An important advantage of this coaxial adapter is that the standing-wave ratio of a coaxial system being measured is not affected by the terminal capacitance of the bridge.

For measurements on 50-ohm coaxial systems, the only effect of the adapter is to increase the electrical length of the 50-ohm coaxial line that would ordinarily be used to connect the unknown network to the bridge. The total electrical length can be determined from a reactance measurement with the far end shorted. Then, from an impedance measurement

Figure 7. Plot of the impedance of a single element in the WCBS-TV antenna. Numbers on curve indicate frequency in megacycles.

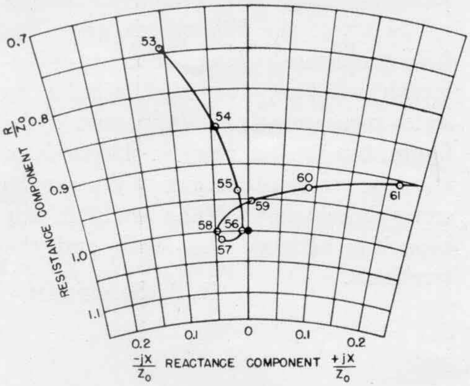
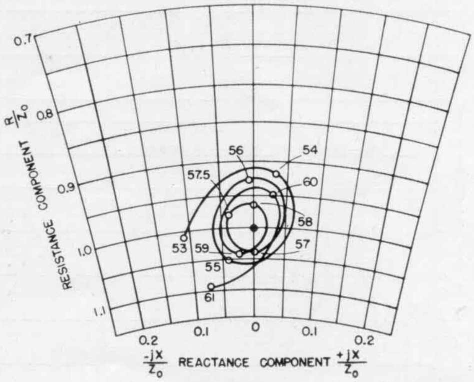


Figure 8. Plot of the impedance of the entire 16-element array, as seen from the transmitter.



with the line terminated in the unknown impedance, transmission line equations or charts can be used to determine the unknown impedance.

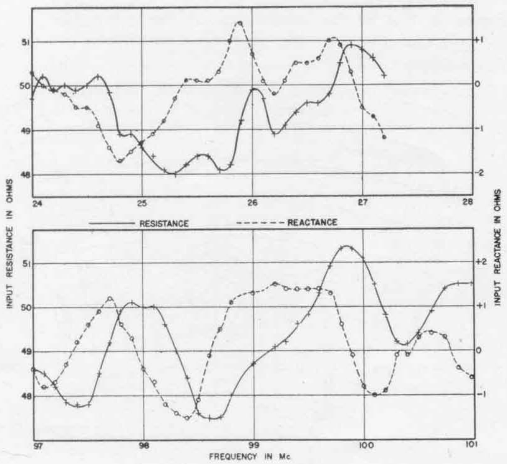
CORRECTIONS

As previously mentioned, residual parameters cause small errors in the bridge measurements. The most serious of these is the effect of inductance in the capacitor C_A used for measuring resistance. The error varies with frequency and with the magnitude of the resistance measured. A chart is provided to correct the bridge readings for this effect.

Residual parameters also cause a small error in resistance which is proportional to the magnitude of the reactance measured. This error is so small that it is important only when the resistive component of a high Q circuit is measured. When important, the error can be reduced appreciably through the use of the correction chart supplied.

At the highest frequencies, distributed inductance and capacitance in the reactance capacitor, C_P, cause a small error in reactance. A chart is provided for correction when this effect is important.

Figure 9. Input impedance of a 2400-foot length of General Radio Type 874-A2 Coaxial Cable.



TYPICAL MEASUREMENTS

Some of the applications of the bridge are the measurement of resistors, capacitors, inductors, transmission-line networks, and antennas. Following are a few typical examples.

Figures 7 and 8 show the results of measurements made by WCBS-TV on their new television antenna located near the top of the Chrysler Building in New York City. The antenna consists of 16 radiating elements, four on each of the four faces of the building. Figure 7 shows the impedance variation of an individual element over the operating frequency band, and Figure 8 shows the impedance of the whole array as seen by the transmitter.

Figure 9 shows the input impedance variation with frequency of a 2400-foot length of 50-ohm coaxial cable. The cable is sufficiently long as to act as an infinite line, and the variations in impedance are caused by variations in the characteristic impedance of the cable along its length.

Figure 10 shows the impedance variation with frequency of a 2100 $\mu\mu$f Type 848 Variable Air Capacitor in the vicinity of anti-resonance. The resonance is actually a transmission-line resonance because the capacitor is electrically similar to a high-capacitance transmission line as shown in the equivalent circuit. The anti-resonance indicated is the half-wavelength resonance. Another resonance was measured at about 142 megacycles where the line was electrically a full wavelength long. The ¾-wavelength resonant condition, similar to series resonance, is also apparent in the figure, but its frequency is shifted from the true resonant frequency due to the series inductance of the leads in the capacitor between the stack and the terminals.

— R. A. Soderman

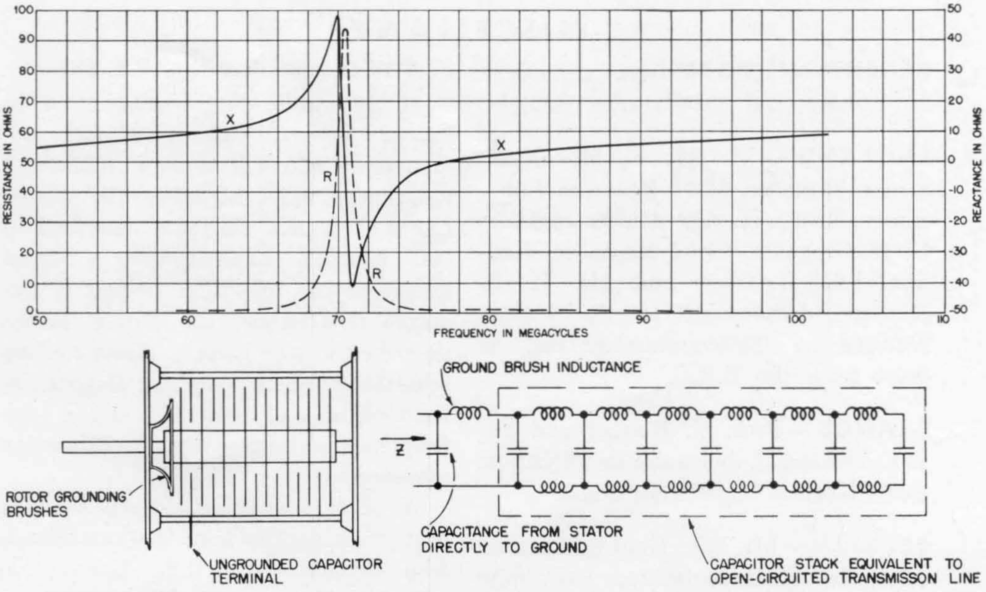


Figure 10. Resistance and reactance of a Type 848-C Variable Air Capacitor at frequencies above its normal operating range. Approximate equivalent circuit of the capacitor is shown below the plot.

SPECIFICATIONS

Frequency Range: 10 Mc to 165 Mc. Satisfactory operation can, for some measurements, be obtained at frequencies as low as 2 Mc and as high as 175 Mc, but the bridge sensitivity decreases markedly at frequencies beyond the nominal range of 10 to 165 Mc. In addition, the accuracy of measurement of small reactances decreases as the frequency decreases, owing to lack of precision in reading the reactance dial, whose range is inversely proportional to frequency, and at frequencies above the nominal range the corrections become larger.

Reactance Range: ±230 ohms at 100 Mc. Dial range varies inversely with frequency and is calibrated at 100 Mc.

Resistance Range: 0 to 200 ohms, independent of frequency.

Accuracy: For resistance, ±(2% + 1Ω) subject to correction for inductance in the capacitor used to measure resistance. The correction increases with frequency and the magnitude of the resistive component. A correction chart is supplied with the instrument. The ohmic uncertainty indicated in the accuracy statement, namely 1 ohm, is roughly proportional to the magnitude of the reactive component of the unknown impedance. The indicated value is the maximum obtainable, and the minimum is 0.1 ohm.

For reactance, ±(5% + 2Ω). The ohmic uncertainty is roughly proportional to frequency and to the magnitude of the resistive component. The maximum value is indicated and the minimum value is 0.1 ohm at 100Mc.

Accessories Supplied: Two Type 874-R20 Cables; one Type 1601-204 Coaxial Extension Assembly; one Type 874-WN Short Circuit Termination; one Short-Circuiting Cap.

Other Accessories Required: R-F generator and receiver covering the desired frequency range; Type 1208-A Oscillator is recommended for frequencies above 65 Mc. Both oscillator and receiver should be reasonably well shielded.

Additional Accessories Recommended: A Type 874-WM 50-ohm Termination is useful in checking the bridge. The bridge is equipped with Type 874 Coaxial Connectors, and if connection is to be made to equipment using Type N Connectors, Type 874-Q1 Adapters will be needed. See price list below.

Dimensions: (Length) 13½ x (height) 9 x (depth) 10½ inches, overall.

Net Weight: 17½ pounds.

Type		*Code Word*	*Price*
1601-A	**V-H-F Bridge***†	FLORA	**$385.00**
874-WM	**50-Ohm Termination***	COAXNUTTER	**8.00**
874-Q1	**Adapter to Type N Connectors***	COAXMEETER	**6.00**

*U. S. Patent No. 2,125,816; also patent applied for.
†U. S. Patent No. 2,376,394.

MISCELLANY

RECENT VISITORS from abroad to our plant and laboratories include:

ENGLAND — Mr. H. A. M. Clark, Senior Engineer, EMI Research Laboratory, Ltd., Hayes, Middlesex; Mr. G. B. Ringham, Chief Engineer, Redifon, Ltd., London; and Mr. H. B. Rantzen, Consultant to the United Nations on Telecommunications, on leave from the B.B.C.

FRANCE — Prof. Y. Rocard and Dr. J. F. Denisse, Laboratoire de Physique, Ecole Normal Superieure, Paris.

BELGIUM — Mr. Paul Hontoy, Laboratoire de Radioelectricite, Universite Libre de Bruxelles, Brussels.

SWEDEN — Mr. J. C. J. von Utfall, Deputy Director, Telecommunications Service, United Nations, on leave from the Swedish Broadcasting Corporation.

Visit Our Booth at the I.R.E. Show

At the Radio Engineering Show in Grand Central Palace, March 6-9, General Radio will show a number of new instruments, including the slotted line and coaxial elements described in last month's *Experimenter*, a signal generator for television testing, a dynamic polariscope, the V-H-F bridge described in this issue, a direct-reading admittance comparator for frequencies between 85 and 1000 Mc, and a two-frequency audio generator for distortion measurements.

We shall be at Booths 92 and 93, as in past years, and we hope that our friends who attend the I.R.E. Convention will drop in to see us. Representatives of the Sales Engineering, Development Engineering, and Service Departments will be on hand to answer questions and to discuss applications of our equipment.

THE General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in communication-frequency measurement and control problems. When sending requests for subscriptions and address-change notices, please supply the following information: name, company address, type of business company is engaged in, and title or position of individual.

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PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXIV No. 10 MARCH, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A STANDARD-SIGNAL GENERATOR FOR FREQUENCIES BETWEEN 50 AND 920 MC

Also

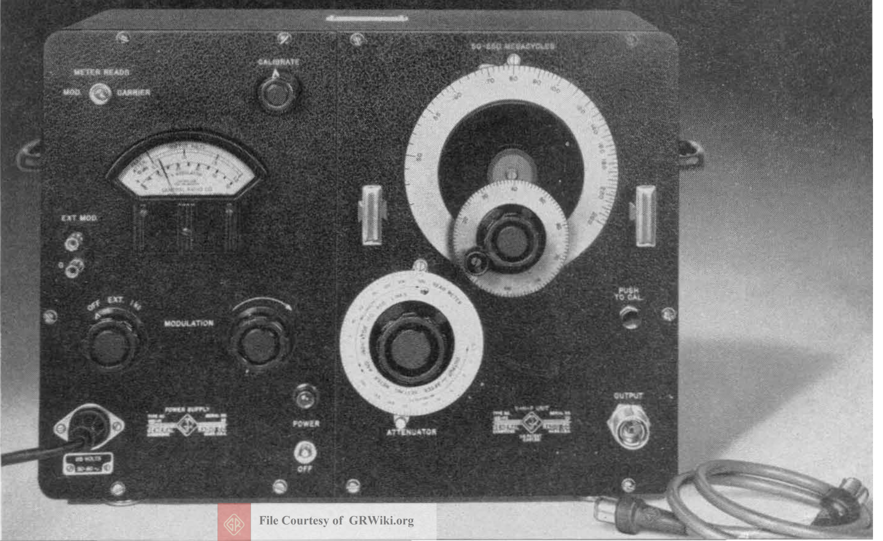
IN THIS ISSUE

●**THE NEW** TYPE 1021-A Standard-Signal Generator performs at very-high and ultra-high frequencies all the functions of the common standard-signal generator which is ordinarily limited to much lower frequencies. Its main use is the determination of radio-receiver and circuit characteristics in the engineering laboratory and in production. In addition it is a convenient and well-shielded source of power for measurements with bridges, impedance comparators, and slotted lines.

In combination with a simple crystal-diode modulator (TYPE 1000-P6) and a source of video signals, it can be used to produce television picture modulation on all channels between 50 and 920 Mc.

With the TYPE 1023-A Amplitude Modulator, the generator out-

Figure 1. Panel view of the Type 1021-AV V-H-F Standard-Signal Generator.



put, up to 250 Mc, can be modulated to a known percentage at audio frequencies with no significant incidental fm.

Internal amplitude modulation is provided for those uses where a small amount of incidental fm is not serious.

Simplicity, economy, and reliability were important design considerations, and the resulting instrument is moderately priced, compact, light in weight, durably built, and convenient to use. Since range switching is impractical at these frequencies, two separate oscillator units are used, each with its own attenuator and rectifier for measuring output voltage. The V-H-F Unit covers frequencies between 50 and 250 Mc, and the U-H-F Unit, 250 to 920 Mc. A third unit, the power supply assembly, provides filament and plate power, means for amplitude modulation at audio frequencies, and a meter for indicating output voltage and percentage modulation.

For convenience in ordering, the generator is listed in two models, (1) the Type 1021-AV V-H-F Standard-Signal Generator, consisting of the V-H-F Unit and power supply in a cabinet, and (2) the Type 1021–AU, consisting of the U-H-F Unit and power supply in a cabinet. When both ranges are desired, the Type 1021-AV can be ordered plus the additional U-H-F Oscillator Unit as a separate item. Oscillator units are interchangeable mechanically, and the replacement of one by the other is easily and quickly accomplished.

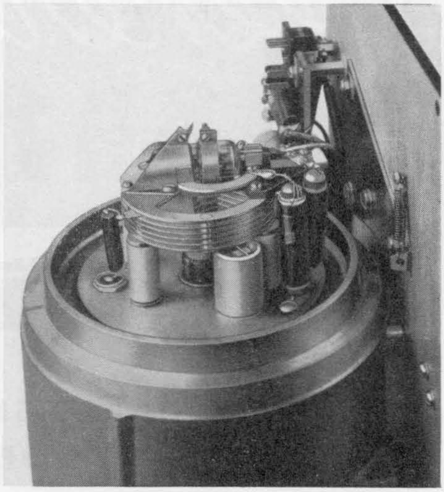


Figure 3. View of the oscillator portion of the U-H-F Unit, with cover removed from casting to show tube, butterfly, and attenuator input.

R-F OSCILLATORS

Structurally, the two carrier oscillator units are much alike. They differ in carrier frequency range covered, but each uses as the tuning element a butterfly circuit[1,2], in which the inductive and capacitive components are built integrally, and tuning is achieved by simultaneous variation of both without use of sliding contacts. The U-H-F Unit uses a 2½″ diameter symmetrical butterfly circuit adapted for use with the Sylvania Type 5767 Coplanar U-H-F Triode, or Rocket Tube, while the V-H-F Unit uses a 4½″ semibutterfly with a standard miniature twin triode (12AT7) in a push-pull connection.

[1]Eduard Karplus, "The Butterfly Circuit," *General Radio Experimenter*, October, 1944.
[2]Eduard Karplus, "Wide-Range Tuned Circuits and Oscillators for High Frequencies," *Proceedings I. R. E.*, July, 1945.

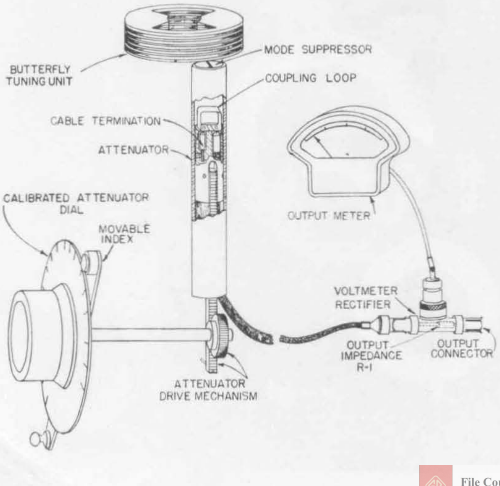


Figure 2. Functional diagram of the output system.

POWER SUPPLY UNIT

The power supply unit provides regulated plate and heater power for the oscillator. A modulator tube is connected in a simple *L-C* oscillator circuit to provide internal amplitude modulation at 1000 cycles per second, or as an amplifier to permit amplitude modulation over the audio frequency range. A single panel meter is used to indicate carrier output voltage and modulation percentage, and to check the calibration of the crystal detector used in the output meter. An internal calibrating voltage derived from the regulated power supply is provided for this check.

OUTPUT SYSTEM

Output between 0.5 microvolt and 1.0 volt, at an internal output impedance of 50 ohms, is available at a coaxial connector on the panel. This output is obtained through a mutual inductance (waveguide-below-cutoff type) attenuator. A coaxial cable connects the attenuator to a crystal voltmeter on the front panel. Following the voltmeter is a 50-ohm resistor which determines the output impedance. The rectifying element of the voltmeter and its mounting are similar to the Type 874-VR Voltmeter Rectifier[3]. The indicating meter is in the Type 1021-P1 Power Supply Unit. At 920 Mc the voltmeter error caused by resonance is about +6%.

Voltages between 0.5 volt and 2 volts are indicated directly by the output meter. Since the meter is connected across the output of the attenuator, it will not read at low output voltage settings.

[3]W. R. Thurston, "Simple, Complete, Coaxial Measuring Equipment for the U-H-F Range," *General Radio Experimenter*, January, 1950.

For voltages under 0.5 v, the output is first set to 0.5 volt, as indicated by the meter, and the adjustable attenuator index is moved to the 0.5-volt point on the attenuator dial which is calibrated down to 0.5μv. Other low output voltages are then determined accurately by setting the attenuator dial, as long as the load is not changed. In this output system, the accuracy of output voltage at the panel terminal is determined by the accuracy of the voltmeter and attenuator alone, and the effective output impedance is determined by the resistor R_1. The resistor R_2 at the attenuator input is a matching resistance which prevents high-amplitude standing waves from being set up in the cable when the output is open circuited.

The output system used here differs from the more conventional arrangement[4,5,6] whereby the field at the attenuator input is sampled by a probe and indicated on a panel meter. The out-

[4]Eduard Karplus, "Components of U-H-F Field Meters," *Electronics*, November, 1946.
[5]Arnold Peterson, "Output Systems of Signal Generators," *General Radio Experimenter*, June, 1946.
[6]D. B. Sinclair, "A Simple Standard-Signal Generator for F-M Broadcast Use," *General Radio Experimenter*, November, 1949.

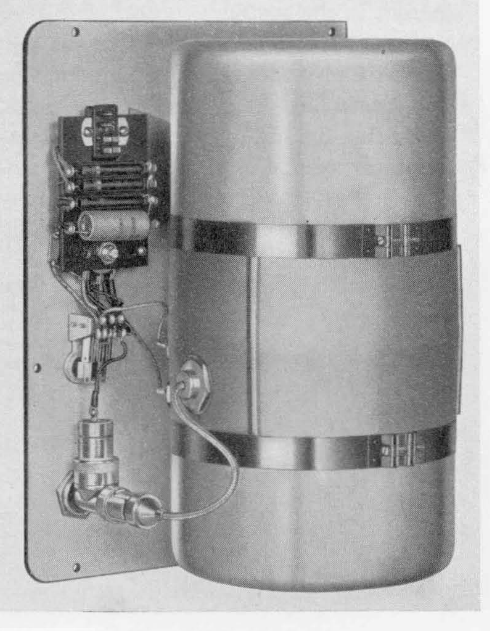


Figure 4. Rear view of the V-H-F Unit showing the casting that completely encloses the oscillator. Connections to the power supply unit are made through the connector at the upper right.

put voltage is then independent of load, and the internal impedance is that seen when looking back into the attenuator cable terminated in a coupling loop and resistor. Such a system can be made to work satisfactorily at frequencies up to a few hundred megacycles, but, at higher frequencies, both higher output voltages and more accurate voltage indications can be obtained with the system chosen for use in this generator.

MODULATION

A general-purpose internal amplitude modulation system is provided, and external modulation can be applied, but no provision is made for pulsing or for frequency modulation.

In addition to its obvious uses in receiver testing, the modulated signal has a considerable advantage when the generator is used as a power source for impedance measurements with bridges, slotted lines, and admittance comparators, because it permits audio amplification to be used following the detector to increase sensitivity.

The oscillator is modulated directly, and consequently incidental fm is inherent in the system.

Where incidental fm cannot be tolerated, and where wide-band modulation is desired, external modulating units, operating on the output side of the attenuator, can be used. Because the modulator is isolated from the oscillator by the attenuator, reaction on the oscillator frequency, with its attendant incidental fm, is completely negligible. Two such external modulating units are available, the Type 1023-A Amplitude Modulator and the Type 1000-P6 Crystal Diode Modulator.

The Type 1023-A Amplitude Modulator[7] can be used at carrier frequencies up to 250 Mc and will give output up to 150 millivolts. Percentage modulation can be adjusted accurately up to a maximum of 80%.

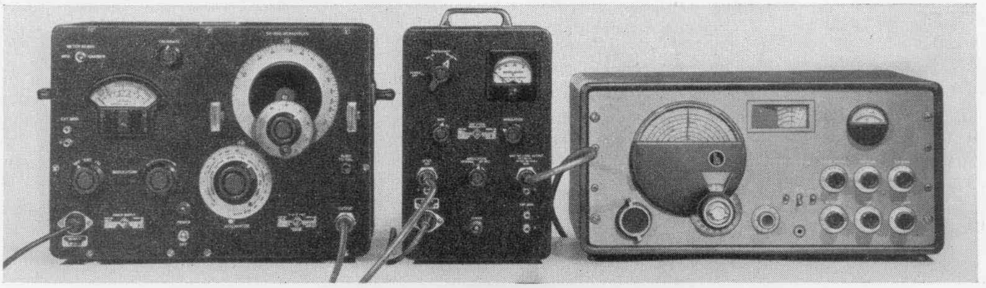
For amplitude modulation, without incidental fm, over the entire range of the Type 1021-A Standard-Signal Generator, the simple Type 1000-P6 Crystal Diode Modulator, described in the following article, is recommended. The output of this modulator is of the order of 10 millivolts. The actual percentage modulation, which is limited to about 50%, is not accurately known without measurement, but the modulation characteristic is flat within 2 db up to 5 Mc. It is possible, therefore, to produce television picture signals on all channels between 50 and 920 Mc. A convenient source of television video signals is a standard television receiver tuned to a local station.

FEATURES

Probably the outstanding feature of the Type 1021-A Standard-Signal Generator is its convenience and reliability.

[7] D. B. Sinclair, "A Versatile Amplitude Modulator for V-H-F Signal Generators," *General Radio Experimenter*, November, 1949.

Figure 5. The Type 1021-AV V-H-F Standard-Signal Generator and the Type 1023-A Amplitude Modulator, arranged for tests on a communications-type receiver.



It brings to the V-H-F and U-H-F ranges the same ease of operation that is characteristic of most signal generators at lower frequencies, but which has not hitherto been available at frequencies as high as 920 Mc.

The carrier oscillators cover wide frequency ranges with smooth control, since no sliding contacts are used in the tuned circuits. The tuning element is driven by a worm gear. The driving shaft carries a 100 division dial which makes over eleven turns to cover the range. Frequency calibration extends over 270° on a 6″ dial. The oscillator units are enclosed in double shields, and all supply leads are well filtered. Residual output voltage and leakage are below the sensitivity of most receivers. The butterfly oscillators are of rugged design, which ensures good stability and low drift. Regulated supply voltage helps to produce clear beat tones when the output is heterodyned. The mutual inductance type attenuator has a smooth rack and pinion drive. The output terminals are fitted with the new Type 874 Universal Coaxial Connectors, which fit a wide variety of output accessories.

—Eduard Karplus
Ervin E. Gross

SPECIFICATIONS

Type 1021-AU U-H-F Standard-Signal Generator

Carrier Frequency Range: 250 Mc to 920 Mc in one band.

Frequency Calibration: Direct reading to ±1%.

Output Voltage: Continuously adjustable from 0.5 μv to 1.0 volt, open-circuit.

Output Impedance: 50 ohms ±10%.

Output Voltage Accuracy: Over-all accuracy of output voltage is better than ±20%. The accuracy of output voltmeter calibration between 0.5 volt and 1.0 volt is better than ±10%. The accuracy of the attenuator dial calibration for voltages between 1.0 μv and 0.1 volt is better than ±5%; from 0.1 volt to 0.5 volt, better than ±10%. At 920 Mc, the reasonance error in the voltmeter is +6%.

Amplitude Modulation: Adjustable, 0 to 50%. Internal, 1000 c ±5%. External, flat within 3 db from 30 c to 15 kc. For 50% modulation, external audio oscillator must supply 12 volts across a 100 kilohm load.

Envelope Distortion: Approximately 5% at 50% modulation.

Noise Level: Carrier noise level corresponds to about 0.2% modulation.

Incidental Frequency Modulation: For 50% amplitude modulation the incidental fm is approximately 100 parts per million for frequencies up to 400 Mc and is approximately 1000 parts per million at 920 Mc. When lower values of incidental fm are required, the Type 1000-P6 Crystal Modulator is recommended.

Leakage: Stray fields and residual output voltage cannot be detected with a receiver having 2 to 3 μv sensitivity.

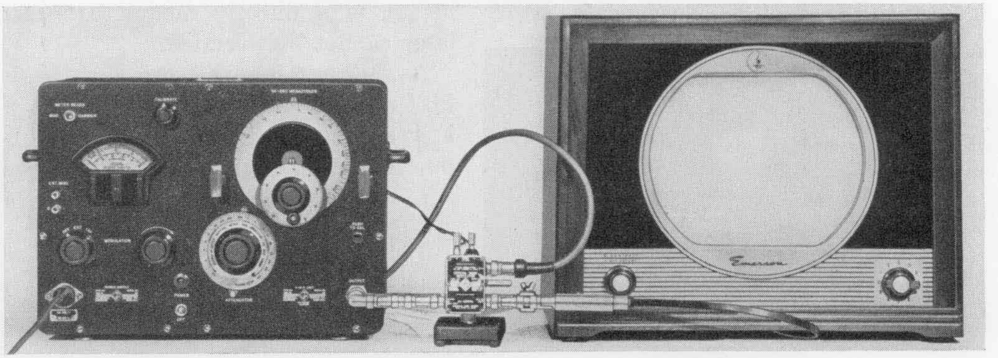
Terminals: Type 874 Coaxial Terminals are provided for the output connection.

Power Supply: 115 or 230 volts, 50 to 60 cycles. Power input is approximately 50 watts.

Tubes: Supplied with the instrument:

1 Sylvania 5767 (Oscillator)	
1 6X5-GT	1 Amperite 6–4
1 6K6-GT	2 OC3/VR105

Figure 5. The Type 1021-AV V-H-F Standard-Signal Generator with Type 1000-P6 Crystal Diode Modulator, set up for tests on a television receiver.



Accessories Supplied:
1 Type 874-R20 3-foot Coaxial Cable (50 Ω)
1 Type 874-C Coaxial Cable Connector
1 Type CAP-35 Power Cord

Other Accessories Available: Not supplied, but available on order are Type 874-GF 20 db Attenuator Pad, Type 874-GG 10 db Attenuator Pad, Type 874-K Coupling Capacitor, and Type 1000-P6 Crystal Modulator.

Mounting: The aluminum cabinet has a black wrinkle finish. The left-hand side houses the Type 1021-P1 Power Supply; the right-hand side houses the Type 1021-P2 U-H-F Unit. Panels are black crackle-finished aluminum.

Dimensions: (Height) 14$\frac{3}{8}$ x (width) 20$\frac{1}{4}$ x (depth) 10$\frac{9}{16}$ inches, overall.

Net Weight: 34 pounds.

Type 1021-AV V-H-F Standard-Signal Generator

Same as Type 1021-AU (above) except as noted.

Carrier Frequency Range: 50 Mc to 250 Mc in one band.

Incidental Frequency Modulation: For 50% amplitude modulation the incidental fm is approximately 100 parts per million for frequencies up to 100 Mc, and is approximately 500 parts per million at 250 Mc. When lower values of incidental fm are required, the Type 1000-P6 Crystal Modulator or the Type 1023-A Amplitude Modulator is recommended.

Tubes: Supplied with the instrument:
1 GE 12AT7 (Oscillator)
Other tubes as listed above.

Net Weight: 36 pounds.

Type		*Code Word*	*Price*
1021-AU	U-H-F Standard-Signal Generator, 250–920 Mc*	EVADE	$615.00
1021-AV	V-H-F Standard-Signal Generator, 50–250 Mc*	EVENT	595.00
1021-P2	U-H-F Oscillator Unit only, 250–920 Mc*	ETHIC	420.00
1021-P3	V-H-F Oscillator Unit only, 50–250 Mc*	EVOKE	400.00

*U. S. Patent No. 2,125,816; also Patent Applied For.

AN AMPLITUDE MODULATOR FOR VIDEO FREQUENCIES

The Type 1000-P6 Crystal Diode Modulator is a small, convenient device for amplitude modulating the output of a radio-frequency source. With standard-signal generators it modulates the radio-frequency signal at normal attenuator output levels, and, because it is isolated from the oscillator by an attenuator, reaction on the oscillator frequency, or incidental fm, is usually completely negligible.

The crystal diode modulator is designed for wide-band modulation, 0 to 5 megacycles, at carrier frequencies between 20 and 1000 megacycles. Hence it is particularly useful in testing television receivers, whether in the laboratory, in production, or in the service shop. It converts a conventional standard-signal generator or oscillator to a useful test-signal generator for television receivers, and its range covers both the currently used bands and the proposed new u-h-f bands, as well as receiver intermediate frequencies.

This modulator is also useful with other types of receivers operating within its carrier-frequency range, for a-m tests where the incidental fm that is inherent in a directly modulated oscillator cannot be tolerated.

As shown in Figure 2, the Type 1000-P6 Crystal Diode Modulator consists of a crystal diode between input and output terminals, a simple output filter to

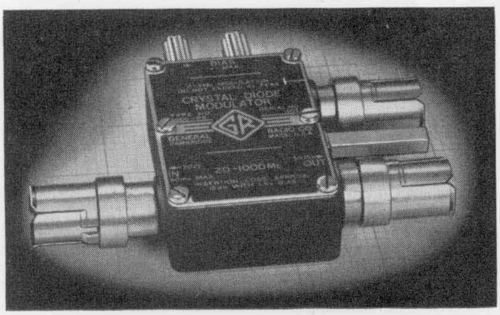


Figure 1. View of the Type 1000-P6 Crystal Diode Modulator.

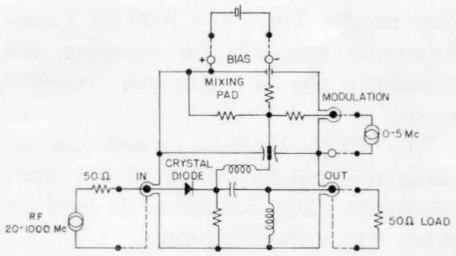


Figure 2. Circuit of the modulator.

prevent appreciable modulating voltage appearing in the output, and a means of isolating and applying modulating and bias voltages. Since the resistance of the crystal diode is a function of the voltage across it, this resistance can be modulated by applying a varying voltage. This unit, therefore, when inserted in series with a radio-frequency generator and its load, will produce amplitude modulation.

The modulator has been designed to operate between 50-ohm source and load impedances. The r-f source impedance must be low, not only at the carrier frequency but also at the modulating frequency and dc, in order that the modulation and bias will be properly applied to the crystal. The use of 50-ohm, 10- or 20-db, resistive pads[1] at the input and output of the modulator will make its characteristics relatively independent of the source and load impedance and, in addition, the combination will present an essentially constant impedance to the source and load. 20-db pads are preferable if the attenuation can be tolerated.

The maximum r-f input voltage should be limited to about 50 millivolts behind 50 ohms to avoid serious carrier and modulation distortion. Below this level, the percentage modulation is practically independent of the radio frequency applied so that any desired attenuation can be introduced ahead of the modulator.

For sine-wave modulation, bias can be applied by connecting a 1.5-volt battery to the bias terminals. This reduces the crystal resistance from the high unbiased condition to a value that is approximately in the center of the characteristic of an average crystal. Increasing the bias increases the output. If means are available for observing the modulation characteristic, some improvement may be had by adjusting the bias for optimum results. With an asymmetrical modulating signal, an adjustable bias supply is recommended if the maximum capabilities of the modulator are to be obtained. Since dc can also be applied through the modulation terminals, the bias may be included as part of the modulating voltage. If no bias at all is applied, the modulator will function on the negative cycles of the modulating voltage to produce a chopped output. Of course, no bias is necessary if the applied modulation consists only of negative pulses.

A suitable source of television video signals for test purposes is a standard television receiver tuned to a local television station. The output can be taken from the plate circuit of the last video amplifier by means of a large coupling capacitor and a suitably compensated voltage divider. The polarity of the video signal obtained at this point is

[1]Such as General Radio Type 874-GF Fixed Attenuator (20 db) or Type 874-GG Fixed Attenuator (10 db).

