the GENERAL RADIO Experimenter

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VOLUME 32 No. 3 AUGUST, 1957

Photograph courtesy of Hycon Eastern

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the GENERAL RADIO **Experimenter**

Published Monthly by the General Radio Company

VOLUME 32 • NUMBER 3 AUGUST, 1957

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The General Radio EXPERIMENTER is mailed without charge each month to engineers, scientists, technicians, and others interested in electronic techniques in measurement. 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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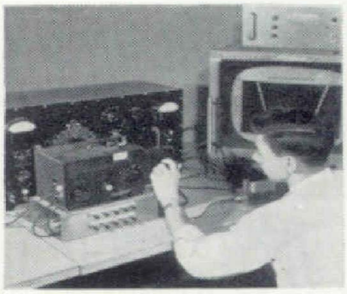


Production testing the Hycon Eastern Model 13MA Crystal Filter for i-f shaping. The filter operates at 13 Mc and has a 30-kc bandwidth. The sweep frequency is supplied by the Type 805-C Standard-Signal Generator, whose slow-motion dial is driven by the Type 1750-A Sweep Drive.

THE MEASUREMENT OF CABLE CHARACTERISTICS (Part IV)

MEASUREMENT OF CHARACTERISTIC IMPEDANCE (Z_o)

In Part I it was shown that the characteristic impedance of polyethylene-dielectric and teflon-dielectric cables is constant at very low frequencies, decreases somewhat in a medium-frequency range, and is again constant at a lower value at very high frequencies. (See Figure 3a.) Characteristic impedance can easily be determined at any desired frequency if a suitable impedance bridge[13] is available with which to measure the open-circuit reactance, X_{oc}, and short-circuit reactance, X_{sc}, of a sample length of cable.[14] The characteristic impedance is then $Z_o = \sqrt{X_{oc}X_{sc}}$.

The bridge method is the most satisfactory method for measurements on cables at low frequencies, such as 1 Mc, where the inductance varies with respect to frequency, and for measurements on rubber-dielectric cables and other types of cables in which capacitance is not independent of frequency. Twin-conductor cables are more difficult but can be measured by use of the TYPE 874-UB Balun connected between the bridge and the cable sample and adapted to the desired frequency of measurement.

Since polyethylene-dielectric and teflon-dielectric cables have practically constant Z_o for all frequencies above about 20 to 40 Mc, and since it is this value of Z_o that enters into most applications and is usually listed, an indirect method of measuring Z_o can be used. This method is based upon the following simple relation to velocity of propagation (v) and capacitance (C):

$$Z_o = \frac{101{,}600}{(v \text{ in per cent}) \times (C \text{ in } \mu\mu f \text{ per ft.})}$$

ohms. Since C for polyethylene-dielectric or teflon-dielectric cables is independent of frequency, it can be measured at any convenient low frequency, such as 1,000 cycles. (MIL-C-17B Specification allows any frequency from 1,000 cycles to 1 Mc.) The relative velocity of propagation, v, can be determined, as outlined in the following section, at any convenient frequency above the region of changing characteristic impedance. Then Z_o can be calculated from the formula given. The advantages of this indirect method are that it is simple and requires less expensive equipment than the impedance-bridge method, and the high-frequency part of the measurement (measurement of v) can be made using some of the same equipment that is necessary for the measurement of attenuation. Thus we have reduced the measurement of Z_o to the easier measurements of v and C. Because of the small variations in characteristics that occur from point to point along a flexible cable, it is desirable to use the same piece of cable for both measurements.

MEASUREMENT OF VELOCITY OF PROPAGATION (v)

The usual reason for making this measurement is, as implied above, to determine characteristic impedance (Z_o), but the value of v is occasionally required for other reasons. Since v is constant at high frequencies (Figure 3b), the frequency of measurement is not at all critical provided that it is above 20 to 40 Mc. The measurement can be made with the equipment shown in Figure 9.

