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Signal Generator And Receiver Impedance

TO MATCH . . . OR NOT TO MATCH

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Engineering Manager

The above question might logically be followed by two additional queries: "If not, why not?" and "If not, what then?" These are loaded questions. The Technician in his screened room as well as the Engineer at his desk had best tread carefully lest he bring down upon himself a barrage of counter-queries. Perhaps we can provide a few good rounds of ammunition for both sides, and may the best man win.

The purpose of a signal generator is to make available in the Laboratory a calibrated source of radio frequency signals which is equivalent to the antenna system with which the receiver eventually will operate. The signal generator, with the associated dummy antenna, must therefore behave the same as the antenna system with respect to ability of the receiver to absorb energy. Failure to meet this condition invalidates the signal generator as a substitute for the antenna.

Let us look briefly at an interesting situation. Failure to take into account the internal impedance of an antenna system can very easily lead to an error of 2:1 in the realizable sensitivity of a receiver as compared to the measured value. It would require a change of 4:1 in the antenna power of the transmitter at a fixed distance to compensate for the apparent error of 2:1 in the sensitivity of the receiver.

Other considerations, such as signal-to-noise ratio or selectivity, may impose contradictory requirements on the input impedance characteristics of a receiver as compared with the requirements dictated for maximum microvolt sensitivity alone. In such a case, what does the calibration of the signal generator tell us about the actual sensitivity of the receiver?

The necessity for making the same measurement on a receiver using different generators or comparing the results of measurements on different receivers requires an understanding of what we are about when making measurements of receiver sensitivity.

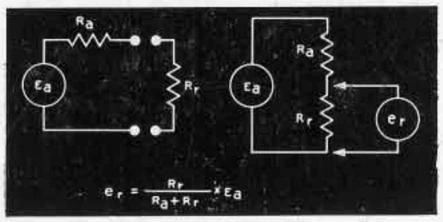

Figure 1. I.R.E. Standard for introducing signal voltage E_a through antenna impedance R_a into receiver input impedance R_r.

DUMMY ANTENNAS

The sensitivity of a radio receiver is NOT the number of microvolts applied directly to the input terminals of the receiver to produce standard output, even though this frequently is assumed to be the case.

The Institute of Radio Engineers has defined the INPUT SENSITIVITY OF A RECEIVER as the number of microvolts required to produce standard output when applied through a dummy antenna having the characteristic impedance of the antenna with which the receiver is intended to operate, to the input terminals of the receiver.[1,2]

To appreciate the logic leading to this choice let us consider the source of energy from which the combined system of the antenna and receiver is driven. Electromagnetic energy flowing in free space encounters a conductor and excites in it a voltage which acts in series with the antenna radiation resistance. Like the open-circuit electro-motive-force of a battery this voltage is available to us only in series with the internal impedance of the power source itself. The variation of this impedance with frequency may require a series-parallel combination of R, L, and C in the dummy antenna. Part of all of it may be contained in the signal generator output impedance.

POWER TRANSFER

We have mentioned above that considerations of signal-to-noise-ratio, selectivity and the like may have an effect on our choice of load for the antenna system and it is useful to see how the power transfer from the antenna to the receiver will be affected by deliberate mis-matches in load. Figure 1 is the basic circuit describing the test conditions specified by the Institute of Radio Engineers in which we have conveniently assumed that only resistances are involved. The total power intercepted by the antenna system will be dissipated in two portions of the network (1) the internal impedance of the antenna and (2) the input load presented by the receiver. The power delivered to the receiver load will equal:

$$P_r = \left[\frac{R_r}{(R_a + R_r)} E_a\right]^2 \left(\frac{1}{R_r}\right) = \frac{R_r \ E_a^2}{(R_a + R_r)^2}$$

Figure 2 indicates the efficiency

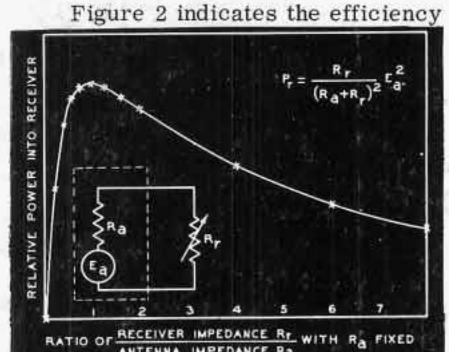

Figure 2. Effect of variation of receiver input impedance R_r on power into receiver with fixed antenna impedance R_a and voltage E_a.

YOU WILL FIND. . .

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of power transfer which takes place as we vary the ratio of load to antenna resistance. This curve shows that the maximum power at the input terminals of the receiver is obtained when the receiver input impedance matches the antenna impedance. The maximum is fairly broad, but a relatively small shift downward in the input impedance of the receiver results in a very large change in the amount of power delivered to the receiver as compared to the effect of an equal increase in the receiver input impedance.

MIS-MATCHING FOR IMPROVED SELECTIVITY

Up to this point we have been discussing the title of this paper, namely: "To match or not to match". We are now faced with the second question, "If not, why not?" The curve we presented in Figure 1 shows the way in which power is transferred from one resistive circuit to another. A similar relationship exists for coupling between primaries and secondaries of tuned transformers.