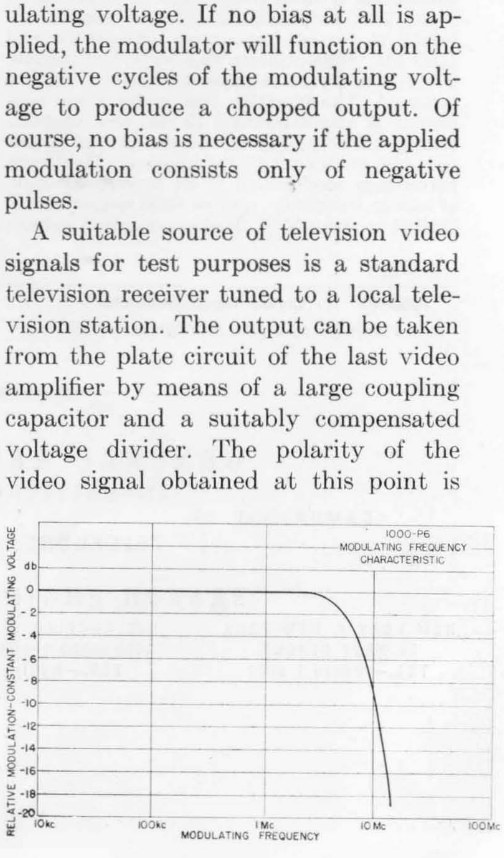


Figure 3. Modulating frequency characteristic.

correct for applying to the modulator, and a large voltage division is possible, permitting a minimum disturbance of the receiver circuit conditions. The exact modulating and bias voltages required are best determined experimentally. A 60:1 voltage divider at the output of the television receiver supplying the video signal has been found to give satisfactory results. The TYPE 1000-P5 Transformer is available for coupling the modulator to a television receiver input.

The TYPE 1N21-B crystal can be easily replaced by taking off the input connector. The connector is held in place with a threaded ring.

—W. F. BYERS

SPECIFICATIONS

Carrier Frequency Range: 20 to 1000 megacycles. The insertion loss increases approximately 10 db at a carrier frequency of 10 megacycles due to output filter.

Modulating Frequency Range: 0 to 5 megacycles. Response is approximately 2 db down at 5 megacycles with a gradual roll-off to prevent serious phase distortion of video signals.

Impedance: The impedance looking into either the input or output terminals is a function of the bias and modulating voltages. This unit was designed for use with a 50-ohm source and a 50-ohm load. The impedance at the modulation terminals is approximately 600 ohms.

Modulation: With no greater than 50 millivolts r-f input, 30% amplitude modulation can be obtained at carrier frequencies between 20 and 1000 Mc. For optimum sine-wave modulation, an average crystal requires 1.5 volts at the bias terminal. The insertion loss under these conditions is approximately 12 db, and approximately 0.2 volt r-m-s at the modulation terminals will produce 30% modulation. Maximum percentage modulation is an inverse function of carrier frequency, and at 1000 megacycles is limited to about 30%. Peak modulation voltage with respect to ground should not exceed 4 volts.

Terminals: The radio-frequency and modulating terminals are provided with TYPE 874 Coaxial Connectors. The modulation terminals will accept either a TYPE 874 Coaxial Connector or a TYPE 274-M Plug.

Crystal Diode: 1N21B.

Accessories Supplied: One TYPE 274-M Plug.

Other Accessories Required: Terminal adaptors, unless generator and load are equipped with TYPE 874 Coaxial Connectors; 1.5-volt battery for fixed bias, or a 3-volt battery and a 10,000-ohm rheostat for adjustable bias.

Accessories Available:
TYPE 874-GF Fixed Attenuator, 20 db
TYPE 874-GG Fixed Attenuator, 10 db
TYPE 874-R20 Patch Cord
TYPE 1000-P5 V-H-F Transformer
(For descriptions and prices, see *Experimenter*, Nov. '49 and Jan. '50.)

Dimensions: (Width) 5 x (height) 4 x (depth) 1 1/16 inches, overall.

Net Weight: 1 pound.

Type		*Code Word*	*Price*
1000-P6	**Crystal Diode Modulator***	APPLE	**$35.00**

*U. S. Patent No. 2,125,816; also Patent Applied For.

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PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXIV No. 11 APRIL, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

THE TYPE 1803-A VACUUM-TUBE VOLTMETER A QUALITY PRODUCT AT A MODERATE PRICE

Also
IN THIS ISSUE

● **DURING AND SINCE** the war years, there has been a tendency for engineers when designing test equipment to strive for the ultimate in performance and adaptability, regardless of price. There is still, however, a need for simple, straightforward instruments of adequate scope that will give accurate results at a price within a modest laboratory budget.

The TYPE 1803-A Vacuum-Tube Voltmeter substantially duplicates the performance of our older TYPE 726-A. It is just an a-c voltmeter, with no d-c scales, no ohm scales, and no other frills, but in many respects it is a better instrument. Nevertheless, through advances in circuit design and manufacturing techniques, the new instrument sells for $20 less than its predecessor did over ten years ago. Obviously, such a low price was not achieved without careful attention to the cost of every detail of electrical and mechanical design, and a firm resistance to the temptation to add just one little feature here and there, the combined cost of which would increase the selling price by a substantial amount.

Figure 1. Panel view of the Type 1803-A Vacuum-Tube Voltmeter, showing how probe can be stored on side of cabinet.

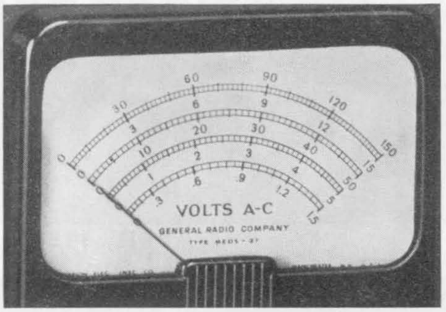


Figure 2. Close-up of the meter scales.

Although the over-all range of the voltmeter corresponds to that of the TYPE 726-A, the new instrument is improved over the old in several respects. In particular, (1) it is smaller and lighter, (2) the probe is smaller and completely shielded, (3) a single zero adjustment takes care of all ranges, and (4) the power supply is not limited to operation at a single supply frequency.

RANGE AND ACCURACY

The face of the meter, shown in Figure 2, has four scales to cover the five ranges of 0 to 1.5, 0 to 5, 0 to 15, 0 to 50, and 0 to 150 volts, a-c. There are separate, non-linear scales for the 1.5-volt and 5-volt ranges. Voltages from 5 to 50 volts are read on the 0 to 50 linear scale, and voltages from 5 to 15 volts or 5 to 150 volts are read on the 0 to 150 linear scale. A voltage below 5 volts should always be read on the appropriate non-linear scale in order to obtain the best accuracy.

The scales are calibrated to read the r-m-s value of a sine-wave voltage. The accuracy on all ranges is ±3% of the full-scale value.

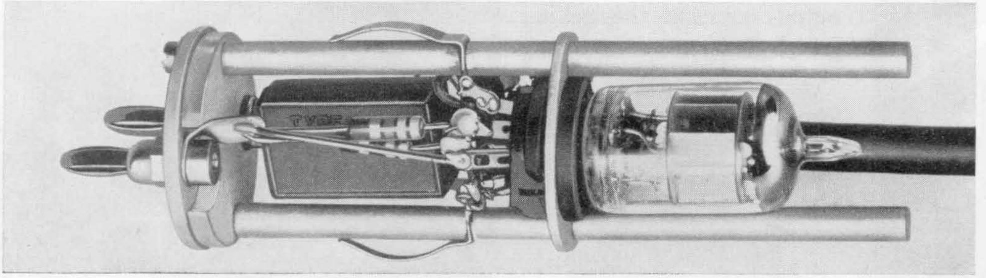
As on the TYPE 1800-A, the meter pointer is broad over the two inner scales in order to be visible at a distance, and the upper portion is knife-edged in order to make it easier to read small differences and to reproduce voltage readings or settings more accurately.

GENERAL CONSTRUCTIONS

The voltage input terminals are on the probe. Provision is made, as shown in Figure 1, for storing the probe by attaching it to the side of the cabinet, and in this position it provides a convenient pair of fixed input terminals, to which test leads can be connected. To facilitate connections there are also furnished a TYPE 274-MB Double Plug; a pair of 30-inch test leads, one red and one black, for attachment to the plug; a pair of test prods, one red, one black, that plug into the test leads; and two alligator clips into which either the leads or the prods can be plugged.

The welded, heavy-gauge aluminum cabinet is finished in black wrinkle, and is painted black on the inside to aid heat dissipation. Rubber feet are provided to support the voltmeter with the panel either vertical or horizontal, and a simple carrying handle is located on the top.

Figure 3. View of probe with case removed to show construction.



Both the power cord and the probe cable are permanently attached to the chassis and are led out through notches in the cabinet edges. The probe cable is completely shielded.

The photograph in Figure 3 shows the construction of the probe. Standard parts are used wherever possible, and expensive machine work is eliminated. The rectifier is a Type 6AL5 twin-diode, one diode of which is used to rectify the a-c voltage to be measured. The other, or inactive, diode is connected to the d-c amplifier to balance the effect of the contact potential of the active diode on the indicating meter.

FREQUENCY CHARACTERISTICS

The resonant frequency of the probe input circuit, with the Type 274 Plugs removed, is 410 Mc. Correction curves for several values of indicated voltage are shown in Figure 4. From these it is evident that the voltmeter can be used, without correction, up to 120 megacycles with a maximum error of 10%. The rise of the curves for low indicated voltages is the result of the transit-time error being larger than the resonance error and in the opposite direction. In order to approach the high-frequency performance indicated by the curves, it is important that short leads be used to connect the voltage source to the probe.

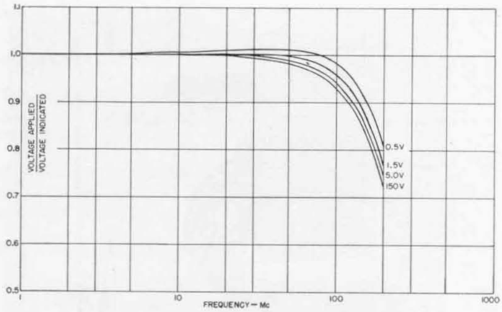


Figure 4. Plot of frequency response for different voltage levels.

The equivalent parallel input capacitance of the probe input circuit is 11.5 μμf without the connecting plugs which add about 0.5 μμf. The equivalent parallel input resistance is 7.7 megohms at low frequencies and falls off with frequency as shown by the curves of input impedance in Figure 5.

CIRCUIT

A simplified schematic of the d-c amplifier and probe is shown in Figure 6. The amplifier is a simplified version of that used in the Type 1800-A and consists of a twin-triode tube, V-2, used in a balanced circuit. The inactive section of the twin-diode in the probe is connected to the grid of one triode while the active section is connected to the grid of the other triode.

Degeneration of the amplifier is obtained by a resistance of approximately

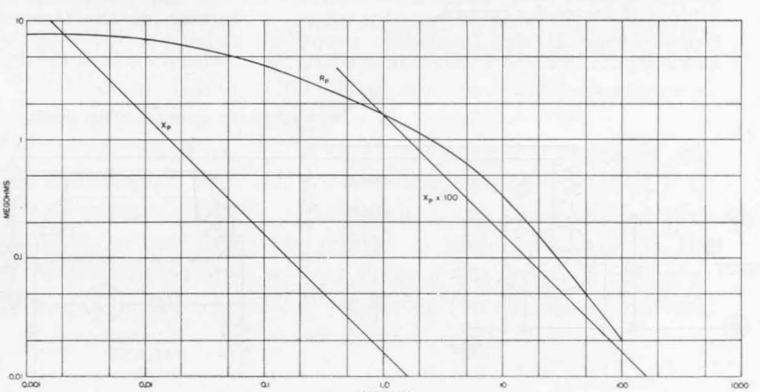


Figure 5. Plot of effective parallel reactance and resistance at the input terminals.

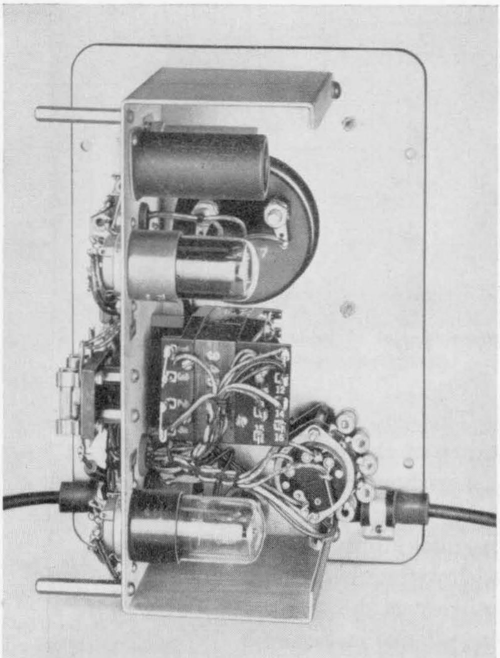


Figure 6. Rear view of the voltmeter panel and chassis.

600 kilohms connected from each cathode to B–. Part of this resistance is a potentiometer that is used as a zero control. The 200-microampere meter is connected between the cathodes of the two triodes in series with a highly stable, composition-type multiplier resistor. When the range is switched, only the multiplier resistor is changed, and, therefore, the zero adjustment is not affected.

A single internal control in the meter circuit adjusts the calibration for the particular tube, V-2, being used. Variations in the transconductance of V-2 are in effect variations in the multiplier resistance and can be compensated by a variable resistance in series with the multiplier resistance.

The balanced amplifier circuit insures very little shift in zero or in calibration when the line voltage varies. Very satisfactory results are obtained with no regulation of the plate-supply voltage or the diode heater voltage. A line shift of 10 volts changes the reading only one division on the 15-volt scale.

— C. A. Woodward, Jr.

SPECIFICATIONS

Voltage Range: 0.1 to 150 volts, a-c, in five ranges (1.5, 5, 15, 50, and 150 volts, full scale).

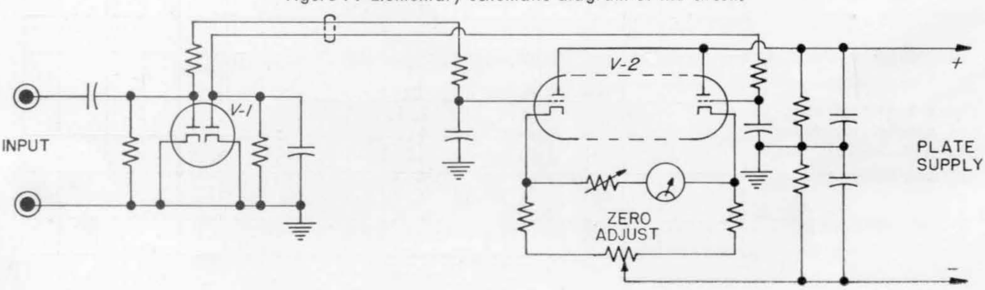
Accuracy: ±3% of full scale on all ranges, for sinusoidal voltages, subject to frequency correction above 50 megacycles. Correction curve supplied in instruction book (see accompanying plot).

Waveform Error: The instrument is peak reading and indicates r-m-s value of a sine wave or peak value of a complex wave. On distorted waveforms the percentage deviation of the reading from the r-m-s value may be as great as the percentage of harmonics present.

Frequency Error: At high frequencies resonance in the input circuit and transit-time effects in the diode rectifier introduce errors in the meter reading. The resonance effect causes the meter to read high and is independent of the applied voltage. The transit-time error is a function of the applied voltage and tends to cause the meter to read low. Figure 4 gives the frequency correction for several different voltage levels. It will be noted that at low voltages the transit-time and resonance effects tend to cancel, while at higher voltages the error is almost entirely due to resonance. The resonant frequency is about 410 Mc.

At low frequencies the response drops off because of the increasing reactance of the series capacitance of the input circuit. At 20 cycles per second the drop is 2% or less.

Figure 7. Elementary schematic diagram of the circuit.



Input Impedance: The equivalent a-c input circuit is a resistance in parallel with a capacitance. At low frequencies the equivalent parallel resistance is 7.7 megohms. At high frequencies this resistance is reduced by losses in the shunt capacitance. The equivalent parallel capacitance at radio frequencies is 10$\mu\mu$f. At audio frequencies the capacitance increases to 11.5 $\mu\mu$f. The curves of Figure 5 give the variations of R_p and X_p with frequency.

Accessories Supplied: One TYPE 274-MB Double Plug; 2 test leads; 2 test prods; 2 alligator clips.

Power Supply: 105 to 125 volts or 210 to 250 volts, a-c, 50 to 60 cycles. The power input is about 11 watts.

Tubes: One TYPE 6AL5, one TYPE 6SU7-GT, and one TYPE 6X5-GT/G are used; all are supplied.

Dimensions of Cabinet: (Width) 7¼ x (depth) 6 7/16 x (height) 11¾ inches, overall. Probe in storage position adds 1 inch to width.

Net Weight: 9¼ pounds.

Type		*Code Word*	*Price*
1803-A	**Vacuum Voltmeter**	ABOOM	**$145.00**

NEW PERSONNEL

ENLARGED QUARTERS FOR OUR NEW YORK ENGINEERING AND SALES OFFICE

To provide more complete engineering and commercial service for our customers in the greater New York area, the staff of our New York office has recently been increased. William R. Thurston and George G. Ross, both from our Engineering Department, now make their headquarters in New York and are available for consultation on the purchase, performance, and use of General Radio equipment. This increase in office personnel will make possible much better service to many friends and customers in New Jersey and eastern Pennsylvania.

Mr. Thurston was graduated from the Massachusetts Institute of Technology with the degrees of S.B. and S.M. in Electrical Engineering. Before graduation he was a cooperative student at our plant. He joined the Development Engineering Staff of the General Radio Company in 1943 and has specialized in the development of high-frequency measuring equipment and techniques. One of the important developments with which he was associated is our new line of TYPE 874 Coaxial Measuring Equipment. During 1945 he was on leave of absence for work at the M.I.T. Radiation Laboratory. Mr. Thurston transferred to the Sales Engineering Department in 1949.

Mr. Ross was graduated from Northeastern University in 1942 with the degree of B.S. in Electrical Engineering and while an undergraduate was also a cooperative student in our plant. After graduation he served as a degaussing analyst with the Bureau of Ordnance, U. S. Navy, leaving in 1943 to enter the Navy as a Lieutenant, j.g. At the close of the war he joined the staff of our Standardizing Laboratory, later transferring to the Sales Engineering Department.

Ivan G. Easton, who was manager of our New York office from 1946 to 1949, has now returned to the Cambridge office and is working with Dr. D. B. Sinclair, Chief Engineer, on important engineering projects.

Miss Mary Arms continues as our efficient secretary and receptionist.

On March 1 our New York office was moved to larger quarters on the seventh floor of the Brady Building at 90 West Street (no change of address).

The new space provides two private offices, adequate room for exhibiting and demonstrating our equipment, and a storeroom for the maintenance of a stock of smaller instruments and parts including Variacs. Our telephone number continues as WOrth 2-5837. We cordially invite all our friends in the greater New York area to visit our new offices.

LOS ANGELES STAFF INCREASED

The addition of James G. Hussey to our Los Angeles office staff doubles the technical personnel now available to our Western customers and will permit better coverage of the Mountain States.

Mr. Hussey joins General Radio with an A.B. degree in Physics received from the University of California, Los Angeles, and with the benefit of Navy wartime electronic experience. Mr. Hussey's prior years of electronic equipment production-test and quality-control supervision in the Los Angeles area have qualified him with an understanding of regional problems and industrial instrumentation.

The Los Angeles office remains under the direction of Frederick Ireland.

D. B. SINCLAIR BECOMES CHIEF ENGINEER

Dr. Donald B. Sinclair has been appointed Chief Engineer of the General Radio Company, succeeding Melville Eastham who retired from that post on February 15.

Dr. Sinclair was born in Winnipeg, Manitoba, and was educated at the University of Manitoba and the Massachusetts Institute of Technology, receiving the degree of Doctor of Science from M.I.T. in 1935. He was a Research Assistant and later Research Associate at M.I.T. from 1932 to 1935, and he joined the General Radio Engineering Staff in 1936. He has been Assistant Chief Engineer since 1944. During the war he worked in the Countermeasures Division and the Guided Missiles Division of NDRC, receiving the President's Certificate of Merit for outstanding services.

Dr. Sinclair is a Fellow of the Institute of Radio Engineers, a member of the American Institute of Electrical Engineers, and a member of Sigma Xi. He is Treasurer of the Institute of Radio Engineers and has been on the Board of Directors of the Institute since 1944.

George G. Ross

William R. Thurston

James G. Hussey

Donald B. Sinclair

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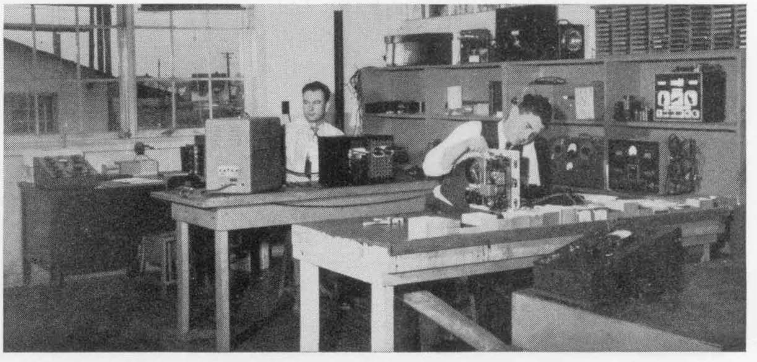
Bayly Engineering, Limited, is owned and operated by Professor B. de F. Bayly of the University of Toronto. He has had many years of experience in the electrical and electronic industries and is already well known to most of our Canadian customers.

By telephone, Bayly Engineering can be reached through the Toronto exchange, at WAverly 6866.



View of a portion of the laboratory at Bayly Engineering, Limited.

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PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXIV No. 12 MAY, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A DIRECT-READING IMPEDANCE-MEASURING INSTRUMENT FOR THE U-H-F RANGE

Also IN THIS ISSUE

INTRODUCTION

Now that television is getting ready to move into the u-h-f range, the need for direct-reading measuring equipment that will give accurate results quickly is becoming increasingly evident. For impedance measurement, specifically, there is a need for a null-type device that will be as convenient and rapid to use as are the bridges that have been developed for lower frequencies.[1, 2, 3, 4]

[1] D. B. Sinclair, "The Twin-T—a New Type of Null Instrument for Measuring Impedance at Frequencies up to 30 Megacycles," *Proc. I.R.E.*, July, 1940.

[2] D. B. Sinclair, "A Radio-Frequency Bridge for Impedance Measurements from 400 Kilocycles to 60 Megacycles," *Proc. I.R.E.*, November, 1940.

[3] R. A. Soderman, "A New Bridge for Impedance Measurements at Frequencies between 50 Kilocycles and 5 Megacycles," *General Radio Experimenter*, March, 1949.

[4] R. A. Soderman, "A New Bridge for the Measurement of Impedance between 10 and 165 Mc," *General Radio Experimenter*, February, 1950.

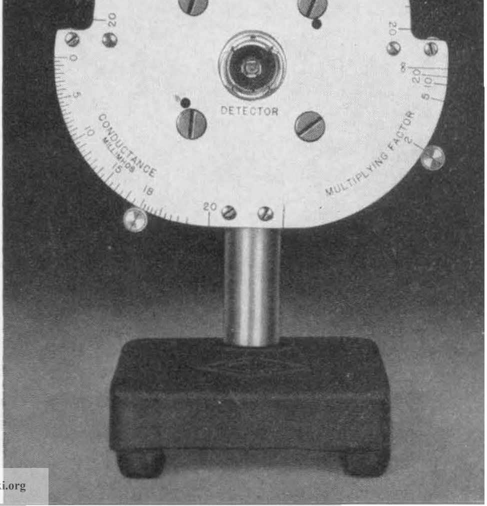
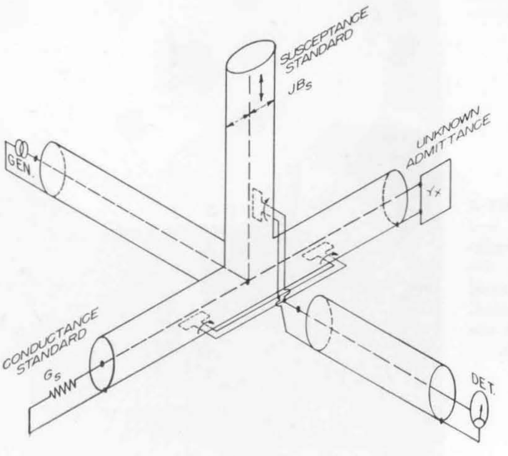


Figure 1. Front view of the Type 1602-A Admittance Meter, showing dial and sliding indicators. The extreme simplicity of operation is evident from this photograph. The indicators are moved along the scales until a null is obtained, and the conductance and susceptance are then read directly from the dial.

At these lower frequencies, it is not difficult to design and construct a bridge to perform a specific task. As the frequency increases, however, it becomes more and more difficult to isolate specific impedances and to arrange them in a predictable system. It has been found, in fact, that lumped-parameter elements cannot generally be connected satisfactorily in conventional bridge circuits above about 150 Mc, and that new arrangements based on coaxial-line techniques offer greater promise.

The Type 1602-A U-H-F Admittance Meter is a null device based on these techniques. Through adjustable loops, it samples the currents flowing in three coaxial lines fed from a common source at a common junction point. The outputs of the three loops are combined and, when the loops are properly oriented, the combined output becomes zero. The device therefore balances in the same manner as a bridge. It indicates conductance and susceptance on direct-reading dials, the calibrations of which are independent of frequency, and the null settings for both components are completely independent.

As a null instrument, the U-H-F Admittance Meter can be used to measure conductances, and susceptances of either sign, from 1 millimho to 400 millimhos (1,000 Ω to 2.5 Ω) over a frequency range from 70 Mc to 1000 Mc. It can also be used as a comparator to indicate equality of one admittance to another, or degree of departure of one from the other. As a direct-indicating device, in addition, it can be used to determine the magnitude of the reflection coefficient of a coaxial system, or the magnitude of an unknown admittance, from ratios of output voltages read on a meter.



PRINCIPLE

Figure 2 shows the functional arrangement of the admittance meter with standards connected. The standard conductance, G_s, is a resistor having a value equal to the characteristic impedance, Z_o, of the line, and the standard susceptance, jB_s, is an adjustable stub which is set to one-eighth wavelength at the operating frequency.

Since the voltage from the generator is common to all three lines, the sending-end current in each line is proportional to the sending-end admittance. This admittance is Y_x for the line terminated in the unknown, $G_s = \frac{1}{Z_o}$ for the line terminated in the standard conductance, and $jB_s = -j\frac{1}{Z_o}$ for the line terminated in the eighth-wave stub.

The induced voltage in each loop is proportional to the mutual inductance (M_X, M_G, or M_B), and to the current in the corresponding line. Thus, the induced voltage in the loop associated with the unknown admittance is proportional to the product,

$$M_X Y_X = M_X G_X + jM_X B_X;$$

the induced voltage in the loop associated with the standard conductance is proportional to the product, $M_G G_S$; and

Figure 2. Schematic diagram of admittance meter circuit, with standards, generator, and null dectector connected for admittance measurements.

the induced voltage in the loop associated with the standard susceptance is proportional to the product, $jM_B B_S$. It follows that these three induced voltages add up to zero and produce a null when the couplings of the three loops have been adjusted to have the following relations:

$$G_X = -\frac{M_G}{M_X} G_S, \text{ and } B_X = -\frac{M_B}{M_X} B_S.$$

G_S and B_S are constants, so the M_G scale can be calibrated in terms of G_X, the M_B scale in terms of B_X, and the M_X scale in terms of a multiplying factor to be applied to the other two scale readings. Since each coupling can be varied through zero, the two balance equations show that the theoretically measurable ranges of conductance and susceptance extend from zero to infinity. However, the percentage accuracy of reading the scales naturally decreases as the position of zero coupling is approached, and the 1 millimho to 400 millimhos range is found practical for reading and setting.

The loops associated with the unknown admittance and the standard conductance can each be rotated through an angle of 90°, but the loop associated with the standard susceptance is arranged to be rotatable through an angle of 180°, thus allowing the measurement of positive as well as negative values of unknown susceptance with a single susceptance standard. Figure 1 is a detailed view of the calibrated scales.

A unique feature of the U-H-F Admittance Meter, which distinguishes it from bridges and other null devices, is that the susceptance scale, as well as the conductance scale, is independent of frequency. This comes about because the stub that forms the susceptance standard is always adjusted to one-eighth wavelength at the operating frequency and therefore presents a constant susceptance.

CONSTRUCTION

Various views of the external and internal appearance of the admittance meter are shown in Figures 1, 3, 4, and

Figure 3. Rear view of the admittance meter, showing the four lines making up the generator junction assembly. The three arms for the sliding indicators can also be seen.

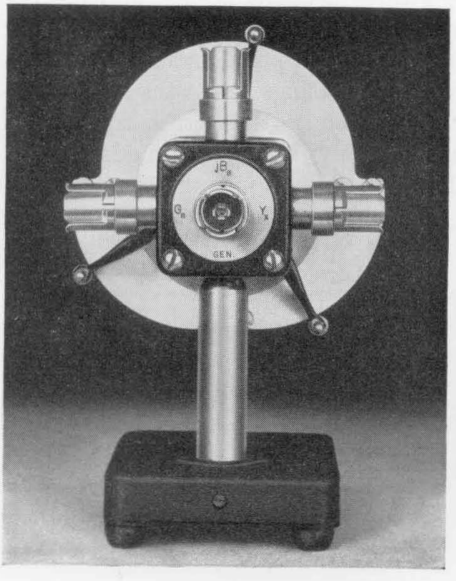
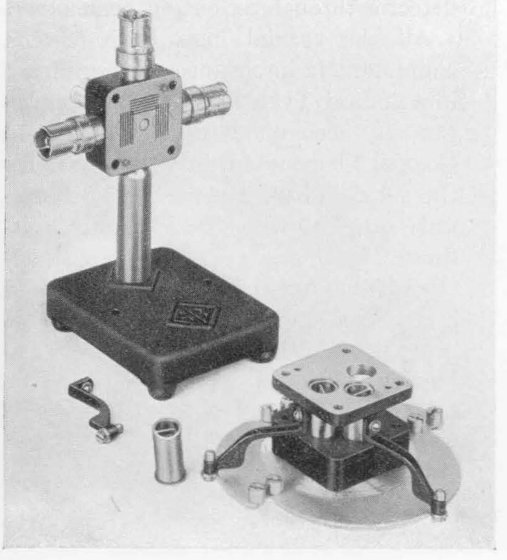


Figure 4. View showing internal parts of the admittance meter. The pickup-loop assembly has been removed from the generator junction assembly to show the coupling slots and the coupling loops.



5. The instrument consists basically of a generator-junction assembly, a pickup-loop assembly, and a detector-junction assembly. The generator-junction assembly is made up of four coaxial lines coming together in a common junction. Three of these lines are arranged in a "T" configuration that can be excited through the fourth line, which is perpendicular to the plane of the "T." At their outer ends the lines are terminated by coaxial connectors, so that unknown and standard admittances and a generator can be readily connected.

The pickup-loop assembly comprises three loops, each of which couples through slots to the magnetic field in one of the three coaxial lines making up the "T." Each loop can be rotated by means of an arm to vary its coupling, and the position of the end of the arm with respect to a fixed scale is used to indicate degree of coupling. The maximum values of coupling of all three loops are the same, and the loops are carefully shielded from one another so that they pick up voltage only from the line to which they are directly coupled.

The detector-junction assembly consists of a connection of all three loop outputs in parallel to drive an external detector through an output connector.

All the coaxial lines have 50-ohm characteristic impedance and terminate in standard Type 874 Coaxial Connectors to accommodate the Type 874 Coaxial Elements already developed for the v-h-f and u-h-f ranges.[5] The standards supplied with the U-H-F Admittance Meter are a Type 874-WM 50-Ohm Termination for conductance, and Type 874-D20 and 874-D50 Adjustable Stubs, modified by the addition of frequency scales, for susceptance.

[5] W. R. Thurston, "Simple, Complete Coaxial Measuring Equipment for the U-H-F Range," *General Radio Experimenter*, January, 1950.

ERRORS AND CORRECTIONS

Errors in the U-H-F Admittance Meter can be classified generally as (1) errors arising from departures from perfection in fabrication and (2) errors resulting from the practical geometry of the system.

Errors of the first kind are principally caused by necessary manufacturing tolerances and are small enough to be ignored at frequencies up to 1000 Mc within the accuracy limitations specified.

Errors of the second kind are amenable to systematic correction. They are caused by the physical requirements that (1) the pickup loops cannot be located exactly at the junction of the three lines that form the "T," and that (2) the conductance and susceptance standards, and the unknown admittance, cannot be connected to the lines at a point directly under the corresponding pickup loop.

The first of these errors is minimized by making the outer-conductor diameter of the line sections between the coupling points and the junction point only slightly larger than the inner-conductor diameter. The resulting very low impedance of the connecting sections prevents large voltage differences among the three coupling points, and the decreased diameter of the sections relative to their length prevents appreciable unwanted couplings across the junction.

The second of these errors is of significance for only the unknown admittance. For the line terminated in the conductance standard, $G_s = \frac{1}{Z_o}$, no error results from the spacing between the standard and loop because the line is matched. For the line terminated in the susceptance standard, $jB_s = -j\frac{1}{Z_o}$, no error results since the system is smooth through the connector and the total electrical length from loop to plunger is set at $\lambda/8$. For the line terminated in the unknown admittance, Y_x, however, a "lead correction" must be made to account for the short section of line between the loop and connector. This can be readily made through the use of a Smith Chart,[6] which can also be used to convert admittance parameters to impedance, if desired.

[6]Phillip H. Smith, "Transmission Line Calculator," *Electronics*, January, 1939, and January, 1944.