The TYPE 1208-B Unit Oscillator, amplitude-modulated, delivers power

[13]Our Sales Engineering Department will be glad to make recommendations for any specific measurement problems.
[14]Preferably near an electrical length of one-eighth wavelength.

through a Type 874-G10 10-db Pad and a patch cord to a Type 874-Q2 Adaptor fitted with banana plugs. These plug into the jack-top binding posts of a second Type 874-Q2 Adaptor,[15] and one end of the cable sample is also connected across these binding posts. (Connectors are not used on the cable sample for this measurement.) The coaxial end of the second adaptor connects to one end of the Type 874-VQ Voltmeter Detector, whose other end is terminated in a Type 874-WM 50-ohm Termination. The demodulated audio envelope signal is connected by a patch cord to the Type 1212-A Unit Null Detector. The Type 720-A Heterodyne Frequency Meter is strongly recommended in order to improve the accuracy with which the frequency is known from 2% to 0.1% and to reduce very significantly the danger of miscalculating the number of quarter-wavelengths, k, in the cable sample, as described below.

It can be seen that this system can be described as consisting of a 50-ohm generator of variable frequency driving an untuned voltmeter in parallel with the cable sample input. If the other end of the cable sample is open-circuited, and if the oscillator frequency is varied, the cable-sample input impedance will vary between alternate maximum and minimum values, with the minima marked by minimum indications on the voltmeter. It is well known that the minima occur when the length of the cable sample is equal to an odd number of quarter-wavelengths.

The measurement is made by finding the frequencies for two adjacent voltmeter minimum readings. Before using the frequencies so found, it is desirable to find also the next several frequencies for minima and to check that the separations between any two adjacent frequencies are reasonably uniform, thus guarding against being misled by a possible spurious minimum. Call the lower of the two frequencies to be used f_1 and the next higher one f_2. The physical length, l, of the cable sample is also measured. To calculate per cent velocity from these data, first determine the number, k, of quarter-wavelengths contained in the sample length at the frequency of f_1 by means of the following approximate[16] relation:

[15]The Type 874-Q2 Adaptor is supplied with two banana plugs and two binding posts.

[16]This formula is approximate because of normal measurement errors in determining $f1$ and $f2$, and because k must be an exact, odd integer.

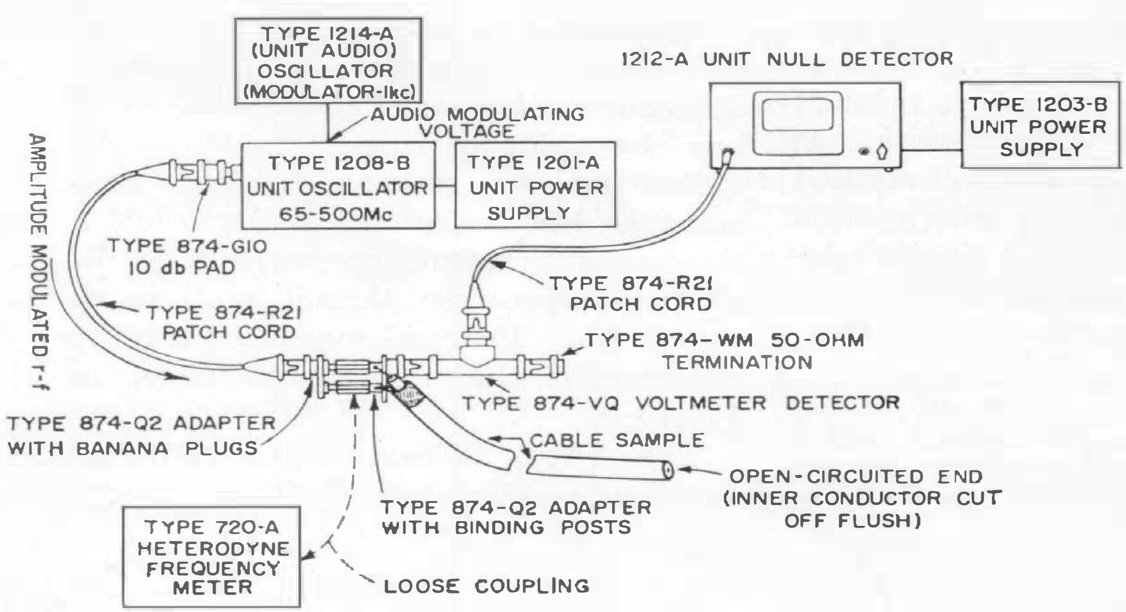


Figure 9. Arrangement of equipment for measurement of velocity of propagation in coaxial cables.

