the GENERAL RADIO Experimenter

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In This Issue

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GENERAL RADIO COMPANY

275 Massachusetts Avenue, Cambridge 39, Mass.

Telephone: TRowbridge 6-4400

BRANCH ENGINEERING OFFICES

NEW YORK: Broad Avenue at Linden, Ridgefield, New Jersey
Telephone — N. Y., WOrth 4-2722
N. J., WHitney 3-3140

CHICAGO: 6605 West North Avenue, Oak Park, Illinois
Telephone — VIllage 8-9400

PHILADELPHIA: 1150 York Road, Abington, Pennsylvania
Telephone — HAncock 4-7419

WASHINGTON: 8055 13th St., Silver Spring, Maryland
Telephone — JUniper 5-1088

LOS ANGELES: 1000 North Seward St., Los Angeles 38, Calif.
Telephone — HOllywood 9-6201

SAN FRANCISCO: 1182 Los Altos Ave., Los Altos, Calif.
Telephone — WHitecliff 8-8233

REPAIR SERVICES

WEST COAST: Western Instrument Co., 826 North Victory Boulevard, Burbank, Calif.
Telephone — VIctoria 9-3013

CANADA: Bayly Engineering, Ltd., First St., Ajax, Ontario
Telephone — Toronto EMpire 8-6866

COVER

Measuring the attenuation of a coaxial cable at a frequency of one megacycle. The equipment consists of the Type 1606-A Radio Frequency Bridge, the Type 1211-A Unit Oscillator with Type 1203-B Unit Power Supply, the Type 1212-A Unit Null Detector with the Type 1203-B Unit Power Supply, and the Type 1212-P2 1-Mc Filter.

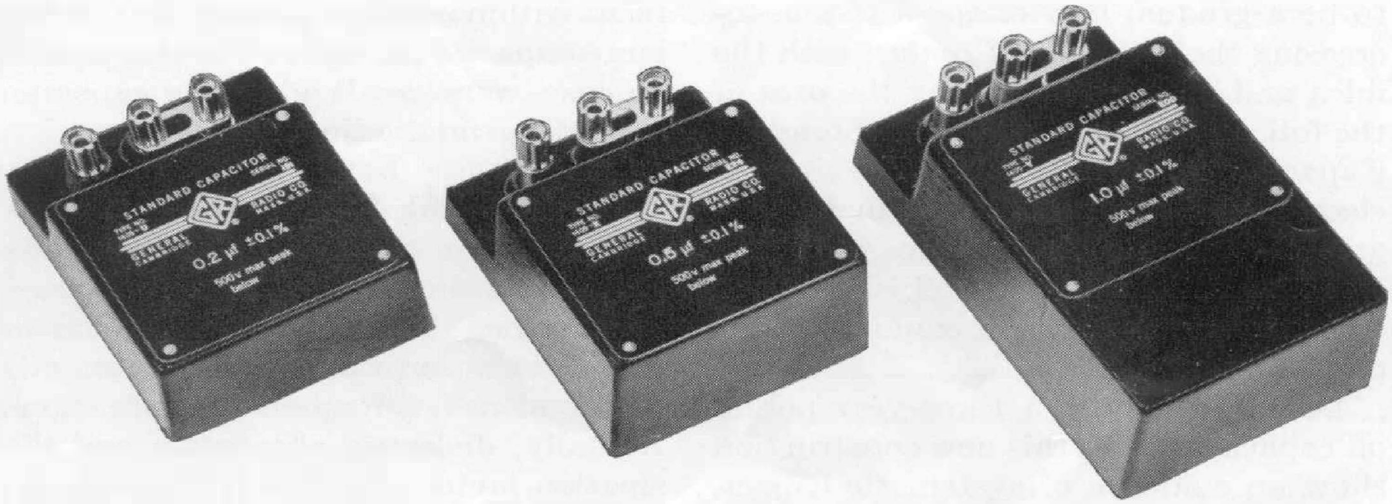


Figure 1.

NEW, SILVERED-MICA, STANDARD CAPACITORS, TYPE 1409

It has been almost twenty-five years since the General Radio line of standard mica capacitors was developed under the direction of the late G. W. Pickard. The characteristics sought for these capacitors were stability, accuracy, low losses, and convenience of use. These characteristics are still the objective in a laboratory standard capacitor, but today's criteria are necessarily somewhat more severe than were those of a quarter-century ago. It is, therefore, a tribute to the soundness of the original design that a great many of its details as well as its principles are included in the new Type 1409 Standard Capacitors, currently in production.

Primarily, the new capacitors take advantage of the improvements possible with properly processed silvered mica, but in the course of the development all phases of design and manufacture were reviewed and a considerable number of changes made.