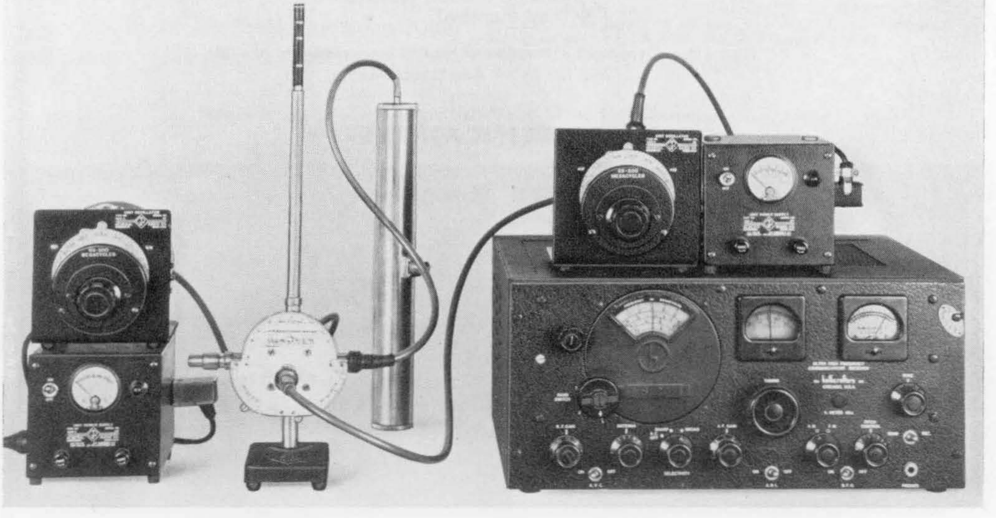
OPERATION

Equipment suitable for use as generator and detector with the U-H-F Admittance Meter has been developed and is described elsewhere in this issue. The Type 1208-A and Type 1209-A Unit Oscillators are particularly suited for use as generators and, when combined with the Type 874-MR Mixer Rectifier, as frequency converters to adapt conventional communication-type receivers for use as v-h-f and u-h-f detectors. The component instruments of this system are all fitted with Type 874 Coaxial Connectors and are easily interconnected by Type 874-R20 Patch Cords. The Type 1021-AV and Type 1021-AU Standard-Signal Generators also make satisfactory generators and, at frequencies above those covered by conventional communication-type receivers, the Type AN/APR-1 and Type AN/APR-4 Search Receivers also make excellent detectors.

In general, superheterodyne-type detectors are preferable to superregenerative types because their greater dynamic range makes it possible to locate the null quickly, without recourse to progressive adjustment of the input level over a wide range, and makes possible the use of a simple, inexpensive generator.

In addition to its use as a null device, the U-H-F Admittance Meter can be used as a direct-indicating device. It can, for instance, measure reflection-coefficient magnitude and impedance magnitude directly and simply by voltage-ratio methods. These measurements require the generator or the detector to have a calibrated attenuator or a calibrated indicator, and the answer is obtained from the ratio of two voltages

Figure 5. View of the admittance meter in use with standards and unknown connected. The generator is a Type 1208-A Unit Oscillator and the null detector is a communications-type receiver, with a second unit oscillator and Type 874-WM Mixer acting as a frequency converter. The unknown admittance being measured is an u-h-f transformer.

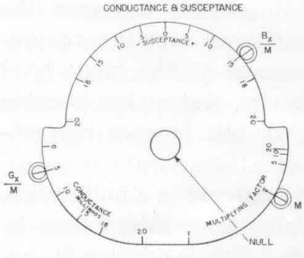


with the controls of the admittance meter set at two different positions. As with null measurements, there are no frequency corrections.

Figure 6 outlines the operating procedure to follow in making some of the many types of measurement of which the instrument is capable. Others will suggest themselves to the user as he becomes familiar with the instrument. The wide variety of applications illustrates the flexibility and adaptability of this new approach to u-h-f impedance measurements.

This flexibility of application combined with the simplicity and ease of operation of the instrument makes the U-H-F Admittance Meter well suited for measurements in the FM and TV bands including the proposed new u-h-f bands.

— W. R. Thurston



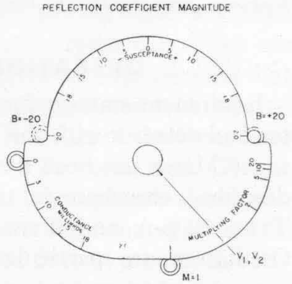
CONDUCTANCE AND SUSCEPTANCE

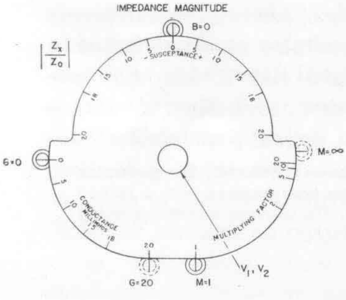
Set G and B controls to obtain null.
Read G and B scales and multiply by M.

REFLECTION-COEFFICIENT MAGNITUDE

Replace stub by 50-ohm termination.
Set $G = 0$ and $M = 1$. Set $B = -20$ mmhos.
Read output V_1. Reset B to $+20$ mmhos. Read output V_2.

$$|\rho| = \frac{V_1}{V_2}$$





IMPEDANCE MAGNITUDE

Set $B = 0$, $G = 20$, and $M = \infty$. Read output V_1.
Reset G to 0 and M to 1.
Read output V_2.

$$\left|\frac{Z_x}{Z_o}\right| = \frac{V_1}{V_2}$$

MATCHING TO 50 OHMS

Set $B = 0$, $G = 20$ mmhos, and $M = 1$.
Adjust network to be matched until null occurs. Network is then matched.

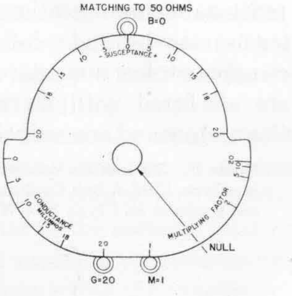


Figure 6. Graphical illustration of typical measurements possible with the U-H-F Admittance Meter.

SPECIFICATIONS

Range: Theoretically, zero to infinity; practically, the lower limit is determined by the smallest readable increment on the scale which is 200 micromhos (0.2 millimho). The upper limit is 1000 millimhos. Range is the same for both conductance and susceptance, but susceptance can be either positive or negative, i.e., the susceptance dial is calibrated from −20 to +20 millimhos. Multiplying factors from 1 to 20 are provided, and factors from 20 to 100 can be determined approximately.

Frequency Range: 70 to 1000 Mc.

Accuracy: For both conductance and susceptance:

From 0 to 20 millimhos $\pm(5\% + 0.2$ millimho)

From 20 to ∞ millimhos $\pm 5\sqrt{M}\%$

Where M is the scale multiplying factor.

Accessories Supplied: Type 874-WM 50-Ω Termination, for use as conductance standard, and one each Type 1602-P1 and Type 1602-P2 Adjustable Stubs, for susceptance standards; two Type 874-R20 Patch Cords for connections to generator and detector.

Additional Accessories Required: Generator, covering desired frequency range and delivering between 1 volt and 10 volts, such as TYPE 1208-A, 65 – 500 Mc, and TYPE 1209-A, 250 – 920 Mc, Unit Oscillators with TYPE 1205-A Unit Power Supply, or TYPE 1021-A Standard-Signal Generator. Detector, with sensitivity better than 10 microvolts. Ordinary communications-type receivers can be used, in conjunction with a TYPE 1208-A or TYPE 1209-A Unit Oscillator and a TYPE 874-MR Mixer Rectifier. The receiver should have a bandwidth of at least 20 kc. An AN/APR-4 Receiver with TN-17 Tuning Unit for 75-300 Mc, or with TN-18 Tuning Unit for 300 – 1000 Mc, or AN/APR-1 Receiver with appropriate tuning units also is a satisfactory detector.

Other Accessories Recommended: TYPE 874-WN Short-Circuit Termination.

Terminals: All terminals are TYPE 874 Coaxial Connectors, generator, detector, standards, and unknown. Adaptors are available for TYPE N Connectors.

Dimensions: 7½ x 5½ x 5½ inches without standards and unknown connected.

Net Weight: 8 pounds.

Type		*Code Word*	*Price*
1602-A	**U-H-F Admittance Meter***	HONEY	**$295.00**

*U. S. Patent 2,125,816. Patent Applied For.

V-H-F AND U-H-F UNIT OSCILLATORS

The TYPE 1208-A and TYPE 1209-A Unit Oscillators are compact, moderately priced, general-purpose power sources for the electronics laboratory. They cover the frequency ranges of 65 to 500 Mc and 250 to 920 Mc, respectively, and can deliver 100 to 500 milliwatts of power. Output terminals are TYPE 874 Coaxial Connectors, for connection to General Radio measuring equipment as well as to the wide variety of TYPE 874 Coaxial Elements previously described.[1]

These oscillators are recommended as power sources for the TYPE 874-LB Slotted Line, the TYPE 1601-A V-H-F Bridge,[2] and the TYPE 1602-A U-H-F Admittance Meter.[3] In conjunction with TYPE 874 Coaxial Elements such as attenuators, rectifiers, filters, terminations, modulators, and coupling devices, they can be adapted for a wide variety of uses in the laboratory which would otherwise require specialized and expensive equipment.

Three of these applications are described in detail below, and others will suggest themselves after a study of the complete list of TYPE 874 Coaxial Elements.[1]

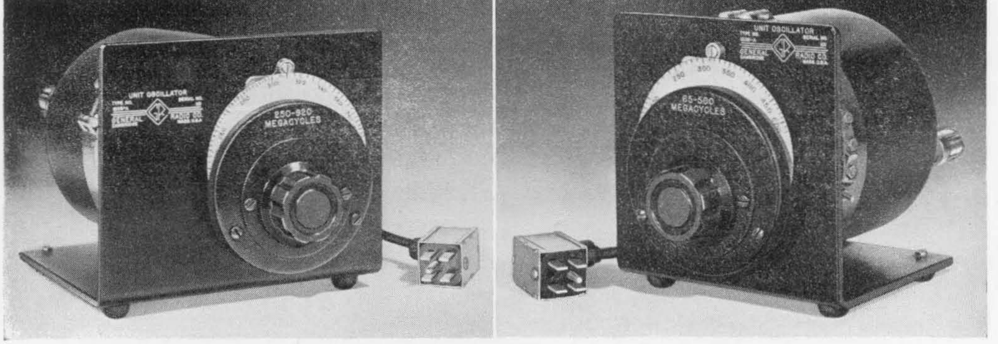
The two unit oscillators cover very wide ranges in that part of the frequency spectrum that is beyond the region of conventional lumped circuit techniques and below the region of lines and cavities. Oscillators in that range cannot be

[1] W. R. Thurston, "Simple, Complete Coaxial Measuring Equipment for the U-H-F Range," *General Radio Experimenter*, Vol. XXIV, No. 8, January, 1950.

[2] R. A. Soderman, "A New Bridge for the Measurement of Impedance between 10 and 165 Mc," *General Radio Experimenter*, Vol. XXIV, No. 9, February, 1950.

[3] See first article in this issue.

Figure 1. Panel views of the U-H-F and V-H-F Unit Oscillators. ***Left,*** **Type 1209-A;** ***right,*** **Type 1208-A.**



put together readily from standard components, and much time and effort will be saved by using the small, convenient, and reliable unit oscillators for the everyday jobs of electronic engineering.

Both oscillators are mounted on L-shaped brackets which require a minimum of bench space. All components are mounted on a flat base casting which carries the supply line filters on one side and the tuned circuit on the other. The tuned circuit is enclosed in a cylindrical shield which carries the output circuit and the output connector.

The tuning system of the TYPE 1208-A Unit Oscillator covers the 8:1 range of 65 to 520 Mc. It is a sliding contact type of circuit that combines a variable air capacitor and a variable inductor in a single unit. The range of capacitance variation is from 8 to 100 $\mu\mu$f and of inductance, from 0.01 to 0.06 μh. Rotor and stator are shaped to give a logarithmic variation of frequency with dial rotation.

The 250 to 920 Mc TYPE 1209-A Unit Oscillator uses a Butterfly Circuit[4] as the tuning element. Variation of inductance is considerably smaller (0.004 to 0.011 μh), but sliding contacts, which might cause erratic behavior at the higher frequencies, are eliminated. The capacitance variation (7 to 40 $\mu\mu$f) is determined by the rotor, the shape of which resembles the wings of a butterfly. To obtain the maximum possible frequency span, the plates have not been cut away at the leading edge as would be necessary to give a logarithmic scale and, hence, percentage variation of frequency increases at the high-frequency end.

[4]Eduard Karplus, "Wide-Range Tuned Circuits and Oscillators for High Frequencies," *Proc. I.R.E.*, July, 1945.

Eduard Karplus, "The Butterfly Circuit," *General Radio Experimenter*, October, 1944.

U. S. Patent No. 2,367,681.

In both oscillators the vernier dial makes about 4½ turns for the 270° rotation of the 4-inch main dial which carries the frequency calibration. In the 1208-A Oscillator the tuning unit turns 270°; in the 1209-A it is geared down to 80° rotation. The frequency calibration is accurate within ±1%.

The oscillator tubes used are the TYPE 2C43 Lighthouse Tube in the 65 to 500 Mc Unit Oscillator and the TYPE 5767 Rocket Tube in the 250 to 920 Mc Oscillator. Both tubes are coplanar triodes with indirectly heated cathodes. They have been chosen because their external electrode structure is particularly well adapted for use with tuning units of these two oscillators. Plate and grid of the tube are connected to the tuned circuit, which has no connections to ground. Feedback is determined essentially by the tube electrode capacitances, but a small amount of plate-to-cathode capacitance has been added in the higher frequency unit.

Output of the oscillators is limited by the plate current and plate dissipation ratings of the oscillator tubes. Best operation is obtained near the maximum plate current rating, since the tubes then have the highest transconductance. The output system is a short coaxial line with a coupling loop on one end and a TYPE 874 Coaxial Connector on the other. Coupling between the loop and the oscillator can be adjusted over a wide range, and the loop can be clamped in the desired position by tightening a wing nut. Maximum power can be delivered to load impedances normally encountered in coaxial systems. The output power into a 50-ohm load is over 100 milliwatts at any frequency and over 400 milliwatts near the center of the frequency ranges.

A plate supply of approximately 275 volts at 36 milliamperes is required to operate both oscillators at their maximum rating. The heater supply is 6.3 volts at 0.9 amperes for the TYPE 1208-A and 0.4 amperes for the TYPE 1209-A. The TYPE 1205-A Power Supply is recommended as a convenient and low-priced source of power. The multiconnector plug of the unit oscillators plugs directly into this power supply.

For some applications a well-regulated power supply with low hum voltage will be found more desirable, in order to avoid frequency variations caused by line voltage fluctuation and to produce a clearer beat tone. For a 20% line voltage variation, the frequency change is of the order of 0.01% at the low frequency end of the range. At the high end, the change is 0.05% for the TYPE 1209-A and 0.5% for the TYPE 1208-A.

Amplitude modulation over the audio range can be obtained by superimposing a-f voltage in the plate supply. Convenient terminals have been provided for this purpose. Incidental fm inherent in this system is of the order of 0.01% for 30% am in the lower part of the tuning range and increases rapidly at the high-frequency end. For applications where incidental fm must be neglible, external modulators such as the TYPE 1000-P6[5] and the TYPE 1023-A[6] are recommended.

[5] W. F. Byers, "An Amplitude Modulator for Video Frequencies," *General Radio Experimenter*, Vol. XXIV, No. 10, March, 1950.

[6] D. B. Sinclair, "A Versatile Amplitude Modulator for V-H-F Standard-Signal Generators," *General Radio Experimenter*, Vol. XXIV, No. 6, November, 1949.

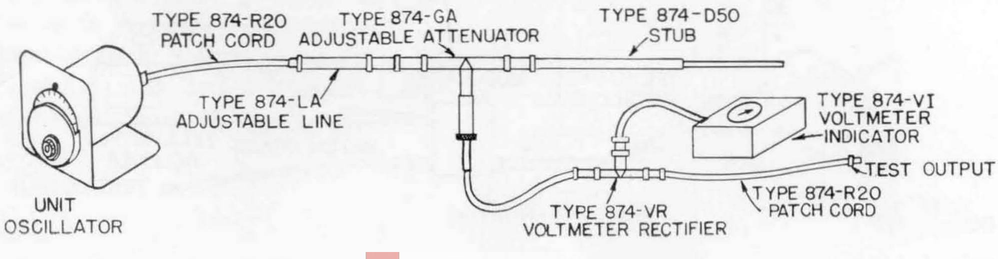
Unit Oscillator as Signal Generator for Receiver Testing

Since the unit oscillator is a well-shielded source of power, it can be used as signal generator for receiver testing if means are provided to measure and to attenuate the output. The TYPE 874-VR Voltmeter Rectifier, the TYPE 874-VI Voltmeter Indicator, and the TYPE 874-GA Adjustable Attenuator are suitable for this purpose and should be connected to the unit oscillators as shown in Figure 2. In addition to these three instruments, a TYPE 874-D50 Adjustable Stub is required at the higher frequencies (300 Mc and above) to produce a current maximum at that point of the attenuator where the adjustable output loop is coupled. At lower frequencies a TYPE 874-WN Short-Circuit Termination can be used. The TYPE 874-LA Adjustable Line must be added to increase the available output.

Current from the unit oscillator is fed through the exciting line of the attenuator into the short circuit or the stub. The attenuator is calibrated in db. At minimum attenuation the attenuator output is measured by a crystal diode in the voltmeter rectifier and read on the meter of the voltmeter indicator. Means are provided to standardize the meter indication. The crystal is followed by a 50-ohm resistor which determines the output impedance.

The arrangement just described is practically the same as that used in the TYPE 1021-A Standard-Signal Generator. The maximum available output

Figure 2. Functional diagram of the unit oscillator and accessories, connected to work as a standard-signal generator.



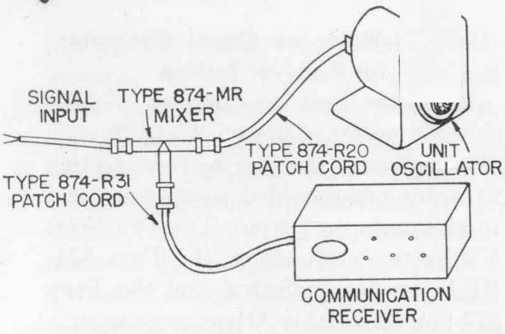


Figure 4. Functional diagram of the unit oscillator and mixer rectifier used as a frequency converter.

voltage is of the order of several tenths of 1 volt. The calibration of the attenuator covers 120 db, but the shielding of the unit oscillator and the various other components is not sufficient for making accurate measurements in the microvolt region.

Unit Oscillator as Television Signal Generator

In combination with a Type 1000-P6 Crystal Diode Modulator and a Type 874-GF 20-db Fixed Attenuator, the unit oscillator is a convenient source of television signals over its entire carrier-frequency range if video modulating voltage is available. The circuit arrangement is shown in Figure 3. The video modulating voltage required can be obtained from a standard television receiver tuned to the local station.

Since the modulator is separated from the oscillator by an attenuator pad, amplitude modulation free from incidental frequency modulation is obtained. The output is of the order of 10 millivolts.

Unit Oscillator as Frequency Converter

Connected to a Type 874-MR Mixer Rectifier, the unit oscillator can provide the local signal in a heterodyne converter to adapt a low-frequency communications receiver for use as a sensitive detector for v-h-f and u-h-f signals. This circuit is shown in Figure 4. Without additional tuning the conversion loss is approximately 12 db at an intermediate frequency of 30 Mc. The bandwidth of the communications receiver should be at least 20 kilocycles to allow for frequency fluctuations of the received signal and of the unit oscillator.

—Eduard Karplus

SPECIFICATIONS
Type 1209-A

Frequency Range: 250–920 Mc.

Tuned Circuit: Butterfly, with no sliding contacts.

Frequency Control: 4-inch dial with calibration over 270°. Slow-motion drive, 4½ turns.

Frequency Calibration Accuracy: 1%.

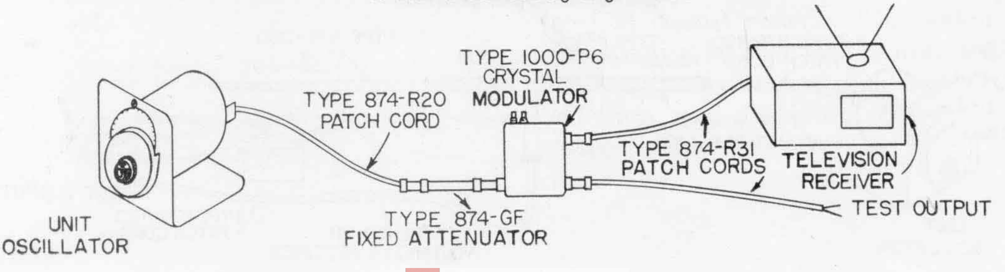
Warm-Up Frequency Drift: 0.2%.

Output System: Short coaxial line with a coupling loop on one end and a Type 874 Coaxial Connector on the other. Coupling between loop and oscillator can be adjusted over a wide range and the loop can be clamped in the desired position. Maximum power can be delivered to load impedances normally encountered in coaxial systems.

Output Power: Into 50 Ω, 100 mw at any frequency; 400 mw in center of range.

Modulation: Amplitude modulation of 30% at audio frequencies can be produced by an external source of 40 volts. Input impedance is about 8000 ohms. Type 1000-P6 Crystal Diode Modulator can also be used with either oscillator.

Figure 3. Functional diagram of the unit oscillator with video modulator to form a television signal generator.



Power Supply Required: 300 v; 40 ma
6.3 v; 0.4 a

Type 1205-A Power Supply is recommended.

Tube: Sylvania 5767 Rocket.

Mounting: Oscillator is mounted in an aluminum casting surrounded by a spun aluminum container. Assembly is then mounted on an L-shaped panel and chassis piece.

Accessories Supplied: Type 874-R20 Patch Cord, Type 874-P Panel Connector, and Type 874-C Cable Connector.

Accessories Available: Type 1000-P6 Crystal Diode Modulator, Type 874 Coaxial Elements such as attenuators, filters, coupling devices, stubs, voltmeter, and mixer. See the January, 1950, *Experimenter* for details.

Dimensions: 7 x 6¼ x 9¼ inches, overall.

Net Weight: 5½ pounds.

Type 1208-A

Specifications for Type 1208-A are the same as those for the Type 1209-A, with the exceptions noted below.

Frequency Range: 65–500 Mc.

Tuned Circuit: Sliding contact type.

Frequency Calibration Accuracy: 2%.

Warm-Up Frequency Drift: 0.5%.

Output Power: Into 50 Ω, 100 mw at any frequency; 500 mw in center of range.

Power Supply Required: 300 v; 40 ma
6.3 v; 0.9 a

Type 1205-A Power Supply is recommended.

Tube: Lighthouse 2C 43.

Dimensions: 6¼ x 6¼ x 8¼ inches, overall.

Net Weight: 4 pounds, 14 ounces.

Type		*Code Word*	*Price*
1209-A	**Unit Oscillator, 250–920 Mc.***	AMISS	**$235.00**
1208-A	**Unit Oscillator, 65–500 Mc.***	AMEND	**190.00**

*U. S. Patent 2,125,816. Patent Applied For.

TYPE 874-MR MIXER RECTIFIER

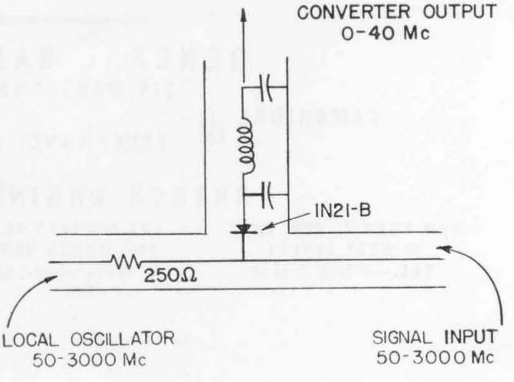
A new rectifier unit has been added to the line of Type 874 Coaxial Elements, which can be used as a mixer in a heterodyne-frequency converter. Signals at frequencies over 50 Mc, for which receivers are not always available, can be converted to frequencies under 40 Mc and detected with a standard communication-type receiver.

The Type 874-MR Mixer Rectifier is similar to the Type 874-VR Voltmeter Rectifier, except for the 50-ohm termination resistor which has been changed to 250 ohms to increase the input impedance for the received signal and for the filter at the output which now has a cutoff frequency of 40 Mc instead of a large by-pass capacitor.

Figure 1 is a diagram of the mixer rectifier. All three terminals are fitted with Type 874 Connectors. The local oscillator voltage appearing at the crystal must be limited to about 2 volts to prevent damage to the crystal. At this high level of local oscillator input, strong harmonics will be produced in the crystal, and satisfactory operation with some loss in signal-to-noise ratio will be obtained with signal frequencies several times as high as the local oscillator frequency.

The bandwidth of the receiver used to detect the converter output should be sufficiently wide to allow for normal frequency variation in both the local oscillator and the input signal.

Figure 1. Schematic diagram of the Type 874-MR Mixer Rectifier.



The 65–500 Mc Type 1208-A and the 250–920 Mc Type 1209-A Unit Oscillators described elsewhere in this issue have been found very suitable for use as local oscillators. With an input of 4 μv at 500 Mc for instance, an output of 1 μv at 30 Mc has been obtained, using the Type 1209-A Unit Oscillator tuned to 530 Mc. — Eduard Karplus

SPECIFICATIONS

Operating Frequency: 50 to 3000 Mc.

Maximum Input from Local Oscillator: 2 volts.

Cutoff Frequency of Output Filter: 40 Mc.

Conversion Loss at 30 Mc Output Frequency: 12 db.

Type		*Code Word*	*Price*
874-MR	**Mixer Rectifier***	COAXVERTER	**$35.00**

*U. S. Patent 2,125,816. Patent Applied For.

MISCELLANY

SPEAKERS — Harold B. Richmond, Chairman of the Board, General Radio Company, delivered the principal address at the 1950 Annual Banquet of the Institute of Radio Engineers, held at the Hotel Commodore, New York, March 5. His subject: "For the Radio Engineer — Fission or Fusion."

Robert F. Field, of the General Radio Engineering Staff, delivered a paper on "Inductors, Their Calculation and Losses" at the Symposium on Basic Circuit Elements, held at the 1950 I.R.E. Convention March 8.

Kipling Adams, of General Radio's Chicago Engineering Office, spoke at the March 19th meeting of the Chicago Section, I.R.E., on "Basic Facts You Should Know about Slotted Lines."

RECENT VISITORS TO GENERAL RADIO

SWEDEN — Dr. Hans Werthen, Swedish Telephone Committee, Stockholm.

FRANCE — Mr. R. J. Audouin, Le Matériel Electrique, Lyon.

ITALY — Professor F. Vecchiacchi, School of Engineering of Milan, and Dr. E. Fagnoni, Officine Galileo, Florence.

SWITZERLAND — Dr. E. A. Keller, Werkzeugmaschinenfabrik Oerlikon, Zurich.

JAPAN — Professor Issac Koga, University of Tokyo, and Mr. Hiroshi Shinkawa, Radio Regulatory Agency, Tokyo.

At a recent visit to Cambridge, Mr. Paul Fabricant of Radiophon, Paris, our representatives in France and the French Colonies, addressed a group of foremen from the General Radio plant on the subject, "Customers Appreciate General Radio Quality."

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PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXV No. 1 JUNE, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

35 YEARS OF INSTRUMENT MANUFACTURE

Also

IN THIS ISSUE

● **JUNE, 1950,** marks a significant anniversary for the General Radio Company. Founded in June, 1915, the Company completes this month its 35th year in the manufacture of precision electronic test equipment, and also sees the retirement from Company affairs of its founder, former President and Chief Engineer, Melville Eastham. Another retirement, earlier this year, was that of Henry S. Shaw, former Treasurer and later Chairman of the Board, who became associated with the Company in 1917.

These two men are largely responsible for today's General Radio Company, for one was its founder and the other did much to assure its continued existence during its formative years.

Instrument companies were few in 1915, and it took an unusual combination of courage and vision to start one of a different kind, to serve

Melville Eastham

Henry S. Shaw

an industry still in its infancy. Proof of the soundness of Melville Eastham's judgment is found in the electronics industry of today, providing a continuing market for not only one but many test-equipment makers.

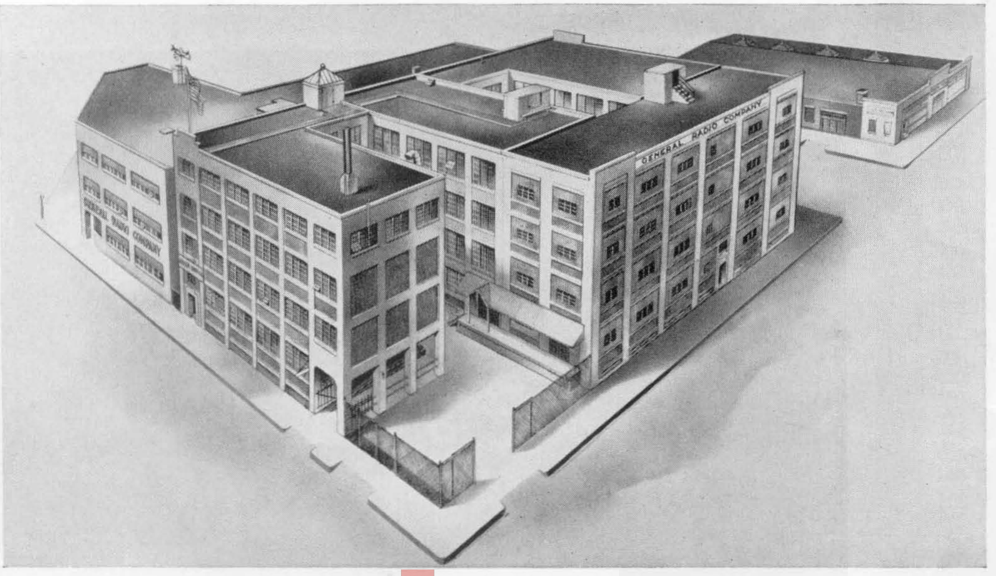
Mr. Eastham held the office of President from 1915 to 1944, and during most of this period, as well as the years from 1944 to 1950, also functioned as Chief Engineer. For these thirty-five years, his wise counsel has guided the Company's technical developments, its employee relations, and its business and management philosophy.

In 1917, Henry S. Shaw joined the Company, becoming Treasurer the following year and Chairman of the Board in 1926, holding that post until 1944. Through his help, the Company weathered both the violent expansion necessitated by World War I and the equally serious deflation that followed. His keen interest in employee welfare and business management have contributed immeasurably to the Company's success.

Retirement is mandatory at sixty-five in the General Radio Company. Messrs. Eastham and Shaw have chosen also to retire as directors, thus severing all active connection with Company affairs. "Retirement," however, is hardly a valid description of the future activities of these men, for the freedom from routine duties will give even greater scope to their wide-ranging scientific and business interests.

At the annual meeting of the General Radio Company, held on February 15, 1950, Charles C. Carey, Vice-President for Production, and Arthur E. Thiessen, Vice-President for Sales, were elected directors to replace Mr. Eastham and Mr. Shaw. Subsequently, at their meeting on the same date, action was taken by the Board of Directors, as indicated by the following extract from the minutes of the meeting:

". . . The signal service rendered this Company by Messrs. Eastham and Shaw can never be duplicated by any other officer. . . . It was felt that appropriate recognition should be given to the services of these two gentlemen. It was, therefore, on motion duly made and seconded, VOTED: That Melville Eastham be designated Honorary President of the Company and that Henry S. Shaw be designated Honorary Chairman of the Board of Directors."



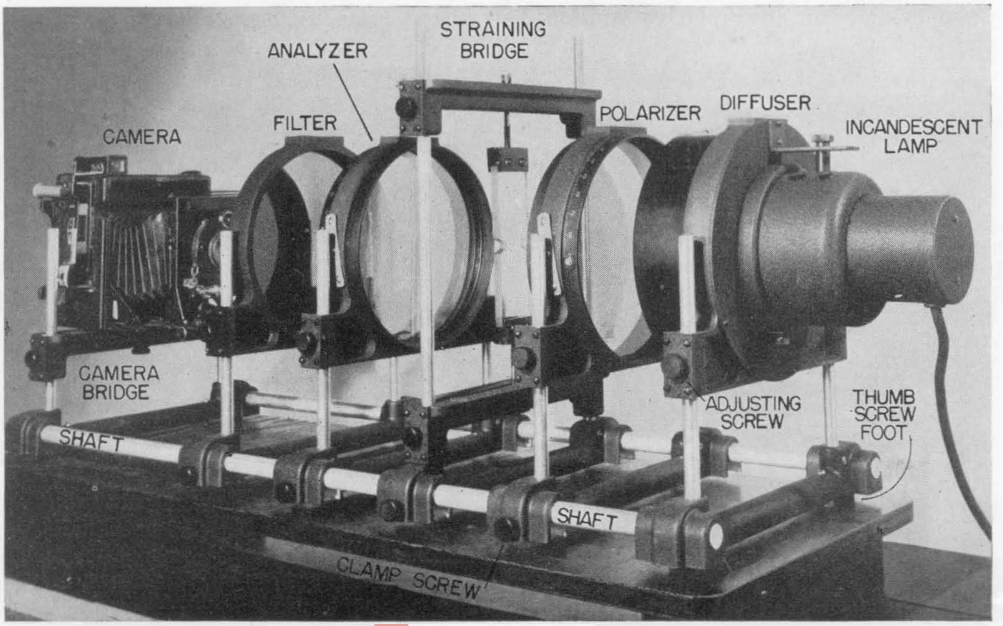
A POLARISCOPE FOR DYNAMIC STRESS ANALYSIS

One of the more useful tools in mechanical research is the photoelastic polariscope for stress analysis. The science of photoelastic stress analysis is based on the property of certain transparent materials which causes them to exhibit, when strained, a degree of optical double-refraction exactly proportional to the net stress. Such materials, under stress, are no longer isotropic to light, a ray of which, entering such a stressed material, will travel faster in one plane than in the plane at right angles to it. Further, the retardation in the "slow" plane is a direct function of the causative stress.

Monochromatic polarized light traversing such a stressed material is resolved into two vector components, fast and slow respectively, the effect of which, through cancellation and reinforcement depending upon the relative delay, is visible as a pattern of light and dark bands when the model under stress is viewed through a polarizing analyzer. Since the relative delay is a function of the net stress, the number of bands or "fringes" at a given point indicates net stress at that point. Furthermore, stresses parallel to the direction of plane polarization produce no effect under plane polarized light, so that unaffected areas represent the locus of all stresses parallel to the plane of polarization. Such clear areas are called isoclynics and may be used to determine the direction of the principal stresses. Under circularly polarized light the isoclynics disappear, since circularly polarized light represents a plane polarized light, whose plane of polarization is rotating at the frequency of the monochromatic light employed, thus blurring out the isoclynics. Thus both the magnitude (under circular polarization) and direction (under plane polarization) of the net stresses can be derived from observation of a photoelastic model in the polariscope.*

*M. M. Frocht, "Photo-Elasticity," John Wiley and Sons, N. Y.

Figure 1. View of complete polariscope with incandescent light source and camera.



