the GENERAL RADIO
Experimenter

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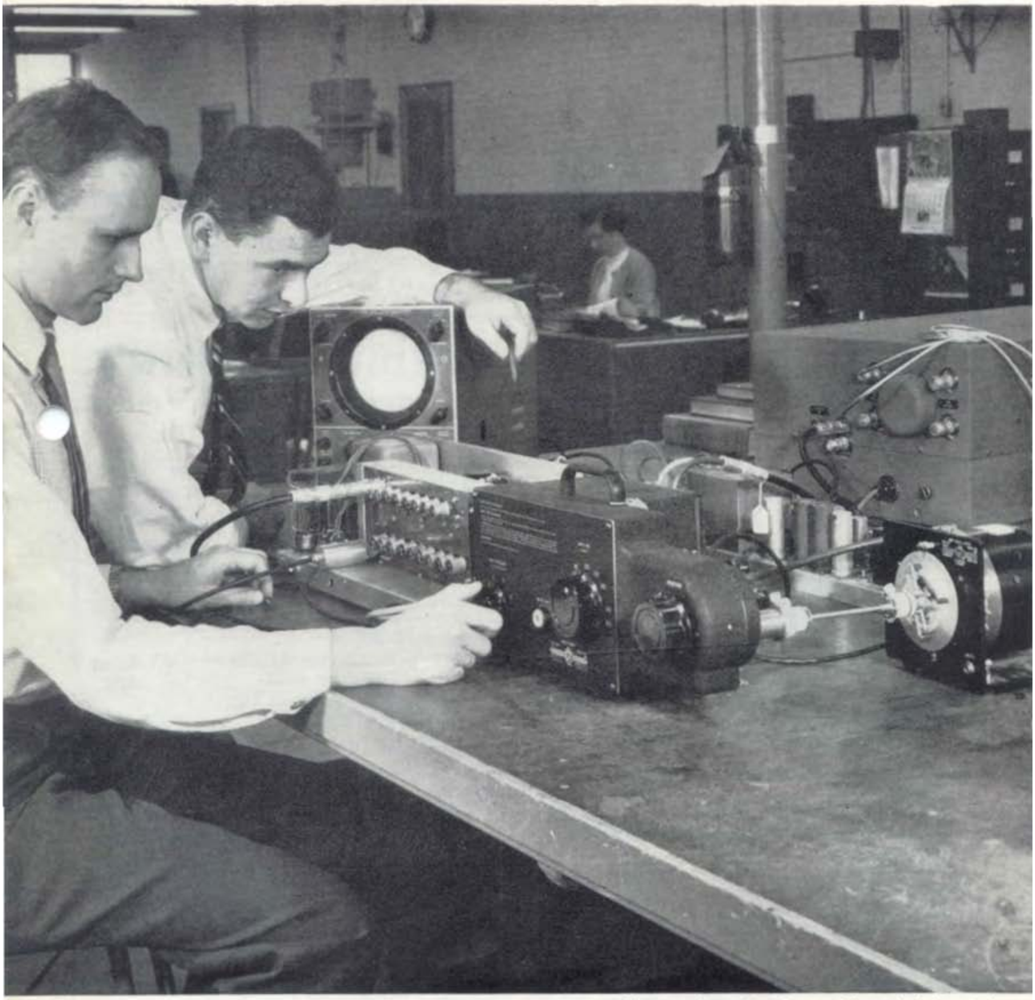

Photograph courtesy Spencer-Kennedy Laboratories

In This Issue

COVER

Engineers at Spencer-Kennedy Laboratories use the GR Type 1750-A Sweep Drive and Type 1208-B Unit Oscillator in development work on the SKL Model 206 Ultra-Wide-Band Amplifier (600 cps to 320 Mc). For wide-band testing, both in development and in production, Spencer-Kennedy finds that this sweep drive speeds up testing, saves time and money while maintaining accuracy.

the GENERAL RADIO Experimenter

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ON THE TRA

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ON THE TRACKING OF SATELLITES

The technical press has carried recently several letters[1] and articles about Doppler-shift measurements of the radio transmission from the satellites Sputnik I and Sputnik II and the calculation of slant height directly from the frequency shift data.

This article discusses a similar set of measurements and certain refinements in the handling of the data, which were used to predict the path of the satellite and its time of transit for use by the local Moon-Watch group.