As the coupling is increased, the effective Q of the resonant winding decreases until a point is reached at which the Q drops to one-half the uncoupled value. At this point (i.e. critical coupling), there is the optimum energy transfer between the circuits.

However, that value of coupling which produces optimum energy transfer has simultaneously dropped the Q of our resonant selective circuit to one-half and thereby degenerated the selectivity of the front end of the receiver. In order to obtain better selectivity characteristics, we may deliberately mis-match the receiver to the generator to reduce loading on the resonant circuit. We will shortly find out how this mis-match can be accounted for in our measurements.

MIS-MATCHING FOR IMPROVED SIGNAL-TO-NOISE RATIO

Another consideration which may lead to a deliberate mis-match of the receiver to the antenna impedance is the necessity for improving the signal-to-noise-ratio over that which would be obtained from a perfect match.[3]

The noise and the signal are intermixed in the antenna and the receiver should select them as favorably as possible. The noise voltage generated in the antenna is proportional to the square root of the antenna impedance. The noise power induced into the matched input circuit of a receiver is independent of the receiver input impedance. The signal power for a given voltage is, however, a function of the input impedance of the receiver. The ratio of signal to noise can therefore be affected by deliberately mis-matching the receiver to the antenna impedance in exchange for a loss in microvolt sensitivity.

SIGNAL GENERATOR CALIBRATION

Having seen above that there are reasons to match and reasons not to match the receiver input to the antenna impedance there remains to investigate the question: "If not matched, what then?" It should be carefully noted that the IRE standards requiring the use of a dummy antenna say nothing whatsoever about the impedance of the receiver.

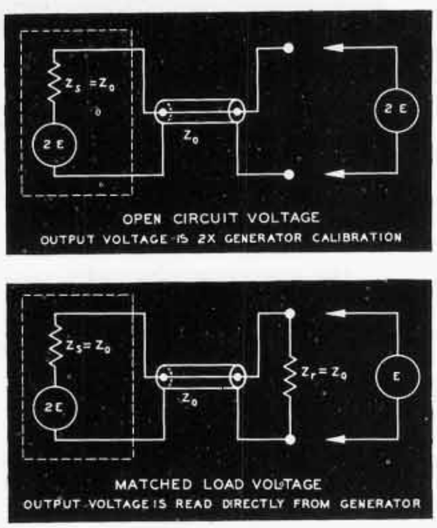

Figure 3. Output voltage calibration for a generator having its source impedance equal to the characteristic impedance of the output cable.

To use a signal generator intelligently we must understand how the output system behaves under different conditions. Signal generators can be divided roughly into two classes: a. Low source impedance, and b, matched source impedance. In low source impedance generators, the output transmission line is driven directly by a pick-up loop having the lowest possible inductance. In a matched source generator, a low inductance pick-up loop provides a very low impedance source of voltage which feeds through a matching resistor to the output cable. The value of the resistor is carefully controlled to match the characteristic impedance of the transmission line.

The output meters and dials of signal generators of both the matched and low internal impedance varieties are almost universally calibrated in terms of the voltage developed at the output jack on the front panel of the generator when this jack is terminated in a resistive load equal to the characteristic impedance of the coaxial line or the rated output impedance of the generator.

The heart of the problem lies in the length of coaxial cable commonly used to connect the point of generation of the radio frequency signals to the input to the receiver. At the frequencies generally encountered in communications and television this length of cable can approach and exceed 1/4 wavelength. A 1/4 wavelength piece of transmission line has a transforming property for both impedance and voltage which acts somewhat like a teetertotter, the midpoint of which is the characteristic impedance of the line. A low-loss 1/4 wavelength piece of line driven by a low impedance source will produce a very high voltage at the open circuit end of the line. Conversely, if the driving source impedance is high the output voltage will be low. If the source impedance equals the characteristic impedance of the line, the output voltage will equal the input voltage.

In matched signal generators the calibrated voltage is fed through the characteristic impedance of the generator and the connecting cable to the matched terminating load. In order for the dial to be calibrated in terms of the voltage, E, developed across the load alone it is necessary to deliver twice this voltage, 2E, to the input to the internal generator impedance. This means that the open-circuit voltage available at the front panel, 2E, will be twice that obtained, E, when the output jack is terminated in a matching impedance, and hence twice the dial calibration, as shown in Figure 3.

Looking back into the generator from the end of the connecting line one sees a properly terminated line. Therefore the length of line has no effect on the voltage at the output.

