THE General Radio EXPERIMENTER

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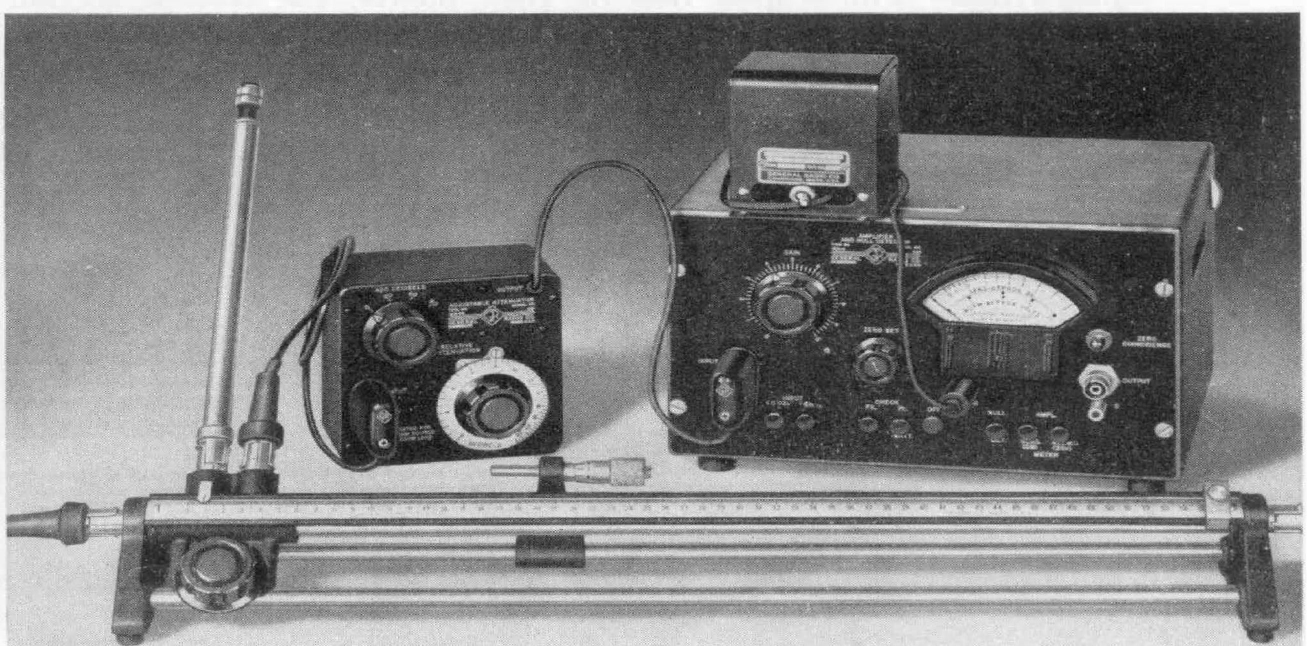
ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

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.

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

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

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

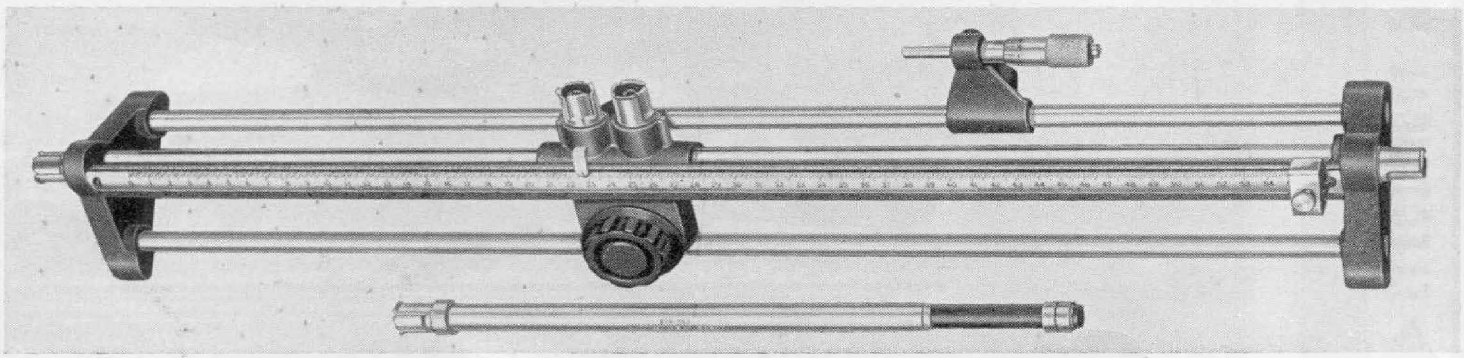


TABLE 1. DETECTOR CHARACTERISTICS

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 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.