The measurements described here were made by two members of the General Radio engineering staff, W. F. Byers and R. J. Ruplenas, who happen also to be radio "hams." From their measurements, it has been possible to calculate the distances of closest approach for each observed transit of the satellite. As one can note from the quoted times of transit, the whole project was extracurricular, undertaken in the true amateur spirit.

Since the satellites travel at almost 18,000 miles per hour, the total Doppler shift at 20 Mc is over 1000 cps, and at 40 Mc it is over 2000 cps. Thus, by listening to the received signal with a suitable reference oscillator beating against it, one can hear and measure the change in beat frequency as the satellite goes by. Simple equipment is adequate for this measurement. Byers and Ruplenas used harmonics of quartz-crystal-controlled oscillators for the reference signals at 20 Mc and 40 Mc. They measured the audio beat tone by comparing it with a stable, calibrated audio oscillator set to multiples of 50 cps, noting the times of coincidence in terms of clocks standardized against WWV time signals. More elaborate techniques using tape recorders were considered, but this simple technique was sufficiently good to give useful results.

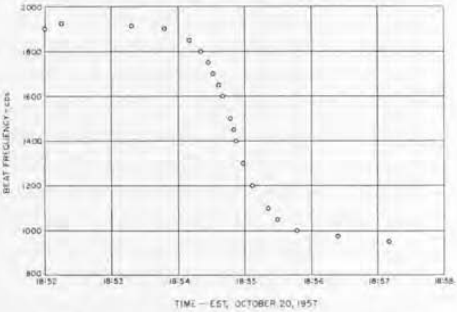

Figure 1. Measured frequency shift of signal from Sputnik I.

The simple Doppler equation used for the calculation of distance is based on straight-line motion and is:

$$\Delta f \simeq \frac{\pm f_0 v}{c\sqrt{1 + \left(\frac{D}{v\Delta t}\right)^2}} \qquad (1)$$

where

Δf is the frequency shift

v is the velocity of the satellite

c is the velocity of light

f_0 is the mean frequency of the observed signal

Δt is the time relative to the time of closest approach

D is the distance of closest approach (slant range).

This equation can be analyzed to find the distance in terms of the total frequency shift and of the rate of change of frequency at the time of closest approach.[2] But, in order to obtain good accuracy from the data, some refinements were introduced.

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[1] Letters to the Editor from the Lincoln Laboratory, M.I.T., and the Stanford Research Institute appeared in the November, 1957, issue of *Proceedings of the IRE*.

[2] This procedure is described in the letters of Reference 1.

The plotted results of one measurement on the signal from Sputnik I are shown in Figure 1. The observed frequency shifted downward as the satellite passed by almost overhead. The total shift of about 1000 cps at 20 Mc indicates a velocity of about 16,760 miles per hour on the basis of the simple Doppler calculations. The actual velocity was higher, and the deviation is accounted for by the curved path of the satellite, variation in propagation paths, and difficulties in measuring the weak signal when the satellite was over 1000 miles away.

The velocity of the satellite is one of the factors in the calculation of distance. The indicated velocity is close enough to the true velocity so that a fair estimate of distance can be obtained using that figure. The distances that will be quoted, however, are based on an estimate of actual velocity (assuming undisturbed motion and neglecting perturbations) obtained by use of Kepler's "third law"[3] for the period of an elliptical orbit and by use of the equation for the velocity at any point in an orbit about the earth. Such an estimate is probably close enough to the true value so that the accuracy of distance calculation is limited by the accuracy of other measurements.

The semimajor axis, a, of the elliptical orbit of an earth satellite is obtained from the equation:

$$a^3 = \frac{gR_e^2T^2}{4\pi^2} \qquad (2)$$

where g is the acceleration of gravity
R_e is the radius of the earth
T is the period of the orbit.

The period of the satellite is, therefore, essential for this calculation. One can easily determine this by listening and noting the times of successive transits, and then of transits one or more days apart to include many complete orbits. When minor corrections are made, the period can be obtained to a high degree of accuracy.

Then the velocity, v, at any point in an orbit of an earth satellite is obtained from

$$v^2 = gR_e^2\left(\frac{2}{r} - \frac{1}{a}\right) \qquad (3)$$

where r is the distance from the center of the mass of the earth to the desired point in the satellite's orbit.