STABILITY

Stability was secured in the original design by: (1) the omission of impregnants, such as wax, which could change with time and ambient conditions; (2) silica gel sealed into the case with the stacked unit to protect from any residual moisture; (3) a clamping structure having a low-rate spring so that pressure on the stacked unit would be sensibly constant with time and temperature; and (4) artificial aging by temperature cycling. These features, which are retained in the new units, produced an excellent capacitor, which, nonetheless, showed a tendency to increase in capacitance over the years at a slow but predictable rate. Figure 2, which is the record of our own working standards over a 22-year period, shows a linear increase after the first year, when percentage change in capacitance is plotted against the logarithm of time. The initial and normal first-year drift of these units was largely eliminated by the artificial aging; hence a drift of 0.1% in approximately ten years after shipment was the expected performance. It is interesting to speculate whether the units in question will continue at the indicated rate and drift another 0.1% in the next 100 years, but the matter is obviously of somewhat academic interest to most of us.

The mechanism of the drift in a capacitor with foil electrodes is believed to be a gradual flow of the soft foil, increasing the intimacy of *contact* with the mica and perhaps increasing the *area* of the foil. In the new TYPE 1409 Standard Capacitor each sheet of mica has silvered electrodes, assuring a much higher degree of contact between mica and electrode. Additionally, soft foil is still used to insure low-resistance contact to the electrodes.

Data taken over a three-year period on capacitors with this new construction show no evidence of systematic capacitance drift. Such changes as have been observed are random and less than .01% (100 ppm). An order-of-magnitude improvement over the previous design is indicated, with a distinct possibility that the improvement is even greater than this.

ADJUSTMENT ACCURACY

The older type capacitors were adjusted within 0.25% of nominal accuracy by trimming; large capacitance values were adjusted by a second, small unit in *parallel*, while small capacitance values were adjusted by a large unit in *series*. In the new construction the use of silvered-electrode mica permits adjustment within 0.1% in a single unit for the large capacitance values. In the smaller values a very small adjusting capacitor is used for final adjustment.

ELECTRICAL CHARACTERISTICS

In addition to low dissipation factor and high ultimate insulation resistance, interest has focused in recent years on dielectric absorption, of importance in d-c or ultra-low-frequency applications. Actually, dielectric absorption and dissipation factor at audio frequencies are aspects of the same phenomenon, both being chargeable to interfacial polarizations occurring at frequencies below one cycle per second. The typical rise in dissipation factor at low audio frequencies is shown in Figure 5.

The mica used in the TYPE 1409 is selected to have average dissipation factor of no more than 0.0002 at 1 kilocycle and insulation resistance of at least 5,000 megohm-microfarads. This usually means clear, or clear and fair-stained, ruby mica, but selection is ultimately on the basis of electrical performance rather than on arbitrary visual quality.