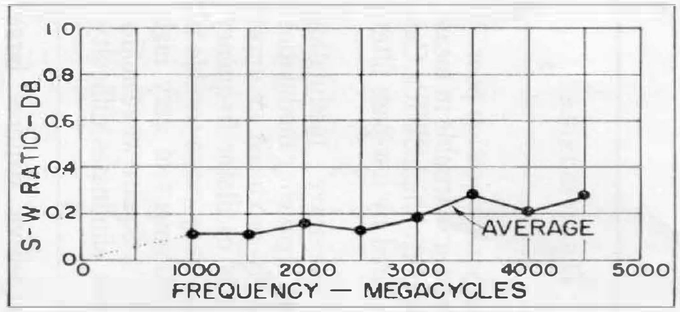


Figure 4. Standing-wave ratio of Type 874 Coaxial Connectors as a function of frequency. The values plotted are the averages of measurements made on a group of connectors. The maximum SWR measured at any point was 0.5 db.

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.

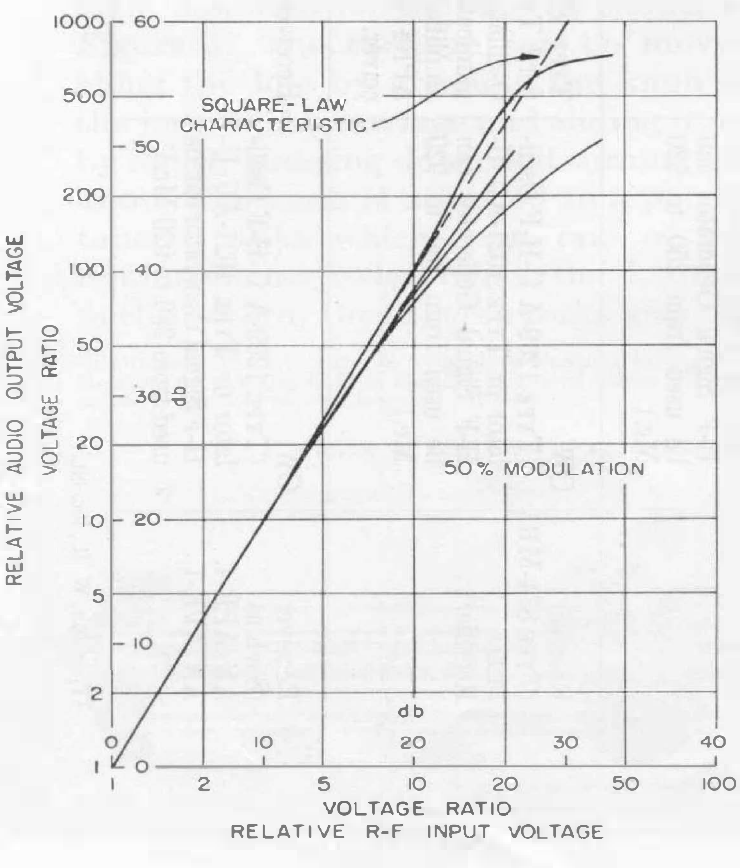


Figure 3. Rectification characteristics of several typical crystals, as measured on the Type 1231-P4 Adjustable Attenuator with the Type 1231-B Amplifier set at maximum sensitivity and full-scale deflection. The deviation from the square-law characteristic is less than ½ db for an input voltage range 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.