The value of r used in this equation was estimated at first from the initial Doppler measurements to be the radius of the earth plus 200 miles. Subsequent Doppler measurements then made it possible to refine this estimate.

In order to utilize the values in the curved portion of the plotted relation between frequency and time, the theoretical curve, calculated from the simple Doppler equation by use of the value of v obtained above, was fitted to the points. Since no large-scale digital computer was available for this extracurricular calculation, the fitting was done in a preliminary way graphically, and then a final value of D was obtained from the numerical data by an averaging process. In general, the simple graphical fitting was adequate.

The distance of nearest approach thus calculated from the data represented on the graph is 159 miles, and the time of nearest approach was 18:54:51 EST. Some other observations on Sputnik I are as follows:

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[3] Kepler's third law states that "the squares of periods of circulation around the sun of the several planets are in the same ratios as the cubes of their mean distances." This was first formulated by Johann Kepler in 1619 and published in his treatise, "De Harmonice Mundi."

Date	*Time (Nearest Approach)*	*Distance (Nearest Approach)*
10/17/57	19:09:30 EST	410 miles
	20:48	850
10/18/57	19:05:12	284
	20:43:42	1040
10/19/57	19:00:15	197
10/20/57	18:54:51	159
	04:56:30	1210
10/21/57	18:48:42	236

The values for the closer transits are more accurate in both time and distance than those for greater distances. We have not attempted a careful estimate of accuracy for these points but, for the 159-mile distance, the consistency of the data is sufficiently good to lead to an estimate of ± 2 miles as the probable accuracy, except, of course, for possible systematic errors or blunders.

If one considers the transits at 19 hours on succeeding days, the path shifted with respect to the point of observation from east to west. On October 20 it was almost overhead. The data of October 19 and 21 indicate that on the 20th it was actually west of the observation point by about 30 miles so that the elevation was about 156 miles.

Similar data on Sputnik II are as follows:

Date	*Time*	*Distance (Nearest Approach)*
11/4/57	06:24:24 EST	340 miles
11/5/57	06:36:22	629
11/6/57	06:47:48	876
11/7/57	06:58:37	1137
	05:12:00	162
11/8/57	05:21:50	317

From the relative motion of the observer and the path from day to day, one concludes that Sputnik II was almost directly overhead at about 160 miles elevation at the 05:12 transit on 11/7/57. The 05:01 transit on 11/6/57 would have been interesting, but the earlier data indicated that the supreme effort of getting out of bed at this hour should be made on 11/7/57, since then the satellite would be nearly overhead.

The prediction of approximate transit times after two measurements have been obtained is simple, because the period is then reasonably well known. Since the plane of the orbit is inclined with respect to the earth's axis, however, corrections should be made for the fact that the points of the orbit of nearest approach for successive transits do not correspond to exact intervals of one period. A similar correction is necessary from day to day, because of the relative shift of the orbit and the observer.

The distances between successive transits can be used to obtain a rough estimate of the inclination of the orbit. A better estimate can be obtained by measurement of satellite transits for both directions of travel (provided one is not close to the equator). In fact, if convenience and working hours did not have to be considered, it would be possible to make at least four measurements every 24 hours. When enough data are then obtained to find the altitude for both directions of travel, the simple elliptical approximation to the orbit can be specified from measurements at one station. Naturally, better accuracy in specifying the orbit would be possible if data from stations at different latitudes were available.

The task of Moon-Watch teams is made much easier by a knowledge of when the satellite will be visible in a particular area and of the proper orientation of the Moon-Watch telescopes in terms of predicted azimuth and elevation.

The information derived from these Doppler-shift data was used along with other information by the Harvard Observatory Moon-Watch team.

The Doppler-shift measurements have the advantage over visual sightings that they can be obtained regularly without regard to atmospheric conditions or the position of the sun, and there is little chance of a false radio sighting when the Doppler shift is observed. When the radio signals stop, however, optical and radar observations are all that remain. The use of solar batteries to power the satellite transmitters should make Doppler-shift measurements possible over long periods, and then more radio engineers and amateurs can dabble in this new branch of radio astronomy.