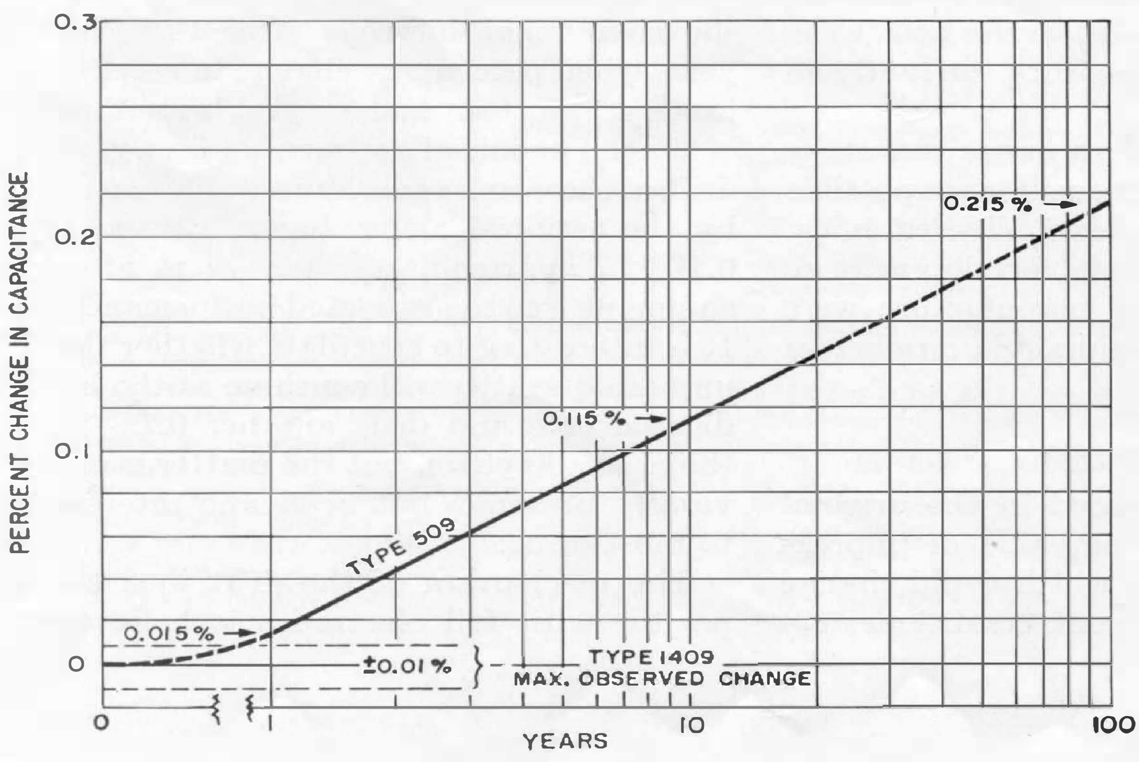


Figure 2. Record of change in capacitance of Type 509 Standard Capacitors in General Radio laboratories over a 22-year period. Range of observed changes in the new Type 1409 units for a 3-year period is shown by the dashed lines.

Moisture is the deadly enemy of good electrical performance in mica, and extreme care must be taken to exclude moisture during assembly of the capacitor. The mica is stored at an elevated temperature for an extended period before assembly. Actual assembly is done in an air-conditioned room with relative humidity maintained at 30% or lower. The assembled capacitor stacks are placed in desiccators until final assembly into their cases.

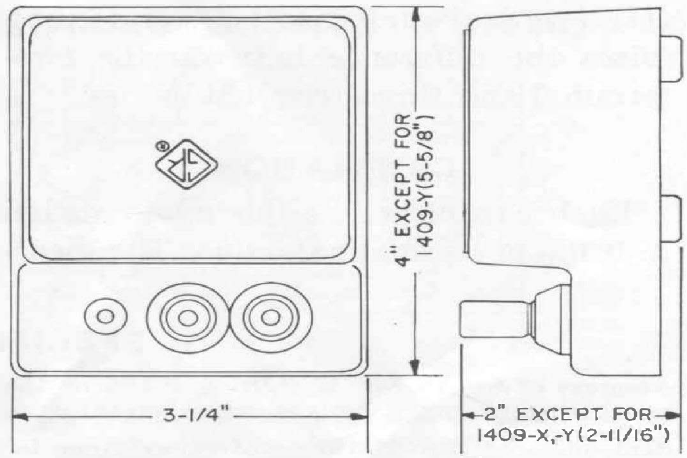


Figure 3. Dimensions of the Type 1409 Standard Capacitors.

HOUSING AND CALIBRATION

Like their predecessors, the new TYPE 1409 Standard Capacitors are encased in a cast-aluminum enclosure, but this also has been redesigned. Weight has been reduced, center of gravity moved nearer the binding posts, and four units have been substantially reduced in volume and weight. An independent ground binding post has been added so that these units may be used either as two-terminal or three-terminal capacitors. Indicated stability and uniformity of temperature coefficient are good enough so that an accurate knowledge of the temperature is useful. Hence, provision has been made for the insertion of a dial-type, bimetallic thermometer into a wall of the case.

To absorb any residual moisture that may remain in spite of all precautions, a quantity of silica gel is sealed into the unit. To insure a good seal and anchorage between the metal and the sealing compound, a groove is milled into the inside walls of the case. Finally, a metal plate is fastened to the bottom to complete the electrostatic shielding.

Mica and foil are so stacked that the two outside foils are connected to the low (L) terminal. This partial shield reduces the capacitance between the high

Figure 4. Mica for the Type 1409 Standard Capacitors is selected for low losses in this test setup using the Type 1605-A Impedance Comparator.

(H) terminal and case (G), and minimizes the difference between the two-terminal and three-terminal values.

CALIBRATION

Each capacitor is adjusted to within ± 0.1% of its nominal value. The measured capacitances for both the two-terminal and the three-terminal connections, at one kilocycle, are entered on the calibration certificate supplied with each capacitor.

— IVAN G. EASTON
P. K. MCELROY

SPECIFICATIONS

Accuracy of Adjustment: Within ± 0.1% of the nominal capacitance value engraved on the case.

Calibration: Measured values of capacitance for both the two-terminal and the three-terminal connections at a specified room temperature are entered in the calibration certificate. These values are obtained by direct comparison, to a precision of better than 0.01%, with a like standard periodically certified by the National Bureau of Standards to an accuracy of ± 0.03% in absolute capacitance.

The TYPE 1409 Standard Capacitors may be connected in parallel with no cumulative error, by plugging them together.

Temperature Coefficient of Capacitance: +35 ±10 ppm per degree Centigrade between 10° and 70° C.

Dissipation Factor: Less than 0.0003 at 1 kc and 23° C. See Figure 5.

Frequency Characteristics: See Figure 5. Values of series inductance and series resistance at 1 Mc are given in the table below. This resistance varies as the square root of the frequency for frequencies above 100 kc.