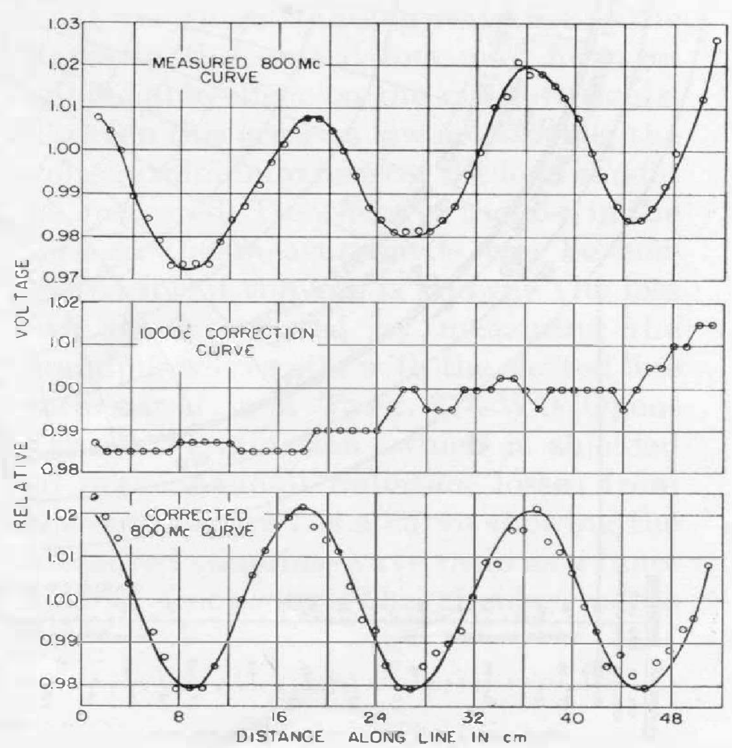


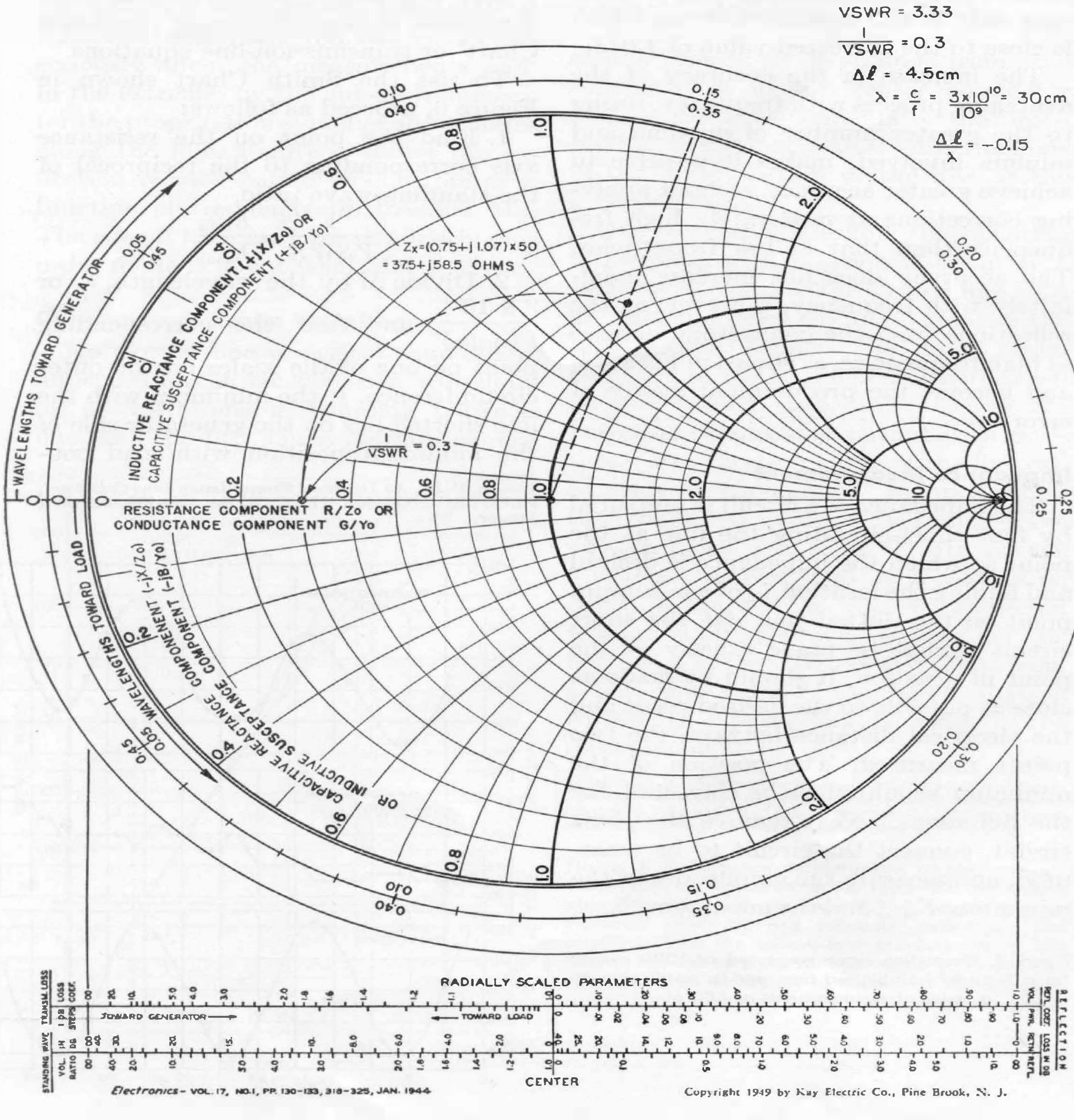
Figure 5. Correction curve measured at 1000 cycles, for a Type 874-LB Slotted Line, and its application to a series of measurements at 800 Mc.