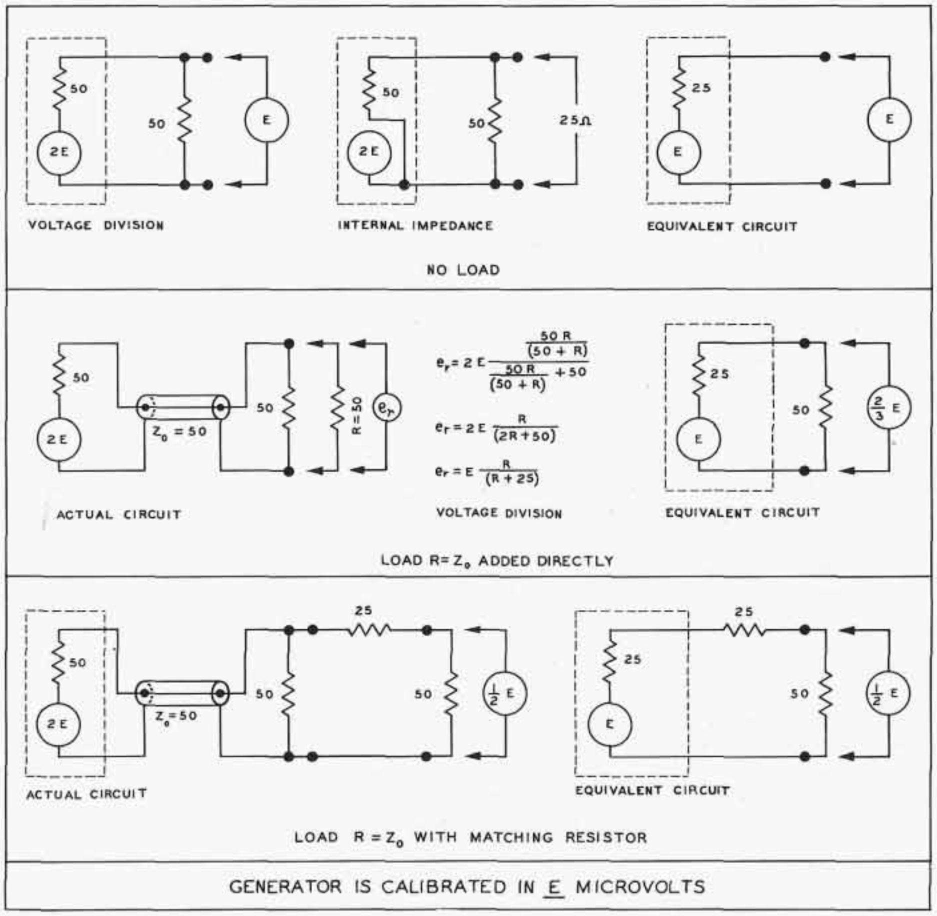

Figure 4. Application of Thevenin's Theorem to a cable terminated in Z_o.

TERMINATED CABLES

A terminating resistor frequently is used in the end of extension cables, and the voltage developed across it is exactly equal to the reading on the dials. By the application of Thevenin's theorem, the equivalent circuit of the generator now appears to be the output voltage acting in series with the paralleled matching resistor and the generating source. Thus, as we see in Figure 4, we have the equivalent of 25Ω internal impedance acting in series with the indicated number of microvolts. (Ref. 3, p. 47)

If we wish to match 50Ω it is necessary to add an additional 25Ω in series with the output cable. This gives us the equivalent of an antenna having induced in it E microvolts and having an internal impedance of 50Ω. Only half of the antenna voltage is delivered to the input terminals of the receiver as shown in Figure 4.

To the engineer struggling to meet receiver sensitivity specifications this may look like hitting oneself over the head just for the fun of it. In fact, the apparent loss of receiver sensitivity caused by accounting for the antenna impedance when making measurements with a signal generator has given rise to the expression of "hard" vs "soft" microvolts. One must work much harder to obtain sensitivity with "hard" microvolts than with "soft" ones, which pour directly out of a low impedance signal generator. Unfortunately, microvolts are hard to get out of all antenna systems.

ATTENUATOR PADS

Let us consider the impedance and voltage distribution along another commonly used system; that in which a 6 db, or 2:1, attenuator pad has been used in the line between the generator and receiver. Figure 5 shows the arrangement of the elements.

The output of the pad is equivalent to the characteristic impedance of the generator in series with E microvolts. A 20 db, or 10:1, pad is equivalent to E/5 microvolts in series with the generator impedance where E is the reading on the generator dial. A pad can be designed to match the generator output to a different value of receiver input impedance The 2:1 or 10:1 voltage division acts on the 2E supplied in series with the 50 ohm internal generator impedance

UNMATCHED LOADS

We have implied above that the output system of an internally matched generator will maintain 2E microvolts at the input to its internal impedance regardless of the termination at the end of the coaxial cable. This can be shown as follows.

In signal generators using a piston-type (or wave-guide-below-cut-off) attenuator the metered voltage is generated in a primary coil at the input end of the attenuator tube. At any particular distance down the tube a definite amount of voltage, 2E, where E is the voltage shown on the generator dials, will be induced in the secondary loop which drives the output transmission line. In an internally matched generator the matching resistor is located between the low-impedance pick-up loop and the input to the transmission line.