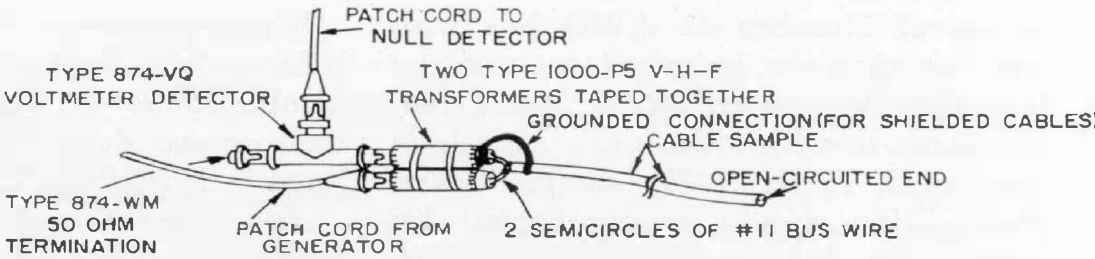


Figure 10. Method of connections to twin-conductor cables. The remainder of the measuring system is identical with that of Figure 9. Instead of copper foil and tape, Type 874-ZC Clamps can be used, if desired.

$$k \cong \frac{2f_1}{f_2 - f_1},$$

using for the quantity $(f_2 - f_1)$ the average difference between successive frequencies. As calculated, k should be very close to an odd integer and should be rounded off to this integer, which is then used in the following formula to determine per cent velocity:

$$v = \frac{(l \text{ in ft.}) \text{ x } (f_1 \text{ in Mc})}{(2.46) \text{ x } (k, \text{ integer})} \text{ per cent.}$$

A convenient length for the cable sample is about 25 feet, which will result in values for $(f_2 - f_1)$ of around 12 Mc for polyethylene-dielectric cables and around 15 Mc for polyethylene-and-air-dielectric cables. It is convenient to choose f_1 in the 100- to 200-Mc range, since the heterodyne frequency meter is direct reading in this range. If much longer cable samples or higher frequencies are used, successive minima are more closely spaced percentage-wise, and there is the possibility that k will not be selected properly, an error that is not easy to detect. If the frequency meter is not used, it is recommended that lower frequencies and/or shorter cable samples be used to minimize this danger. The frequency range of the Type 1208-B Oscillator (65-500 Mc) is adequate for most applications.

The error of measurement equals the sum of the error in determining l and the error in determining f_1. The physical length of the cable sample can probably be measured with an accuracy of ±½ inch or better, but end effects must also be considered. The equivalent electrical "length" (due to fringe capacitance) of the open circuit at the far end of the cable can be kept to less than ¼ inch, and the length of cable input connections to the binding posts kept to less than ½ inch with reasonable care and for all but the largest cable types. These end effects will be approximately compensated if ¼ inch (or more for larger cables) is added to the measured length of the cable proper. All things considered, in typical cases the error of measuring l is about ±0.4% for a 25-foot length. The error of measuring frequency is ± 2% if the calibration of the Type 1208-B Oscillator is used directly, but the use of the Type 720-A Heterodyne Frequency Meter improves this to ±0.1%. Therefore, the over-all accuracy of determining per cent velocity can be about ±0.5%. Because of the variations in characteristic impedance along the cable, mentioned earlier, this accuracy is probably somewhat better than is significant.

The measurement of twin-conductor cables, shielded or unshielded, is made in exactly the same way as just described, except that two Type 1000-P5 V-H-F Transformers (untuned, balanced-to-unbalanced transformers for the 50-250-Mc range) are used to connect the generator and the voltmeter, respectively, to the input end of the cable sample, as shown in Figure 10. The two transformers are strapped together with copper foil (to provide a common ground) and tape, and two short semicircles of Number 11 AWG bus wire join together the balanced ends of the transformers and are at the same time terminals to which the cable sample is connected. If the cable sample has a shield, this should be connected by means of a short, wide copper strap to the common ground of the transformers.