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.



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.

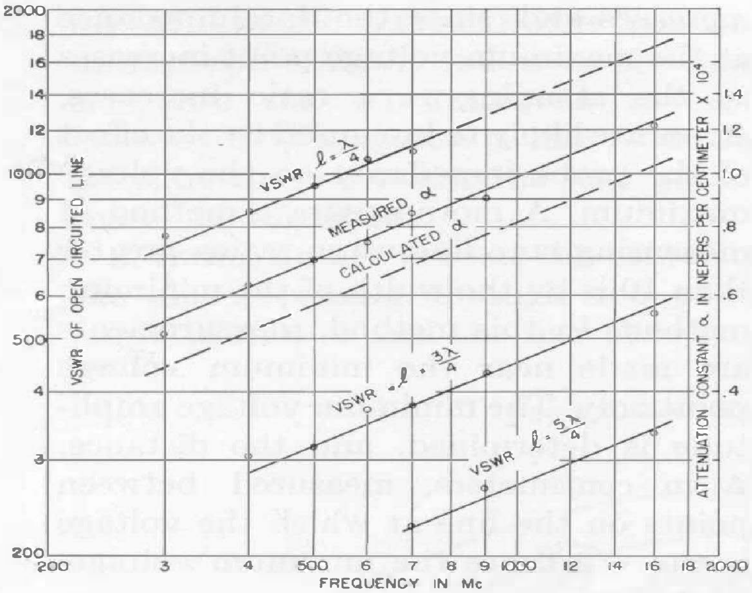


Figure 7. VSWR and attenuation constant of a Type 874-LB Slotted Line terminated in an open circuit.

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.