The arrangement described above forms a transmission line having a zero-impedance voltage source, E_g = 2E, in series with the sending end impedance, Z_s, which is matched to the characteristic impedance of the line, Z_o. The resulting voltage at the receiving end, E_r, as the receiving end impedance, Z_r, is varied can be derived from the transmission line equation for I_r (Ref. 3, p. 139., eq. 29):

$$E_r = I_r Z_r = \frac{2E_g Z_o Z_r}{(Z_o+Z_r)(Z_s+Z_o)e^{\gamma l}+(Z_o-Z_r)(Z_s-Z_o)e^{-\gamma l}} \quad \text{(e)}$$

If $Z_s = Z_o$

$$E_r = \frac{2E_g Z_o Z_r}{(Z_o + Z_r)(2Z_o)e^{\gamma l}}$$

$$E_r = \frac{E_g Z_r}{(Z_o + Z_r)e^{\gamma l}}$$

For a lossless line, the "propagation constant, γ, reduces to a "phase shift factor", $j\beta$, which usually is of no interest to us. The output voltage then is,

$$E_r = \frac{Z_r}{Z_o + Z_r} E_g$$

In the above derivation no restrictions were placed on the length of line or the receiving end impedance, provided the sending end impedance is matched to the characteristic impedance of the line. This result is logically appealing. Looking back into the generator from the receiving end of the lossless cable we see a matched load regardless of the length of cable. Even if we reduce it to zero, we are left with the matching impedance, $Z_s = Z_o$, in series with a source of voltage, E_g = 2E, where E is the dial calibration.

MULTI-FREQUENCY MEASUREMENTS

In the above discussions we have treated relatively simple configurations of resistors and cables. Actually, dummy antenna systems may become quite complicated, involving series and parallel combination of resistors, inductors, and capacitors in order to duplicate the frequency characteristics of the antennas being used with the receiving equipment.[1] [2] The values obtained for intermediate frequency direct transmission and for image rejection ratios in superheterodyne receivers may be seriously affected by the accuracy of the dummy antenna since quite large ratios exist between the resonant frequency and the frequency under test. The impedance mis-match caused by off-resonance operation of the input system of the receiver, such as when taking standard selectivity curves, produces wide impedance variations which affect the calibration of the output system of a non-matched generator, and hence the validity of the selectivity curves obtained.

CONCLUSION

The function of the signal generator and dummy antenna is to reproduce in the laboratory the conditions presented by the antenna system with which the receiver is to operate.

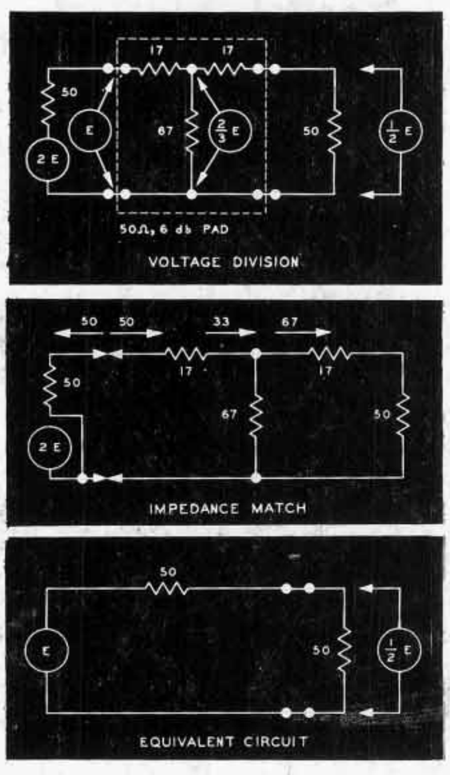

Figure 5. Equivalent circuit of a 50-ohm, 6 db symetrical attenuating pad.

The output system should place at the end of a probe the equivalent antenna voltage and internal impedance.

The standards of measurement for RECEIVER SENSITIVITY established by the IRE reflect the physical requirements that the signal input from the antenna shall be delivered through a dummy antenna representing the antenna impedance.

The input impedance characteristics of the receiver should be designed to work with the impedance characteristics of its associated antenna system. This may or may not result in actual matching of the two impedances.

Signal generator calibrations are valid only when the output is terminated in a specified value of impedance.

The equivalent circuit for the output impedance of a matched signal generator and the impedance of the load reduces to a simple voltage divider having twice the indicated voltage across the divider regardless of length of cable or value of load impedance.

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Transmission Line Measurements
WITH THE RX METER

NORMAN L. RIEMENSCHNEIDER, *Sales Engineer*

The RX Meter has found wide application in the measurement of characteristic impedance, attenuation, and velocity of propagation of transmission lines. The rapidity with which the measurements can be accomplished on relatively short pieces of cable and the accuracy realized in using the simple, direct techniques described below has made the instrument a valuable tool for the design engineer concerned with coaxial elements, as well as for the quality control engineer making spot checks during the manufacture of cable.

In this article we will describe, briefly the methods used in measuring each of the above characteristics with the RX Meter. In order to clarify the approach used in each case we have included, at the end of this article, a brief review of the basic transmission line formulas involved.