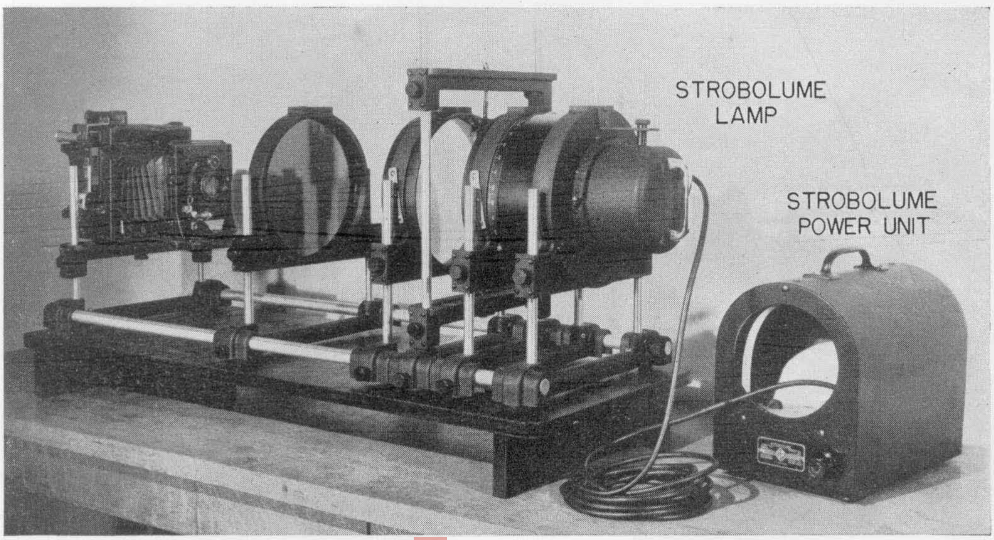
A polariscope, basically, requires a source of monochromatic light, or a light source and means for effectively securing monochromatism; a polarizer and analyzer, both capable of plane and circular polarization with means for determining the inclination of the axis of plane polarization; and a means of visual or photographic observation of the stress patterns exhibited by a strained photoelastic model interposed in the light beam between polarizer and analyzer.

The fullest employment of photoelastic methods of stress analysis has, in the past, been hampered by the cumbersome and costly nature of the equipment required for visual or photographic observation. If a sizable field for easily manipulated models was required, the optical requirements imposed by the use of available monochromatic light sources, natural polarizing media, and model substances of relatively low photoelastic sensitivity could only be met by expensive, bulky apparatus with relatively weak illumination. Photographic exposures ran into minutes, so that the "bench," as such a setup is termed, had to be carefully designed to minimize vibration or any relative motion between its multiple parts. Bench assemblies weighing many tons are commonplace in photoelastic laboratories. Sensitivity of model materials was still further reduced by the choice of monochromatic light of long wavelength, due to the low radiation of blue-violet by most artificial light sources adaptable to the purpose.

Many of the earlier limitations were removed by the appearance of synthetic polarizing materials in sheet form. These relatively inexpensive materials replaced costly natural media and simultaneously reduced the optical problem by removing the narrow dimensional limits imposed by natural polarizers. Nevertheless, photographic exposure times were still sufficiently long to require stability, attained through bulk; and the cost reduction, while appreciable, was not great enough to bring equipment into more general use.

The General Radio Type 1534-A Polariscope removes most of the remaining obstacles to wider use of photoelastic techniques, through the use of the Type 1532-A Strobolume as a light source. The intense, short flash of the Strobolume reduces the exposure time

Figure 2. View of polariscope with Strobolume flash source.



to 40 microseconds, which effectively "stops" motion in a dynamic stress pattern as well as pattern motion originating in vibration. As a result, the TYPE 1534-A Polariscope is much lighter in weight and lower in cost than polariscopes designed for longer exposures, where vibration effects must be minimized.

The blue-green monochromatic light band used in the TYPE 1534-A Polariscope is peaked at 4800 Ångstrom units. This is a much shorter wavelength than is ordinarily used in polariscopes. The blue-richness of the Strobolume spectrum is the secret. Since photoelastic sensitivity (expressed as bands or "fringes" per unit stress per unit thickness) varies inversely with the wavelength of the incident light, the 4800 Å. monochrome materially increases sensitivity as compared with conventional practice.

The TYPE 1534-A Polariscope is made up of several subassemblies all tied together horizontally by two TYPE 1534-P7 Shafts to form an optical "bench." The light beam traverses, in order, a TYPE 1534-P2 Diffuser, a TYPE 1534-P1 Polarizer, the model mounted in a TYPE 1534-P3 Straining Bridge, a TYPE 1534-P1 Analyzer, a TYPE 1534-P5 Filter, and terminates in the camera, mounted on a TYPE 1534-P4 Camera Bridge. The TYPE 1534-P2 Diffuser accepts either the TYPE 1532-A Strobolume lamp housing (Figure 2) or the TYPE 1534-P6 Incandescent Light Source (Figure 3) for steady visual observation. The TYPE 1534-P1 Polarizer-Analyzer assemblies are identical. Both mount a plane polarizer and quarter-wave retardation plate, removable without tools, mutually rotat-

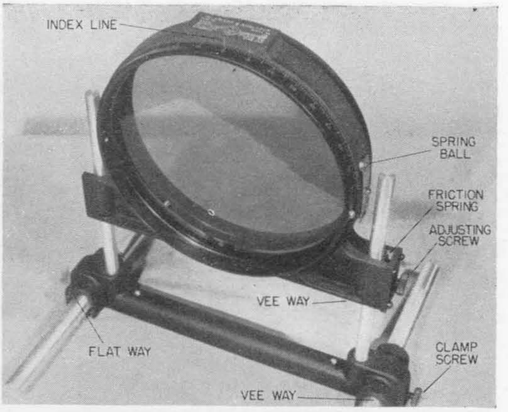


Figure 3. View of Type 1534-P1 Polarizer-Analyzer Assembly.

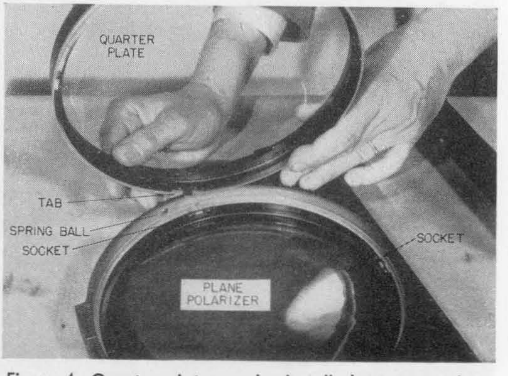


Figure 4. Quarter plate can be installed or removed without tools as shown here.

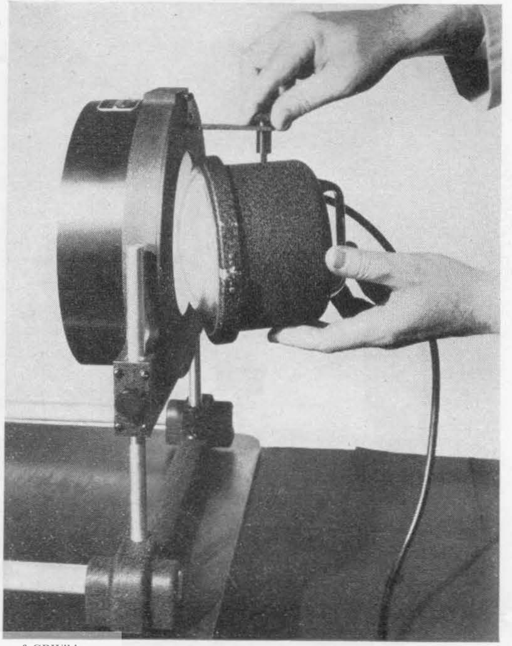


Figure 5. Either Strobolume or incandescent light source can readily be mounted on the diffuser.

able, and registering for right- or left-hand circular polarization. Plane polarizers carry a degree scale calibrated from zero to both plus and minus ninety degrees for isoclinic (loci of equi-directional stresses) determination. The TYPE 1534-P4 Camera Bridge has a captive ¼″ x 20 thumbscrew for mounting the user's camera by means of its tripod socket.

All elements are horizontally adjustable along the TYPE 1534-P7 Shafts and vertically adjustable over some nine

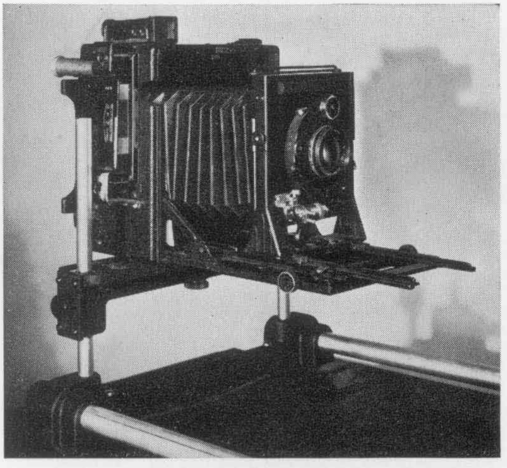
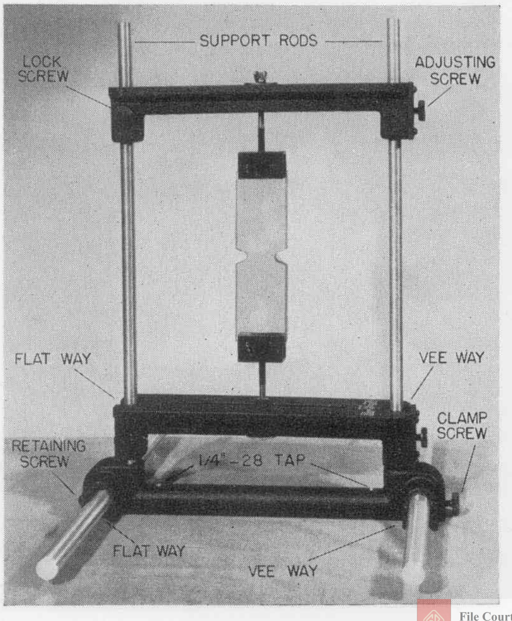


Figure 6. View of camera mounted on camera bridge.



inches. Vee and flat ways insure optical alignment. Thumbscrews hold desired settings.

The bases of all components are provided with mounting holes for use when the TYPE 1534-P7 Shafts are not required. Note, please, that TYPE 1534-P7 Shafts are supplied 36″ long unless specifically ordered in other lengths.

Necessary accessories not furnished as a part of the polariscope include the TYPE 1532-A Strobolume and a camera, the choice of which latter is left to the user. A ground glass focusing system and a lens speed of not less than f/4.5 are essential requirements. Flash synchronizing contacts are a convenience, though a simple bulb or time shutter will be perfectly satisfactory.

Dynamic stress analysis problems call for a certain amount of ingenuity. We can but suggest the use of contacts that close, or circuits that break at some predetermined deflection of the model. Our TYPE 1535-A Contactor is available for synchronizing the TYPE 1532-A Flash with rotary devices such as might be used in cyclical straining, and is continuously adjustable for proper phasing.

The TYPE 1534-P3 Straining Bridge will serve for certain simple setups, but is in no way intended as an accurately calibrated straining frame. Such latter equipment may be obtained from a number of reliable suppliers or may be devised by the user to fit his particular problem.

Models of water-white Catalin are most satisfactory. High sensitivity and transparency to the 4800 Å. monochrome are definitely in its favor. It is strong and relatively inexpensive. Models contour-cut from sheets cast between

Figure 7. View of notched specimen mounted in straining frame.

plate glass surfaces require no further finishing for proper optical properties.

For photographic use, a Wratten No. 75 front-of-lens filter may be substituted for the TYPE 1534-P5 Filter, though the latter is preferable for visual observation. The Wratten 75 filter prevents most of the normal room illumination from reaching the film, so that the camera shutter can be opened for some time without danger of fogging.

Process film is recommended for optimum results, although other film may be used. The process film spectral response yields the narrowest monochromatic band for sharp resolution in regions of steep stress gradient. Process film is easily handled, being relatively fog-free to incandescent light. It has a fine grain and a bright contrast for clear enlargement and projection.

Despite the severe requirements imposed by the large, eight-inch diameter field and diffuse illuminating system of the TYPE 1534-A Polariscope, a single Strobolume flash is adequate for full exposure at a relative aperture of f/4.5. While diffuse illumination is theoretically inferior to a collimated beam, its

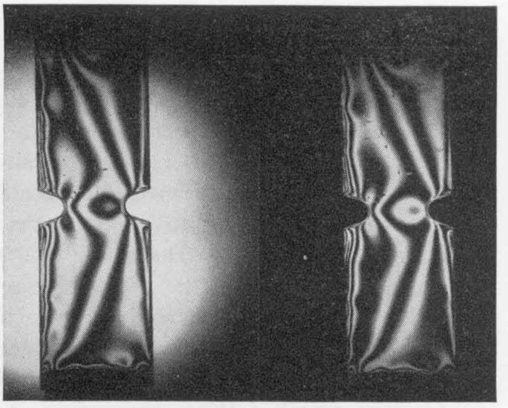


Figure 8. Light- and dark-field photographs of specimen shown in Figure 7, illustrating fringe patterns shown under circular polarization.

use in the TYPE 1534-A is justified by its far greater simplicity and the excellent results obtained in practice.

The simplicity of operation and the low price of the TYPE 1534-A Polariscope bring photoelastic measurements within the reach of the small laboratory with a modest budget and limited space, and should greatly extend the field of application of photoelasticity in mechanical research and design.

— GILBERT SMILEY

SPECIFICATIONS

Components Supplied:
1 TYPE 1534-P1 Polarizer
1 TYPE 1534-P1 Analyzer
1 TYPE 1534-P2 Diffuser
1 TYPE 1534-P3 Strain Bridge
1 TYPE 1534-P4 Camera Bridge
1 TYPE 1534-P5 Filter
1 TYPE 1534-P6 Incandescent Light Source
2 TYPE 1534-P7 Shafts (furnished 36 inches unless otherwise specified)

Optical Field: 8-inch diameter.

Vertical Adjustment: 12 inches.

Accessories Required: TYPE 1532-A Strobolume, camera with ground glass and lens of f/4.5 or faster.

Other Accessories Recommended: Wratten No. 75 front-of-lens filter.

Dimensions: 36 x 14¼ x 16½ inches, overall.

Net Weight: 32 pounds.

Type		*Code Word*	*Price*
1534-A	**Polariscope**	FOCUS	**$490.00**

Strobolume

The TYPE 1532-A Strobolume was described in the May, 1949, issue of the *Experimenter*. Complete description will be supplied on request.

Type		*Code Word*	*Price*
1532-A	**Strobolume**	TITLE	**$225.00**

MISCELLANY

DECADE ATTENUATORS

ERRATA: It has been called to our attention that the low frequency (d-c) errors of the TYPE 829 Decade Attenuator Units and the TYPE 1450 Decade Attenuators are substantially less than were quoted in the December, 1949, *Experimenter*. Since the individual resistor elements are all calibrated within ±¼% of their theoretical values, Mr. Lamson's analysis shows that, for any switch setting, the actual d-c attenuation will be correct within 0.001 db ±¼% (indicated db value). The 0.001 db term is due to switch resistance.

Mr. P. K. McElroy was responsible for the excellent mechanical design of these units.

SUMMER CLOSING

VACATION — During the weeks of July 24 and July 31 most of our employees will be vacationing. Manufacturing departments will be closed and other departments will be manned by a skeleton staff. Every effort will be made to take care of urgent business, but repairs cannot be made, except in hardship cases. Our Service Department requests that shipments of material to be repaired be either scheduled to reach us well before this vacation period or delayed until afterward.

INSTRUMENT EXHIBITS

At the annual meeting of the American Society for Testing Materials, to be held in Atlantic City June 26 to 30, 1950, General Radio instruments for the materials testing field will be exhibited, including the TYPE 1534-A Polariscope described in this issue of the *Experimenter*.

General Radio products will be on display at two important meetings next September, the Pacific Electronics Exhibit at Long Beach, California, and the National Electronics Conference in Chicago.

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PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXV No. 2 JULY, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A BOLOMETER BRIDGE FOR THE MEASUREMENT OF POWER AT HIGH FREQUENCIES

I. Introduction

● In the u-h-f region, power measurements are of fundamental importance. While, at lower frequencies, current or voltage is generally measured in preference to power, at ultra-high-frequencies most practical devices for the measurement of these quantities are relatively large with respect to a wavelength, and their accuracy is impaired by the effects of resonance and standing waves. Power measurements, however, can be made with good accuracy at high frequencies by dissipating the power in a bolometer, which is a resistive element with a large temperature coefficient of resistance. The magnitude of the r-f power can be determined either from the measured change in resistance or from the change in bias power required to bring the bolometer resistance back to its original value with no r-f power applied.

The two most generally used types of bolometer elements are the thermistor and the fuse or barretter. A thermistor has a large negative temperature coefficient and consists of a small bead of semi-conducting material in which are embedded two fine wires. The fuse

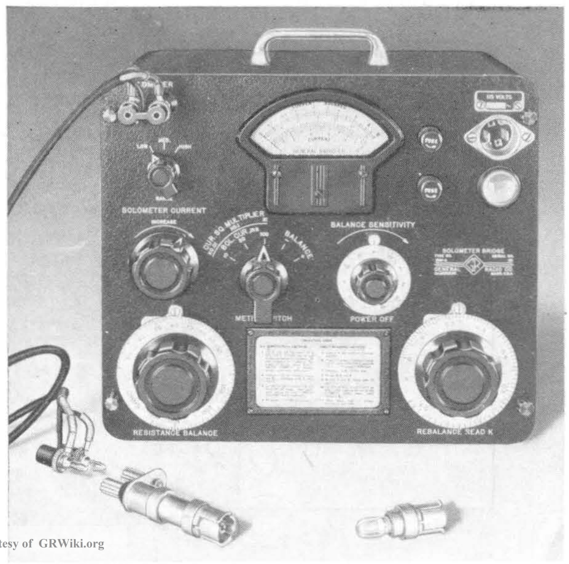


Figure 1. Panel view of the Type 1651-A Bolometer Bridge, with Type 874-H25 Thermistor Unit in left foreground.

or barretter is usually a short length of very fine platinum wire connected between two electrodes.

The change in bolometer resistance resulting from power dissipation is usually measured with a low-frequency or d-c bridge. The TYPE 1651-A Bolometer Bridge is designed for this measurement. It is a general-purpose bridge, flexible and adaptable in operation so that it can be used not only with General Radio bolometers,[1] but with those of other manufacturers as well. A wide range of bolometer resistances can be accommodated, and measurements can be made by either a substitution or a direct-reading method.

In the substitution method, d-c power is substituted directly for r-f power. All readings are made after the final balance, and the measured power is a simple product of dial and meter readings. The direct-reading method depends upon the change in bolometer resistance with power, and in this method the meter is calibrated at one point by substitution, after which other power levels can be read directly from the meter.

II. Circuit

The heart of the TYPE 1651-A Bolometer Bridge is the Wheatstone Bridge of Figure 2, in which the bolometer element forms one arm. To measure power with this circuit by the substitution method, the bridge is first balanced with the r-f power applied to the bolometer element. The balance is obtained by adjusting the applied d-c voltage until the bolometer element is heated to a temperature at which its resistance is the value required for a balance. At balance, the total power, P_1, dissipated in the bolometer element is

$$P_1 = I_1^2 R_B + P_{r\text{-}f} \tag{1}$$

where I_1 is the d-c current flowing through the bolometer element, R_B is the bolometer resistance at balance, and $P_{r\text{-}f}$ is the r-f power being dissipated in the element.

The r-f power is then removed and the bridge rebalanced by increasing the applied d-c voltage, V. The total power dissipated in the bolometer after this balance is

$$P_2 = I_2^2 R_B \tag{2}$$

Since the same bolometer resistance is required for both balances, the total power dissipated in the bolometer must be the same, therefore

$$P_1 = P_2 \tag{3}$$

Consequently the r-f power is equal to the difference in d-c power between the final and initial balances, or

$$P_{r\text{-}f} = I_2^2 R_B - I_1^2 R_B = I_2^2 R_B \left[1 - \left(\frac{I_1}{I_2}\right)^2\right] \tag{4}$$

With this basic circuit the r-f power can be determined from a knowledge of the d-c current flowing through the bolometer during the initial and final balances and the bolometer resistance at balance.

[1] TYPE 874-HF Fuse Bolometer and TYPES 874-H25 and -H100 Thermistor Units were designed for use with this bridge.

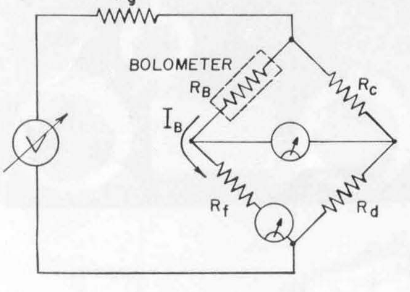


Figure 2. Basic bridge circuit for power measurement.

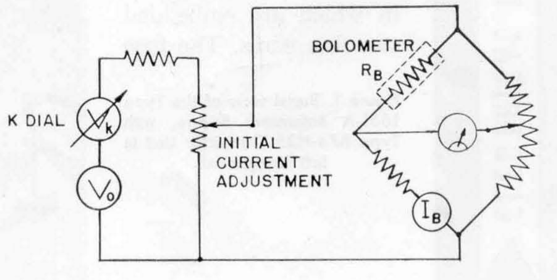


Figure 3. Modified basic circuit.

In order to simplify the measurement and make the bridge more flexible, the actual circuit used in the TYPE 1651-A Bolometer Bridge is the modified circuit shown in Figure 3. Here the bolometer resistance required for balance can be varied over an appreciable range by means of the potentiometer that replaces the fixed resistors R_c and R_d in the simple circuit. The potentiometer is calibrated in terms of the bolometer resistance required for balance, and the bridge is thus adaptable to use with bolometer elements having widely varying characteristics. The supply voltage for the initial balance is fixed at V_o, V_k being set to zero, and the initial current adjustment is made by means of the potentiometer indicated. The final balance is made by means of V_k. Since the total circuit resistance is the same for the initial and final balances, the ratio of the initial and final bolometer currents is

$$\frac{I_1}{I_2} = \frac{V_o}{V_o + V_k} \qquad (5)$$

independent of the setting of the initial current adjustment. The V_k control can therefore be calibrated in terms of $1 - \left(\frac{I_1}{I_2}\right)^2$, which is called the K factor, and, from Equation (4),

$$P_{r\text{-}f} = KI_2^{\,2}R_B \qquad (6)$$

The voltage control, V_k, is a Variac connected ahead of the rectifier that supplies the bridge with d-c, as shown in Figure 4. The Variac dial is calibrated in terms of the factor K. A voltage stabilizer is used ahead of the Variac to minimize the effects of line voltage variations.

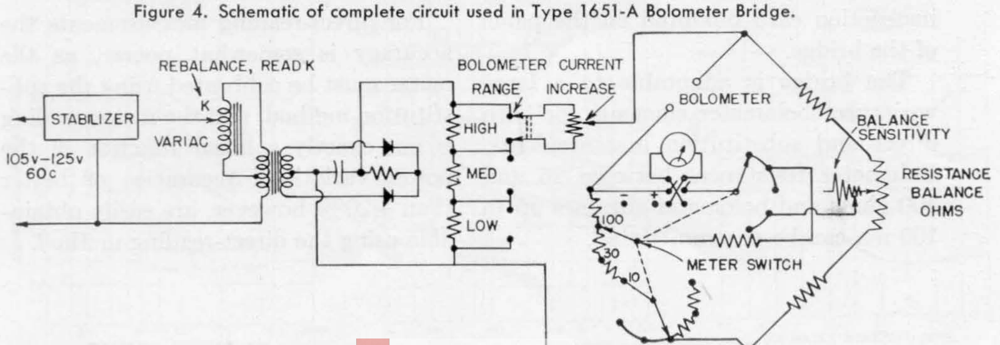
The same meter used to measure the degree of bridge unbalance is also used to measure the bolometer current. In order to minimize the effects of the temperature coefficient of the meter winding on the accuracy of the current measurement, a large resistor is connected in series with the meter, and the current is measured by measuring the voltage drop across taps on the fixed resistance arm of the bridge. The meter has a current-squared scale and a multiplier to permit direct accurate measurements of $I_2^{\,2}$ over a wide range of current. The current-squared scale is labeled A and the multiplier M; therefore, $I_2^{\,2} = MA$ and the magnitude of the r-f power is

$$P_{r\text{-}f} = MARK \text{ milliwatts} \qquad (7)$$

In this type of bridge all quantities are measured after the final balance has been made and after the r-f power has been removed, which eliminates errors due to changes in the r-f power level while readings are being taken and, by permitting the dial and meter measurements to be made slowly and carefully, tends to improve the accuracy of these readings.

The actual operating procedure is simple. The resistance dial is set to the desired bolometer resistance, the K dial

Figure 4. Schematic of complete circuit used in Type 1651-A Bolometer Bridge.



to zero, r-f power is applied to the bolometer, and the bolometer current adjusted for balance. The r-f power is then removed and the bridge rebalanced by means of the K dial. The r-f power is then the simple product $MARK$ as read from the bridge dials and meter.

The circuit is also adaptable to direct-reading measurements of r-f power, but with somewhat less accuracy than is obtainable using the substitution method. It is convenient when a large number of measurements are to be made at power levels not too greatly different from one another. The direct-reading method depends upon the variation in resistance of the bolometer element with r-f power causing an unbalance indication on the meter. The meter indication is closely proportional to the r-f power from zero up to a power level which depends on the type of bolometer element used and the initial bolometer resistance setting. In general, the linear range extends up to power levels of from 10 to 100 milliwatts with less than 10% deviation from linearity. In the direct-reading method, the meter sensitivity is adjusted to read directly in milliwatts after calibration by the substitution method. The initial calibration procedure is more complicated than a single measurement by the substitution method, and in some cases the change in bolometer resistance with r-f power level may have an appreciable effect on the impedance match. Operating procedures for both methods are summarized on an instruction card mounted on the panel of the bridge.

The bridge is adaptable to a large variety of bolometer elements for both direct and substitution measurements. Bolometer resistances between 25 and 400 ohms and bolometer currents up to 100 ma can be accommodated.

III. Accuracy

The accuracy with which the bolometer bridge can measure the change in power dissipated in a bolometer element is controlled by the accuracy of the determination of the various factors involved in the calculation of the power. The accuracy of the meter is the most important factor, because the square of the current is used in the calculations, which means the error in power determination is twice the meter error. The accuracy of the meter on the linear scales is $\pm$(1½% of the reading + ½% of full scale). At full scale this means the meter may contribute as much as $\pm$4% error in the power measured. At one-third of full scale the maximum possible error due to the meter may be as great as $\pm$6%. A range switch is provided to keep the meter readings above ⅓ of full scale for currents above 3 milliamperes. The K dial calibration is accurate to $\pm$(1% of the reading + .005) and the bolometer resistance can be determined with an accuracy of better than $\pm$1%. The over-all accuracy obtainable in a particular measurement depends on the magnitude of the bolometer current and the magnitude of the K dial reading. However, accuracies of better than $\pm$10% can easily be obtained using the substitution method if the measured power is not too small. This compares favorably with the over-all accuracy obtainable with a self-balancing bridge, whose accuracy is usually expressed as a percentage of full-scale reading.

For direct-reading measurements the accuracy is somewhat poorer, as the meter must be calibrated using the substitution method, and the meter reading is not exactly a linear function of the power variation. Accuracies of better than $\pm$20%, however, are easily obtainable using the direct-reading method.

IV. Bolometer Elements

In addition to the TYPE 874-HF Fuse Bolometer Holder and the TYPE 874-H25 and H100 Thermistor Units, which were designed for use with the bolometer bridge, any other unit which is capable of operating within the resistance and current ranges of the bolometer bridge can be used. The power measurement ranges of the fuse bolometer and thermistor overlap one another. The thermistor units have a lower standing-wave ratio, are more rugged, and will measure somewhat lower powers than will the fuse elements, while the fuse elements are cheap and will measure higher powers than will the thermistor units. The fuse elements are limited in their frequency range by errors caused by standing waves on the fuse wire. Above about 1000 Mc these errors become significant. Thermistors can be used up to frequencies beyond the usable range of the coaxial connectors and components as they are physically very small. Both the fuse elements and the thermistor units can be used at frequencies as low as 5 Mc.

The TYPE 874-HF Fuse Bolometer Holder is designed to mount ¼ x 1-inch instrument fuses. Two types of fuses, the type MJR 1/32-ampere and type MJR 1/12-ampere, are supplied which are capable of measuring a wide range of power at the 50-ohm level; however, practically any fuse of the AGX type can be used if desired, although with some sizes it is not possible to obtain a balance at the 50-ohm level.

The TYPE 874-H25 and H100 Thermistor Units are similar to one another except for a difference in the power handling capacity of the thermistor. The maximum ratings of the TYPE 874-H25 and TYPE 874-H100 are 25 and 100 milliwatts, respectively.

The actual power measurement ranges of the fuse and thermistor elements as a function of their initial resistance for measurements by the substitution method are shown in Figure 5. Figures 6 and 7 show the power required for full-scale meter deflection with maximum meter sensitivity and the maximum measurable power for less than 10% deviation from linearity as a function of bolometer resistance, for measurements by the direct-reading method.

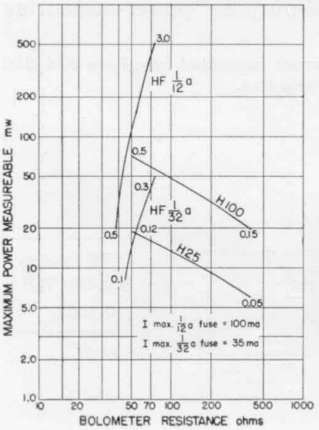


Figure 5. Power-measurement ranges of Fuse and Thermistor Bolometers and the Bolometer Bridge, by substitution method, as a function of bolometer resistance. Minimum detectable power in milliwatts is indicated by the numbers at the ends of each curve.

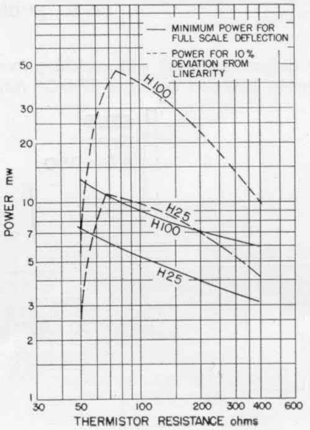


Figure 6. Sensitivity and power-measurement ranges of the Thermistor Units and Bolometer Bridge, for the direct-reading method.

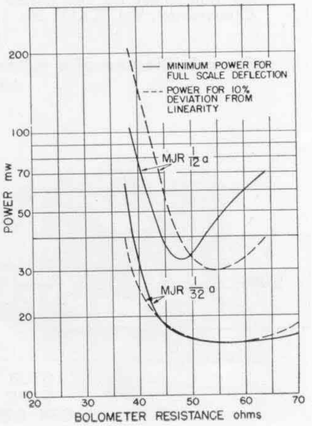


Figure 7. Sensitivity and power-measurement ranges of the Fuse Bolometer and fuses as indicated, for the direct-reading method.

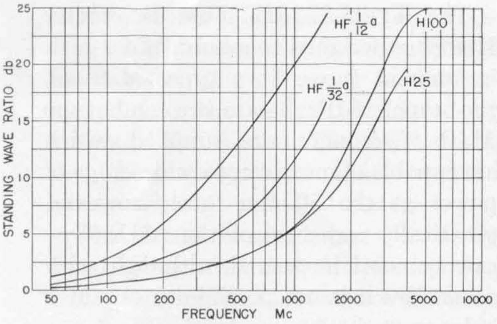


Figure 8. Standing-wave ratio as a function of frequency of the Fuse Bolometer and Thermistor Units.

Figure 8 shows the standing-wave ratio as a function of frequency for the various elements. At the higher frequencies it is necessary to use a matching transformer between the source and the bolometer when the power into a line terminated in its characteristic impedance is desired. A matching transformer can be easily assembled using Type 874 Coaxial Elements[2] as indicated in the block diagram of Figure 9. To match the bolometer to the line, the matching transformer is adjusted until the slotted line indicates the absence of any reflected energy. When the power output of an oscillator into a matched load is to be measured, a transformer made up to Type 874 components can be used to transform the bolometer impedance into the conjugate of the oscillator output impedance. In this application a slotted line is not required, as the transformer is adjusted for the maximum indication on the bolometer bridge.

[2] W. R. Thurston, "Simple, Complete Coaxial Measuring Equipment for the U-H-F Range," *General Radio Experimenter*, Vol. XXIV, No. 8, January, 1950.

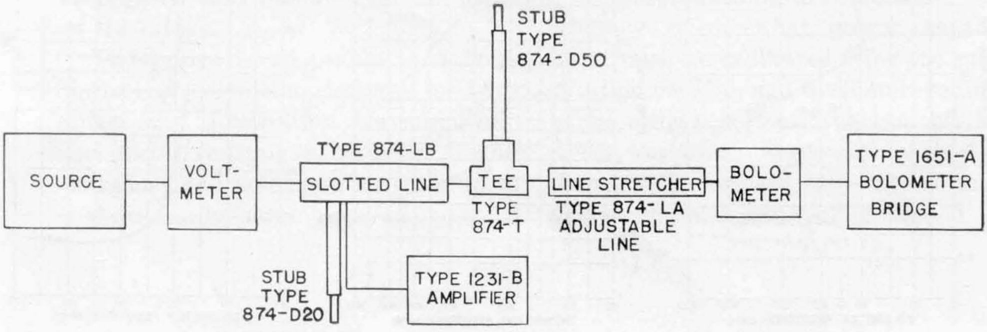
V. Applications

The Type 1651-A Bolometer Bridge can be used for all measurements of power in the medium power range over a frequency range dependent on the characteristics of the bolometer element used. High power measurement can be made by using dissipative attenuators or directional couplers to transmit only a known fraction of the r-f power to the bolometer element.

Typical measurements are the power output of oscillators, loss measurements, the static characteristic of bolometers, and the calibration of voltmeters. Voltmeters can be calibrated using the circuit of Figure 9 with the voltmeter connected between the slotted line and the source. When no standing waves are present, the voltage is constant all along the line and its magnitude can be calculated from the measured power and the characteristic impedance of the line. Figure 10 shows the results of a calibration made of the Type 874-VR Voltmeter Rectifier over a wide frequency range. The rise in indicated voltage is a result of resonance in the crystal and the theoretical slope is indicated by the solid line.