MEASUREMENT OF CAPACITANCE (C) AND CAPACITANCE UNBALANCE[17]

The capacitance per foot (C) of cables, usually required for the determination of characteristic impedance (Z_0) and useful in its own right for inspection purposes and for circuit calculations at low frequencies, can be easily measured with very high accuracy. The high accuracy is desirable for two reasons: (1) The error in Z_0 as determined from measured values of velocity of propagation (v) and capacitance (C) is the sum of the errors in both measurements, and minimizing the capacitance error helps to maintain reasonable accuracy for Zo. (2) In the measurement of capacitance unbalance of shielded twin-conductor cables, the final answer is directly proportional to the difference between two, nearly equal, measured capacitance values, and, if most of the allowed cable tolerance is to be utilized, accurate measurements are essential. We have already seen that for polyethylene-dielectric and teflon-dielectric cables the capacitance is independent of frequency and that MIL specifications allow the use of any frequency between 1,000 cycles and 1 Mc for the measurement. In the interests of accuracy it is best to select a low frequency, and 1,000 cycles is usually most convenient. The TYPE 716-C Capacitance Bridge is well suited for this measurement because of its wide capacitance range and its high accuracy.

The measurement of capacitance unbalance is made by connecting various combinations of the two inner conductors and shield to the bridge as outlined in MIL-C-17B Specification.[17]

For best accuracy the substitution method is recommended. Using the correction chart mounted on the panel of each instrument, one can obtain an accuracy of ±0.1% or ±0.8 μμf, whichever is greater, for capacitance values up to 1,000 μμf. Twenty-five feet of 50-ohm polyethylene cable normally has a capacitance of about 750 μμf, to which the 0.8 μμf accuracy figure applies. If longer samples are used, making the capacitance greater than 1,000 μμf, the 0.1% accuracy can be maintained through the use of TYPE 1409 Standard Condensers. TYPE 505 Condensers are satisfactory for initial balancing. In the measurement of capacitance unbalance, capacitance differences of less than 800 μμf will be encountered, and the accuracy of ±0.8 μμf can be improved to ±0.2 μμf, if desired, by the use of worm correction data supplied with the TYPE 716-C Bridge on special order.

Twin-conductor cables can be measured using the three-measurement method.

The TYPE 1214-A Unit Oscillator (400 or 1,000 cycles), already required for the velocity-of-propagation measurements, is a very satisfactory generator for the bridge, and the TYPE 1212-A Unit Null Detector (also used in the other measurement), with the TYPE 1951-A Filter, is an excellent bridge detector. No other equipment is needed.

— W. R. THURSTON

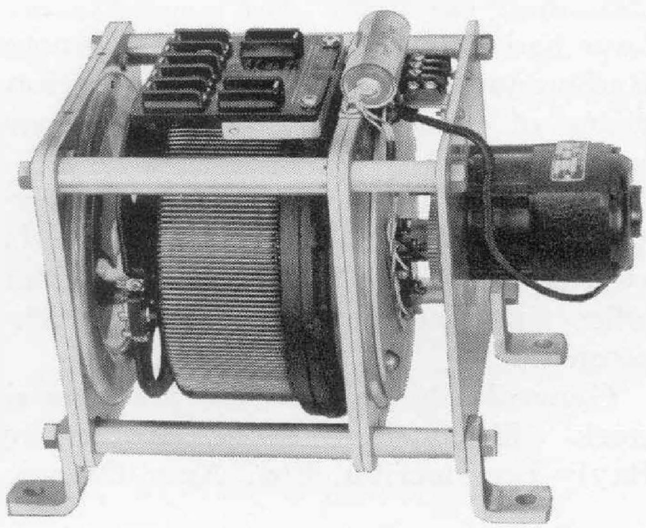
(To be concluded)

[17]Because the measurement of capacitance unbalance, a characteristic of shielded twin-conductor cables, is discussed in MIL-C-17B Specification, it will not be discussed in detail in this article.

The equipment for the measurements discussed in this article includes many items listed in previous installments. In addition, the following are needed:

Quantity	Item		Price
1	Type 1214-A Unit Oscillator		$ 75.00
2	Type 874-Q2 Adaptor	@ $ 4.25	8.50
1	Type 874-WM 50-ohm Termination		12.50
1	Type 874-VQ Voltmeter Detector		30.00
1	Type 1212-A Unit Null Detector		145.00
1	Type 1201-A Unit Power Supply		85.00
2	Type 1000-P5 V-H-F Transformer	@ 27.50	55.00

MOTOR DRIVE FOR V10, V20 VARIACS®



The popular V10 and V20 series of Variacs is now available in motor-driven models, as listed in the table below. These models do not have ball bearings and are supplied without cases.