CHARACTERISTIC IMPEDANCE

Several methods are available for the measurement of characteristic impedance (Z_o) with the RX Meter. One of the most satisfactory involves the familiar relationship, $Z_o = \sqrt{Z_i Z_L}$, where Z_i is the input impedance of a quarter-wavelength line with a given termination, and Z_L is the impedance of the termination itself. For our purpose, this relation is used in the form $Z_o = \sqrt{R_1 R_2}$, where R_1 is a resistance measured directly on the RX Meter terminals and R_2 is the input resistance of the quarter-wave line terminated by R_1. The actual procedure used for this measurement is as follows:

The RX Meter oscillator is adjusted to the desired measuring frequency. A piece of the sample cable is cut to a length corresponding to approximately one quarter-wavelength with both ends dressed back about one-half inch to espose the center conductor and shield. If the cable dielectric is polyethylene, this length may be taken directly from Figure 1. The RX Meter is first balanced with nothing attached to the terminals and with the C_p and R_p dials set at 0 and ∞ respectively. The bridge is then rebalanced by means of the R_p and C_p dials with the cable, shorted at the far end, attached to the binding posts. If the cable length is correct, (i.e. exactly $1/4\lambda$), the C_p dial reads zero. If it reads capacitive, the frequency should be lowered or the cable shortened, while if the C_p reading is negative (indicating inductance) the frequency should be increased or a longer piece of cable used. Since the characteristic impedance does not change significantly at frequencies above approximately 20 mc., it is usually more convenient to make any needed adjustment by varying the frequency. The R_p dial must be used to null the instrument during the above procedure, but its value may be disregarded.

For the termination, select a 1/2 watt carbon resistor whose resistance is roughly equal to the estimated characteristic impedance of the cable. If the latter cannot be estimated, 50 ohms will usually suffice. Removing the short circuit from the end of the quarter wavelength line, connect the resistor in its place, keeping the leads as short as possible. Then balance the bridge and record R_p as R_1. The resistor should then be removed from the end of the cable and measured directly across the RX Meter terminals to provide the value R_2.

In a typical measurement, made on a quarter wavelength section of RG 58/U cable, a resistor which measured 47.0 ohms directly at the bridge terminals was used to terminate the line. The line with this termination measured 63.8 ohms. Then

$$Z_o = \sqrt{63.8 \times 47.0} = 54.7 \text{ ohms}.$$

An equally satisfactory method of determining Z_o (that recommended in Military Specification JAN-C-17A) is based on the relationship

$$Z_o = \frac{101,600}{v \times C},$$

where v is the velocity of propagation factor in percent and C is the cable capacitance in $\mu\mu f$ per foot.

The latter value is determined by attaching a very short length of the cable to the RX Meter binding posts and measuring C_p directly. The velocity of propagation may be determined as described in a later section.

A third method of measuring Z_o may be worth mentioning, although less satisfactory with respect to accuracy.

This method is implied by equation (3) at the end of this article, which indicates that the characteristic impedance of a line is equal to the absolute value of the reactance of a section 1/8 wavelength long.

To obtain the correct length, a 1/4 wave section is first established in the manner described above, at a frequency twice the desired measuring frequency. This frequency is then halved, and reactance of the section (either open or short-circuited) determined from the C_p reading at balance.

ATTENUATION

A very convenient method of measuring attenuation, using short pieces of cable, is provided by the equation

$$\alpha L = \frac{Z_o \times 8.69 \text{ db},}{Z_i}$$

where α is db per unit length and L is length. Here the value of Z_i is determined by measuring the parallel resistance (on the R_p dial) of a piece of cable 1/2 wavelength long. If the frequency is such that a half wavelength is less than approximately 4 feet, a one-or three-halves wavelength piece can be used, with no change in procedure, to minimize the effect of irregularities in the cable, etc. The attenuation in db obtained for the length of cable tested can be readily adjusted to db per 100 feet.

When the desired frequency has been selected, cut the cable to one-half wavelength, and dress one end back one-half inch. After effecting the initial balance of the bridge, connect the cable, with the far end open-circuited, to the RX Meter, making sure that the center conductor is connected to the "HI" post. The bridge should now be balanced and the values of capacity (C_p) and parallel resistance (R_p) read from the respective dials. If $C_p = 0$, the cable is the proper length and the value obtained for R_p substituted for Z_i in the above equation. If the C_p dial indicates a capacity, the cable is too long and a small amount must be cut off the far end, or the frequency must be lowered. If the C_p dial indicates a negative