The Type 1651-A Bolometer Bridge is a general-purpose power-measuring

Figure 9. Diagram of a voltmeter calibration circuit with matching transformer assembled from Type 874-D50 Adjustable Stub and the Type 874-CA Adjustable Line.



instrument designed for maximum utility and adaptability in the u-h-f laboratory. Since tuning systems and transformers are easily assembled from the extensive line of TYPE 874 Coaxial Elements already available in many laboratories, expensive specialized accessories are not necessary. In the educational laboratory, in addition to demonstrating a variety of power measurement problems, the bridge can be used for calibrating bolometers and demonstrating their change in resistance with current. In commercial and industrial laboratories, its flexibility permits operation with many different types and makes of bolometers, and it can be adapted for use with existing equipment of different manufacturers.

— R. A. SODERMAN

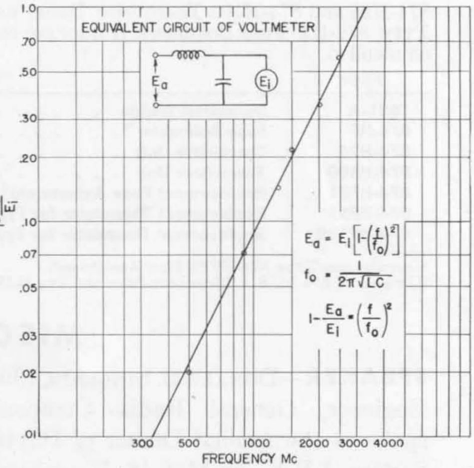


Figure 10. Departure from unity of the ratio of actual to indicated voltage as a function of frequency for Type 874-VR Voltmeter Rectifier, measured with the circuit of Figure 9. The solid line indicates the theoretical slope as determined by the equation.

SPECIFICATIONS

Range and Accuracy — Substitution Method

With TYPE 874-H25 Thermistor Unit		
Thermistor resistance set for max. sensitivity	0 to 6 mw	±(10% + 0.05 mw)
Thermistor resistance set at 50 ohms	0 to 18 mw	±(10% + 0.12 mw)
With TYPE 874-H100 Thermistor Unit		
Thermistor resistance set for max. sensitivity	0 to 20 mw	±(10% + 0.15 mw)
Thermistor resistance set at 50 ohms	0 to 70 mw	±(10% + 0.5 mw)
With TYPE 874-HF Fuse Bolometer Holder, MJR 1/32-ampere fuse		
Fuse resistance set for max. sensitivity	0 to 8 mw	±(10% + 0.1 mw)
Fuse resistance set at 50 ohms	0 to 14 mw	±(10% + 0.15 mw)
Fuse resistance set for max. power range	0 to 50 mw	±(10% + 0.3 mw)
With TYPE 874-HF Fuse Bolometer Holder, MJR 1/12-ampere fuse		
Fuse resistance set for max. sensitivity	0 to 20 mw	±(10% + 0.5 mw)
Fuse resistance set at 50 ohms	0 to 100 mw	±(10% + 0.75 mw)
Fuse resistance set for max. power range	0 to 500 mw	±(10% + 3 mw)

Bolometer Resistance Range: 25 to 400 ohms.

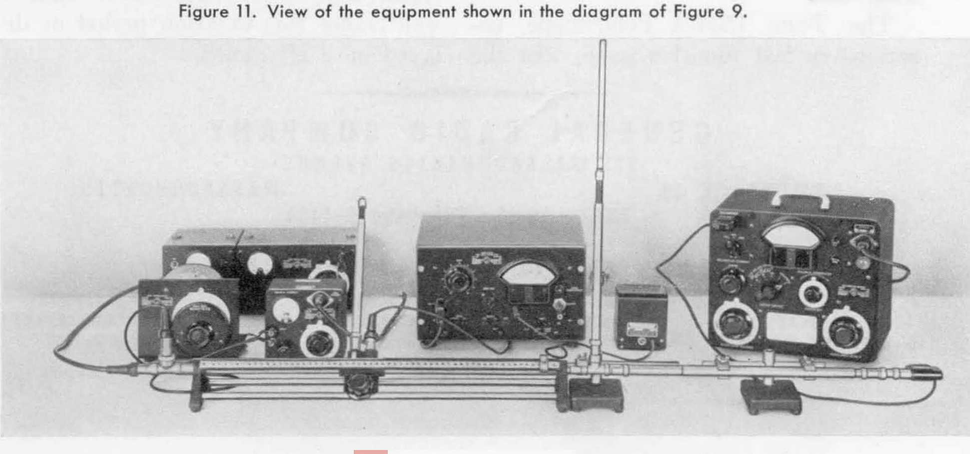
Current Range: 0 to 100 milliamperes.

Power Supply: 105 – 125 volts, 60 cycles.

Accessories Supplied: One CAP-35 Power Cord, one TYPE 274-NE Shielded Connector.

Accessories Required: Bolometer element. TYPES

Figure 11. View of the equipment shown in the diagram of Figure 9.



874-H25 and 874-H100 Thermistor Units, and Type 874-HF Fuse Bolometer Holder are recommended.

Dimensions: (Height) 12 x (width) 12 x (depth) 8¾ inches overall.
Net Weight: 21 pounds.

Type		*Code Word*	*Price*
1651-A	**Bolometer Bridge**	BEGIN	**$325.00**
874-HF	**Fuse Bolometer***	COAXHOLDER	**34.00**
874-H25	**Thermistor Unit**	COAXWARMER	**40.00**
874-H100	**Thermistor Unit**	COAXHEATER	**40.00**
874-HFP1	**Replacement Fuse Assortment†**	FUSOR	**2.50**
874-HP25	**Replacement Thermistor for Type 874-H25**	THERM	**9.00**
874-HP100	**Replacement Thermistor for Type 874-H100**	CALDO	**9.00**

*Includes one Type 874-HFP1 Fuse Assortment.
†Consists of five MJR 1/12-ampere fuses and five MJR 1/32-ampere fuses.

MISCELLANY

SPEAKER—Donald B. Sinclair, Chief Engineer, General Radio Company, spoke at the Annual Dinner of Dayton Section, I.R.E., on May 18. His subject: "The Engineer and His Professional Society."

ELECTED — Kipling Adams, Manager of the General Radio Chicago Office, as Chairman of the Chicago Section, I.R.E., for 1950-51.

RECENT VISITORS to General Radio — J. M. Van Steeden, Hulsewe Ingenieursbureau, Amsterdam, Netherlands; Roger Goublin, Compagnie Française Thomson-Houston, Gennevilliers, France; and Björn Lundvall, Telefonaktiebolaget L. M. Ericsson, Stockholm, Sweden.

CREDITS—The Type 1651-A Bolometer Bridge, described in the article by R. A. Soderman, was developed by W. R. Thurston.

The Type 1534-A Polariscope, described in last month's issue, was the outgrowth of a Master's thesis by Jordan Baruch of M. I. T., at that time a cooperative student at our plant. Baruch's investigation and experimental model provided the basis for the final design, which was executed by Gilbert Smiley. Baruch's advisors in his thesis work were Professor H. E. Edgerton of the Electrical Engineering Department and Professor W. M. Murray of the Mechanical Engineering Department, M. I. T.

VACATION — During the weeks of July 24 and July 31 most of our employees will be vacationing. Manufacturing departments will be closed and other departments will be manned by a skeleton staff. Every effort will be made to take care of urgent business, but repairs cannot be made, except in hardship cases. Our Service Department requests that shipments of material to be repaired be either scheduled to reach us well before this vacation period or delayed until afterward.

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PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXV No. 3 AUGUST, 1950

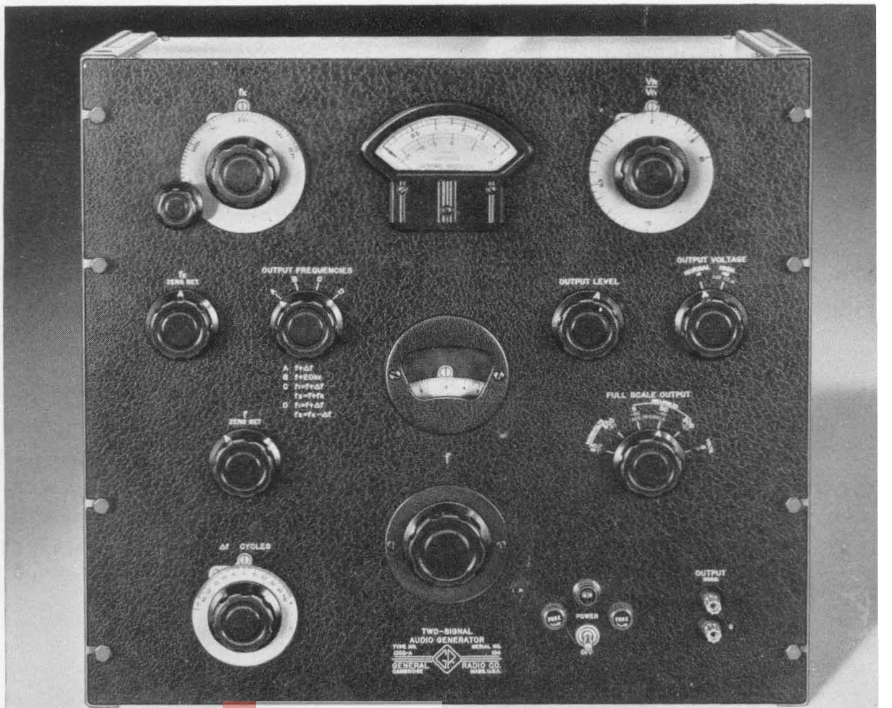
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

AN AUDIO-FREQUENCY SIGNAL GENERATOR FOR NON-LINEAR DISTORTION TESTS

● **MODERN METHODS** of testing audio-frequency devices require a test-signal generator of considerable versatility. In addition to a single, low-distortion, sinusoidal signal for the relatively simple harmonic-distortion and amplitude-frequency response tests, it must also be capable of supplying simultaneously two signals of differing frequencies for the intermodulation measurements that yield important information about the production of unwanted inharmonic difference tones, to which the ear is very sensitive.

These requirements are met by the TYPE 1303-A Two-Signal Audio Generator, which is particularly designed for intermodulation measure-

Figure 1. Panel View of the Type 1303-A Two-Signal Audio Generator.



ments but is also an extremely useful and adaptable instrument for any laboratory where audio-frequency measurements are made. It will supply any of the following signals:

1. A single low-distortion sinusoidal voltage adjustable in frequency from 20 c to 40 kc in two ranges, 20 c to 20 kc and 20 kc to 40 kc.

2. Two low-distortion sinusoidal voltages, each separately adjustable, one to 20 kc and the other to 10 kc.

3. Two low-distortion sinusoidal voltages, with a fixed difference in frequency maintained between the two as the frequency of the one voltage is varied. The fixed difference frequency is adjustable up to 10 kc, and the lower of the two frequencies is adjustable up to 20 kc.

The output is continuously adjustable and is calibrated both in volts and in db with respect to 1 milliwatt into 600 ohms.

These different output combinations make the Type 1303-A Audio Signal Generator an excellent signal source for the three standard non-linear distortion tests. These tests are: (1) The widely used harmonic distortion test.[1] (2) The intermodulation method that evaluates distortion in terms of the resultant modulation of a high-frequency tone by a low-frequency tone[2,3,4] (standardized by the SMPE).[5] (3) The difference-frequency intermodulation method, which evaluates distortion in terms of the amplitude of the difference-frequency components produced by intermodulation of two sinusoidal test signals of equal amplitude (recommended by the CCIF).[6,7,8] The Type 736-A Wave Analyzer is a convenient detector for any of these tests.

This versatile source is necessary for distortion testing because frequently tests by a single method do not show up all the non-linear distortion that can occur in a system.[8] Tests by different methods are particularly necessary in development work, where performance data must be obtained over a wide range of operating levels and frequencies. Later, in production testing, one system can usually be selected as the most satisfactory for checking faults.

Several methods are needed, even in testing audio amplifiers, particularly when large amounts of feedback are used. Some other devices that require tests by a method other than the standard harmonic method are hearing aids, high-efficiency speech-reproducing systems, magnetic and other recording systems,[9,10] f-m systems with pre-emphasis, noise suppressors, filter networks (particularly of the feedback type), loudspeakers, and, in general, any system of restricted frequency range.

The two-frequency signals supplied by this oscillator are also useful in cross-modulation studies on carrier and telemetering systems, meter testing,[11,12] differential phase measurements and psychoacoustic tests. The single-frequency signal can be used for any of the usual tests that require a signal in the frequency range from 20 c to 40 kc. Representative uses are for tests on audio-frequency lines, networks, and amplifiers; for modulating signal generators and test oscillators; and as a voltage source for acoustic tests, recording tests, and bridge measurements. It can also be used for measuring other small audio voltages by substitution methods; for the measurement of generated voltage of microphones, vibration and phonograph pickups, and other transducers by the insert voltage method;[13] and for the measurements of gain or loss, amplitude response, and harmonic distortion, as a function of frequency.

DESCRIPTION

The TYPE 1303-A Two-Signal Audio Generator generates the signals delivered at the output by a beat-frequency method, using the same type of oscillators and mixers that were developed for the TYPE 1304-A Beat-Frequency Oscillator.[14] Three oscillators and three mixers are used to provide the various signals listed above, and the outputs of the mixers are combined in a linear adding network. This combined signal is applied to a low-distortion power amplifier. The output voltage is obtained from the power amplifier through a 600-ohm attenuator system with a voltmeter to monitor the voltage level at the input of the attenuator.

Particular care has been taken to keep the harmonic content and the intermodulation products in the output of the signal generator at a very low level. This feature is, of course, necessary when the generator is used in non-linear distortion measurements. The low level of distortion has been achieved by careful design of the oscillator and mixer system and by using a degenerative, low-distortion, power amplifier.

The high stability characteristics of the TYPE 1304-A Beat-Frequency Oscillator have been duplicated here, so that the generator is well suited for applications that demand a signal source having high stability of voltage and frequency. The frequency drift from a cold start is only a few cycles.

Output System

The output level is adjustable by an *L*-pad output-level control. This level is indicated by a voltmeter calibrated in voltage and in decibels with respect to an output of one milliwatt into a 600-ohm line (dbm). Following the voltmeter is a six-position 600-ohm attenuator also calibrated in decibels. The open-circuit output voltage is adjustable from 5 microvolts to 5 volts on the low-distortion output and up to 50 volts on the high-level output.

The combination of oscillator, voltmeter, and attenuator makes the instrument a standard-signal generator that can be used to measure other small audio voltages by substitution methods and to determine gain and attenuation. In addition, the output voltage of the oscillator is practically constant over the entire frequency range, a feature which greatly facilitates tests of amplitude response and distortion as a function of frequency.

Frequency Controls

The scale of the main frequency-control dial is logarithmically divided over the range from 20 c to 20 kc. It is a duplicate of the scale used on the TYPE 1304-A Beat-Frequency Oscillator, so that the recording systems and recording paper used with that oscillator can also be used with this new generator.

This standard audio-frequency band of the instrument has been extended by a second range, 20 kc to 40 kc, which is selected by a panel switch. This frequency range is an important one for ultrasonic work.

The cycles-increment control permits small variations in frequency to be obtained above and below the setting of the main dial for frequencies up to 20 kc. The span of the cycles-increment dial is −50 to +50 cycles. This control is useful for checking small changes in frequency, for some psychoacoustic tests, and for manually producing a small warble in output frequency.

THE TWO-SIGNAL OSCILLATOR SYSTEM

The method used for generating the two-frequency signals[15] can be understood by reference to the block diagram of Figure 2. When the switches are in the positions *C* and *D*, the two signals are available at the output. In position *C*, oscillator No. 1 and oscillator No. 2 are applied to mixer No. 1 to produce a signal (indicated on the diagram as $f+f_k$) which is filtered and applied to the fader control, labeled $\frac{Vf_2}{Vf_1}$. At the same time oscillator No. 2 and oscillator No. 3 are applied to mixer No. 3 to produce a filtered signal, labeled $f+\Delta f$. This signal is applied to the other half of the fader system, and the generator output is obtained from this fader after being amplified in the low-distortion amplifier and attenuated in the attenuator.

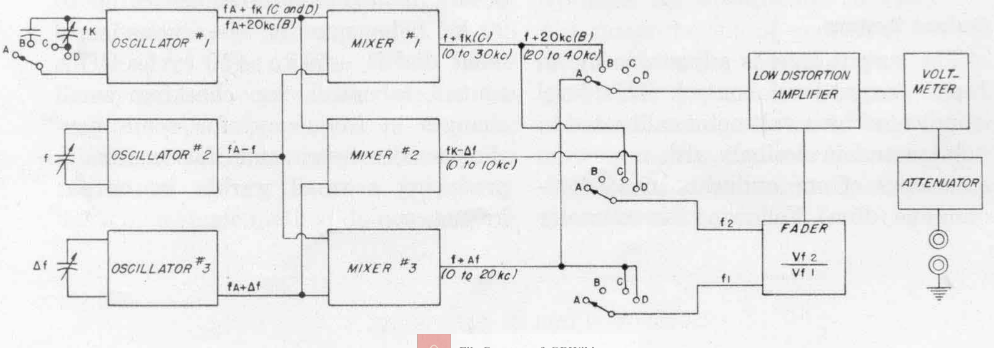
The controls labeled f_k, f, and Δf are initially set to zero, and adjustments are then made so that all three oscillators are operating at the same frequency, labeled f_A. Then the control, f_k, can be set to a desired difference frequency, say 400 cycles, which means that oscillator No. 1 is operating at a frequency of f_A+400. As oscillator No. 2 is adjusted by the control, f, its frequency becomes f_A-f, where f is the reading of the main frequency-control dial. The frequency of the signal from mixer No. 1 is the difference between the two applied frequencies, f_A+400 and f_A-f. This difference is $f+400$. At the same time the frequency of the signal from mixer No. 3 is the difference between the two applied frequencies, f_A and f_A-f. This difference is f. The frequencies of the two signals that make up the output are then $f+400$ and f. As the control, f, is varied, these two signals vary in frequency but the difference in frequency is maintained constant at the value set by the control, f_k, in this case, 400 cycles.

In position *D*, oscillator No. 1 and oscillator No. 3 are applied to mixer No. 2, and oscillator No. 2 and oscillator No. 3 are applied to mixer No. 3. In this case, two beat-frequency generators result with oscillators No. 1 and No. 2 beating with the common fixed oscillator No. 3. The two signals are then separately adjustable in frequency by the controls, f_k and f.

OPERATION — CCIF METHOD

The constant-difference-frequency feature of the two-signal output is particularly convenient for the CCIF type of distortion test. This feature simplifies checking the even-order distortion that produces a distortion component equal in frequency to the difference in frequency between the two applied frequencies. The Type 736-A Wave Analyzer connected at the output of the device under test can be tuned to this constant difference-frequency. Then,

Figure 2. Functional block diagram illustrating the method of generating two-frequency signals.



with the Type 1303-A Two-Signal Audio Generator as a source, this component of distortion can be determined as a function of frequency by turning the main frequency control over the required range. No retuning of the wave analyzer is necessary, and the measurement of this component of distortion is simpler than any other test of distortion over a wide frequency range. The other components of distortion are determined by retuning the wave analyzer as the frequency of the source is changed. However, by using a special analyzer system with a carefully designed square-law rectifier, Thilo and Koschel[7] have reported it possible to extend the above simplicity of observation to determine approximately the other important difference-frequency components.

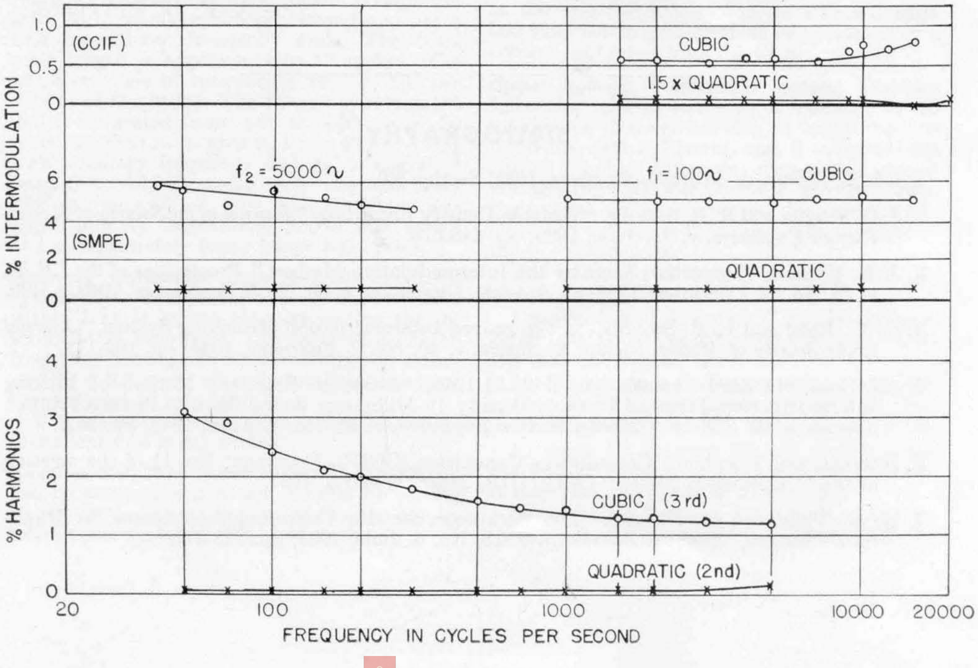
The individual components of the two-signal output are set equal in amplitude for the CCIF test. However, the amplitudes can be set by means of a calibrated control to have any ratio over the range from 0.1 to 10.

OPERATION — SMPE METHOD

The provision of a two-signal output with the frequencies of the two signals separately adjustable makes this generator very convenient for the SMPE type of intermodulation test. With this method, a low-frequency signal, usually about 100 cycles, and a high-frequency signal, often about 5 kc, are used. The low-frequency signal is set by the calibrated control to have an amplitude of four times that of the high-frequency one. Here one uses a wave analyzer to measure the amplitudes of the side-band components spaced about the high-frequency signal at frequency intervals equal to the low-frequency signal frequency. These side-band components are produced by non-linear distortion that causes modulation of the high-frequency signal by the low-frequency signal.

When a Type 736-A Wave Analyzer is used as the detector system for this method, a wide range of input signal frequencies can be used with the Type

Figure 3. Non-linear distortion in an audio amplifier as measured by the harmonic distortion method, the CCIF intermodulation method, and the SMPE intermodulation method. Results are essentially similar for all three methods.



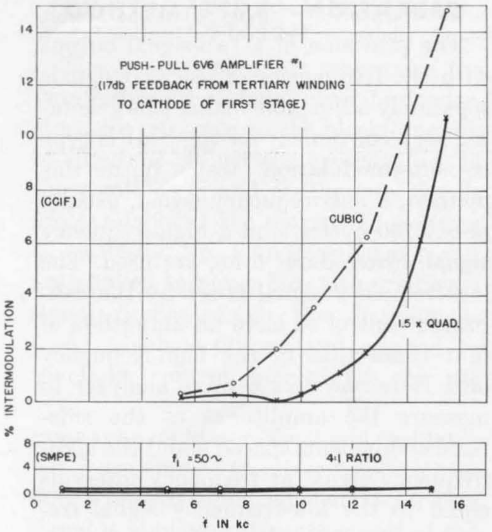


Figure 4. Results of measurements by the two intermodulation methods on an amplifier that shows marked differences for the two methods.

1303-A Two-Signal Audio Generator as the source. If one of the commercially available intermodulation detector systems is used, the range of signal frequencies that can be used is more limited, but the measurements for this SMPE test can be made more quickly.

TYPICAL MEASUREMENTS

Some results of measurements of nonlinear distortion are shown in Figures 3 and 4. The audio amplifier which was measured and gave the results shown in Figure 3 uses four 6B4 tubes in push-pull parallel in the output stage. The operating level was 16 watts in the single-signal case, and the measurements using two signals were made with the same peak-to-peak signal voltage with correspondingly reduced output power level. The results are plotted with the ordinate scales adjusted to show the essential similarity of results by all three methods.[8]

However, this similarity occurs only in some systems; the results shown in Figure 4 show marked differences for the two intermodulation methods. At high frequencies the CCIF method here shows the presence of distortion that is not indicated by the SMPE method. The two amplifiers used here were each uniform in gain as a function of frequency within one decibel from 40 c to 16 kc so that this variation in distortion measurements is not a result of a poor response characteristic.

—A. P. G. Peterson

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SPECIFICATIONS

Frequency Range: Single frequency output: 20 to 40,000 cycles in two ranges, *A*, 20 to 20,000 cycles, and *B*, 20,000 to 40,000 cycles. Double frequency output: There are two combinations of double-frequency output, *C* and *D*.

C: One frequency, f_1, of 20 to 20,000 cycles and a second frequency, f_2, higher than f_1 by a fixed amount, which may be between 0 and 10,000 cycles. As f_1 is varied, the difference frequency remains constant.

D: One frequency, f_1, of 20 to 20,000 cycles and a second frequency, f_2, of 20 to 10,000 cycles.

Frequency Control: The main control is engraved from 20 to 20,000 cycles per second and has a true logarithmic frequency scale. The total scale length is approximately 12 inches. The effective angle of rotation is 240° or 80° per decade of frequency. The frequency-increment dial is calibrated from +50 to −50 cycles. 20 kc is switched in to give 20 kc to 40 kc. A 3¼ inch auxiliary frequency dial, f_k, is engraved from 0 to 10,000 cycles over approximately 180° of dial rotation. The scale distribution is approximately logarithmic above 500 cycles and approximately linear below 500 cycles.

Frequency Calibration: Main dial, 20 to 20,000 cycles: The calibration can be standardized within 1 cycle at any time by setting the instrument to zero beat. The calibration of the frequency control dial can be relied upon within ±(1% + 0.5 cycle) after the oscillator has been correctly set to zero beat.

The accuracy of calibration of the frequency-increment dial is ±1 cycle.

Auxiliary dial, 20 to 10,000 cycles: The frequency can be standardized within 1 cycle by setting to zero beat. The calibration of the dial can be relied upon within ±(3% +10 cycles).

Zero Beat Indicator: The output voltmeter can be used to indicate zero beat.

Frequency Stability: The drift from a cold start is less than 7 cycles in the first hour and is essentially completed within two hours.

Output Attenuator: The output attenuator has six steps from −100 to 0 db with an accuracy of ±1% of the nominal attenuation.

Output Control: For each step of the attenuator the output voltage can be continuously varied from zero to maximum voltage. With two-frequency output, the ratio of the voltages at the two frequencies can be adjusted from less than 0.1 to greater than 10 by means of a control calibrated from 0.1 to 10.

Output Voltage: NORMAL output provides full-scale, open-circuit output voltages of 50 microvolts, 500 microvolts, 5 millivolts, 50 millivolts, 500 millivolts, and 5 volts. HIGH output provides full-scale, open-circuit output voltages from 500 microvolts to 50 volts. When the output voltage is of two frequencies, the indicated voltage is the sum of the voltages at the two frequencies.

The variation of output voltage with frequency is as follows:

f, range *A*, and f_1, ranges *C* and *D:* Between 20 and 20,000 cycles the output voltage varies less than ±0.25 db.

f + 20 kc, range *B:* Between 20 and 35 kilocycles the output voltage varies less than ±0.3 db. It may drop 1 db at 40 kilocycles.

f_2, range *C:* Between 20 and 20,000 cycles the output voltage varies less than ±0.3 db. It may rise 0.75 db at 30 kilocycles.

f_2, range *D:* Between 20 and 10,000 cycles the output voltage varies less than ±0.25 db.

Output Voltmeter: The output voltmeter is calibrated in volts at open circuit and in dbm. Above 10% of full scale, the calibration is accurate within ±5% of the reading.

Output Impedance: The output impedance is 600 ohms resistive within ±2%. One side of the output circuit is grounded.

Output Power: HIGH output is 1 watt maximum into a matched load. NORMAL output is 10 milliwatts, maximum, into a matched load.

Harmonic and Intermodulation Distortion: Distortion of NORMAL output is not affected by the load impedance. Distortion of HIGH output is not affected by the load impedance except in the 0 db attenuator position. Settings of the output control and attenuator have no effect on the distortion.

Harmonic Distortion: For NORMAL output the total harmonic content is less than 0.25% from 100 to 8000 cycles. Below 100 cycles the harmonic content increases and may reach 0.5% at 50 cycles. For HIGH output the total harmonic content is less than 1% from 100 to 8000 cycles. Below 100 cycles the harmonic content increases and may reach 2% at 50 cycles.

Intermodulation Distortion: (1) CCIF: Quadratic and cubic distortion for frequencies above 1000 cycles and a difference frequency greater than 100 cycles are each less than 0.15% on NORMAL output and less than 0.5% on HIGH output.

(2) SMPE: The square root of the sum of the squares of the quadratic and cubic distortion for f_1 between 40 and 300 cycles and f_2 between 1000 and 15,000 cycles is less than 0.5% on NORMAL output and less than 3% on HIGH output.

A-C Hum: The a-c hum is less than 0.1% of the output voltage.

Terminals: TYPE 938 Binding Posts on panel. 4-terminal socket in back.

Mounting: 19-inch relay rack panel with walnut end pieces.

Power Supply: 105 to 125 v., 210 to 250 v., 50 to 60 cycles. Power consumption 135 watts.

Tubes:

4—6SL7-GT	1—5R4GY
3—6SA7	1—6Y6-G
2—6V6-GT	1—6SJ7
2—6SN7-GT	1—OD3/VR-150
1—6J5	1—3-4
1—6H6	

Accessories: Power cord, multipoint plug.

Other Accessories Required: For measurements of harmonic and intermodulation distortion the TYPE 736-A Wave Analyzer is recommended as a detector.

Dimensions: (Width) 19¼ x (height) 17⅞ x (depth) 14⅞ inches overall.

Net Weight: 80 pounds.

Type		*Code Word*	*Price*
1303-A	**Two-Signal Audio Generator**	BEGET	**$1050.00**

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PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXV No. 4 SEPTEMBER, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

IMPROVEMENTS IN THE COUNTING-RATE METER

Also

IN THIS ISSUE

● **SINCE ITS INTRODUCTION** three years ago, the TYPE 1500-A Counting-Rate Meter[1] has found considerable application in laboratories engaged in nuclear physics research. Basically, a laboratory measurement device, rather than a survey instrument, this meter is particularly useful where it is desirable to have a permanent graphical record of changes in rate over a considerable period of time, since a pen recorder, such as the Esterline Angus 5-milliampere model, can be operated directly from the counting-rate-meter output. A continuous visual indication of rate is also provided on a panel meter so that the instrument can be adapted to a great many measurement problems. The advantage of the counting-rate meter over the scaling-circuit method of rate determination lies in its ability to indicate *directly* not only the rate, but changes in the rate as well.

[1] *General Radio Experimenter*, July-August, 1947.

Figure 1. Panel view of Type 1500-B Counting-Rate Meter with counter tube and probe stand.

Experience with this instrument has indicated that its utility would be increased if the response speed were made adjustable and if the counter-tube probe and preamplifier were redesigned to fit the hand and to permit its use with commercially available sample-changers, lead shields, and other accessories.

These two major changes, therefore, have been incorporated in a new model, the TYPE 1500-B.

Response Control

The Geiger-counter tube transforms each burst of radio-active energy into an electrical pulse. In the counting-rate meter, the pulses are standardized in shape and magnitude, and impressed on a resistance-capacitance tank circuit. The voltage across the tank circuit is a function of the rate of arrival of the pulses, and a voltmeter at the tank circuit is calibrated in counts per minute.

If the capacitance of the R-C tank circuit is decreased, the calibration will not be affected, but the time required for the meter to indicate the average or equilibrium value will be reduced, so that the standard deviation and, hence, the probable error and the meter fluctuations due to the random character of the radio-active disintegrations will be increased.

In the improved TYPE 1500 Meter, the tank capacitance can now be varied by setting a four-position switch. The equilibrium time range is from about one second to the 2 or 3 minutes of the original design. A pair of terminals to which an external capacitor can be connected permits the equilibrium time to be extended to values greater than 3 minutes, if desired.

Another circuit improvement added at this time reduces the charging time. When the response switch is in one of the FAST positions, the capacitors that are used in the adjacent SLOW position are charged up rapidly by a cathode follower circuit. When the switch is thrown to the SLOW position, on the average the capacitor has already received its equilibrium charge and the net equilibrium time is reduced.

With this wide response range, the Counting-Rate Meter is now well adapted to meet the requirements of many new specific applications. The slow response speed assures, even for a single meter observation, the low probable error so desirable in routine disintegration rate measurements. With the high response speed, a change in counting rate that occurs in a fraction of a second can now be indicated and recorded. The change in rate to be measured may be due to a change in the position of the sample or of the counter tube. A change in the position of the sample is exemplified by the hydraulics application[1] where a radio-active "slug," more or less dissolved, moves past a Geiger counter; a change in the position of the counter tube is illustrated in the crystal diffraction spectrometer. When the half-life of the sample is comparable to the measurement time, the change is in the disintegration rate of the sample itself. Whatever causes the change in rate, the speed with which the rate changes depends considerably on the particular application. The response control permits a choice of the optimum response consistent with acceptable probable error.

The recorder trace of Figure 2 illustrates the response range in recording the background (160 counts per minute in this case) and in indicating a sudden pulse from a radio-active sample that

[1]R. S. Archibald, "Radioactive Tracers in Flow Tests." *Journal of the Boston Society of Civil Engineers*, vol. 37, pp. 49-116, 1950.

was allowed to fall past the counter tube. The slowest response speed (No. 4) smoothed out the fluctuations and indicated the background value to a high degree of accuracy, but the falling radio-active sample didn't even cause a ripple. At the fastest speed, the fluctuations were quite large, but the falling sample caused the recorder to go beyond half scale.

Probe Redesign

The probe, at the end of a 6-foot connecting cable, consists of a quenching preamplifier and a 4-pin socket for plugging in the Geiger-counter tube.