Leakage Resistance: 5,000 megohm-microfarads or 100,000 megohms, whichever is the lesser.

Maximum Voltage: 500 volts peak at frequencies below the limiting frequencies tabulated below. At higher frequencies the allowable voltage decreases and is inversely proportional to the frequency, approximately. These limits correspond to a temperature rise of 40° Centigrade for a power dissipation of 5, 6, and 7.5 watts respectively, for the three case sizes.

Mounting: Cast aluminum cases with rubber feet.

Terminals: Two insulated jack-top terminals, plus jack-top terminal and ground strap.

Dimensions: See Figure 3.

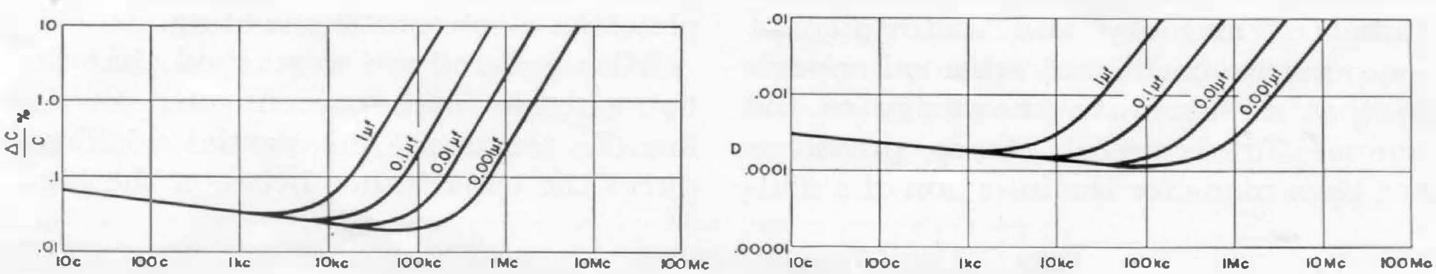


Figure 5. (*Left*) Fractional change in capacitance as a function of frequency. (*Right*) Dissipation factor as a function of frequency.

Type	*Capacitance in μf*	*Maximum Peak Volts*	*Frequency Limit for Max. Volts*	*Series Inductance in μh*	*Resistance in Ohms at 1 Mc*	*Weight in Pounds*	*Code Word*	*Price*
1409-F	0.001	500	4.0 Mc	0.050	0.02	1¼	GOODCONBOY	$ 32.00
1409-G	0.002	500	2.3 Mc	0.050	0.02	1¼	GOODCONBUG	32.00
1409-K	0.005	500	1.1 Mc	0.050	0.02	1¼	GOODCONCAT	34.00
1409-L	0.01	500	640 Kc	0.050	0.02	1¼	GOODCONDOG	34.00
1409-M	0.02	500	370 Kc	0.050	0.02	1¼	GOODCONEYE	36.00
1409-R	0.05	500	175 Kc	0.055	0.02	1¼	GOODCONPIG	39.00
1409-T	0.1	500	100 Kc	0.055	0.02	1¼	GOODCONROD	42.00
1409-U	0.2	500	50 Kc	0.055	0.02	1¼	GOODCONSIN	50.00
1409-X*	0.5	500	20 Kc	0.055	0.02	1¾	GOODCONSUM	80.00
1409-Y†	1.0	500	10 Kc	0.070	0.03	2½	GOODCONTOP	130.00

*Mounted in medium case.
†Mounted in large case.

MEASUREMENT OF CABLE CHARACTERISTICS (Part III)

ATTENUATION OF DUAL-COAXIAL CABLES

Dual-coaxial cables are made up of two, separate, individually shielded, coaxial cables encased in an additional common braided shield and a common jacket. Attenuation is measured for each individual coaxial core separately, and thus the method described above for coaxial cables can be used without modification. The impedance of these cables is usually 62.5 ohms for each coaxial core (125 ohms total for both cores), and the reflection-loss, as determined from Figure 6, is 0.1 db.