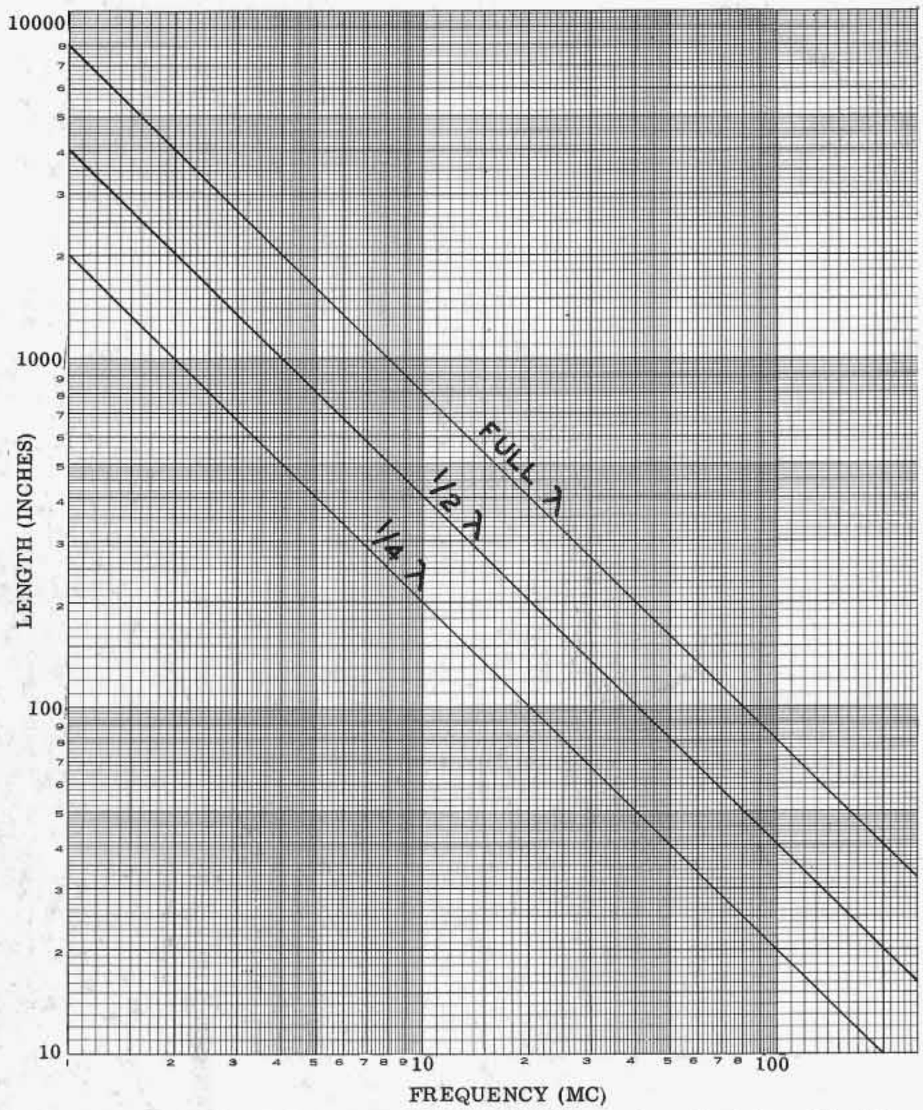

Figure 1. Wave length vs frequency for coaxial cables having polyethylene dielectric.

capacity (inductance), a longer piece must be used or the frequency raised. As an example, a one-half wavelength section of RG-58/U cable at 77 mc (52" long) was found to have an R_p of 2760 ohms. Applying this value to the formula above, together with the known characteristic impedance of 54.7 ohms, and adjusting for the length of the section, the attenuation was found to be 3.98 db/100 feet.

VELOCITY OF PROPOGATION

Since the velocity of propagation factor is equal to the physical length of a one-half wavelength section of cable divided by the length of a one-half wavelength section in air, it is merely necessary to measure the physical length of the cable involved in the preceding measurements and to compare it to the equivalent wavelength in air.

TRANSMISSION LINE EQUATIONS

The general formula for a lossless line of length l, having a characteristic impedance of Z_o, and terminated in an impedance Z_L is,

$$Z_i = Z_o\left(\frac{Z_L \text{Cos}\beta l + jZ_o \text{Sin}\beta l}{Z_o \text{Cos}\beta l + jZ_L \text{Sin}\beta l}\right) \quad (1)$$

where the phase constant $\beta = 2\pi/\lambda$, and λ = wavelength. Now, if the line is 1/4 wavelength long, $l = \lambda/4$ and

$$\beta l = \frac{2\pi}{\lambda} \times \frac{\lambda}{4} = \frac{\pi}{2} \text{ radians, or } 90^\circ.$$

Substituting in (1) above,

$$Z_i = Z_o\frac{(+jZ_o)}{(+jZ_L)} = \frac{Z_o^2}{Z_L} \text{ and}$$

$$Z_o = \sqrt{Z_i Z_L}. \quad (2)$$

If the line is 1/8 wavelength long and is short circuited, then $l = \lambda/8$, $\beta l = \pi/4$ radian or 45^o, and $Z_L = 0$. Substituting in (1), (3)

$$Z_i = Z_o\left(\frac{+jZ_o \text{Sin } 45^o}{Z_o \text{Cos } 45^o}\right) = +jZ_o = X.$$

In a similar manner it can be shown that the input impedance of a 1/8 wavelength line that is open circuited is,

$$Z_i = jZ_o. \quad (4)$$

For the purpose of deriving a means of measuring the attenuation of a transmission line, the general expression for a line with loss is given below.

The impedance, Z_i^1, looking into a line with loss, having a characteristic impedance of Z_o, and terminated in an impedance Z_R can be expressed as,

$$Z_i^1 = Z_o\left(\frac{Z_R + Z_o \tanh\gamma l}{Z_o + Z_R \tanh\gamma l}\right) \quad (5)$$

where, $\gamma l = \alpha l + j\beta l$, and $\beta = 2\pi/\lambda$.

In the case of a half wavelength line, $l = \lambda/2$ and

$\beta l = 2\pi/\lambda \times \lambda/2 = \pi$ and
$\gamma l = \alpha l + j\pi$. Also,
$\tanh\gamma l = \tanh(\alpha l + j\pi) = \tanh \alpha l$,
and if αl is small, then, $\tanh\alpha l = \alpha l$,
and $\tanh \gamma l = \alpha l$.