Prices given in the table are per unit for a minimum quantity of 5 units. For less than 5 units, add the set-up charge.

Type numbers are made up as follows:

V10HG3 D 16 C K S

- V10HG3 — Variac Type No.
- D — Motor Drive
- 16 — Traverse Time
- C — Capacitor*
- K — Microswitches*
- S — **

* Capacitor and microswitches are supplied on all models.

**Add S to all type numbers for motor-driven V10 and V20 models.

Ounce-in. Torque	120	240	480	240	480	960	
Capacitor Included	Yes	Yes	Yes	Yes	Yes	Yes	
Microswitches Included	Yes	Yes	Yes	Yes	Yes	Yes	
Seconds for 320 Traverse	8	16	32	32	64	128	
Variac Type							*Set-Up Charge Prorated 1-4 Units*
V10	$138.00	$138.00	$138.00	$138.00	$138.00	$138.00	$12.00
V10G2	—	184.00	184.00	184.00	184.00	184.00	12.00
V10G3	—	218.00	218.00	218.00	218.00	218.00	12.00
V10H	139.00	139.00	139.00	139.00	139.00	139.00	12.00
V10HG2	—	186.00	186.00	186.00	186.00	186.00	12.00
V10HG3	—	221.00	221.00	221.00	221.00	221.00	12.00
V20	162.00	162.00	162.00	162.00	162.00	162.00	12.00
V20G2	—	236.00	236.00	236.00	236.00	236.00	12.00
V20G3	—	—	292.00	—	292.00	292.00	12.00
V20H	162.00	162.00	162.00	162.00	162.00	162.00	12.00
V20HG2	—	236.00	236.00	236.00	236.00	236.00	12.00
V20HG3	—	—	292.00	—	292.00	292.00	12.00

NEW CANADIAN OFFICE

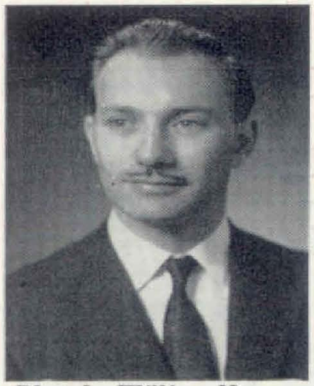


Photo by William Notman

ARTHUR KINGSNORTH

Photo by Ashley Crippen

RICHARD PROVAN

To provide the best service for our Canadian customers, a General Radio factory branch office for Canada was opened August 1.

The new office is located at 99 Floral Parkway, Toronto 15, Ontario, just south of Route 401 at the Keele Street turnoff. We cordially invite you to visit us there. There will be a substantial stock of instruments available, which we hope that many *Experimenter* readers will take the opportunity to inspect.

This extension of our domestic direct-sales policy has terminated a long and cordial association with the Canadian Marconi Company, our representatives for many years.

The new office is in charge of Arthur Kingsnorth, ably assisted by Richard J. Provan. Both are well known to Canadian engineers and scientists and have had much experience with General Radio equipment through their previous years of association with our representatives.

The telephone number is CHerry 4-6221. If you are a resident of Canada, your phone call or letter directly to that office will receive prompt and effective attention.

General Radio service and repair work will continue to be handled by Bayly Engineering, Ltd., Ajax, Ontario.

STORAGE BOX FOR TYPE 1021-P OSCILLATOR UNITS

The versatile TYPE 1021 Standard Signal Generators cover a frequency range from 40 Mc to 2000 Mc by means of three oscillator units and a common power supply cabinet.

Since the safe storage of oscillator units not in use has frequently been a problem, we are making available the TYPE 1021-P10 Storage Box, which will hold one oscillator unit. This box is made of treated, moisture-resistant white wood and is virtually dust tight.

Type		*Code Word*	*Price*
1021-P10	Storage Box	BOXEY	$18.00

General Radio Company

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