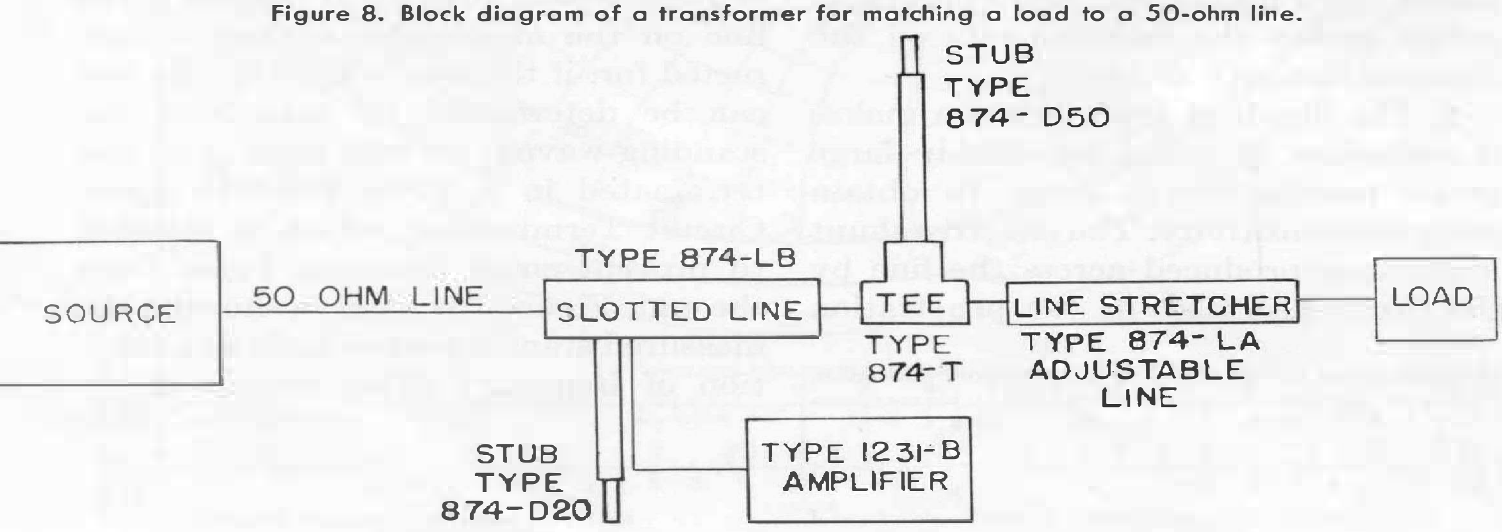
Harmonics

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.



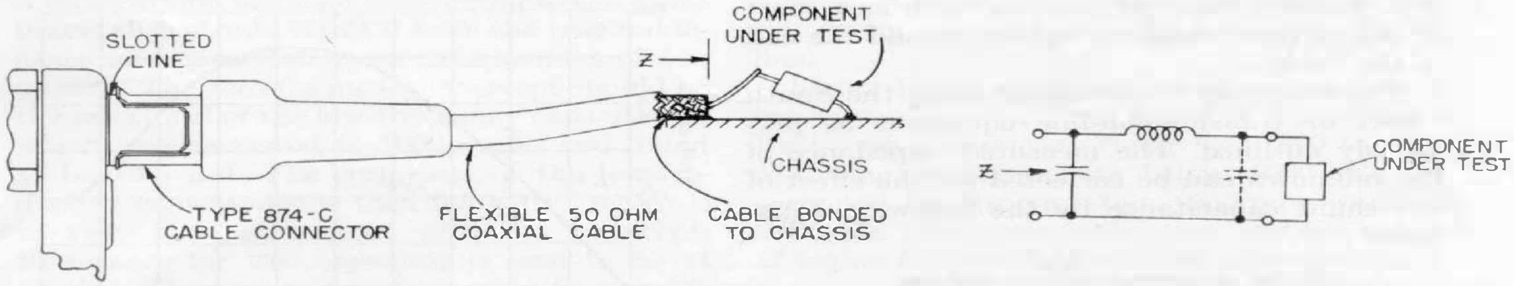


Figure 9. One method of connecting a component to a slotted line. The equivalent circuit is shown at the right.

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.

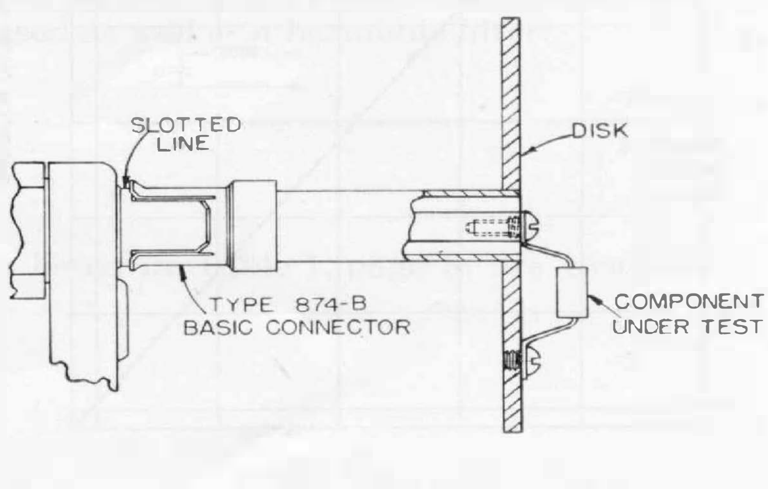


Figure 10. Recommended method of connection when isolated components are to be measured.

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.

[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.