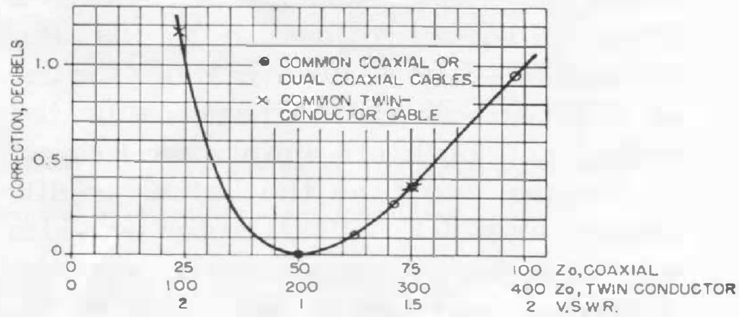


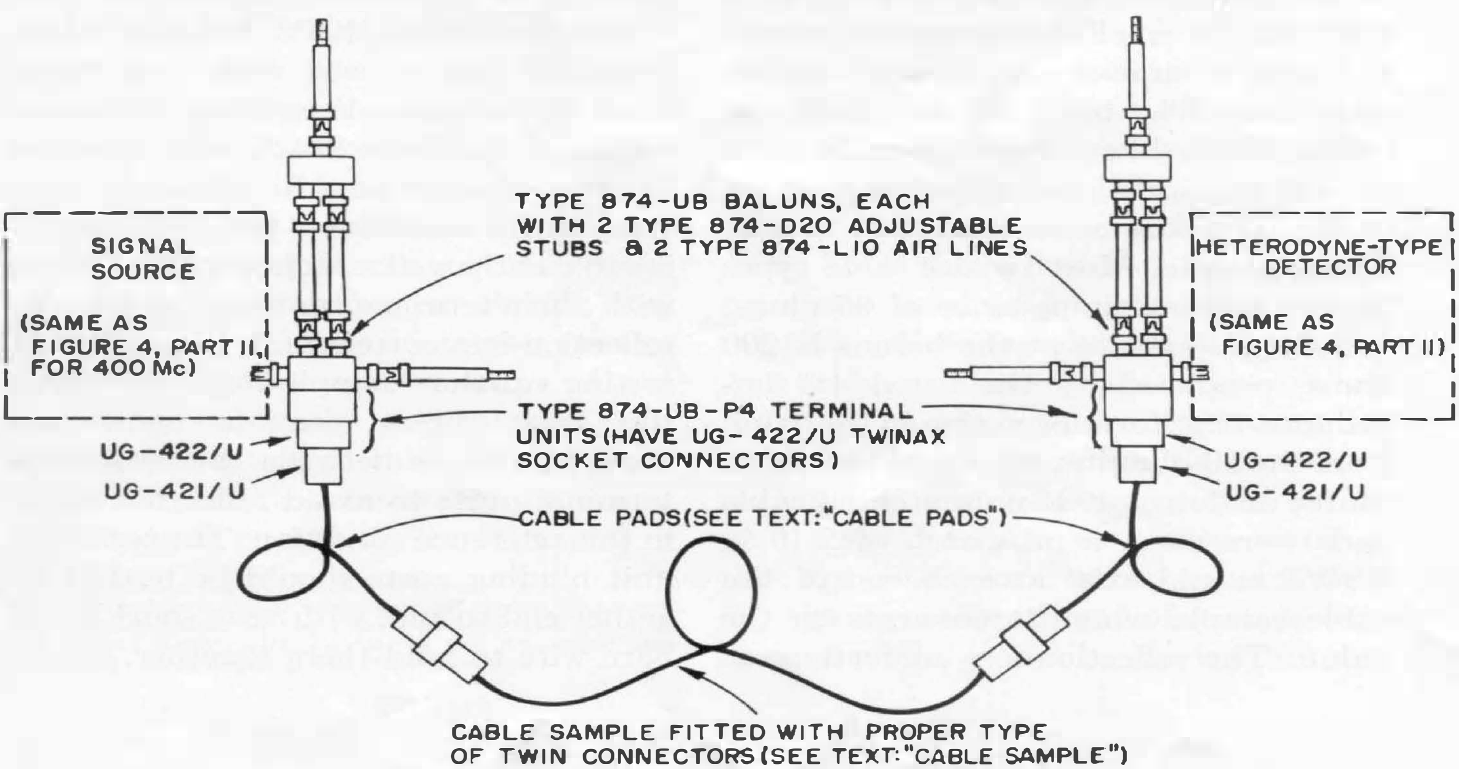
Figure 6. Reflection-loss correction (to be subtracted) vs. cable impedance and VSWR.

ATTENUATION OF SHIELDED TWIN-CONDUCTOR ("Twinax") CABLES

Shielded twin-conductor or "twinax" cables consist, as the name implies, of a pair of parallel, spaced wires surrounded by a shielding braid and must usually be measured only at 400 Mc. They can be measured using the same method with a slight modification of the setup already described for coaxial cables. All that is necessary is the addition of two Type 874-UB Baluns (balanced-to-unbalanced transformers) to the setup at the points where the cable connects to the measuring equipment, as shown in Figure 7.

In this figure the details of the signal source and heterodyne-type detector are not repeated, since they are the same as those shown in Figure 4 (Part II).

Figure 7. Setup for the measurement of attenuation in twinax cables at 400 Mc.