Substituting in (5) above,

$$Z_i^1 = Z_o\left(\frac{Z_R + Z_o\alpha l}{Z_o + Z_R\alpha l}\right)$$

Dividing numerator and denominator of the fraction on the right by Z_R, we obtain

$$Z_i^1 = Z_o \frac{1 + \frac{Z_o\alpha l}{Z_R}}{\frac{Z_o}{Z_R} + \alpha l}. \quad (6)$$

If the half wavelength cable is open-circuited (i.e. $Z_R = \infty$), (5) will reduce to

$$Z_i^1 = (Z_o)\frac{(1)}{\alpha l} = \frac{Z_o}{\alpha l} \text{ and}$$

$$\alpha l = \frac{Z_o}{Z_i l} \text{ nepers. Then}$$

$$\alpha l = \frac{Z_o}{Z_i^1} \times 8.69 \text{ db, where } Z_i^1 \text{ is}$$

resistive and is measured directly on the R_p dial of the 250-A RX Meter.

CONCLUSION

It will be observed that all the measurements described in this article are simple and direct, without involved computation and corrections. In all cases, relatively short length pieces of cable are used and measurements are made directly at the RX Meter terminals without the use of coaxial connectors. It may be of interest to note that a balanced line can be treated in the same fashion as coaxial lines when a "balun" or similar device is used in connecting it to the RX Meter.

Figure 2. The author, measuring the characteristic impedance of a short length of RG-58/U cable on the RX Meter.

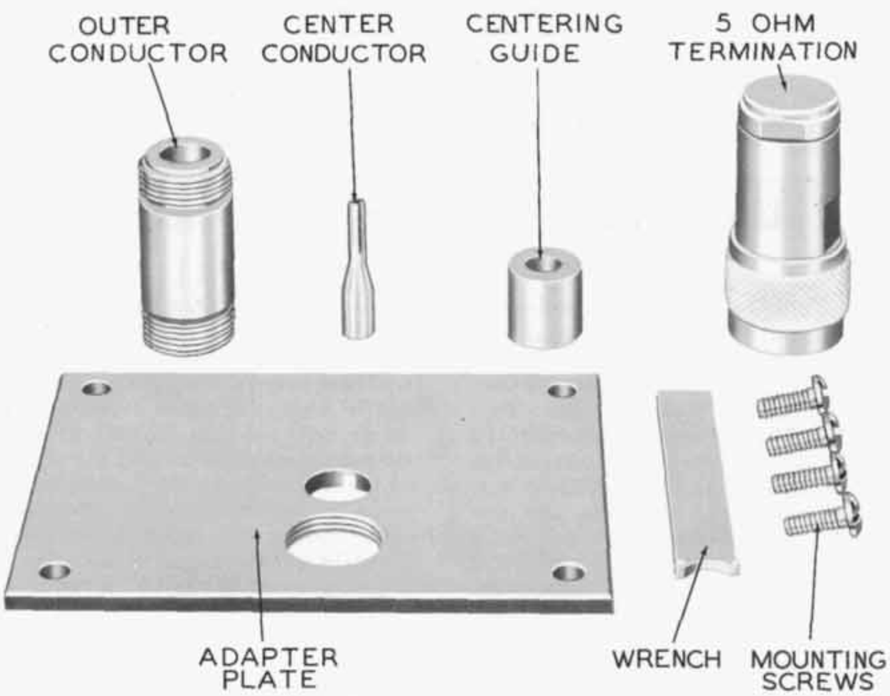

Figure 1. Components of the Co-ax Adapter Kit Type 515-A. The kit is supplied in a convenient wooden storage stand, not shown.

A Coaxial Adapter For The RX Meter

C. G. GORSS, *Development Engineer*

Soon after the RX Meter Type 250-A made its appearance in the field it became apparent that, in addition to measurement of components on the standard binding posts, many of the applications in which this new instrument was being utilized involved the use of coaxial cables and fittings. The evident need for some convenient means of coupling such components, fitted with standard coaxial connectors, to the RX Meter measuring terminals resulted in the design of a special adapter unit. This unit which, together with the necessary accessories, is now available to RX Meter owners in kit form, is disignated as the "Co-ax Adapter Type 515-A."

DESIGN DETAILS

The adapter itself consists of two separate elements; a cylindrical outer conductor about 1 1/2 inches in length, the base of which is grounded to the terminal plate when mounted on the RX Meter, and a tapered center conductor which is fastened to the HI binding post stud. To mount the unit, an adapter plate, supplied with the kit, is first fastened to the terminal plate of the RX Meter. This plate has a large-diameter tapped hole which centers around the HI post stud. After the HI post clamping nut has been removed and the center conductor has been screwed firmly over the stud, the outer conductor is turned down into this hole until its base makes contact with the terminal plate. The open end of the adapter then forms a standard Type N female connector.

When the adapter is installed, ordinary measurements requiring the use of the binding posts are easily made merely by unscrewing the outer and inner conductors of the adapter and replacing the binding post nuts. The adapter plate in no way interferes with such measurements.

Along with the adapter and adapter plate, the kit includes a wrench for removing the ground binding post base nut, a centering guide for accurate positioning of the outer conductor, four screws for fastening the adapter plate, and a special 50-ohm coaxial termination.