— Arnold Peterson

MEASUREMENT OF CABLE CHARACTERISTICS (Part V)

MEASUREMENT OF VSWR OR UNIFORMITY OF IMPEDANCE[18]

While not normally required for most standard cables, this measurement is sometimes desirable in specific applications as a means of checking the uniformity of cable characteristics from point to point along the cable. Furthermore, special experimental cables and new types of transmission lines may have unknown VSWR characteristics, particularly if they are of a radical design. There are several possible methods of making the measurements, and methods of interpreting the results have not been standardized. The measurement usually requires some type of impedance-indicating device, with which the input impedance of a relatively long cable sample is measured continuously or at closely spaced frequencies over one or more frequency ranges. The variation of the impedance is a measure of cable uniformity.

A typical characteristic, measured on a 2400-foot sample of Type 874-A2 Cable by means of a Type 1601-A V-H-F Bridge[19] for two narrow ranges near 25 Mc and 100 Mc, respectively, is shown in Figure 11.

At ultra-high frequencies, either the Type 1602-B U-H-F Admittance Meter[19] (41-1500 Mc) or the Type 874-LBA Slotted Line[19] (300-5000 Mc) can be used for VSWR measurement. The Type 874-UB Balun can be used to supplement these instruments for measurements on shielded or unshielded twin-conductor cables up to 1000 Mc, although this balun, being tuned, requires readjustment whenever frequency is changed. General Radio Unit Oscillators are satisfactory generators, and either the Type 1231-B Amplifier or one of the Type DNT Detectors is a suitable detector for use with the slotted line. The most satisfactory detector for use with the admittance meter is the Type DNT.

More work is needed to devise a fast yet accurate method of making these cable uniformity measurements with simple, commercially available equipment.

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[18] Handrick, E., and Kruege, L., "Determination of the Equivalent Reflection Factor of Wide-Band Cables," *Telefunken Ztg.*, v. 28, 1955, p. 235 (in German).

Kruege, L., "Linear Integration of the Reflected Pulses as a New Standard for the Quality of Television Cable Lengths," *Telefunken Ztg.*, v. 28, 1955, p. 241 (in German).

Cotte, M., "Study of a Factory Length of Cable by Measurements of Terminal Impedance," *Cables and Transmission*, v. 9, 1955, p. 161 (in French).

Rosen, A., "Irregular Transmission Lines," *Wireless Engineer*, v. 31, March, 1954, pp. 59–70.

Lorrin, J., "Testing of Manufactured Lengths of Coaxial Lines for Very High Frequencies," *Cables and Transmission*, v. 7, July, 1953, pp. 218–41 (in French).

Widl, E., "Survey of Methods in Use for Measurements on High-Frequency Cables," *Fernmeldetech. Z.*, v. 8, May, 1955, pp. 262–265 (in German).

Blackband, W. T., and Brown, D. R., "The Two-Point Method of Measuring Characteristic Impedance and Attenuation of Cables at 3000 Mc," *J.I.E.E.*, Part IIIA, *Proceedings at the Radiolocation Convention*, v. 93, n. 9, March-May, 1946, pp. 1383–6.

[19] Directions for making VSWR measurements will be found in the instruction books for these instruments. For specifications and prices, see the latest General Radio catalog.

MEASUREMENT OF INSULATION RESISTANCE

Insulation resistance has to be measured for certain cable types at a potential of not less than 200 volts. General Radio Company manufactures two instruments that will make these measurements: the Type 1862-B Megohmmeter and the Type 544-BA Megohm Bridge. With either of these instruments, the measurement is made at a constant potential of 500 volts, which is a generally accepted value[20], and a guard terminal is available for eliminating, if necessary, any effects of leakage between the leads connecting to the cable sample under test. The basic accuracies of the two instruments are closely comparable. If the measurement of cable insulation resistance is the only application contemplated for the test equipment, the simplicity of operation and lower cost of the Type 1862-B Megohmmeter make it the logical choice in most instances. The Type 544-BA Megohm Bridge, on the other hand, can be adapted more readily to specialized measurements in a research or development laboratory.

FURTHER DISCUSSION OF ATTENUATION MEASUREMENTS

Part II of this series, published in the June *Experimenter*, describes a particular method of attenuation measurement. There are, of course, other ways in which the details of the measurement can be handled, and it is interesting to consider some of these alternatives even though the techniques previously described are still considered the best.

Matched vs. Unmatched Unknown Cable Sample: As previously described specifically, the attenuation of an unknown cable sample is measured essentially by a substitution method. The sample is removed from an *otherwise-unchanged* transmission path, which includes both r-f and i-f circuits, between a constant-output generator (the unit oscillator) and a calibrated meter (part of the Type 1216-A Unit I-F Amplifier). The loss in the sample is partially replaced by increasing the loss of an accurate i-f step attenuator, and the remaining loss is measured by the meter, which interpolates between steps of the attenuator.