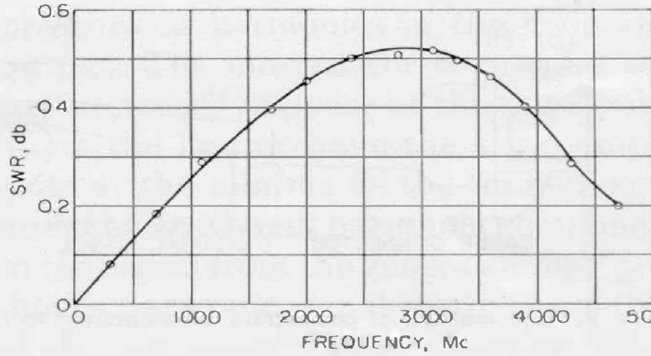
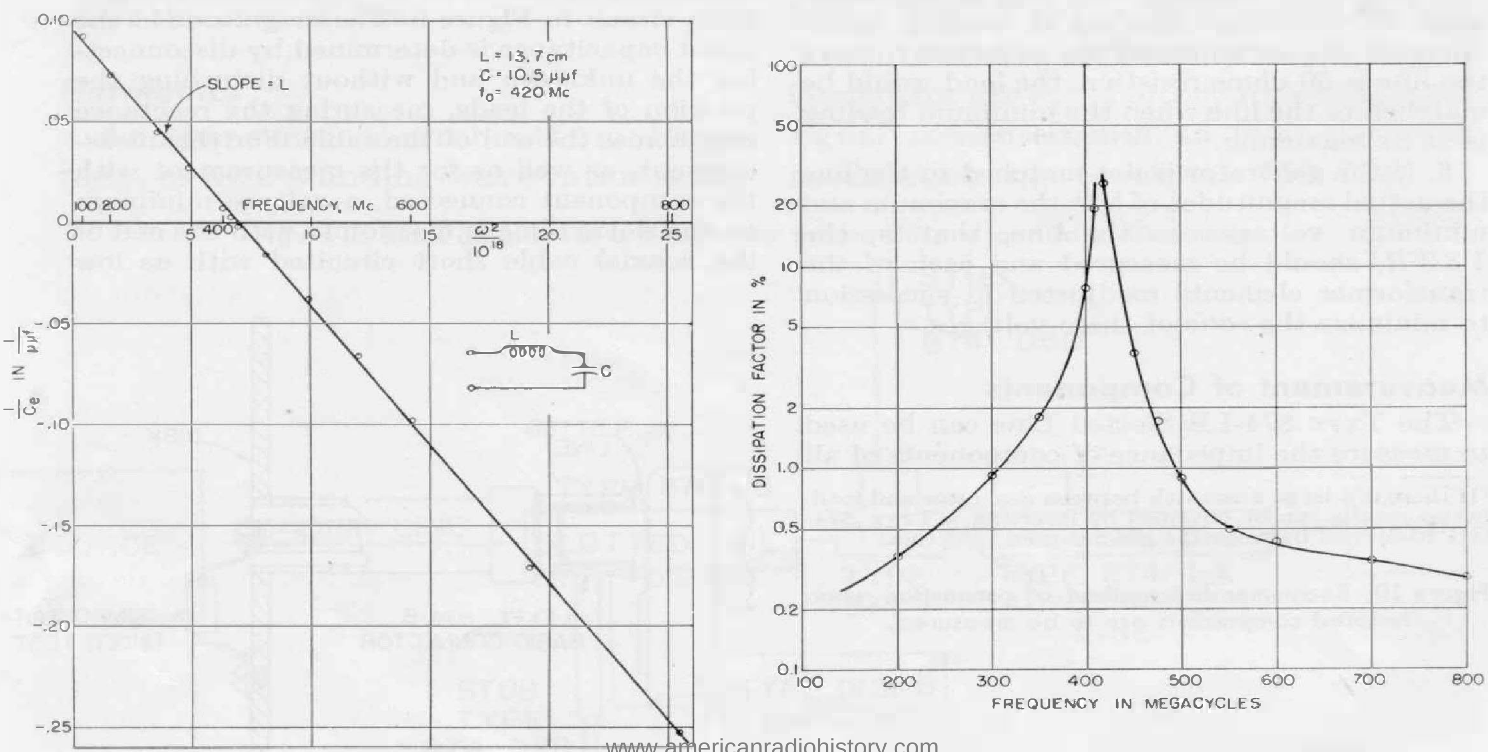


Figure 12. Plot of standing-wave ratio of the Type 874-WM 50-Ohm Termination as a function of frequency.

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.

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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