The unit is designed to have a constant characteristic impedance of 50 ohms. All surfaces are rhodium-plated to insure good contact and to match the plating used on the RX Meter terminal plate.

The termination, which is used in obtaining preliminary balance of the RX Meter bridge, is equipped with a Type N male connector for direct connections to the adapter. Like the adapter, it is actually a short section of transmission line. Its center conductor, however, is actually a special high frequency resistor. The termination produces a voltage standing wave ratio of less than 1.10 up to 800 mc.

APPLICATION

When the adapter is installed a coaxial element may be attached and measured at any selected frequency after two minor preliminary adjustments of the RX Meter bridge circuit controls have been made to establish the correct "zero balance" condition. The first adjustment, made with nothing attached to the adapter and with the R_p dial set at ∞, consists of obtaining a null indication by alternate adjustment of the ZERO BALANCE R controls and the C_p control. This establishes the correct "resistance zero" of the circuit.

The second zero balance adjustment is made with the 50-ohm termination mounted in place on the adapter. This time a null indication is obtained by means of the R_p and ZERO BALANCE C controls, with the C_p dial at 0. This establishes the correct "reactance zero." Actually, it has the effect of adjusting to the proper value the characteristic impedance of a short internal connecting section (several centimeters in length) between the RX Meter binding post and the physical point on the bridge circuit at which the measurement is actually made. Since the characteristic impedance of this section is not, in itself, 50 ohms, that value must be established synthetically by proper adjustment of the ratio L/C. This is automatically accomplished by the setting of the ZERO BALANCE C control described above.

Although the co-ax adapter is useful in facilitating measurement of the characteristics of cables and other coaxial elements, probably its most important application is in providing for the measurement of impedances remote from the RX Meter terminals. When the proper techniques are used, it is possible to measure an impedance at the end of a section of coax line with the same accuracy with which it can be measured directly at the RX Meter terminals. Such measurements may, if desired, be made with random-length sections of 50-ohm coax, in which case the results must be transformed by means of a Smith Chart[1,2] or the familiar transmission line equations in order to obtain the actual impedance of the unknown. In this case, the short internal connection, mentioned above, between the binding post and bridge, becomes part of the transmission line and its effective length

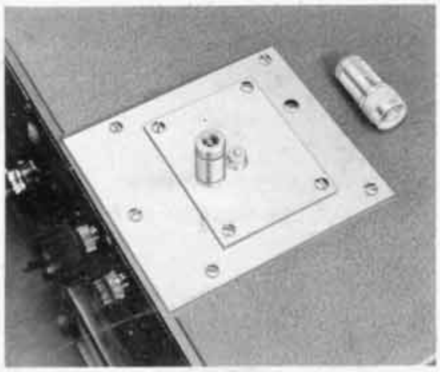

Figure 2. The Co-ax Adapter, mounted on an RX Meter. The 50-ohm termination shown beside the terminal plate is used in obtaining preliminary balance of the RX Meter bridge circuit.

must be determined and added to the physical length of the line itself in computing the results. A somewhat simpler method, when the measuring frequency is high enough for the cable length involved to be practical, is the use of a resonant half-wave section which will transfer almost exactly the value of an impedance connected at one end to the RX Meter measuring terminals connected at the other. In this case, the impedance of the section itself is not a factor, and the only correction necessary is for actual loss in the line which, frequently, is negligible.

D.R. Crosby and C.H. Pennypacker, "Radio Frequency Resistors as Uniform Transmission Lines," Proc. of the IRE, Feb., 1946.

[2] P. W. Smith, "Transmission Line Calculator," Electronics, Jan., 1939.

A NOTE FROM THE EDITOR

This is a very brief note. In fact, our authors were so enthusiastic that they left the editor only enough space to note, with considerable satisfaction, that over 22,000 people asked for the Notebook.

Univerter Signal-To-Noise Ratio

Frank G. Marble, *Sales Manager*

A simple method for extending the frequency range of a signal generator is the use of a broadband frequency converter with a gain of one. Such a converter is the Univerter Type 207-A. This instrument consists of a broadband mixer, a local oscillator and a broadband amplifier with an output impedance of fifty ohms. The output frequency differs from that of the signal generator by the frequency of the local oscillator of the Univerter. The useful frequency range is limited by the upper and lower limits of the mixer and the broadband amplifier (0.1 to 55 mc).

The mixer of the Univerter has a small amount of inherent amplitude modulation resulting from random noise generated in its input impedance. Since the pass band of the Univerter covers a broad frequency range, little selective rejection of this noise occurs. The effect is not noticeable for signal levels above approximately 2.5 microvolts. Below this level, signal level decreases of a given value will cause reductions of receiver output of a smaller value. The use of a 20 db pad, such as the 509-A, at the output of the Univerter will permit use of the signal generator and Univerter down to approximately 0.25 microvolts, since the noise is attenuated directly and the signal levels from the signal generator can be increased by 20 db to compensate for this pad. Additional attenuation can be used for lower outputs.

To allow our customers to make use of the Signal Generator (Types 202-B and 202-C) with the Univerter Type 207-A at these very low levels the Adapter Type 509-A (53 ohms unbalanced to 53 ohms unbalanced with 20 db attenuation) is now supplied with each Univerter at no increase in price.

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