Let us examine more carefully the significance of "otherwise-unchanged" as used in the preceding paragraph. With reference to Figure 4, Part II (June, 1957, *Experimenter*), the transmission path between generator and output meter includes the generator output coupling loop, a low-pass filter, a 10-db pad, a 3-foot patch cord, another 10-db pad, the unknown sample, a 20-db pad, a crystal mixer with local oscillator, a 30-Mc step attenuator, and several stages of i-f amplification. Few of the junctions between these elements are matched, so that there exist so-called "reflection losses" at many of

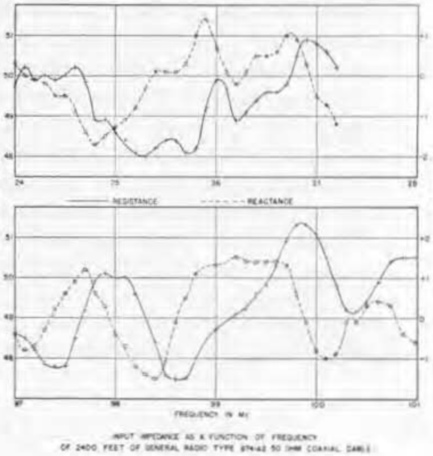

Figure 11. Input impedance as a function of frequency for 2400 feet of General Radio Type 874-A2 50-ohm Coaxial Cable.

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[20] ASTM Standards on Electrical Insulating Materials D257-49T.

these junctions.[21] *However, because of the isolation provided by the pads on either side of the sample, removal of the unknown sample does not* change *conditions at any junctions except those at the sample.* Therefore, the various reflection losses in the system, except possibly for those associated with the sample, are *unchanged* by removal of the sample and consequently have no effect whatever on the measurement.

Reflection losses at the junctions associated with the sample must be considered separately, and there are several different possible situations:

(1) Consider, first, the measurement of a 50-ohm coaxial cable sample. Because of use of 50-ohm pads at both ends of the unknown, matched conditions prevail at both junctions with the sample in, and also at the junction between the pads with the sample out. There are, therefore, no reflection losses associated with the unknown sample in this case.

(2) Consider, next, the measurement of a 75-ohm coaxial cable sample at 3000 Mc. The method that has been described is to fabricate low-reflection pads from extra lengths of the same type cable as that being measured, each length having about 10-db attenuation. One of these "cable pads" is used at each end of the unknown sample between it and the 50-ohm pad in the measuring setup, and both are left in the system when the sample is removed for a measurement. The junctions between the 50-ohm pads and the 75-ohm cable pads are unmatched, of course, like many others in the setup, but these junctions, isolated like the others from the sample by the cable pads, are undisturbed by removal of the unknown, so that this mismatch has no effect on the measurement. It should be especially noted that in this case the nominal impedance of the connectors used between the cable sample and cable pads must equal the nominal impedance of the sample, although the connectors used between the 50-ohm pads and the cable pads are not critical. With the unknown sample in, the cable pads effectively match the sample at both its ends. With the sample out, the cable pads are plugged together directly and match each other. There are, therefore, no reflection losses associated with the unknown sample in this case either.

(3) Consider, finally, the measurement of a 75-ohm coaxial cable sample at 400 Mc. The method we recommend involves using the same 50-ohm pads at both ends as in the case of 50-ohm samples. Cable pads are not recommended, because they would be inconveniently long to give 10-db attenuation at 400 Mc. With the sample in, there is a mismatch at each of its ends corresponding to a VSWR of 1.5 or a reflection coefficient of 0.2,[22] which causes a reflection loss of 0.18 db for each junction or 0.36 db for both.[23] With the sample out and the 50-ohm pads plugged together directly, there is no reflection loss. Therefore, as previously described, a 0.36-db reflection-loss correction must be subtracted from the measured insertion loss to obtain the true attenuation.

The necessity of making this small correction is a very minor disadvantage, which causes no inaccuracy and which is more than justified by the resultant simplicity and convenience of the method. Incidentally, this same method, in which

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[21] "Reflection losses" do not necessarily involve loss of power by dissipation, as is true also for the term "insertion loss," but refers to a reduction or "loss" of power received by a load as a result of mismatched impedance levels between source and load.