For greatest flexibility and convenience, the preamplifier-probe unit must be small yet capable of sturdy mounting. The new Type 1500-P10 Preamplifier was designed for adaptability to the varied types of applications demanded by radio-activity measurements. The preamplifier is small and cylindrical for use as a hand probe. Its case is of anodized aluminum for easy decontamination. It is fitted with a ¼-inch x 20 thread insert for mounting on a camera tripod or on the Type 1500-P11 Bench-Top Mount with its universal joint and its heavy base. The preamplifier dimensions permit its use with commercially available sample-changers, lead shields, and other probe accessories. The preamplifier is fitted with a 4-pin socket for plugging in 4-pin based counter tubes such as the Type 1500-P4 and 1500-P5 Beta-Gamma Mica Window Counter Tubes. It is supplied with a 4-pin adaptor to permit the use of any other counter-tube type. The quenching circuit works equally well with self-quenching or non-self-quenching counter tubes. The quenching tube is a triode-connected 6AU6 type miniature which may, if desired, be pentode connected. The mechanical design permits very easy access to the components for servicing, or for adapting the probe to specific needs.

Another useful circuit improvement is an increase in the sensitivity of the instrument. A negative pulse of about ¼ volt is now sufficient to operate the instrument. As a consequence, the cable from the instrument to the preamplifier can now be extended by 40 or 50 feet without introducing serious losses.

Features

The new Type 1500-B Counting-Rate Meter now includes these several desirable features:

The panel meter is direct reading in counts per minute for *all* ranges.

Counting accuracy not affected by

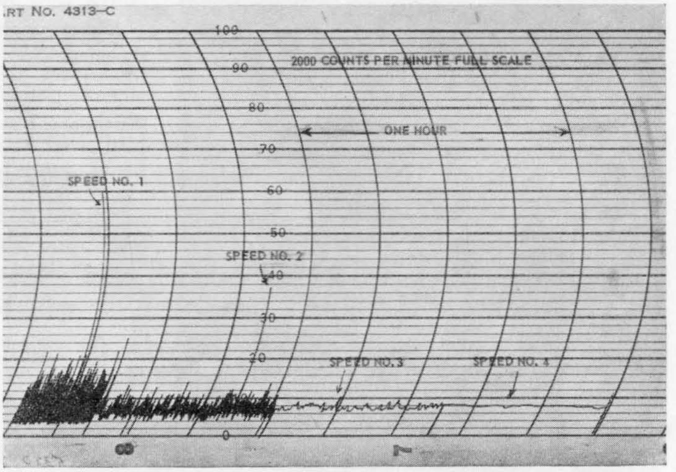


Figure 2. Graphical record of response range of Type 1500-B Counting-Rate Meter to background and to a radio-active sample passing the counter tube. Speed No. 4 gives the most accurate background indication, while Speed No. 1 gives the most pronounced response to the sudden pulse from the sample.

20 per cent line voltage changes.

There are four response speeds for much greater flexibility in application.

The output is adequate for operating a 5 ma pen recorder such as the Esterline Angus Model AW Recorder.

Both the high- and low-voltage power supplies are stabilized.

An internal calibration check and adjustment are provided on the panel.

A loudspeaker on the panel, with volume control, operates as an aural monitor.

A tank circuit shunt aids in speeding up meter changes.

A quenching preamplifier, designed for great adaptability, is supplied.

Increased input sensitivity permits the use of a long cable to the counter tube. — A. G. BOUSQUET

SPECIFICATIONS

Range: Full-scale values of 200, 600, 2000, 6000, and 20,000 counts per minute are provided. The minimum rate that can be read on the meter scale is 5 counts per minute.

Accuracy: The instrument has been calibrated with a generator of equally spaced pulses to yield an accuracy of ±3% of full scale on all ranges.

The resolving time of the instrument is adequate for random counts up to 20,000 per minute.

Preamplifier: The TYPE 1500-P10 Preamplifier is a hand-probe design at the end of a 6-foot cable. It is fitted with a ¼-20 thread for mounting on a camera tripod or on the TYPE 1500-P11 Mount. The preamplifier circuit permits the use of either self-quenched or externally quenched counter tubes. The preamplifier is designed primarily for use with 4-pin based counter tubes; however, an adaptor is supplied to permit the use of any counter-tube design.

Response: There are four response speeds available, starting at about one second at all rates and covering a speed spectrum of over 100 to one. The actual values are also a function of the counting rate.

Counter Circuit Voltage: The voltage applied to the counter circuit is continuously adjustable from 400 to 2000 volts. The value of the voltage is read from an eight-position switch and a calibrated dial which covers the 200-volt interval between switch points. A means is provided for standardizing the voltage so that the accuracy of the voltage readings is within ±5% of the actual value. The power supply is well regulated so that line-voltage fluctuations do not cause changes in the high-voltage supply.

Counter Tube: No counter tube is supplied with the instrument but self-quenching beta- and gamma-ray Geiger-Mueller counter tubes are available as shown in the price list below. The counter tube is mounted in the probe, which is supplied with the instrument, and replacement is simple.

Output: The output of the trigger circuit is available at terminals at the rear of the instrument. The 400- to 2000-volt variable high-voltage supply is also available at the rear of the instrument.

Recorder: A panel jack is provided for connecting a 5-ma recorder into the meter circuit.

Aural Monitor: A small loudspeaker is mounted on the panel for use as an aural monitor. A control, with an off position, is provided for adjusting the volume.

Power Supply: 105 to 125 volts, 50 to 60 cycles. By a simple change in connections on the power transformer, a 210- to 250-volt line can be used.

Power Input: 60 watts.

Accessories Supplied: Plug for connecting recorder, counter-tube adaptor, and line connector cord.

Accessories Required: A counter tube must be obtained separately (see price list below).

Other Accessories Available: Probe Mounting Stand (see photo).

Vacuum Tubes:

3—6SJ7	2—6J5
1—6AG7	1—6C6
1—6X5-GT/G	2—991
1—2X2/879	2—0C3/VR105
1—6SH7	1—6AU6
	1—NE2

All are supplied.

Mounting: The instrument is shipped with end frames for table mounting. For relay-rack mounting, simply remove the end frames.

Dimensions: Panel, 19 x 8¾ inches; depth behind panel, 13 inches.

Net Weight: 38½ pounds.

Type		*Code Word*	*Price*
*1500-B	Counting-Rate Meter	WORRY	$495.00
1500-P4	Beta-Gamma-Ray Counter Tube	WORRYLOBBY	40.00
1500-P5	Beta-Gamma-Ray Counter Tube	WORRYLOCAL	50.00
1500-P11	Probe Mounting Stand	WORRYSTAND	12.50

*Without counter tubes.

Manufactured and sold under United States Letters Patent 2,374,248.

Licensed under patents of the Radio Corporation of America.

TYPE 941-A TOROIDAL TRANSFORMER

This transformer is designed for use as an impedance-matching or bridging transformer in low level 600-ohm communication systems. It employs a toroidal, "doughnut-shaped" core, which is preferable to the familiar shell-type core in two respects.* (1) The toroidal core is much more astatic and thus less susceptible to external magnetic fields while, conversely, it produces smaller external magnetic fields. (2) A tighter degree of coupling between primary and secondary windings can be obtained than with a shell core. The resulting lower leakage reactance extends the high frequency flat characteristic about a decade higher than that of a conventional shell-core transformer, while the high permeability core used is beneficial in the low-frequency range.

This TYPE 941-A Transformer, therefore, is especially useful where either a high degree of astaticism or an ultra-wide frequency range is desired.

The core carries two identical semi-circumferential inner windings, 1-2, 3-4, which are used either in series or in parallel combinations. Over these are wound two identical semi-circumferential outer windings, 5-6, 7-8, which are likewise used either in series or in parallel combinations. These four windings terminate in eight individual terminals on the panel. We have designated such an arrangement as a "duplex" transformer.

Performance Characteristics

Each outer winding has twice the number of turns of each inner winding. This permits the impedance-matching ratios 1:1, 4:1, and 16:1 in either direction.

*Horatio W. Lamson, "Some Advantages of the Toroidal Transformer in Communication Engineering," *Tele-Tech*, May, 1950. Reprints are available on request.

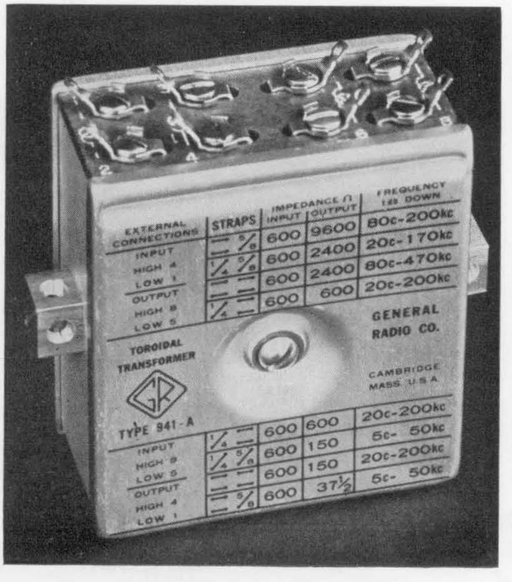
All four windings are employed simultaneously in each case, which is decidedly beneficial. When working either into or out of the design value of 600 ohms, the characteristics shown in the table on page 6 are obtained.

The 941-A may be used as a matching transformer with other terminating impedances. When both terminating impedances are 600 ohms or less (as in Circuits 4, 5, 6, and 7), a frequency span ratio of 10^4 for a 1 db drop from the flat characteristic is obtained. For a conventional shell-core transformer, this ratio is about 10^3. The low-frequency limit of this range is determined by the ratio of the generator impedance, Z, to the primary inductance, L_p. For a 1 db drop:

$$f = \frac{0.156\,Z}{L_p}$$

As either terminating impedance increases appreciably above 600 ohms (as in Circuits 1, 2, and 3), the frequency span ratio will be reduced, since the high-frequency extent is ultimately limited by resonance between leakage

Figure 1. View of the Type 941-A Transformer.



Circuit	Terminating Impedances Ω	Ω	Connect: Inner Windings	Connect: Outer Windings	Frequency for 1 db drop	Flat Insertion Loss Less than
1	600	9600	Parallel	Series	80 c — 200 Kc	0.3 db
2	600	2400	Series	Series	20 c — 170 Kc	0.2 db
3	600	2400	Parallel	Parallel	80 c — 470 Kc	0.2 db
4	600	600	Series	Parallel	20 c — 200 Kc	0.1 db
5	150	600	Series	Series	5 c — 50 Kc	0.7 db
6	150	600	Parallel	Parallel	20 c — 200 Kc	0.2 db
7	37.5	600	Parallel	Series	5 c — 50 Kc	0.8 db

inductance and transformer capacitance. It will be noted that for matching impedances 1:4 or 4:1, a choice of connections is available. Circuits 2 and 5 extend the lower range while Circuits 3 and 6 extend the higher range of the flat characteristic. When the ratio is 1:1, Circuit 4, the leakage inductance is only about 360 microhenries.

A concept of the feasible operating level for this transformer may be gained from the following 60-cycle rms distortion values:

At 31 VU level (1.26 watts), less than 1.0%.
At 30 VU level (1 watt), less than 0.5%.
At 27 VU level (0.5 watt), less than 0.2%.
At 15 VU level (0.032 watt), less than 0.1%.

When the transformer is used in an unbalanced system, it is important that the input or output terminals marked "low" (Nos. 1 and 5) be either directly strapped (if permissible) or be at essentially the same dynamic potential. Otherwise, the extent of the high-frequency range will be shortened appreciably.

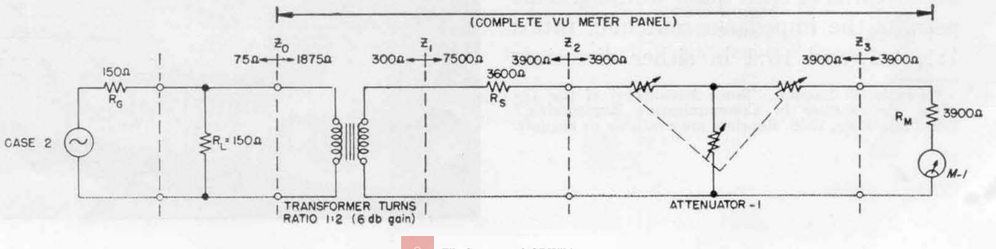
In a typical application, the TYPE 941-A can be used as a bridging transformer, Circuit 5, for applying a 600-ohm VU meter to a 150-ohm audio system, as shown in Figure 2.

Physical Characteristics

The transformer is housed in a rectangular aluminum case. A centricore of spirally-wound, 3-mil tape, specially insulated and annealed, is used. Multilayer progressive windings are applied by a toroidal winding machine developed for this purpose. The impregnated toroid is clamped between felt washers by a central screw which is insulated from the case. All circuits are insulated for 500 volts from the case. The performance data given above, together with appropriate diagrams for strapping the terminals and making external connections, are printed on one large face of the case. One small face consists of a phenolic panel carrying eight combination screw-clamp and solder terminals. These terminals are numerically identified and the internal connections are indicated. Two double-drilled mounting blocks permit the transformer to be mounted: (1) on its large face, (2) on its small face opposite the terminal panel, or (3) projecting through a hole 3⅛" x 1⅝" in an assembly chassis.

—HORATIO W. LAMSON

Figure 2. Circuit showing how the transformer can be used to adapt a 600-ohm VU indicator to 150-ohm lines.



SPECIFICATIONS

Initial Inductance: Inner windings, in series, 5 to 6 henrys; outer windings, in series, 20 to 24 henrys.

Resistance: Inner windings, in series, 9 ohms; outer windings, in series, 34 ohms.

Dimensions: Aluminum case, $3\frac{5}{8}$ x $3\frac{1}{8}$ x $1\frac{5}{8}$ inches. Mounting blocks project $\frac{9}{32}$ inch beyond case in $3\frac{1}{8}$ inch dimension.

Mounting Dimensions: $3\frac{3}{8}$ inches on centers. Mounting holes are drilled for clearance with 10-32 machine screws.

Net Weight: $13\frac{1}{2}$ ounces.

Type		*Code Word*	*Price*
941-A	**Toroidal Transformer**........................	TRANTORCAT	**$35.00**

NEW, SPECIAL TERMINAL BOXES FOR V-5 AND V-10 VARIACS*

Variac users have frequently requested special terminal facilities and features impossible to accommodate in the limited space provided by the standard "T" terminal box regularly supplied on V-5MT, V-5HMT, V-10MT, and V-10HMT Variacs. In response to such requests, we now offer a new, larger, rectangular terminal box with plenty of room for almost any special terminal arrangement that may be required. Unlike the standard "T" box, the new box has a removable cover for easy access to its interior.

Boxes are designated alphabetically, in order of their design. This designation is coordinated with the standard type numbering system already established for "V" line postwar Variacs. Thus a V-5MTC shown in Figure 1 is a 115-volt, 5-ampere Variac with case and terminal box, the latter provided with knockouts. Figure 2 illustrates a V-5MTE Variac, 115-volt, 5-ampere, cased model, with three-wire cord and plug for a safety ground circuit, and a two-pole switch.

These two combinations are carried in stock for both the V-5 and the V-10 sizes. Other combinations are available, including models with fuses, cord, plug, and switch. These can be supplied on special order in quantity lots.

*T.M. Reg. U. S. Pat. Off. U. S. Pat. 2,009,013.

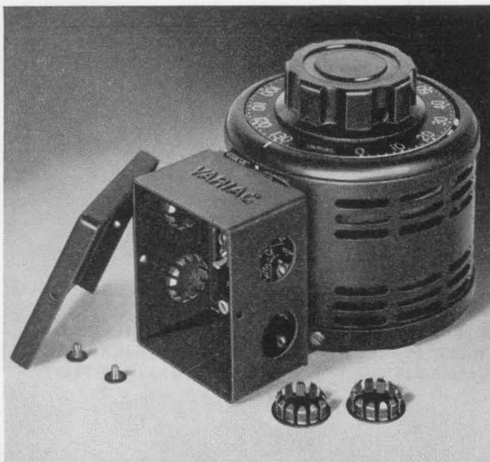


Figure 1. View of the Type V-5MTC Variac with cover to terminal box removed.

Figure 2. View of the Type V-5MTE Variac.

SPECIFICATIONS

Identical with those for V-5 and V-10 Variacs, except for terminal box. Dimensions of box only, 2⅞ inches wide x 3⅝ inches high x 2 inches deep.

Type		Code Word	Price
V-5MTC	V-5 Variac with knockouts in terminal box	COAST	$24.00
V-5MTE	V-5 Variac with 3-wire terminal box, cord, plug, and 2-pole switch	COMET	33.50
V-10MTC	V-10 Variac with knockouts in terminal box	HERON	39.00
V-10MTE	V-10 Variac with 3-wire terminal box, cord, plug, and 2-pole switch	HILLY	48.50

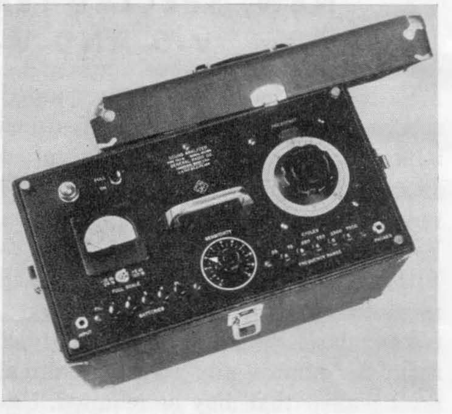
TYPE 760-B SOUND ANALYZER

A new model of the Sound Analyzer, Type 760-B, now supersedes the older Type 760-A. While general performance specifications are unchanged, two important circuit and operating improvements have been made:

(1) A two-range meter is now used, instead of the single-scale type used on the old model.

(2) The output at the PHONES jack is a voltage of the frequency to which the analyzer is tuned, rather than a rectified voltage.

The two-range meter is easier to read and permits associated circuit changes that eliminate, to a considerable degree, the dependence of the calibration upon individual tube characteristics, thus improving the long-time stability. The meter now reads the average value of the signal component and is better suited for continuous-spectrum indications with unpitched noises.



The new output circuit produces a voltage of the frequency to which the dial is set. Output amplitude is linear with respect to input and, with suitable amplification where necessary, can be used to operate a high-speed recorder.

Other specifications remain unchanged.

Type		Code Word	Price
760-B	Sound Analyzer	ATTAR	$495.00

GENERAL RADIO COMPANY

275 MASSACHUSETTS AVENUE

CAMBRIDGE 39 MASSACHUSETTS

TELEPHONE: TRowbridge 6-4400

BRANCH ENGINEERING OFFICES

NEW YORK 6, NEW YORK
90 WEST STREET
TEL.—WOrth 2-5837

LOS ANGELES 38, CALIFORNIA
1000 NORTH SEWARD STREET
TEL.—HOllywood 9-6201

CHICAGO 5, ILLINOIS
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TEL.—WAbash 2-3820

PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXV No. 5 OCTOBER, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

LIGHT METER FOR ELECTRONIC FLASH PHOTOGRAPHY

Also

IN THIS ISSUE

● **ALL PHOTOGRAPHIC** flash lamps, whether electronic or chemical, present a measurement problem that cannot be solved with the ordinary exposure meter, because of the transient nature of the light. What must be measured for flash photography is an integrated value of light vs. time, that is, exposure.

The TYPE 1501-A Light Meter has been designed to make this measurement, and it will be found particularly useful for color photography with electronic flash tubes (called speed lights or strobe lights), where accurate exposure determination is essential. This meter can be used to determine camera aperture with a given arrangement of

Figure 1. Panel view of the Light Meter, showing meter scale and controls.

lights or conversely to adjust lighting for correct exposure with a given aperture. With an auxiliary probe that attaches to the camera ground glass, it can measure the light actually reaching the film. Other important uses include the measurement of the light output of a flash tube, checking flash tubes periodically for deterioration, the measurement of reflector efficiency, and production testing by flash tube manufacturers.

Description

Functionally, the light meter consists of a light attenuator, a vacuum phototube, a capacitor, and a vacuum-tube voltmeter. Light reaching the phototube produces a current, which charges the capacitor. The capacitor voltage is indicated by the voltmeter.

A simplified circuit diagram is given in Figure 2.

The phototube is operated at a voltage high enough to insure that current is proportional to light. The integrating capacitor uses polystyrene dielectric to keep losses low so that no charge leaks off during the period required to take a reading.

The voltage across the capacitor is proportional to the integral of current (and, hence, of light) with time. The high input impedance of the vacuum-tube voltmeter permits the measurement of this voltage without drawing appreciable current, and it is this feature that makes the meter a practical device.

The switches shown in Figure 2 must be operated in the correct sequence to obtain proper performance. First the switch S_1 must be closed to remove any residual charge in the integrating capacitor. With the switch S_1 closed, the zero adjustment is set to bring the indicating meter to zero.

If continuous light falls on the phototube with S_2 closed, current will flow proportional to the light. When the integrating circuit is made active by opening S_1, the capacitor voltage will increase steadily and the meter will drift upscale. This is an undesirable condition when a flash is being measured.

The General Radio Light Meter has a combination push-button switch which serves the functions of S_1, S_3, and S_2 quickly and in proper sequence so that the integrated current due to continuous light will not seriously affect the meter reading. The sequence is as follows: Initially S_1 and S_3 are closed, and S_2 is open, with a spring to hold the switch in this position. A push results in, first, the opening of S_1 which activates the integrating part of the circuit, second, the closing of S_2 which flashes the flash tube and, third, the opening of S_3 which disconnects the phototube. As long as the switch is held in this final position, the meter will hold its reading. The meter returns to zero when the push button is released.

Other panel controls are provided for checking the condition of the batteries. The flash tripping circuit is connected to the meter by plugging into the panel jack.

Spectral Response

The spectral sensitivity of the light meter corresponds to the spectral sensitivity curve of the phototube, a 1P39-type, which peaks in the blue at 4100 angstroms and cuts off at 7000.

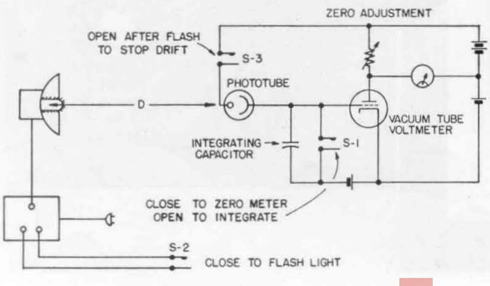


Figure 2. Elementary schematic of the electrical circuit.

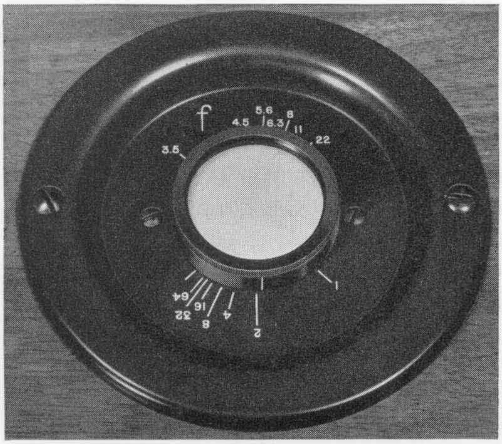


Figure 3. View of the light attenuator, showing f/scale and proportional scale.

Calibration

Light from a standard xenon-filled flash tube is used for calibration. The meter scale is calibrated directly in foot-candle-seconds (lumen-seconds per sq. ft.) of incident light from a xenon flash tube. Table I shows preliminary values of the required incident light at the subject in foot-candle-seconds for various photographic materials. Check measurements of these data are now being made by various manufacturers and users of sensitive photographic materials, and their recommendations will be published elsewhere when available. Until then, the preliminary data will serve as a rough guide for the initial use of the meter.

A Polaroid light attenuator is located on the front of the meter, over the phototube. This permits the range of the meter to be increased by factors of 2, 4, 8, 16, 32, and 64. Corresponding values of f/ numbers are also marked on the scale. A diffusion disk, mounted in front of the attenuator, adjusts the light transmission for correct calibration. This adjustment is made at the factory.

Exposure Determination—Incident Light

The light meter finds its greatest use in color photography in the professional studio, where it takes much of the guess-work out of exposure determination. The normal exposure for professional Kodachrome with average subjects is 100 lumen-seconds per square foot at f/3.5. This basic figure will, of course, be varied for different conditions and lighting arrangements as studio experience and practice indicates.

To measure exposure with a given lighting arrangement, the meter aperture is directed toward the key light, which is then flashed by pressing the CONTROL button and the meter indication noted. From the reading in lumen-seconds per square foot, the normal camera aperture can be determined from a table, or, alternatively, the light attenuator can be varied until the meter reads 100, and the corresponding aperture read from the f/scale of the attenuator.

Conversely, if a particular camera aperture is to be used, the attenuator can be set at that aperture and the key light moved in or out until the meter reads 100. For other types of film, the standard reading would be different, as indicated in Table I.

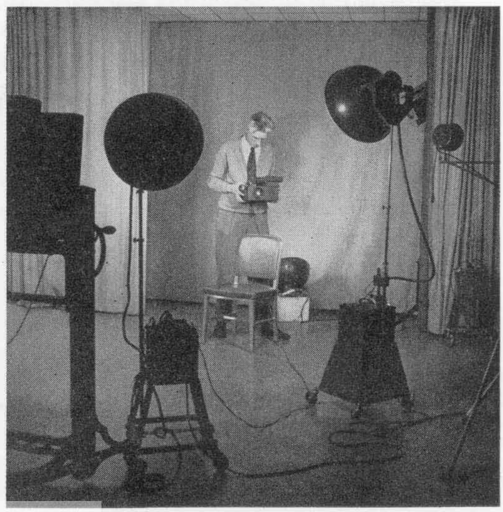


Figure 4. Light Meter in use in a photographic studio.

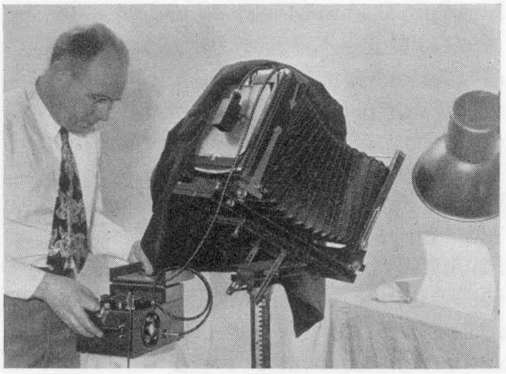


Figure 5. Illustrating use of Type 1501-P1 Probe to measure light reading film. Probe attaches to ground glass with two rubber suction cups.

Fill Lights

The contribution of each fill light is usually measured separately so that their values can be compared to the main key light. For flat lighting the fill may be half that of the key light, while contrast lighting may require one tenth. Experience is required in order for a photographer to get the result he desires. His experiments should be accompanied by light meter records so that he can use the light meter later to achieve the equivalent result.

Reflected Light at Ground Glass

The measurement of the light actually reaching the film is, of course, the most desirable way of measuring exposure. All factors influencing the exposure, such as aperture, lens absorption, and bellows extension, are then taken into account. For this measurement, an auxiliary probe is used. This probe attaches by rubber suction cups to the camera ground glass. The probe contains a photo tube and is connected to the meter through a cord-and-plug arrangement. Standard conditions are achieved by placing a white card at the subject. The image of the card is focused on the ground glass, and the probe is placed over this image. Thus only the light striking the film is measured.

Because of the difficulty of standardizing some of the factors influencing the reading, such as the absorption by the ground glass in different cameras, no calibration for the probe type of measurement is supplied. After a few test exposures with different aperture settings, the user can easily provide the desired calibration for his camera and meter. Since, for a given camera, film type, and meter, there can be but one correct reading, the lights and aperture are adjusted until this reading is obtained.

Other Uses

Two important uses of the light meter are the measurement of the output of flash tubes and of the performance of flash tubes in various reflectors. These are fully discussed in a recent article in the *P. S. A. Journal.*[1]

[1]Harold E. Edgerton, "Light Meter Uses with Electronic Flash," *P. S. A. Journal,* Part II, Photographic Science and Technique, January, 1950.

TABLE I*

Film	*Suggested Filter for Xenon Flash*	*Required Meter Reading (foot-candle-seconds) at f/3.5; Incident Exposure and Average Subject*
Kodachrome Prof. Film, Daylight Type	81-B	100
Ektachrome Prof. Film, Daylight Type	CCO5M	100
Kodachrome Daylight, 35 mm. and Bantam	81-B	80
Kodacolor (Roll only)	81-B	32
Ansco Tungsten# Color positive	Conv. 12	32
Ansco Daylight# Color Positive	CC44 + CC23	90

*Preliminary, subject to revision.
#Ansco recommends the Tungsten type for xenon flash. Processing influences effective speed.

SPECIFICATIONS

Light Range: A light range of 64:1 can be measured at mid-scale deflection, corresponding to 100 to 6400 lumen-seconds per square foot (foot-candle-seconds). The extreme readable range is about 50 to 12,800 lumen-seconds per square foot.

Attenuator Range: F/3.5 to f/22 corresponding to a range of 1 to 64 on the proportional scale.

Tubes: One RCA 929 and one RCA 124.

Batteries: One Burgess 2F, three Burgess XX30E.

Calibration: Meter is standardized in terms of a xenon flash tube operated from a known capacitor at a specified voltage. A diffusion disk is individually fitted to each meter to standardize the reading.

Special Characteristics: The phototube has maximum sensitivity in the blue portion on the visible spectrum.

Response Speed: For reliable results the flash should be 1/20,000 second (50 microseconds), or more, in duration.

Accessories Supplied: Tubes, batteries, diffusion disk, flash synchronizing leads.

Other Accessories Available: A probe for light measurements at the camera ground glass is available at extra cost. See price list below.

Dimensions: 7 x 6½ x 11 inches, overall.

Net Weight: 8⅛ pounds.

Type		*Code Word*	*Price*
1501-A	**Light Meter**	COCOA	**$190.00***
1501-P1	**Probe**	DANDY	**22.50***

*Including 25% Federal tax on photographic equipment.

A VARIAC* PHASE-SHIFT CIRCUIT

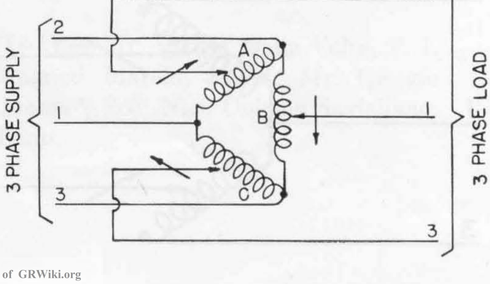
For years we have had to discourage our customers from attempting to operate Variacs in a closed-delta, three-phase circuit for voltage control. Figure 1 illustrates why this circuit cannot be used for conventional voltage control applications. As the brushes move in the direction of the arrows, brush *A* moves from phase wire 1 to phase wire 2; brush *B*, from phase wire 2 to phase wire 3; brush *C*, from phase wire 3 to phase wire 1. Figure 2 shows what occurs to the output during rotation. The voltage is reduced to 50% of its end value and then rises again, and the principal change is in the phase angle, which shifts 120° during rotation.

When, however, a convenient phase-shifter capable of operating smoothly and continuously over a 120° angle is required, this odd delta effect exactly fills the bill. For single-phase output, the closed delta is not needed, however, and an open delta assembly may be substituted as shown in Figure 3. Note that this differs from the conventional open delta three-phase control in that, as one brush moves from phase 1 to phase 2, the other brush moves from phase 3 to phase 1, this latter being opposite to the motion in the conventional open delta. The output, therefore, follows the curves of Figure 2. Obviously, some refinements of the circuit are possible, and the remainder of these remarks will be devoted to their development.

The first refinement concerns a means of correcting the voltage change accompanying the phase shift. Obviously, another Variac, as in Figure 4, will do this nicely. Note that the voltage correcting Variac in Figure 4 is shown *reversed*, in that the input is applied between brush and one end of the coil, from which

*Trademark Reg. U. S. Pat. Office. U. S. Patent No. 2,009,013.

Figure 1. Circuit for closed delta connection of Variacs.



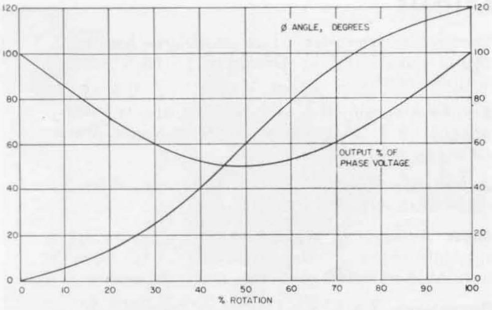


Figure 2. Variation of output voltage and phase angle in the closed delta as a function of dial rotation.

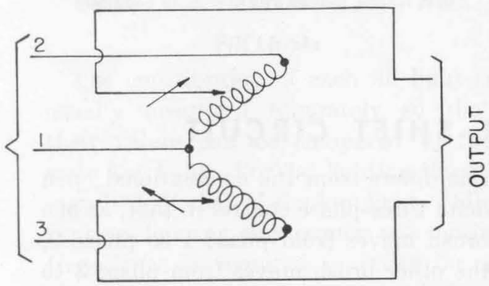


Figure 3. Connections for obtaining adjustable phase angle from open delta.

points output is normally derived. This connection calls for a reasonable amount of discretion in operation, since, *if the brush too closely approaches the low end of the winding, excessive and damaging currents will be drawn.* The use of, and observation of, a voltmeter during adjustment will guard against such difficulties.

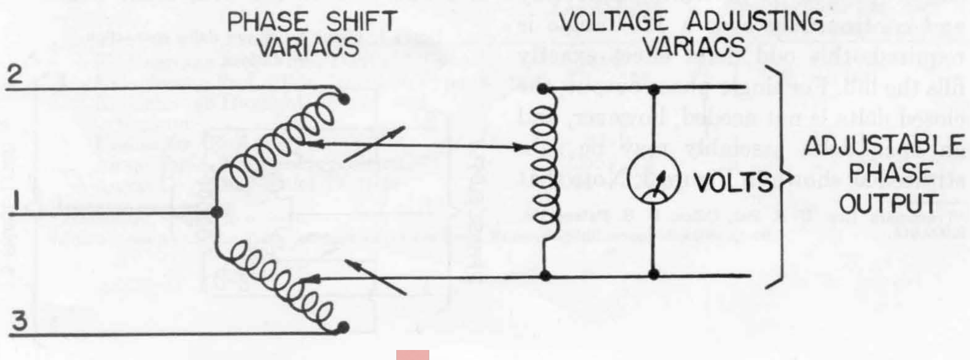
If, in Figure 4, phase 1–3 be considered the reference voltage, then, as the brushes move as indicated by the arrows, the phase angle will be changed smoothly to a maximum of 120° leading or lagging, depending on the phase sense of the supply. Since a phase shift of more than 90° is seldom required, Figure 5 illustrates an alternate circuit, in which the reference voltage is derived from one of the fixed taps on the Variac which are positioned at 14.8% and 42.5% of rotation. If "X" is chosen at 14.8% rotation, the adjustable phase output can be varied from 9° lead or lag to 111° lag or lead. If the tap at 42½% of rotation is used, the phase variation will be from 74½° lead or lag to 45½° lag or lead.