Baluns: The Type 874-UB Balun is a tuned type, and each balun requires 2 Type 874-D20 Adjustable Stubs and 2 Type 874-L10 10-cm Air Lines for use at 400 Mc. The stubs have calibrated scales, and both are simply set to read "17.5 cms." to tune the baluns to 400 Mc. Type 874-UB-P4 Adaptor provides a reliable shielded connection between the output of each balun and a Type UG-422/U twinax socket connector, which connects directly to Type UG-421/U twinax cable plugs on the cable pads.

Cable Pads: These can be made using a length (to give about 10 db attenuation each) of the same cable type as that under test. Small-size twinax cable used for sample and pads can be fitted directly to the UG-422/U series of twinax connectors used on the balun terminal units, using female-to-female adaptors as necessary to make connections. If large-size twinax cable is being used for the sample and for the pads, adaptors from the small-size connectors on the balun terminal units to the large-size series of connectors used on the sample and pads can be readily made from a few inches of RG-22B/U small-size twinax cable with a UG-421/U small-size connector on one end and a large-size connector on the other end. The braid of the small-size cable, if folded back over the cable jacket, will fit nicely into soldering position in the large-size connector.

Cable Sample: Most twinax cable types have a nominal impedance of 95 ohms, and the impedance at the baluns is 200 ohms, produced by the usual 4:1 impedance-transforming action in the balun from the 50-ohm impedance of the signal source or detector. If no matching cable pads were used, a mismatch of 2.10 in VSWR would exist at each end of the cable sample where it connects to the balun. The reflection-loss correction, as determined from Figure 6, would be 1.18 db. (In Figure 6, the impedance scale having 200 ohms opposite a VSWR value of 1 applies when the baluns are used in the measuring setup.) It is recommended, however, that pads be used to match the cable sample between it and the baluns so as to eliminate the need for any reflection-loss correction, partly because the correction is fairly large and partly because, as a result, an appreciable error could then be caused by a small misadjustment of the baluns.

Making the Measurement: The method of measurement is the same as that for coaxial cables, as described previously, and no reflection-loss correction need be made since matching pads are used.

ATTENUATION OF UNSHIELDED TWIN-CONDUCTOR CABLES

There are several 300-ohm cables and one 200-ohm cable in this category. They can be measured by use of the Type 874-UB Baluns in exactly the same way as for the twinax cables just discussed, except that different balun terminal units are used. The reflection-loss correction can always be eliminated.

The Type 874-UB-P3 300-ohm Balun Terminal Pad is used with each balun when 300-ohm cable samples are measured, and the Type 874-UB-P2 200-ohm Terminal Unit is used for 200-ohm cable samples. In both cases, the cable sample is sufficiently well matched by the baluns with their termination units so that no reflection-loss correction is necessary. In setting up the "sample out" condition, the most direct possible connection should be made between the two balun terminal units to avoid reflection errors in this reference condition. The terminal-unit binding posts should be butted together end to end, with very short U's of bare wire to hold them together.

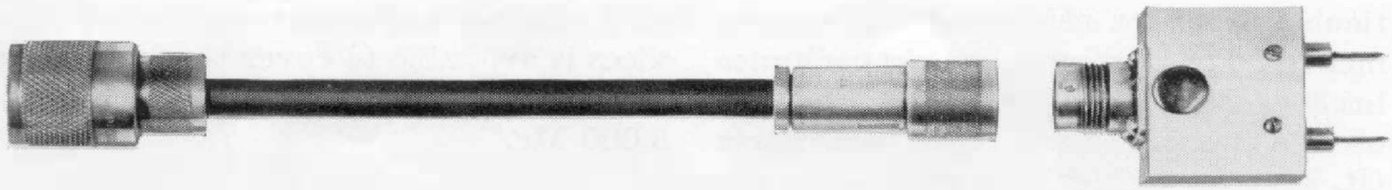


Figure 8. (*Left*) Adaptor made up from RG-22B/U cable with large-size and small-size twinax connectors. (*Right*) Type 874-UB-P4 Adaptor to connect balun to small twinax connector.

Care must be taken to keep the unshielded cable sample well away from interfering objects, including other parts of itself. This requirement rules out measuring a coiled sample and usually requires the sample to be strung around the room, or up and down the hall, on non-metallic hangers and spaced two or three feet from walls, pipes, and the like. This is admittedly a nuisance, but such precautions appear to be unavoidable.