[22] Assuming that the attenuation of cable sample is 6 db or more, which is great enough to make multiple-reflection effects negligible in this example.

[23] These figures can be easily calculated from the formulas given in Part II, pages 6 and 7 of the June, 1957, *Experimenter*, or read directly from Figure 6 on page 7 of that issue.

no cable pads are included, can also be used at 3000 Mc, since the reflection loss is independent of frequency. However, MIL-C-17B Specification requires that the cable sample be matched, and thus we have recommended using the cable pads as described previously.

The possible benefits to be gained by use of reactive matching networks (triple-stub tuners or the like) between each end of the cable sample and the measuring setup should be considered. Actually, the only possible benefit is the elimination of the very small reflection-loss correction just mentioned for the case of cable impedances other than 50 ohms at 400 Mc, where cable pads are too cumbersome. On the other hand, the use of reactive matching networks for this application has important disadvantages. One is that a fair degree of experience is required to set them properly, and, if improperly set, they can introduce both reflection-loss and attenuation-loss errors of *unknown* values which can be *larger* than the minor, *known* reflection-loss correction they are intended to eliminate. Other disadvantages are the necessity of making the extra adjustments, the space taken up by the tuners, and the extra cost.

Comparative Measurements: If desired, suitable reactive matching networks can easily be assembled from GR TYPE 874 Stubs, Tees, and Line-Stretchers. Some comparative measurements were made to illustrate the foregoing discussion.

(1) At 400 Mc, a 160-foot length of RG-59/U 75-ohm coaxial cable was measured first by using 50-ohm pads and correcting for the 0.36-db reflection loss, and next by using reactive matching networks at each end of the sample to eliminate reflection loss. The networks were initially adjusted, first one and then the other, so as to give maximum detector reading. A more accurate, but insignificantly so, adjustment could have been made using a slotted line or admittance meter, but the slight improvement possible does not warrant the extra complication. The results were: 12.1 db less 0.36 db reflection-loss correction equals 11.74 db by the method recommended and 12.0 db using the reactive matching networks. The difference of 0.26 db is within the accuracy of measurement. The higher figure of 12.0 db is probably due to incidental losses in the networks.

(2) At 3000 Mc a 30-foot length of RG-59/U 75-ohm coaxial cable was measured in three ways: (*a*) Using 50-ohm pads and correcting for the 0.36-db reflection loss, (*b*) using two extra 40-foot lengths of RG-59/U cable as 10-db cable pads, with constant-impedance, 75-ohm, Type N Connectors used between the sample and the cable pads, and (*c*) using reactive matching networks. The results were: 7.8 db less 0.36 db reflection-loss correction equals 7.44 db for method (*a*), 7.4 db for method (*b*), and 7.4 db for method (*c*). The maximum difference of 0.04 db is insignificant.

R-F Standard Attenuator vs. I-F Standard Attenuator plus Interpolating Meter: The use of a continuously-variable r-f standard attenuator to measure unknown attenuations avoids dependence on the linearity of a crystal mixer, but the latter is not in the least undependable. When used as a mixer in a heterodyne system, the crystal is inherently linear, in contrast to its less dependable characteristics when used as a square-law rectifying detector. The heterodyne method of measurement has been used at General Radio for many years for the standardization of voltage and attenuation at radio frequencies.[24] The National Bureau of Standards also uses the principle of an i-f standard attenuator in conjunction with a mixer and local oscillator to measure attenuation at microwave frequencies with extremely high accuracy,[25, 26] and Bell Telephone Laboratories' precision transmission and phase measuring set also uses a precision, fixed-frequency, i-f attenuator in measurements to 0.05 db accuracy.[27] To insure precise linearity in a mixer, it is necessary only to be sure that the local oscillator voltage is sufficiently high. This fact can readily be checked, in the setup we have described, by a measurement of the rectified mixer current with the panel meter of the Type 1216-A I-F Amplifier, for which purpose a toggle switch is provided. It should read between 80 per cent and 100 per cent of full scale. The i-f attenuator has the important advantage of operating at a fixed, relatively low frequency where it can be more readily standardized with higher accuracy than can r-f attenuators at higher frequencies. The step attenuator as used in the Type 1216-A I-F Amplifier avoids the high and frequency-variable initial insertion loss of the waveguide-beyond-cutoff, piston type of r-f attenuator and, with its interpolating meter, can be read more easily and precisely than can a typical signal generator output dial covering 120 db or more in one revolution.