If a tap were made on the winding at 32.5% rotation, the range would be from 30° lead or lag to 90° lag or lead.

If a heavy load is to be drawn from the reference output, fixed autotransformers may be substituted for the Variac taps.

Still another possibility is shown in Figure 6 in which the overvoltage feature of the Variacs is used to secure a phase shift in excess of 120°. "Y" is 14.8% of the total winding (standard overvoltage tap). In this case the curves will vary somewhat from those given in Figure 2. The voltage will vary between 108.16% of line voltage to a low of 35.2% of line voltage, while the phase

Figure 4. Circuit showing the use of a third Variac for holding output voltage constant by manual adjustment as phase is varied.



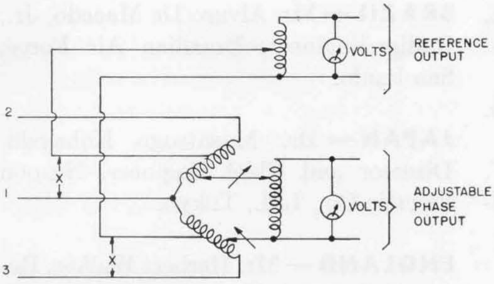


Figure 5. Circuit showing how reference voltage can be derived from fixed taps on Variac.

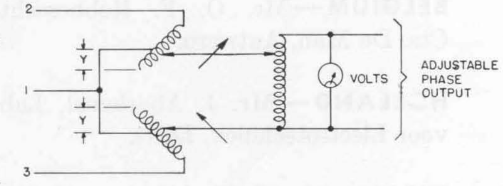


Figure 6. By connecting the input to taps, as shown, phase shifts of more than 120° can be obtained.

angle will vary from 6.89° lead or lag to 126.89° lag or lead. Note, however, that, if "Y" becomes as much as 50% of the total winding, the voltage will drop to *zero* at 50% rotation, though this connection yields a total phase shift of 180° (from 30° lead or lag to 150° lag or lead).

We hope that Variac users will find this discussion helpful in such applications as the testing of low power factor wattmeters, where a convenient phase-shift network is of material assistance.

— Gilbert Smiley

MISCELLANY

PAPERS PRESENTED—At the meeting of the Acoustical Society of America, Pennsylvania State College, June 22 and 23, 1950, "Calculation and Measurement of the Loudness of Sounds," by J. L. Marshall, L. L. Beranek, A. L. Cudworth, M. I. T., and A. P. G. Peterson, General Radio Company; "A Null-Balance Apparatus for Measuring Acoustic Impedance," by J. R. Cox, M. I. T., and W. M. Ihde and A. P. G. Peterson, General Radio Company. No copies of these papers are at present available for distribution, although both will be submitted for publication later.

At the Symposium on Improved Quality Electronic Components, Washington, D. C., May 9–11, 1950, under the sponsorship of AIEE, IRE, and RTMA, "The Need for Quality Performance in Laboratory Equipment," by P. K. McElroy, General Radio Company; "Reduction of Losses in Air-Cored Coils," by Robert F. Field, General Radio Company. These papers will be published in the *Proceedings* of the Symposium, obtainable from the Trilectro Co., 1 Thomas Circle, Washington 5, D. C., at $3.50, postpaid. Reprints of Mr. Field's paper are also available from the General Radio Company.

RECENT VISITORS from abroad to our plant and laboratories include:

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ENGLAND—Mr. Herbert Walker, Research Engineer, British Insulated Callender's Cables, Ltd., London.

*From the Foreign Student Summer Project, Massachusetts Institute of Technology.

THE TYPE 1501-A LIGHT METER described in this issue was developed by Dr. Harold E. Edgerton of the Massachusetts Institute of Technology, who also did the pioneer development work in speed-flash photography.

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THE General Radio EXPERIMENTER

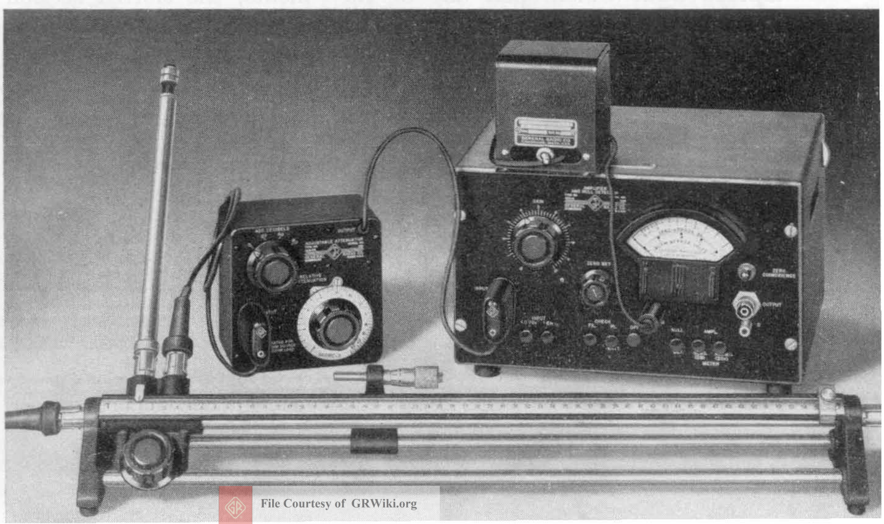
VOLUME XXV No. 6 NOVEMBER, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

U-H-F MEASUREMENTS WITH THE TYPE 874-LB SLOTTED LINE

● **ONE OF THE IMPORTANT BASIC MEASURING INSTRUMENTS USED** at ultra-high frequencies is the slotted line. With it the standing-wave pattern of the electric field in a coaxial transmission line having a known characteristic impedance can be accurately determined. From a knowledge of the standing-wave pattern several characteristics of the circuit connected to the load end of the slotted line can be obtained. For instance, the degree of mismatch between the load and the transmission line can be calculated from the ratio of the amplitude of the maximum of the wave to the amplitude of the minimum of the wave, which is called the voltage standing-wave ratio, *VSWR*. The load impedance can be calculated from the standing-wave ratio and the position of a minimum point on the line with respect to the load. The wavelength of the exciting wave can be measured by obtaining the distance between minima, preferably with a lossless load to obtain

Figure 1. View of equipment for standing-wave and impedance measurements, consisting of Type 874-LB Slotted Line with Type 874-LV Micrometer Vernier, Type 1231-P4 Adjustable Attenuator, Type 1231-B Amplifier with Type 1231-P2 Tuned Circuit, and Type 874-R32 Patch Cord.



the greatest resolution, as successive minima or maxima are spaced by one-half wavelength. The properties outlined above make the slotted line valuable for many different types of measurements on antennas, components, coaxial elements, and networks.

DESCRIPTION

The TYPE 874-LB Slotted Line[1] is a 50-ohm, air-dielectric, coaxial transmission line with a longitudinal slot in the outer conductor. The inner conductor is supported, at its ends only, by two TYPE 874 Connectors, thus minimizing reflections and discontinuities caused by dielectric supports. An electrostatic pickup probe, mounted on a sliding carriage, projects through the slot and samples the electric field within the line. Coupling between line and probe is adjustable by changing the probe penetration, and the maximum longitudinal travel of the probe is 50 cms., which is one-half wavelength at 300 Mc. The position of the probe is indicated on an adjustable centimeter scale mounted on the line as shown in Figure 1. The carriage can be moved along the line by grasping the knob or the base of the carriage and sliding it, or by lightly pressing down and turning the knob. The knob is attached to a pair of tapered disks which span one of the reinforcement rods. When the knob is pushed down, the tapered disks grip the rod and roll along it when turned, thus driving the carriage.

[1]Thurston, W. R., "Simple Complete Coaxial Measuring Equipment for the U-H-F Range," *General Radio Experimenter*, Vol. 24, No. 8, January, 1950.

Either a crystal rectifier or a receiver can be used as a detector of the r-f voltage induced in the probe. A built-in crystal mount is incorporated in the carriage, and a TYPE 874 Connector is provided for the receiver. When the crystal is used as a detector, it is tuned to the operating frequency by a TYPE 874-D20 Adjustable Stub, which plugs into a connector on the probe carriage. Usually an amplitude-modulated signal is used with the crystal detector, and the crystal output is an audio-frequency voltage, which is fed through a calibrated attenuator into an amplifier supplied with an indicating meter, such as the TYPE 1231-P4 Adjustable Attenuator and the TYPE 1231-B Amplifier and Null Detector. The a-f voltage is very closely proportional to the square of the r-f input voltage over a wide range of input voltage as shown in Figure 3. The characteristics of several detectors are outlined in Table 1.

PERFORMANCE

Frequency Range

The usable frequency range of the TYPE 874-LB Slotted Line is determined by the type of measurement being made. For general impedance measurements, the slotted section of the line must be at least half a wavelength long, which sets the lower-frequency limit at 300 Mc. However, satisfactory operation for many applications at somewhat

Figure 2. Top view of slotted line, with Micrometer Vernier and 20-cm. stub.

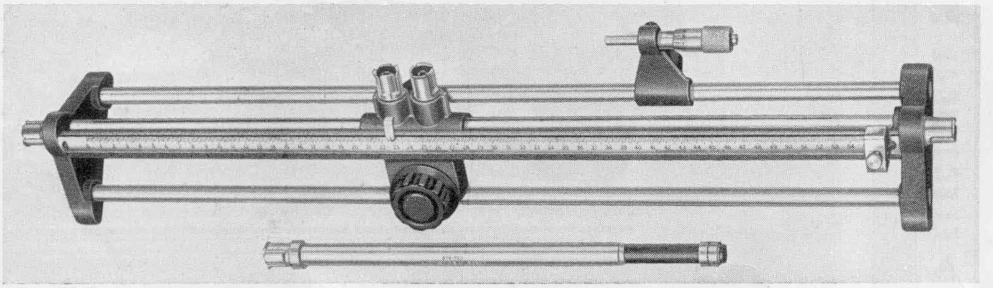


TABLE 1. DETECTOR CHARACTERISTICS

Detector	Oscillator Signal	Equipment	Advantages	Disadvantages
Crystal (Built in)	Modulated (Type 1209-A U-H-F Oscillator and Type 1207 Modulator, or Type 1021-AU U-H-F Signal Generator can be used from 250 to 920 Mc.)	Audio amplifier[2] with indicating meter (Type 1231-B Amplifier with Type 1231-P2 Filter and preferably Type 1231-P4 Calibrated Attenuator).	1. Good sensitivity if audio amplifier gain adequate. 2. Simple. 3. Well shielded. Leakage in measurement of high SWR's rarely a problem. 4. Performance when used with Type 874-F500 and Type 874-F1000 Low-Pass Filters satisfactory for most measurements. 5. Covers a very wide frequency range.	1. Harmonic rejection poor. May cause trouble in measurement of high SWR's. Can be cured by low-pass filter. 2. If sine-wave modulation used, frequency modulation usually produced at upper end of oscillator frequency range may cause trouble in measurement of very high SWR's. Square-wave modulation eliminates difficulty.
Crystal (Built in)	CW (Type 1209-A U-H-F Oscillator or Type 1021-AU U-H-F Signal Generator can be used from 250 to 920 Mc.)	Microammeter with sensitivity of 50 μa or better.	1. Simple. 2. Covers a very wide frequency range.	1. Insensitive, requires large oscillator power. Oscillators referred to do not have adequate output even for moderately high SWR measurements.
Receiver (Type 874-MR Mixer Rectifier)	CW (Type 1209-A U-H-F Oscillator or Type 1021-AU U-H-F Signal Generator can be used from 250 to 920 Mc.)	Type 874-MR Mixer Rectifier,[3] Type 1208-A or 1209-A Oscillator and either a communications receiver or the i-f amplifier section of an AN/APR4 or an AN/APR1 receiver.	1. Good sensitivity. 2. Very well shielded against leakage. 3. Covers a wide frequency range. 4. Good selectivity.	1. Requires several pieces of equipment. However, much of this is usually available in the laboratory.
Receiver (Such as AN/APR-4, AN/APR-1, etc.)	CW (Type 1209-A U-H-F Oscillator or Type 1021-AU U-H-F Signal Generator can be used from 250 to 920 Mc.)	Receiver.	1. Good sensitivity. 2. Good selectivity.	1. Some receivers are not sufficiently well shielded for use at very high frequencies.

[2]Thurston, W. R., loc. cit.

[3]Karplus, E., "Type 874-MR Mixer Rectifier," *Experimenter*, Vol. 24, No. 12, May 1950.

lower frequencies can be obtained by adding lengths of TYPE 874-L30 Air Line between the load and the slotted line and moving them to the other end of the slotted line to make measurements closer to the load. The lengths should be moved ahead of the slotted line rather than completely removed, as under the former conditions the generator sees a constant impedance and, hence, its voltage and frequency do not change. The upper frequency limit is set by the frequency at which the reflections from the connectors seriously affect the measurements and, in the extreme, by the cut-off frequency for the propagation of higher order modes along the line. Figure 4 shows the reflection from a pair of connectors as a function of frequency up to 4500 Mc. The cut-off frequency for the first higher order mode is about 9000 Mc.

Constancy of Probe Coupling

No slotted line is perfect, and slight imperfections in construction will show up as variations in coupling between line and probe. These variations are

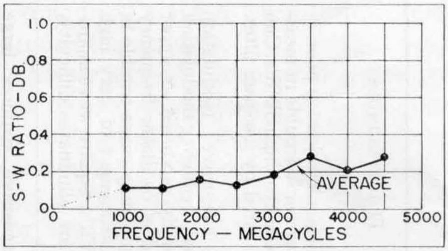


Figure 4. Standing-wave ratio of Type 874 Coaxial Connectors as a function of frequency. The values plotted are the averages of measurements made on a group of connectors. The maximum SWR measured at any point was 0.5 db.

caused mainly by deviations from true concentricity in the center conductor and by radial movements of the probe produced by mechanical imperfections in the outer surface of the line or the probe carriage.

One method of checking the variation in coupling with position is to apply a 1000-cycle signal to the slotted line with its load end open-circuited, remove the tuning stub, connect the input of an amplifier to the terminals formerly used for the tuning stub, and observe the variation in amplifier output with position. A calibration curve of the line can be made in this manner.[4] Figure 5 shows the measured voltage standing-wave pattern along a line at 800 Mc on the top, the measured 1000-cycle calibration curve in the middle, and the corrected voltage standing-wave pattern on the bottom. The deviation of the points from a true sine wave in the lower curve is within the experimental accuracy of the measurements.

[4]Although some experimenters on other types of slotted lines have not found a reasonable agreement between low-frequency and high-frequency calibrations, the experience with this line has shown the agreement to be good.

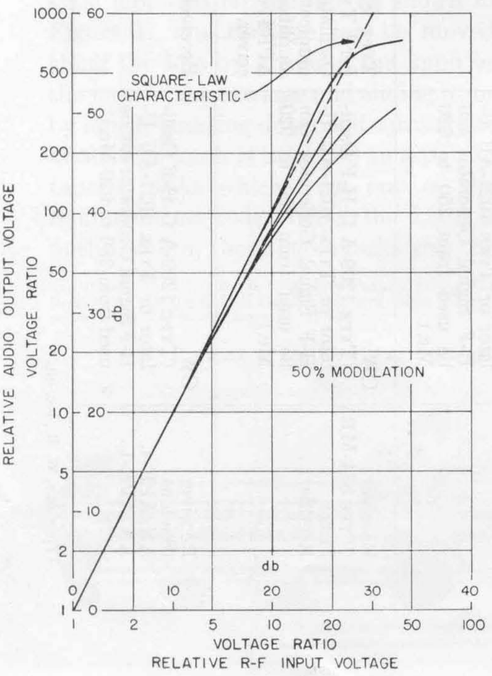


Figure 3. Rectification characteristics of several typical crystals, as measured on the Type 1231-P4 Adjustable Attenuator with the Type 1231-B Amplifier set at maximum sensitivity and full-scale deflection. The deviation from the square-law characteristic is less than ½ db for an input voltage range of 15 db. This range can be increased to about 20 db by using lower scale deflections on the amplifier output meter.

As shown in the figure, the maximum variation in probe coupling is three per cent, but this is not necessarily the actual uncertainty in the measurements, even if no corrections are used. If the frequency is high enough so a number of maxima and minima can be measured and averages obtained, the actual errors may be reduced greatly. For example, in Figure 5, a voltage standing-wave ratio of 1.035 is obtained by taking averages only of the measured curve, which is close to the corrected value of 1.043.

The increase in the accuracy of the averaging process with frequency, owing to the greater number of maxima and minima involved, makes it possible to achieve greater accuracy without applying corrections at moderately high frequencies than that at low frequencies. The accuracy does not increase indefinitely with frequency, however, as the reflections from the connectors increase at high frequencies, as shown in Figure 4, and become the predominant source of error.

Impedance Measurement

The impedance of a circuit is measured by first short-circuiting the line at the point at which the impedance is desired and finding the location, l_1, of a minimum point on the slotted line. (If the short circuit cannot be made exactly at the point in question, it should be made as close as possible to the desired point and the electrical distance between the two points measured. The position of the minimum should then be corrected for the difference.) Next remove the short circuit, connect the circuit to be measured, and measure the amplitudes of the minimum, E_{min}, and the maximum, E_{max}, points and the position, l_2, of the minimum nearest the original minimum. (Do *not* neglect to correct for the square-law characteristic of the crystal, if used.) The voltage standing-wave ratio, *VSWR*, is then

$$VSWR = \frac{E_{max}}{E_{min}}$$

and

$$\Delta l = |l_1 - l_2|$$

The impedance is determined from these data through the use of the Smith Chart[5] or transmission-line equations.

To use the Smith Chart shown in Figure 6, proceed as follows:

1. Find the point on the resistance axis corresponding to the reciprocal of the standing-wave ratio,

$$\frac{1}{VSWR} = \frac{E_{min}}{E_{max}}$$

2. Divide Δl by the wavelength, λ, or $\frac{3 \times 10^{10}}{f\ (cycles)}$, and find the corresponding point on one of the scales on the outer circumference. If the minimum with the line shorted lies on the generator side of the minimum position with load con-

[5] Smith, P. H., *An Improved Transmission Line Calculator*, ELECTRONICS, Vol. 17, No. 1, pp. 130–133, 318–325, January, 1944.

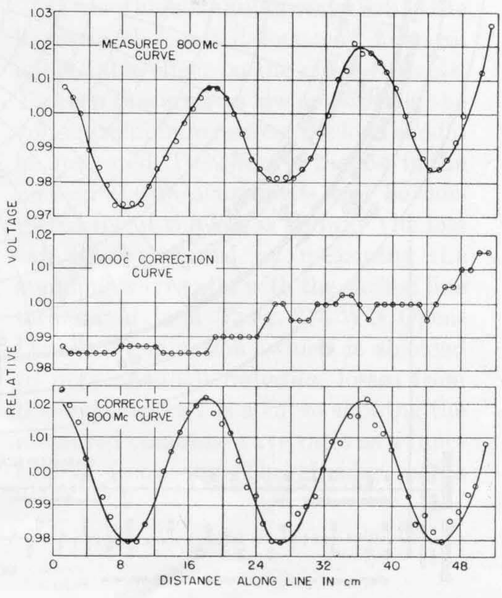


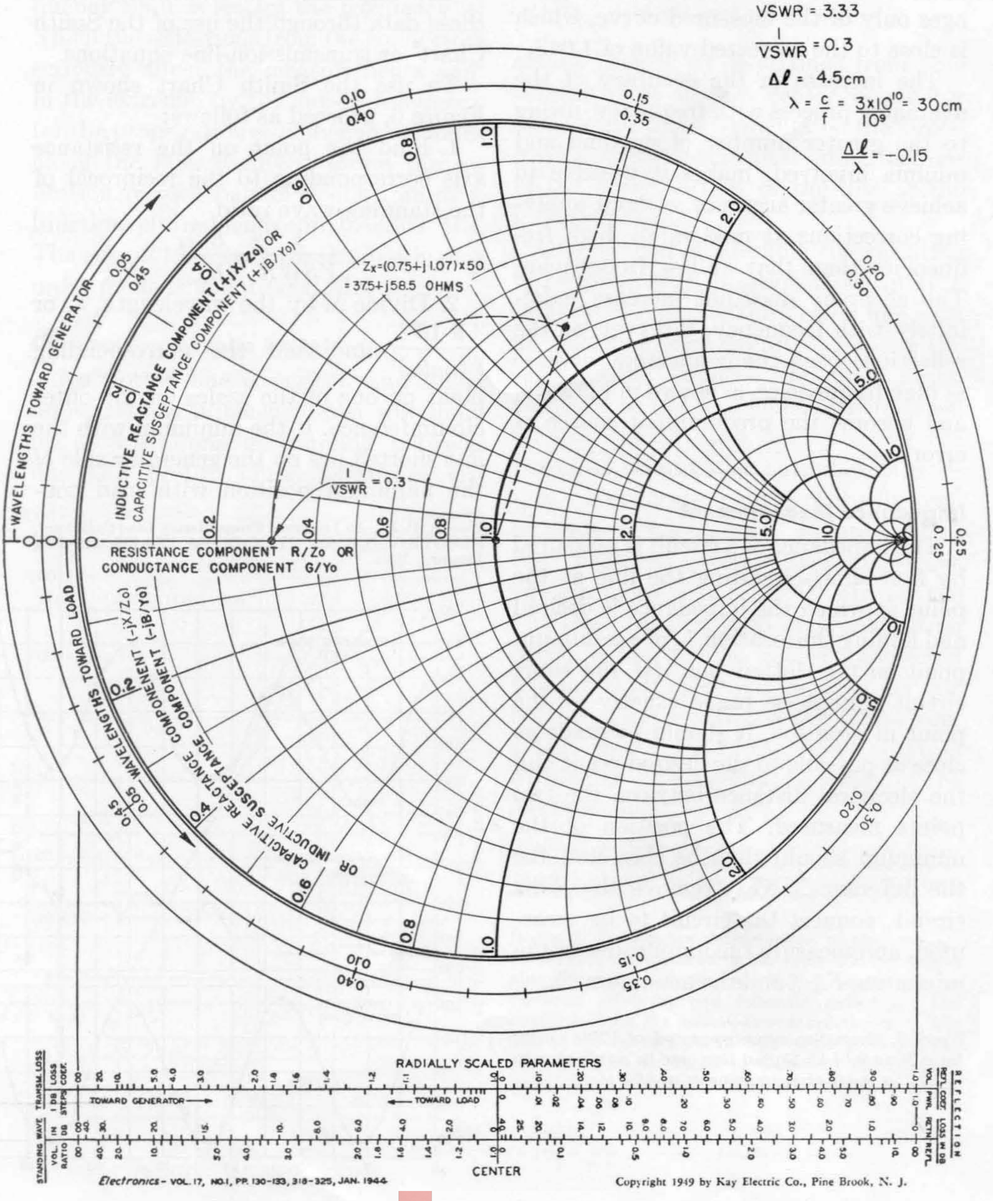
Figure 5. Correction curve measured at 1000 cycles, for a Type 874-LB Slotted Line, and its application to a series of measurements at 800 Mc.

nected, use the WAVELENGTHS TOWARD GENERATOR scale. If it lies on the load side, use the WAVELENGTHS TOWARD LOAD scale. Then draw a line from the point on the WAVELENGTHS scale to the center of the chart.

3. Swing an arc around the center of the chart, passing through the point found in Step 1 and the line drawn in Step 2. The coordinates of the point of intersection of the arc and line are the normalized components of the impedance of the unknown circuit. Multiply these values by 50 to obtain the impedance in ohms.

The admittance of the unknown circuit rather than the impedance can be obtained in manner similar to that out-

Figure 6. Smith Chart with example plotted.



Electronics - VOL. 17, NO. I, PP. 130-133, 318-325, JAN. 1944

lined for impedance. Also, corrections can easily be made for the loss in the transmission line between the unknown and the slotted line on the impedance or admittance. A slide rule version of the chart[6] is available which eliminates the necessity of marking the chart.

If the standing-wave ratio is measured in db, as it is with the TYPE 1231-B Amplifier and the TYPE 1231-P4 Adjustable Attenuator, it is more convenient to determine the radius of the arc directly from the STANDING-WAVE scale shown below the Smith Chart.

The transmission-line equation which can be used for this calculation and which is more accurate, although much more tedious to use, is

$$Z = Z_o \times \frac{1 - j\,(VSWR)\tan\theta}{(VSWR) - j\tan\theta}$$

where $\theta = \frac{2\,\Delta l}{\lambda}$ radians.

The sign of Δl is positive when the short-circuit minimum is on the load side of the load minimum, and vice versa.

High Standing-Wave Ratio Measurements

When the standing-wave ratio is high, the determination of the *VSWR* by measurements of the maximum and minimum voltage amplitudes is difficult for the following reasons:

1. The large difference in voltage between the maximum and minimum points makes the requirements on the detector linearity severe.

2. The depth of the minimum makes it necessary to use a reasonably large probe penetration in order to obtain adequate sensitivity. The effective shunt impedance produced across the line by the probe decreases as the penetration increases and, since the line impedance at the maximum voltage point increases as the standing-wave ratio increases, errors are likely to be caused by the effect of the probe impedance on the voltage maximum. A more accurate method of measuring standing-wave ratios greater than 10 is by the width of the minimum method. In this method, measurements are made near the minimum voltage point only. The minimum voltage amplitude is determined, and the distance, Δ in centimeters, measured between points on the line at which the voltage is the $\sqrt{2}$ times the minimum voltage. Then

$$VSWR = \frac{\lambda}{\pi\,\Delta} = \frac{3 \times 10^{10}}{\pi\, f\, \Delta}$$

where λ is the wavelength in centimeters and f the frequency in cycles of the exciting signal. The expression is actually an approximation, which is accurate as long as the standing-wave ratio is large. At a standing-wave ratio of 10, the error is one per cent.

With the TYPE 874-LV Micrometer Vernier Attachment, the width of the minimum can be determined to an accuracy of approximately ±0.002 centimeter.

At very high standing-wave ratios the losses in the slotted line may have an appreciable effect on the measurements. To keep this error as low as possible, the voltage minimum nearest the load should be measured. The effect of the loss in the line on the measurements can be corrected for, if the loss is known. The loss can be determined by measuring the standing-wave ratio with the slotted line terminated in a TYPE 874-WO Open-Circuit Termination, which is shielded to prevent small radiation losses from the end. Figure 7 is a curve showing the measured standing-wave ratio as a function of frequency. The circular points

[6]Manufactured by the Emeloid Corporation, Arlington, N. J.

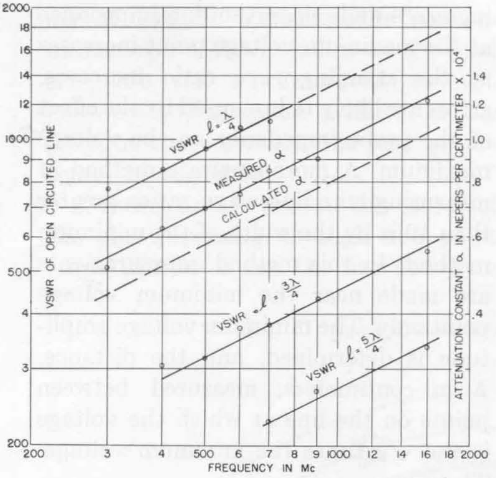


Figure 7. VSWR and attenuation constant of a Type 874-LB Slotted Line terminated in an open circuit.

are the measured points for the ¼, ¾, and 5⁄4 wavelength resonances. Figure 7 also shows the attenuation constant of the line calculated from the measured *SWR*. The dotted line indicates the attenuation constant calculated from the conductivity of the plating on the inner and outer conductors. These points are seen to lie close to the theoretical curve. The use of these data to correct the measured *VSWR* is detailed in the instruction book supplied with the slotted line.

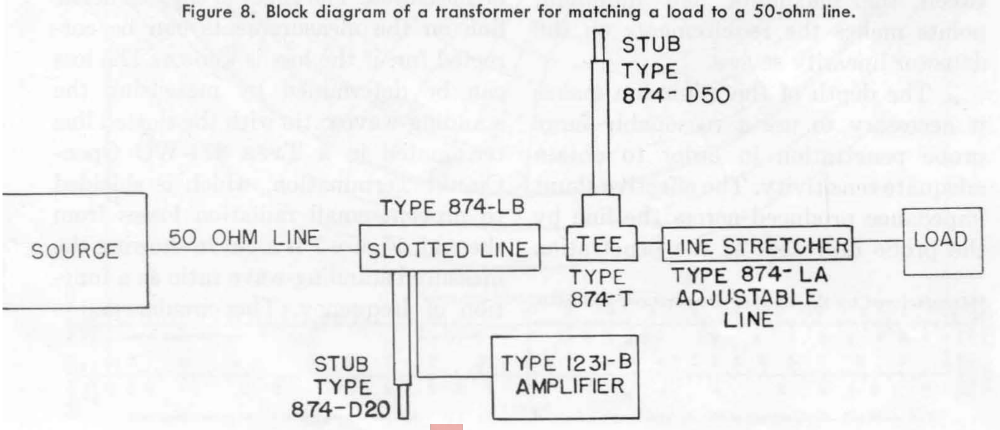
Harmonics

Another source of error in the measurement of high standing-wave ratios is the presence of harmonics in the generator output. The minima for harmonics will not necessarily appear at the same point along the line or have the same amplitude at the minima as the fundamental and, hence, a small harmonic component in the signal from the generator may produce a harmonic signal many times that of the fundamental at a minimum point. Therefore, if the detector will respond at all to harmonics, difficulty may be encountered. Receivers in general have good harmonic rejection; but the tuned crystal detector may respond as well to various harmonics as to the fundamental because the tuning stub has higher order resonances. When the crystal detector is used, and preferably even when a receiver is used, a good low-pass filter such as the Type 874-F500 or F1000 Low-Pass Filters are required for measurements of high standing-wave ratio to reduce the harmonics to an insignificant magnitude.

Frequency Modulation

The presence of appreciable frequency modulation on the applied signal may also have a serious effect on the results when the standing-wave ratio is very high. The Type 1209 Oscillator and Type 1021-AU or Type 1021-AV Signal Generator are satisfactory for modulated signal measurements at fifty per cent modulation up to about 750 Mc. At

Figure 8. Block diagram of a transformer for matching a load to a 50-ohm line.



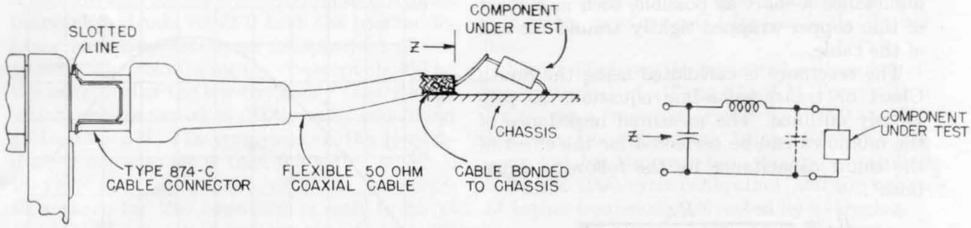


Figure 9. One method of connecting a component to a slotted line. The equivalent circuit is shown at the right.

higher frequencies, reasonably large errors are produced in measurements of standing-wave ratios of the order of 500 to 1000. At standing-wave ratios below 100, the error is usually negligible.

APPLICATIONS

Matching

The Type 874-LB Slotted Line is useful in matching a load to a line by means of a matching transformer as shown in the block diagram in Figure 8. The adjustment of the two transformer elements may be very tedious unless a systematic procedure is followed. One procedure which usually gives good results is as follows[7]:

1. Set the probe in the slotted line to a minimum point and adjust the detector sensitivity until a reading of about twenty per cent of full scale is noted on the detector meter.
2. Adjust one element in the transformer and *follow* the minimum with the probe on the slotted line. Continue the adjustment until the minimum reading reaches a maximum value.
3. Then adjust the other element in the transformer in the same manner as above.
4. Alternate between the two adjustments until the minimum reading is roughly maximized. If the impedance of the generator driving the line is 50 ohms resistive, the load would be matched to the line when the minimum reading is at its maximum.
5. If the generator is not matched to the line the actual magnitudes of *both* the maximum and minimum voltages on the line, that is, the *VSWR*, should be measured and each of the transformer elements readjusted in succession to minimize the *ratio* of these voltages.

Measurement of Components

The Type 874-LB Slotted Line can be used to measure the impedance of components of all types. At high frequencies, the measured impedance of any component is greatly affected by lead length and position, and, for the most accurate results, measurements should be made with the component connected in the circuit in which it is used. If this cannot be done, measurements should be made under conditions as closely approximating the operating conditions as possible. Large errors can be caused by the reactance of leads used to connect the component under test to the end of the slotted line and, hence, the length of leads not actually a part of the component under test must be minimized.

One method of obtaining flexible connecting leads without introducing large errors is to make the connecting lead a flexible coaxial cable having the same characteristic impedance as the slotted line. The center conductor of the cable is extended a short distance beyond the end of the braid to connect to one end of the unknown, and the braid itself connected to the other. The actual leads thus are made very short.

The leads effectively introduce a shunt capacitance across the end of the coaxial cable and an inductance in series with the unknown impedance as shown in the approximate equivalent circuit in Figure 9. The magnitude of the shunt capacitance is determined by disconnecting the unknown and without disturbing the position of the leads, measuring the reactance seen across the end of the cable. For this measurement, as well as for the measurement with the component connected, a voltage minimum on the slotted line is first found with the end of the coaxial cable short circuited with as low

[7]If there is a large mismatch between generator and load, better results can be obtained by inserting a Type 874-GG 10-db pad between the generator and the line.

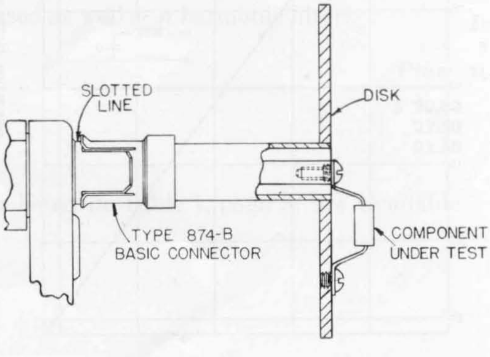


Figure 10. Recommended method of connection when isolated components are to be measured.

inductance a short as possible, such as a sheet of thin copper wrapped tightly around the end of the cable.