MEASUREMENT OF ATTENUATION AT OTHER FREQUENCIES

There are several military cables that require a measurement of attenuation at 1 Mc. The attenuation values are generally so low that the accurate use of the insertion-loss method requires very long cable lengths. A better method is to use an impedance bridge, with which the open-circuit and short-circuit reactance of a cable sample having an electrical length of one-eighth wavelength and the open-circuit or short-circuit resistance of a cable having an electrical length of a quarter wavelength can be measured. (The electrical length equals the physical length multiplied by the square root of the effective dielectric constant of the insulating material.) Attenuation can then be accurately calculated from these resistance and reactance values, using the following equations.[12]

$$\alpha = \frac{Z_O}{R_{SC}} \times \frac{868.6}{\text{length, ft.}}\ \text{db/100 ft.}$$

or

$$\alpha = \frac{R_{OC}}{Z_O} \times \frac{868.6}{\text{length, ft.}}\ \text{db/100 ft.}$$

where $Z_O = \sqrt{|X_{SC}| \cdot |X_{OC}|}$, X_{SC} and X_{OC} are the short- and open-circuit reactances, respectively, of the eighth wavelength section used to determine Z_o, and R_{SC} and R_{OC} are the resistances for the quarter wavelength section. Measurements at 5 Mc can be made in the same manner.

The TYPE 1606-A R-F Bridge is well suited for measurements at 1 Mc and 5 Mc.

Departing from military specifications for a moment, there are occasions when a cable designer or a development engineer making use of cable might want to measure a particular cable at frequencies other than 1 Mc, 5 Mc, 400 Mc, and 3,000 Mc. The insertion-loss method as described can be used at any frequency between about 20 Mc and 4,000 Mc, a range that includes the UHF television band (475 to 890 Mc), assuming that suitable oscillators are on hand. The bridge method mentioned above can be used at almost any frequency for which a bridge is available, provided that cable lengths can be selected to give resistance and reactance readings that are within, or can be brought within, the accurate range of the bridge. Special methods can be devised in par-

[12]For a detailed discussion of this bridge method, including a refined technique for getting maximum accuracy, see "Measurements of the Characteristics of Transmission Lines," by Ivan G. Easton, in the November and December, 1943, issues of the *Experimenter*.

ticular problems using standard instruments. For example, a capacitance bridge (Type 716-C) can sometimes be used to measure all four cable parameters (R, L, G, and C) of a short cable length (25 ft.) at low frequencies (100 Kc), and attenuation can then be calculated. A large selection of General Radio bridges and similar impedance-measuring devices is available to cover the frequency range from low audio frequencies to 5,000 Mc.[13]

— W. R. Thurston

(To be continued)

[13]Our Sales Engineering Department will be glad to make recommendations for any specific measurement problems.

LIST OF EQUIPMENT

In addition to the items listed in previous installments, the following units are used in measuring twin-conductor cables.

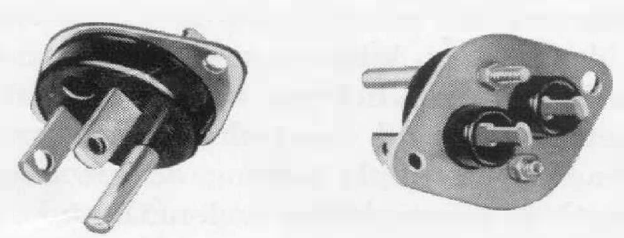
Quantity	Item	Price
2	Type 874-UB Balun .... @ $75.00	$150.00
2	Type 874-UB-P2 200-ohm Terminal Unit .... @ 6.50	13.00
2	Type 874-UB-P3 300-ohm Terminal Pad .... @ 15.00	30.00
2	Type 874-UB-P4 Adaptor .... @ 50.00	100.00
4	Type 874-L10 Air Lines .... @ 5.50	22.00
4	Type 874-D20 Adjustable Stubs .... @ 14.00	56.00

For measurements by the bridge method at 1 Mc, the following instruments are recommended:

Quantity	Item	Price
1	Type 1606-A Radio-Frequency Bridge	$620.00
1	Type 1212-A Unit Null Detector	145.00
1	Type 1211-B Unit Oscillator	275.00
1	Type 1212-P2 1-Mc Filter	30.00
2	Type 1203-B Power Supplies .... @ $40.00	80.00

NEW COMBINATION 3-WIRE AND 2-WIRE POWER RECEPTACLE

As rapidly as production schedules will permit, General Radio ac-operated instruments are being equipped with 3-contact power-input receptacles that will accept either the standard 2-wire power cord, Type CAP-35, or the new 3-wire cord CAP-15.* The 2-wire cord will be supplied with instruments unless the 3-wire type is specified in the order.



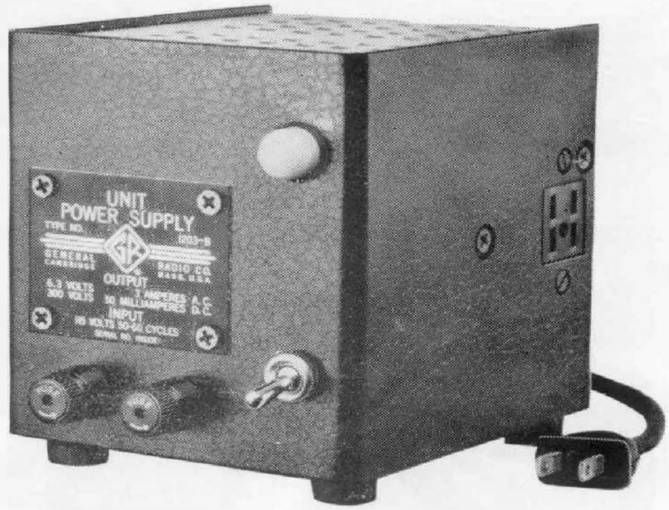
Front and rear views of the Type 109-A 3-wire receptacle.