Before the Type 1216-A I-F Amplifier became available, the Type 874-GA Attenuator, which is a continuously-variable, accurate, r-f attenuator, was recommended for cable attenuation measurements, and many cable manufacturers are today using this device with excellent results. Nevertheless, everyone who has tried the i-f step attenuator system that is now available has quickly appreciated the improved convenience, speed, and ease of reading of the new system.

Monitoring Generator Output: The inexpensive unit oscillators recommended do not have output meters, and one must depend upon their constancy of output. In order to insure the latter, it is necessary to drive them with a Type 1201-A Unit Regulated Power Supply as previously described. In addition, and this was not mentioned before, it is desirable to operate the entire setup from a regulated line, because the Type 1201-A Supply does not regulate heater voltage, which influences oscillator output to a small extent. Regulation of the entire setup also will stabilize local-oscillator output, which is especially desirable for 3000-Mc measurements.

The saturable-core, constant-voltage transformer is generally satisfactory for this application and is probably, because of the availability of units with small ratings, the most practical type of regulator if no other equipment requires a regulated line. However, for regulating power to additional equipment also, which would require a larger-capacity regulator, a Type 1570-A Automatic Voltage Regulator[28] is highly recommended.

With regulation as described, recordings show no perceptible change in output, either as a function of time or of input voltage; so it can be safely as-

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[24] L. B. Arguimbau, "Standardizing the Standard-Signal Generator," *General Radio Experimenter*, 12, 3 and 4, August-September, 1937.

[25] Grantham, R. E., and Freeman, J. J., "A Standard of Attenuation for Microwave Measurements," *Transactions, AIEE*, v. 64, 1948, p. 535.

[26] Albred, C. M., "Precision Piston Attenuators," National Bureau of Standards, *NBS Report 5078*, May 1, 1957.

[27] Alsberg, D. A., and Leed, D., "A Precise Direct Reading Phase and Transmission Measuring System for Video Frequencies," *Bell System Technical Journal*, Vol. XXVIII, No. 2, April, 1949, p. 221.

[28] It can handle up to 6 KVA, is accurate to ± ¼%, introduces no waveform distortion, and is smaller and lower in price than most competitive regulators. Although it is electromechanical, for most line fluctuations, which are small ones, it is practically as fast as most of the so-called "instantaneous" regulators.

sumed that errors will not be introduced into cable attenuation measurements from this source.

Checking Over-all Accuracy: The equipment that has been described will hold its accuracy for a long time, but a simple check can verify it at any time. Merely use the setup to measure the attenuation of an extra TYPE 874-G10 10-db Pad, which can in turn be checked at d-c or audio frequencies. The frequency characteristic of this pad is dependably known and is negligible between d-c and 400 Mc. At 3000 Mc its attenuation is known to be 0.3 db higher than its low-frequency value.

The detector system can also be checked directly at 30 Mc by connecting an accurate signal generator to the i-f amplifier input. However, many signal generators cannot be read so precisely as can the i-f amplifier meter and attenuator.

NEW CABLE MEASUREMENT KITS

Since we can supply everything necessary to measure nearly all cable types, it has been suggested by customers that we offer "cable measuring kits" to simplify the job of selecting the right equipment and to avoid the nuisance of overlooking one or two small parts and having to place a separate order for them later. Furthermore, a single source of supply gives assurance that all the equipment will work together properly. We think the suggestion is a good one, and we, accordingly, have worked out a basic kit with two supplementary kits. Order by kit type number; it is not necessary to list individual items.

TYPE 1671-A BASIC COAXIAL CABLE ATTENUATION MEASURING KIT $1456.40

Complete equipment for measuring attenuation of most coaxial cables at 400 and 3000 Mc. Includes all instruments needed plus large assortment of connectors, replacement ferrules, and adaptors for making connections to various cable types.