The reactance is calculated using the Smith Chart or transmission-line equations as previously outlined. The measured impedance of the unknown can be corrected for the effect of the shunt capacitance by the following equations[8]:

$$R_e = \frac{R_m}{\left(1 - \frac{X_m}{X_a}\right)^2 + \left(\frac{R_m}{X_a}\right)^2}$$

$$X_e = \frac{X_m - \frac{R_m^2}{X_a} - \frac{X_m^2}{X_a}}{\left(1 - \frac{X_m}{X_a}\right)^2 + \left(\frac{R_m}{X_a}\right)^2}$$

where R_m and X_m are the measured resistance and reactance and X_a is the measured reactance of the shunt capacitance. Since X_a is capacitive, the quantity inserted in the equations will be negative.

The reactance of the lead inductance is measured by disconnecting the unknown and connecting the ends of the leads to a metal sheet without disturbing the position of the leads. The lead reactance, X_L, is subtracted from the effective reactance, X_e.

$$R_x = R_e$$
$$X_x = X_e - X_L$$

The simplified method of measuring the lead capacitance and inductance outlined above breaks down as the lead inductance and capacitance approach resonance. The capacitive reactance of the leads should be at least five times the inductive reactance.

Another method of mounting components for measurement is to connect to the slotted line a short length of air line with its outer conductor terminated in a metal disk or plate as shown in Figure 10. In this case, the unknown is connected directly to the end of the inner conductor of the slotted line and to the ground plate. If the component is connected with the leads normally used with it, only the terminal capacitance need be corrected for as indicated previously. The effect of any additional leads required can be corrected for.

The results of measurements made on a 10 $\mu\mu f$ ceramic capacitor with its own leads approximately ⅜ of an inch long are shown in Figure 11, in which the reciprocal of the effective capacitance is plotted as a function of ω^2.

[8]These will be recognized as the same equations that are used to correct for lead capacitance in the TYPE 916-A Radio-Frequency Bridge.

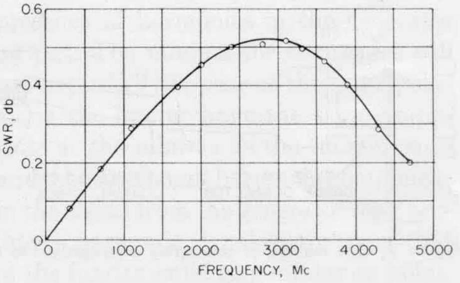
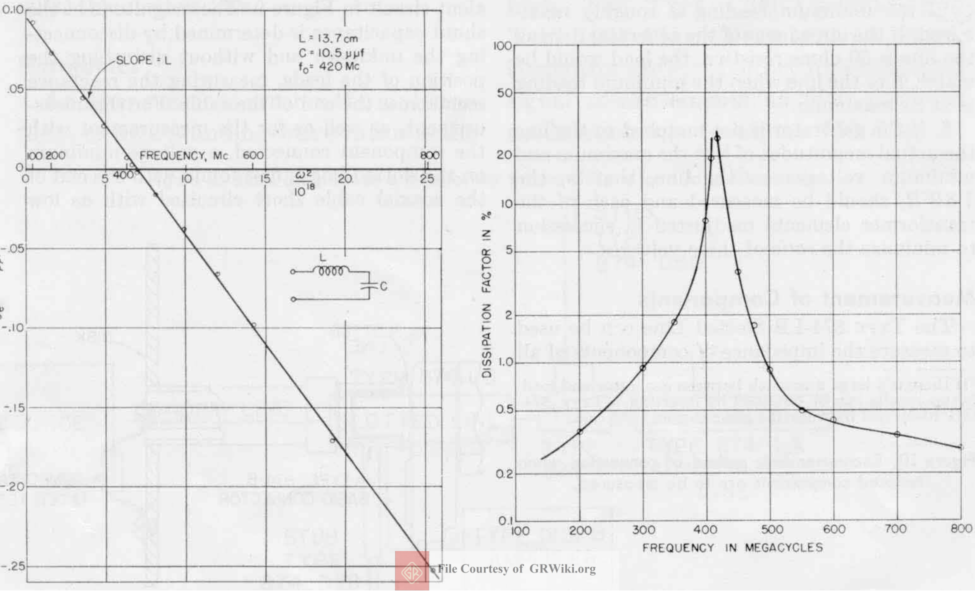


Figure 12. Plot of standing-wave ratio of the Type 874-WM 50-Ohm Termination as a function of frequency.

Figure 11. Plots of measured dissipation factor and reciprocal capacitance of a 10 $\mu\mu f$ ceramic capacitor, using the disk connection shown in Figure 10.



A straight line having a slope equal to the series inductance should result if both the true inductance and capacitance are independent of frequency. The zero-frequency intercept should be the reciprocal of the low-frequency capacitance, which was measured at 1000 cycles and found to be 10.5 $\mu\mu f$. The reciprocal of the low-frequency capacitance is then 9.5 x 10^{10} which is in very good agreement with the intercept. Resonance for this capacitor is seen to be at 420 Mc. The variation in dissipation factor with frequency is also plotted and seen to rise to infinity at resonance. These values of dissipation factor were corrected for loss in the slotted line.

Figure 12 shows the measured voltage standing-wave ratio of a TYPE 874-WM Termination Unit over a frequency range from 300 to 4500 Mc. The measurements below 1000 Mc are corrected for the variations in probe coupling using the 1000-cycle calibration, and the values at higher frequencies corrected by averaging.

— R. A. SODERMAN
W. M. HAGUE

RECOMMENDED EQUIPMENT

The equipment necessary to make the measurements described in the preceding article can be selected from the extensive line of coaxial elements manufactured by the General Radio Company. A recommended group of elements is available as the TYPE 874-EK Elementary Coaxial Kit, and includes the following:

Type	*Name*	*Quantity*	*Unit Price*	*Price*
874-A2	**Coaxial Cable**	25 feet	$27.00/100 feet	**$ 6.75**
874-B	**Basic Connector**	2	1.25	**2.50**
874-C	**Cable Connector**	2	2.00	**4.00**
874-C8	**Cable Connector**	2	2.00	**4.00**
874-D20	**Adjustable Stub**	1	10.50	**10.50**
874-D50	**Adjustable Stub**	1	12.00	**12.00**
874-LA	**Adjustable Line**	1	15.00	**15.00**
874-LB	**Slotted Line**	1	220.00	**220.00**
874-P	**Panel Connector**	2	2.50	**5.00**
874-Q1	**Adaptor to Type N**	1	4.50	**4.50**
874-R20	**Patch Cord**	2	8.00	**16.00**
874-R32	**Patch Cord**	1	5.75	**5.75**
874-T	**Tee**	1	7.50	**7.50**
874-WM	**Matched (50Ω) Termination**	1	10.50	**10.50**
874-WN	**Short-Circuit Termination**	1	3.50	**3.50**
874-WO	**Open-Circuit Termination**	1	2.00	**2.00**
874-Z	**Stand**	1	12.50	**12.50**
TOTAL	**Type 874-EK Elementary Coaxial Kit**			**$342.00**

If very high standing-wave ratios are to be measured, a TYPE 874-LV Micrometer Vernier Attachment should also be purchased as well as a harmonic filter.

Type		*Price*
874-LV	**Micrometer Vernier Attachment**	**$ 20.00**
874-F1000	**Low-Pass Filter**	**22.50**
874-F500	**Low-Pass Filter**	**22.50**

Power sources and detector equipment listed in Table 1, page 3, are available as follows:

Power Sources

I

Type		*Price*
1209-A	Unit Oscillator, 250 to 920 Mc	$235.00
1207-A	Unit Oscillator (modulator)	73.00
1207-P2	Tuning Unit	17.50
1205-A	Unit Power Supply	70.00
874-R20	Patch Cord	8.00
		$403.50

or

II

Type		*Price*
1021-AU U-H-F	Signal Generator, 250 to 920 Mc	$615.00

Detectors

I — For use with crystal rectifier in slotted line:

Type		*Price*
1231-B	Amplifier	$250.00
1231-P2	Tuned Circuit	25.00
1231-P4	Adjustable Attenuator	52.00
		$327.00

or

II — For use with communications-type receiver:

Type		*Price*
874-MR	Mixer Rectifier	$ 35.00
1209-A	Unit Oscillator	235.00
1205-A	Unit Power Supply	70.00
		$340.00

NOTE: If desired, the TYPE 1208-A Unit Oscillator can be used instead of the TYPE 1209-A, and the second harmonic used to cover the frequencies above 500 Mc. The price of the TYPE 1208-A Unit Oscillator is $190.00, making the total price of oscillator, mixer, and power supply $295.00.

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PRINTED IN U.S.A.

THE General Radio EXPERIMENTER

VOLUME XXV No. 7 DECEMBER, 1950

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

A WIDE-FREQUENCY-RANGE BRIDGE OSCILLATOR

Also IN THIS ISSUE

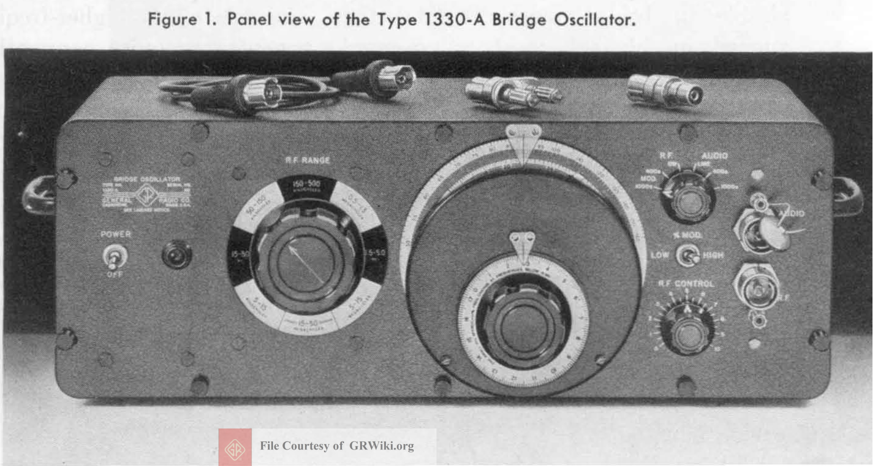
● **BRIDGE MEASUREMENTS,** antenna measurements, and many laboratory procedures require a stable, variable-frequency source of moderate power output. The standard-signal generator, while adequate for most purposes, is not an economical solution because its output is low and because it includes amplifiers, meters, attenuators, etc., which are essential to its proper function but are needless components in a laboratory signal source.

The Type 1330-A Bridge Oscillator was designed to provide a more satisfactory solution both technically and economically. This new oscillator is recommended for use with General Radio bridges such as the Type 716-C Capacitance Bridge, the Types 916-A and 916-AL Radio-Frequency Bridges, and the Type 821-A Twin T.

RANGE AND OUTPUT

The Type 1330-A Bridge Oscillator supplies three audio frequencies (power line frequency, 400 cycles, and 1000 cycles) and a wide continu-

Figure 1. Panel view of the Type 1330-A Bridge Oscillator.



ous range of radio frequencies (5 kilocycles to 50 megacycles), either modulated or unmodulated.

The output voltage is of the order of ten volts. The output power into a 50-ohm load is more than one watt over most of the frequency spectrum. Typical output performance is indicated in Figure 4.

MOUNTING AND SHIELDING

In view of its rugged construction, wide-frequency range and appreciable power output, the new bridge oscillator is surprisingly compact. The relay-rack-type panel is only seven inches high. The aluminum cabinet is about nine inches deep and provides double shielding which reduces the stray field at one megacycle to about 50 microvolts per meter two feet from the instrument. The instrument can be easily removed from its cabinet and mounted in a relay-rack. Since the radio-frequency circuits are completely enclosed in a shielding compartment, the stray-field level is still sufficiently low for most applications.

Type 874 Coaxial Output Jacks are provided; the coaxial cable and adaptors supplied with the instrument permit complete shielding from the oscillator to the measuring instrument.

CONSTRUCTION

Since frequency stability is very desirable in bridge measurements, the rugged mechanical construction used in the Type 1001-A Standard-Signal Generator[1] was adopted for the new oscillator. The tuning capacitor has preloaded ball bearings mounted in 3/16-inch end plates and the end-plate supports are ½-inch diameter rods. The entire oscillator assembly is mounted on a ¼-inch subpanel for complete rigidity. The radio-frequency range switch is taken bodily from the signal generator design to provide the eight coil turret positions. The r-f oscillator coils, however, are of different design, since the oscillator must deliver power directly to the load. For the same reason, the r-f oscillator tube is the higher-power type 6AQ5 miniature tube which has a rating of 12 watts plate dissipation.

The oscillator assembly plugs into a deep brass box and the double cover completes the shielding. Since the two leads entering the box are fully filtered and the four shafts extending from the box are enclosed in shielding sleeves, the leakage is at a minimum over the entire frequency range in spite of the high voltage level inside the box, necessitated by the power output requirements.

The power-supply, on a separate bracket, is mounted alongside the r-f compartment.

CIRCUIT

The radio-frequency oscillator is the Hartley type with its tapped coil and "floating" rotor and stator of the tuning capacitor. The higher-frequency components are quite conventional in design. At the lower radio frequencies, the plate and grid coils are mounted adjacent to each other to permit propor-

[1] A. G. Bousquet, "General Purpose A-M Standard-Signal Generator," *General Radio Experimenter*, September, 1949.

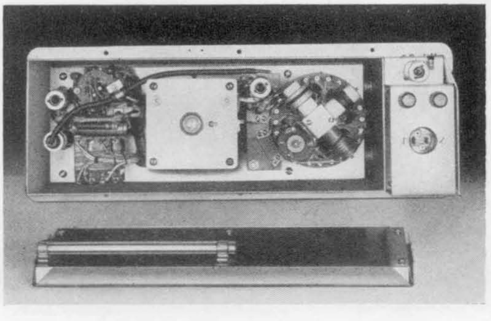


Figure 2. Rear view with shield removed. Power supply unit is at the right of the assembly.

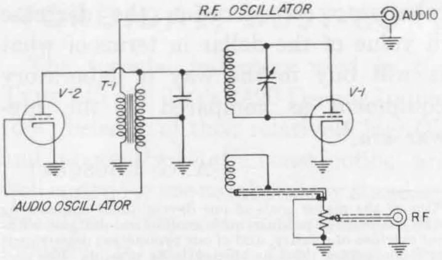


Figure 3. Elementary wiring diagram of Type 1330-A Bridge Oscillator.

tioning the coupling between the output coil and the plate and grid coils, for low carrier distortion.

Modulation of such a wide-frequency-range oscillator by the usual methods is not a simple matter. Since modulation is limited to two audio frequencies (400 and 1000 cycles), a novel and very effective method was devised for providing plate modulation. The plate-supply by-pass capacitor of the r-f oscillator is used as the tuning capacitor of the audio oscillator, thus dispensing with the modulating choke coils and r-f filters that inevitably cause dips in output at some frequency or other and upset the normal operating condition of the r-f oscillator. The method has resulted in excellent modulation characteristics over the 15 kc to 50 Mc span. The shape of the tube characteristic is fortunately such as to compensate for any distortion in the audio oscillator. As a consequence, even though the audio oscillator distortion is about 5%, the envelope distortion of the modulated carrier is usually less than 5%, and at many points is less than 1%. The modulation level is either 30% or 60% as selected by the toggle switch on the panel.

COMPARISON

It is interesting to compare the new instrument with the prewar TYPE 684-A Modulated Oscillator[2] that for many years was the standard bridge oscillator. The new instrument is eleven pounds lighter, consumes only half as much power, and has about half the volume, yet it covers a wider frequency range, is more rugged, and supplies about ten times the output power at a much lower impedance level.

All of these improvements have been achieved at a lower real price, when we

[2] "A Radio-Frequency Source for the Laboratory," *General Radio Experimenter*, November, 1937.

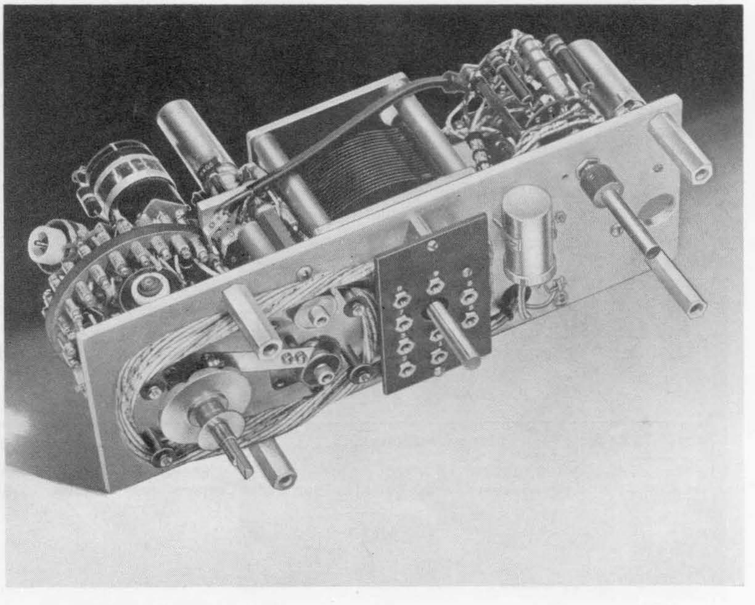


Figure 4. View of oscillator unit removed from cabinet. Servicing cable is shown coiled in its storage position.

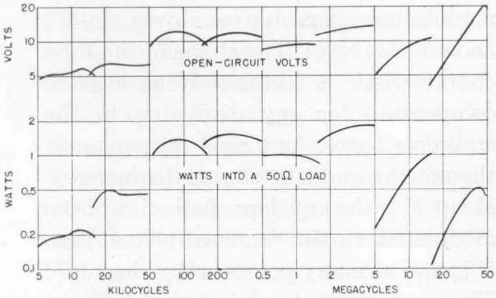


Figure 5. Output characteristics of the Type 1330-A Bridge Oscillator.

take into consideration the decrease in value of the dollar in terms of what it will buy in the way of laboratory equipment as compared to the pre-war era.[3]

—A. G. Bousquet

[3]One of the major goals of our development engineering staff has been to produce more economical designs, without sacrifice of quality, and of our production department to manufacture them as efficiently as possible. The success of this effort is attested to by the fact that General Radio prices have increased since 1939 by about 57%, as compared to an increase of over 84% in the general price index and over 100% in many other lines of durable goods.

SPECIFICATIONS

Frequency Range: Three fixed audio frequencies (power line frequency, 400 c, and 1000 c) and a continuous frequency spectrum from 5 kc to 50 Mc in eight direct-reading ranges as follows: 5 to 15 kc, 15 to 50 kc, 50 to 150 kc, 150 to 500 kc, 0.5 to 1.5 Mc, 1.5 to 5 Mc, 5 to 15 Mc, and 15 to 50 Mc.

Frequency Accuracy: ±5% for the 400- and 1000-cycle fixed frequencies, ±2% for the carrier frequencies above 150 kilocycles, and ±3% for the carrier frequencies below 150 kilocycles under no-load conditions. A 50-ohm resistive load may cause a frequency shift of as much as +5% at some of the lower carrier frequencies; above 150 kilocycles, the frequency shift due to a 50-ohm load is usually less than +1%. From 5 kilocycles to 15 Mc, the dial calibration is logarithmic.

Incremental-Frequency Dial: The slow-motion dial indicates frequency increments of 0.1% per division from 5 kc to 15 Mc.

Output Voltage and Power: The AUDIO output jack provides a fixed voltage output of about 12 volts open circuit, or a power output of about ¾ watt into a matching 50-ohm load; the output at the R-F jack is controlled by the R-F control, and supplies adjustable output for the 5 kc to 50 Mc range; over the mid-frequency range, the open circuit output voltage is about ten volts and the output power into a 50-ohm load (output control at maximum) is about one watt. The output falls off at the upper and lower ends of the frequency spectrum.

Output Impedance: 50 ohms at the AUDIO jack; between 20 and 80 ohms, depending on frequency, at the R-F jack when the 300-ohm output control is at maximum.

Modulation: The R-F range (15 kc to 50 Mc) can be internally amplitude-modulated at either 400 c or 1000 c at the two modulation levels of approximately 30% and 60%. There is no provision for external modulation.

Envelope Distortion: Between 1% and 6% at the 60% modulation level.

R-F Distortion: 3% over most of the range; at the lower radio frequencies it is about 6%.

Leakage: Stray fields at 1 Mc are about 50μv per meter at two feet from the oscillator. With the instrument out of its cabinet, the stray field may be greater by a factor of ten.

Controls: A switch for selecting between AUDIO (LINE, 400 c, or 1000 c) and R-F output (CW or MODulated — 400 c or 1000 c); a switch for selecting between HIGH and LOW modulation; a voltage divider for controlling the R-F output; a range switch; a calibrated dial and a vernier dial for setting the radio frequency; a power switch.

Accessories Supplied: TYPE 874-R21 3-foot Coaxial Cable, TYPE 874-Q2 Adaptor, TYPE 874-Q7Adaptor, TYPE TO-44 Adjustment Tool, and a power cord.

Mounting: Aluminum panel finished in black-crackle lacquer. Aluminum cabinet is finished in black wrinkle and is provided with carrying handles. Cabinet can be removed for relay-rack mounting.

Power Supply: 115 (or 230) volts at 40 to 60 cycles. The power input is about 30 watts.

Tubes: Supplied with the instrument: Two 6AQ5-type tubes and one 6X4-type tube.

Terminals: TYPE 874 Coaxial Terminals are provided for both the AUDIO output and the R-F output.

Dimensions: (Height) 7½ x (width) 21¾ x (depth) 11¼ inches overall.

Net Weight: 36½ pounds.

Type		*Code Word*	*Price*
1330-A	**Bridge Oscillator**	ACORN	**$525.00***

*U. S. Patent No. 2,125,816.
Patent applied for. Licensed under patents of the Radio Corporation of America.

TOROIDAL, DUST-CORE STANDARD INDUCTORS

The toroidal inductors used in the TYPE 940 and TYPE 1490 Decade Inductors[1], because of their relatively high Q's and inherently astatic construction, are well suited for use as laboratory standard inductors. They are now offered individually, in cases, as the TYPE 1481 Standard Inductors.

They complement, rather than supersede, the air-core TYPE 106 Standard Inductors, and each type has its advantages for particular applications. As compared to the air-core type, the TYPE 1481 Standard Inductor has higher Q values, and the maximum Q occurs at lower frequencies. The ohmic resistance is less for a given value of inductance, and Q remains greater than unity down to a frequency of six cycles per second or lower. They have a somewhat smaller temperature coefficient of inductance at room temperatures. They are inherently much more astatic, so that coupling between adjacent units and to external fields is completely negligible, and they can be electrostatically shielded.

On the other hand, accuracy of adjustment is limited to the change produced by a single turn of the winding, which is one per cent for the smaller units. Since they are wound on ferromagnetic cores, the inductance changes somewhat with voltage or current while that of air-core coil does not.

Summarizing, the TYPE 1481 Standard Inductors are smaller in size for a given inductance, have higher Q's, and are much more astatic than are the TYPE 106 Standard Inductors, but they have a somewhat lower stability of inductance and cannot be adjusted as precisely.

Figure 1 is a view of the TYPE 1481 Standard Inductor. The impregnated toroid is clamped between two felt washers in a rectangular aluminum case, which is finished in black crackle and affords an electrostatic shield for the inductor element. One terminal is permanently grounded to the case so that, between the two terminals, we have a definite impedance value with resistive and reactive components which are independent of its environs, an advantageous feature. These specific components can then be measured with any desired precision. The nominal value of inductance is engraved on the case together with the precision limits within which its absolute *initial* value L_o (corresponding to a vanishingly small a-c excitation) at essentially zero frequency was calibrated. The case also carries a legend indicating the r-m-s a-c current which will produce a 0.25% increase in the initial inductance. This value, listed as I_1 in the table, corresponds to the

[1]Horatio W. Lamson, "A New Decade Inductor," *General Radio Experimenter*, Vol. XXIV, No. 2, July, 1949.

Figure 1. Assembled view of Type 1481 Standard Inductor. Note that one terminal is grounded to the case.

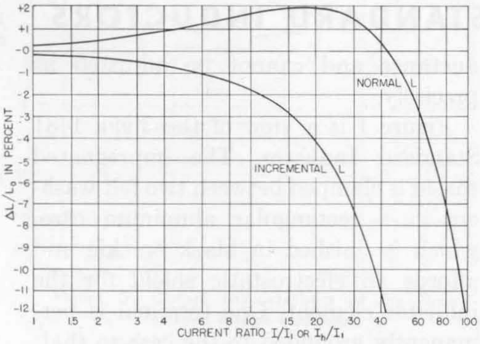


Figure 2. Per cent change in normal and incremental inductance with a-c and bias current. Incremental curve is limited to an a-c excitation less than I_1.

ampere turns which define the upper limit of the Rayleigh range, within which the increase of inductance above its individual initial value is directly proportional to the current.

VARIATION IN INDUCTANCE WITH APPLIED A–C AND WITH D–C BIAS

In the description of the decade inductors, previously published,[2] the changes in inductance with current and the incremental inductance resulting from d-c bias were discussed. Figure 2 shows the magnitude of both of these changes as a function of the ratio of either the normal r-m-s a-c exciting current I, or the d-c biasing current I_b, to I_1, the a-c current which produces the low level linear 0.25% rise in inductance. For the incremental curve the normal signal is considered to be less than I_1.

[2]Lamson, loc. cit.

DISSIPATION FACTOR

Figure 3 shows the variation of the dissipation factor, D (reciprocal of Q), as a function of frequency, computed at zero level so that hysteresis loss is nil. As analyzed in the *Experimenter* for July, 1949[1], D is the sum of three core or magnetic components and three winding components. The core components are (1) residual loss, D_r, a value independent of frequency; (2) hysteresis loss, D_h, likewise independent of frequency and the only component dependent upon the operating level; and (3) *core eddy current* loss, D_e, which is directly proportional to f. The winding components of D are (4) *copper ohmic* loss, D_c, which is inversely proportional to f and evaluated from the d-c resistance; (5) *dielectric* loss, D_d, which is proportional to f^2; and (6) *copper eddy current* loss, D_s, which is proportional to f. When plotted on log-log paper, each component is represented by a straight line having an appropriate slope. The resultant composite curves are shown in Figure 3.

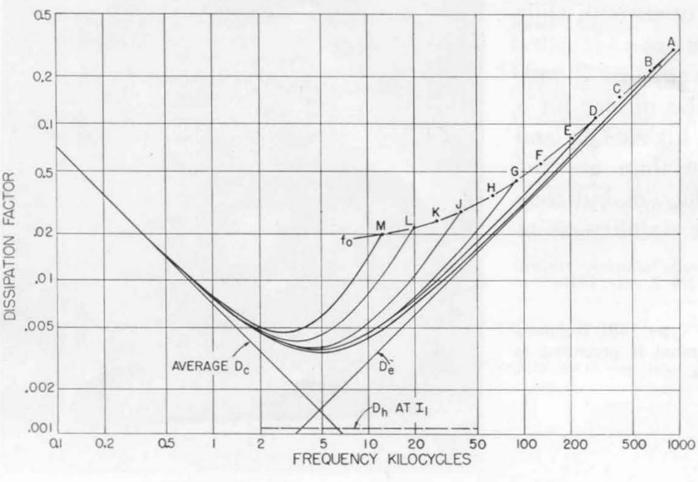


Figure 3. Initial D versus f curves ($D_h = 0$) for typical units. See Specification: Storage Factor.

SAFE OPERATING LIMITS

The maximum safe operating level at which these inductors can be energized is limited by whichever of two specifications is first applicable.

(1) The terminal voltage ($=I\omega L$) should not exceed 500 volts rms.

(2) The r-m-s current should be limited to 70 times the listed I_1 values.

This limitation produces about 0.3 watt copper loss and, from Figure 2, reduces the initial inductance by about five per cent, so that the units are no longer precise inductance standards.

—Horatio W. Lamson

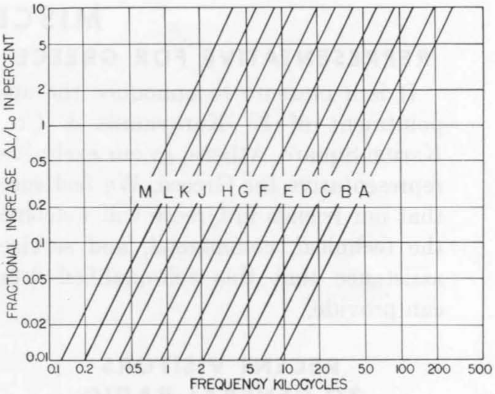


Figure 4. Per cent increase in L_o with frequency. For a 0.1% increase f varies between 400 cps for 5 h and 30 kc for 1 mh.

SPECIFICATIONS

Accuracy of Adjustment: See table below. Accuracy of adjustment is limited to the change produced by a single turn of the winding.

Storage Factor, Q: Maximum initial Q is between 230 and 300. Figure 3 shows the variation of dissipation factor ($D=\frac{1}{Q}$) as a function of frequency for zero level, i.e., with no hysteresis loss. For an r-m-s current I, the plotted D values must be increased by $D_h=0.00107(\frac{I}{I_1})$.

Current Coefficient of Inductance: Per cent change in inductance as a function of $\frac{I}{I_1}$ is given in Figure 2, where I is the operating current and I_1 the current that would produce a 0.25% linear increase in L_o.

Incremental Inductance: D-C bias will reduce the initial inductance as shown in Figure 2.

Frequency Characteristics: Effective inductance at any frequency f below resonance can be computed from the expression $L=\frac{L_o}{1-\left(\frac{f}{f_r}\right)^2}$, where L_o is the initial inductance and f_r is the listed resonant frequency. Per cent change in inductance with frequency is plotted in Figure 4. Variation in dissipation factor, D, with frequency is shown in Figure 3.

Temperature Coefficient of Inductance: Stabilized to be approximately −24 parts in 10^6 per degree C., between 16° and 32°C.

Safe Operating Limits: (1) Maximum terminal voltage, 500 volts rms, or (2) Maximum r-m-s current = 70 I_1, whichever limit is pertinent.

Distributed Capacitance: Between 28 $\mu\mu$f for the 1 millihenry and 33 $\mu\mu$f for the 5 henry inductor.

Dimensions: Case, (height) 3⅝ x (width) 3⅛ x (depth) 1⅝ inches; over-all height, including terminals, 4⅝ inches.

Net Weight: 14 ounces.

Type Inductor	*Nominal Inductance L*	*Calibrated within*	*R-M-S Current, I_1, for 0.25% increase in L_o*	*Resonant Frequency f_r*	*Approx. D-C Resistance*	*Code Word*	*Price*
1481-A	1 mh	±1 %	39 ma	940 kc	0.043 Ω	INDUCTOSAP	**$24.50**
1481-B	2 mh	±1 %	28 ma	660 kc	0.15 Ω	INDUCTOSET	**24.50**
1481-C	5 mh	±1 %	17 ma	420 kc	0.25 Ω	INDUCTOSIG	**24.50**
1481-D	10 mh	±0.5 %	12 ma	300 kc	0.44 Ω	INDUCTOSOT	**24.50**
1481-E	20 mh	±0.5 %	8.7 ma	210 kc	0.95 Ω	INDUCTOSUM	**24.50**
1481-F	50 mh	±0.5 %	5.5 ma	130 kc	2.31 Ω	INDUCTOPAL	**24.50**
1481-G	100 mh	±0.25%	3.9 ma	91 kc	4.3 Ω	INDUCTOPEG	**24.50**
1481-H	200 mh	±0.25%	2.8 ma	64 kc	7.2 Ω	INDUCTOPIT	**24.50**
1481-J	500 mh	±0.25%	1.7 ma	40 kc	22 Ω	INDUCTOPOD	**24.50**
1481-K	1 h	±0.25%	1.2 ma	28 kc	40 Ω	INDUCTOPUB	**24.50**
1481-L	2 h	±0.25%	0.87 ma	20 kc	91 Ω	INDUCTORAM	**24.50**
1481-M	5 h	±0.25%	0.55 ma	12.5 kc	230 Ω	INDUCTORED	**27.50**

MISCELLANY

REPRESENTATIVE FOR GREECE

It is a pleasure to announce the appointment of K. Karayannis & Co., Karitsi Square, Athens, as our exclusive representative for Greece. We feel sure that our friends in Greece will welcome the technical, commercial, and service assistance that this well-qualified firm can provide.

RECENT VISITORS TO GENERAL RADIO

From France (Paris) — Mr. L. Simon, Director, SOTELEC; Mr. M. Leduc, Director, Lignes Telegraphiques and Telephoniques; Mr. E. H. Jensen, Consulting Engineer, Société Anonyme de Telecommunications; and Mr. A. Pagès, Technical General Secretary, Société Alsacienne de Constructions Mécaniques.

From the Netherlands — Mr. H. J. Lindenhovius, N. V. Philips Gloeilampenfabrieken, Eindhoven.

From Netherlands East Indies — Professor G. J. Levenbach, Faculty of Technology, University of Indonesia, Bandung.

From Norway — Mr. Arve Rambol, Royal Norwegian Council for Scientific and Industrial Research, Oslo.

From Switzerland — Mr. Jurg Keller, Seyffer and Co., Zurich, Representatives for General Radio in Switzerland.

From Italy — Dr. Emilio Montruschi and Dr. Roberto Nicoli, Ministero della Difesa-Aeronautica, Rome.

From Japan — Mr. Keizo Nishimura, President, and Dr. Keizo Ikada, Plant Manager, Furukawa Electric Co., Ltd., Tokyo; Dr. P. Uenishi, Shimadzu Seisakusho, Ltd., Kyoto; Professor Yosushi Watanabe, Department of Electrical Engineering, Tohuku University, Sendai; Professor Nobuyoshi Kato, Department of Electrical Engineering, Kyoto University, Kyoto; and Professor Yoshihiro Asami, Department of Electrical Engineering, Hokkaido University, Sapporo.

ELECTED — Kipling Adams, Manager of the General Radio Chicago Engineering Office, to the presidency of the Radio Engineers Club, of Chicago.

HIGH-FREQUENCY MEASUREMENTS CONFERENCE

The second high-frequency measurements conference sponsored by the A.I.E.E., the I.R.E., and the National Bureau of Standards will be held in Washington, D. C., on January 10, 11, and 12, 1951. Conference headquarters will be at the Hotel Statler, and technical sessions will be held in the auditorium of the Department of the Interior.

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PRINTED IN U.S.A.