The new 3-wire receptacle is available for installation by our customers in instruments that now have the 2-wire receptacle. Designated Type 109-A, this receptacle, unlike the old 2-wire type, is not recessed, which would require an excessively large diameter. Instead, the new receptacle is interchangeable with the old 2-wire receptacle on existing instruments, without change in mounting holes.

Type		Code Word	Price
109-A	3-wire Receptacle	TRIPU	$1.25

*"3-Wire Power Cord" *General Radio Experimenter*, 31, 9, February, 1957.

TYPE 1203-B UNIT POWER SUPPLY



View of the Type 1203-B Unit Power Supply.

The popular, general-purpose Unit Power Supply TYPE 1203-A, designed primarily to provide a-c heater and d-c plate power for General Radio Unit Instruments, has been replaced by an improved version TYPE 1203-B. The circuit of the new model has been revised to include additional filter capacitance, thereby reducing the output ripple. By a rearrangement of components, the fuses have been moved to the front panel for greater convenience of servicing.

The 230 v, 50-cycle model TYPE 1203-AQ11 has been replaced by the TYPE 1203-BQ18 for 230 v, 50- to 60-cycle service.

In both new models these changes have been accomplished at no increase in price.

SPECIFICATIONS

Output (at 115-v input): 300 v dc (±5%) at 50 ma; 6.3 v ac at 3 amp; (with a-c load at 1.5 amp or less, max d-c load is 65 ma, about 285 v dc).

Regulation: At no load, d-c output is 380 v.

Ripple: Less than 80 mv (120 cps) at full load.

Input: 105-125 v, 50-60 cps, 50 w full load at 115 v.

Connectors: Line cord permanently attached to instrument. Standard 4-point connector mounted on cabinet side for other Unit Instruments.

Rectifier: 6X4.

Accessories Supplied: Mating plug for equipment other than Unit Instruments; spare fuses.

Housing: Black-crackle-finish aluminum panel and sides. Aluminum cover finished in clear lacquer.

Dimensions: Width 5 in., height 5¾ in., depth 6¼ in. over-all, not including power cord.

Weight: 5 pounds.

Type		*Code Word*	*Price*
1203-B	(115 volts, 50-60 cycles)	ALIVE	$40.00
1203-BQ18	(230 volts, 50-60 cycles)	ALIVEREGAL	50.00

VACATION CLOSING

During the weeks of July 22 and July 29, our Manufacturing Departments will be closed for vacation.

There will be business as usual in the Sales Engineering and Commercial Departments. Inquiries, including requests for technical and commercial information, will receive our usual prompt attention.

Our Service Department requests that, because of absences in the manufacturing and repair groups, shipments of equipment to be repaired be scheduled to reach us after the vacation period.

CHAIRMAN RETIRES

Harold B. Richmond, for the past thirteen years Chairman of the Board of the General Radio Company, retired on June 30, 1957, having reached the Company's mandatory retirement age.

After his graduation from the Massachusetts Institute of Technology in 1914, he served with Stone & Webster and later was a member of the electrical engineering teaching staff at MIT. He was called to active duty as an officer in the Coast Artillery Corps in the first World War. He joined the General Radio Company as an engineer in 1919 and two years later was elected its Secretary. He became Treasurer in 1926, which position he held until his election as Chairman of the Board of Directors.

His principal interests have always been in the business and managerial affairs of the Company. In addition to carrying on this work with vigor and high ability, Mr. Richmond has found time for notable work in outside affairs. He has been director and president of the Radio Manufacturers Association (now RETMA); director, president and chairman of the Scientific Apparatus Makers Association; director of the Liberty Mutual Insurance Company and of the Boston Woven Hose and Rubber Company. In addition, because of a deep interest in education, he has served for many years as a member of the corporation of the Massachusetts Institute of Technology and as a trustee of Northeastern University and of Norwich University.

During the second World War, he was Chief of the Guided Missile Division of the National Defense Research Committee at a time when few had much faith in the future of guided missiles. For his energy and foresight in promoting continued research along these lines, he was awarded the Presidential Medal for Merit and was later Chairman of the National Academy of Science Ordnance Advisory Committee on Guided Missiles.

His wise leadership and counsel have contributed much to the establishment of many of the Company's basic policies and to its present position in the industry.

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