Quantity	*Type*	*Name*	*Unit Price*	*Total*
1	1208-B	Unit Oscillator		$200.00
1	1220-A2	Unit Klystron Oscillator		272.90
1	1201-A	Unit Regulated Power Supply		85.00
1	874-F500	500-Mc Low-Pass Filter		16.00
3	874-G10	Fixed Attenuator	$25.00	75.00
1	874-G20	Fixed Attenuator		25.00
1	874-MR	Mixer Rectifier		32.50
1	1209-B	Unit Oscillator		235.00
1	1216-A	Unit I-F Amplifier		335.00
6	874-C	Cable Connector	2.00	12.00
6	874-C8	Cable Connector	2.00	12.00
6	874-C9	Cable Connector	2.00	12.00
6	874-C58	Cable Connector	2.00	12.00
6	874-C62	Cable Connector	2.00	12.00
50	FEC-2	Ferrule	.10	5.00
50	FEC-3	Ferrule	.10	5.00
50	FEC-7	Ferrule	.10	5.00
50	FEC-9	Ferrule	.10	5.00
2	874-QNJ	Adaptor with Type N Jack	3.75	7.50
2	874-QNP	Adaptor with Type N Plug	4.50	9.00
2	874-QBJ	Adaptor with Type BNC Jack	4.75	9.50
2	874-QBP	Adaptor with Type BNC Plug	4.75	9.50
2	874-QCJ	Adaptor with Type C Jack	4.75	9.50
2	874-QCP	Adaptor with Type C Plug	6.25	12.50
2	874-QHJ	Adaptor with Type HN Jack	6.50	13.00
2	874-QHP	Adaptor with Type HN Plug	6.50	13.00
2	874-QUJ	Adaptor with Type U-H-F Jack	4.00	8.00
2	874-QUP	Adaptor with Type U-H-F Plug	4.25	8.50
			Total	$1,456.40

TYPE 1671-A2 SUPPLEMENTARY KIT FOR MEASURING COAXIAL CABLE Zo, v, AND C $1447.00

Adds to basic Type 1671-A Kit all instruments and accessories needed to measure characteristic impedance, velocity of propagation, and capacitance of most coaxial cables as well as capacitance and capacitance unbalance of most shielded or unshielded twin-conductor cables.

Quantity	*Type*	*Name*	*Unit Price*	*Total*
1	1214-A	Unit Oscillator		$ 75.00
2	874-Q2	Adaptor to GR Type 274	$4.25	8.50
1	874-VQ	Voltmeter-Detector		30.00
1	874-WM	50-ohm Termination		12.50
1	1212-A	Unit Null Detector		145.00
1	1203-B	Unit Power Supply		40.00
1	1951-A	Filter		75.00
1	716-CM	Capacitance Bridge		600.00
1	505-F	Capacitor		6.00
1	720-A	Heterodyne Frequency Meter		455.00
			Total	$1,447.00

TYPE 1671-A3 SUPPLEMENTARY KIT FOR MEASURING BALANCED, TWIN-CONDUCTOR CABLES $462.00

Adds to basic Type 1671-A Kit and supplementary Type 1671-A2 Kit all accessories needed to measure attenuation, characteristic impedance, and velocity of propagation of shielded or unshielded twin-conductor cables.

Quantity	*Type*	*Name*	*Unit Price*	*Total*
2	874-UB	Balun	$75.00	$150.00
4	874-D20	Adjustable Stub	14.00	56.00
4	874-L10	50-ohm Air Line	5.50	22.00
2	874-UB-P2	200-ohm Terminal Unit	6.50	13.00
2	874-UB-P3	300-ohm Terminal Unit	15.00	30.00
2	874-UB-P4	Adaptor	50.00	100.00
2	874-UB-P4A	Adaptor Cable	18.00	36.00
2	1000-P5	V-H-F Transformer	27.50	55.00
			Total	$462.00

Insulation resistance measurements are usually handled separately from the high-frequency measurements; so the following instruments for measuring insulation resistance are listed below separately:

Type 1862-B Megohmmeter	**$255.00**
Type 544-BA Megohm Bridge	**365.00**

For automatic line-voltage regulation:
Type 1570-AL Automatic Voltage Regulator $480.00
(Bench, rack, or wall model)

The author wishes to acknowledge the many helpful suggestions received from Robert A. Soderman and the assistance of Edward F. Sutherland, who made the comparative measurements reported.

This article concludes the series, "The Measurement of Cable Characteristics." Reprints will be available soon to anyone who requests them.

— W. R. Thurston

General Radio Company

extends to all *Experimenter* readers its best wishes for a Merry Christmas and a Happy New Year.

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