measuring coax cable loss

with an SWR meter

One solution to the high cost of exotic test equipment for measuring transmission-line losses

Have you ever wondered how much loss a piece of coaxial cable has at a particular frequency? You could consult a chart or graph in a reference book. However, that would only tell you the *approximate* loss for coax from the manufacturer who supplied data to the editor of the book. Age and environment affect cable loss. Does the chart in the book include an age factor? The easiest way to determine loss in a piece of coax is by measuring it. You don't need expensive test equipment to do this. All you need is a) an SWR meter or a bidirectional wattmeter, b) a transmitter, and c) the desire to perform a few simple calculations.

determining cable loss

The loss in coaxial cable can be determined by connecting it to a source of rf (the transmitter) and measuring the SWR at the transmitter when the far end of the line is an open circuit. At first this method may sound too simple to work, but it does, and here's why.

Transmission line theory tells us that the SWR will be:

$$SWR = \frac{R}{Z} \tag{1}$$

where R is the load resistance, and Z is the line impedance.[1] An open circuit would present an infinite load resistance and therefore an infinite SWR. Trans-

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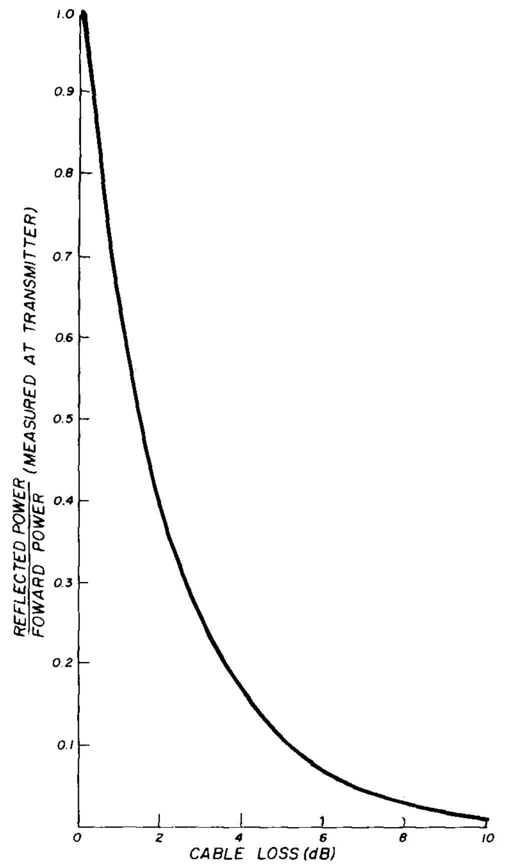

fig. 1. Ratio of reflected power to forward power as a function of cable loss (*eq. 4*).

mission line theory also tells us that the reflection coefficient[2] will be:

$$K = \frac{SWR - 1}{SWR + 1} \qquad \textbf{(2)}$$

Since the SWR of an open circuit will be infinite, the reflection coefficient will be, for all practical purposes, unity (100 per cent). Therefore, all the power reaching the end of the line will be reflected to the source.

However, not all the power from the source reaches the end of the line; some is lost along the way. And not all the reflected power returns to the source; some of it is also lost along the way.

The reflected power measured at the source represents twice the loss of the coax: the loss forward and loss reflected. The standard formula for calculating the dB loss or gain[3] is:

$$dB = 10 \log \frac{P1}{P2} \qquad \textbf{(3)}$$

In this application, **eq. 3** would tell us the loss for the round trip. Since we are interested in the loss in only one direction, and since the loss forward should be the same as the loss reflected, **eq. 3** becomes:

$$dB = 5 \log \frac{reflected}{forward} \qquad \textbf{(4)}$$

Eq. 4 is fine if you have a bidirectional wattmeter. Since many low-priced SWR meters measure SWR *without* indicating actual power in watts, and since SWR is a function of forward and reflected power, **eq. 4** can be transposed:

$$dB = 5 \log \left(\frac{SWR - 1}{SWR + 1}\right)^2 \qquad \textbf{(5)}$$

Eq. 4 is shown graphically in **fig. 1**. **Eq. 5** is shown in **fig. 2**.

examples

Before going any further, let's consider two simple hypothetical examples. A transmitter feeds 100 watts of rf power into a length of RG-58 cable. A bidirectional wattmeter at the transmitter indicates a reflected power of 25 watts. From **eq. 4** we can calculate

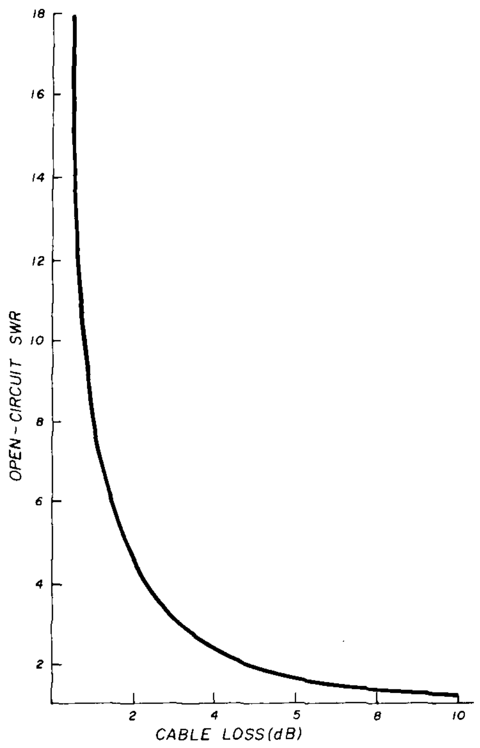

fig. 2. Open-circuit SWR as a function of cable loss (*eq. 5*).

$$5 \log \frac{25}{100} = 5 \log 0.25$$

$$= 5(-0.602) = -3.01\,dB \qquad (6)$$

The minus sign indicates a loss. To further verify **eq. 4**, let's consider what happened to the rf as it made its round trip through the coax. If the coax really did have 3 dB of loss, approximately 50 watts would reach the open end. When that 50 watts was reflected, the same 3 dB loss would result in *25 watts being lost in the coax*. Thus, only 25 watts would be measured as reflected power at the source.

For our second hypothetical case, let's assume the use of an SWR meter that doesn't indicate forward power; the meter scale reads directly in SWR. A transmitter of unknown output is connected to a length of RG-8/U cable, and the SWR at the transmitter is 6:1. We can use **eq. 5** to calculate the loss:

$$5 \log \left(\frac{6-1}{6+1}\right)^2 = 5 \log (0.714)^2$$

$$= 5(-0.29) = -1.45\,dB. \qquad (7)$$

Again, the minus sign indicates a loss.

system accuracy

This will depend on the accuracy of the SWR meter or wattmeter used to make the measurement. Several precautions must be observed:

1. Some lengths of coax at some frequencies could act as resonant circuits and cause inaccurate measurements.

2. Short lengths of good-quality coax will show a very high SWR. Make sure the transmitter used as a source of rf can withstand a high SWR.

3. The transmitter impedance must match that of the coax.

4. Measurements should be made at the frequency at which the coax will be used.

One more item must be taken into account. This system for measuring loss in coaxial cable assumes that the load will be perfectly matched to the line. Any mismatch will create standing waves that will cause additional loss.[4]

references

1. William I. Orr, W6SAI, *The Radio Handbook*, 21st edition, page 25.8.
2. *The ARRL Antenna Book*, 11th edition, page 77.
3. J.J. DeFrance, *General Electronics Circuits*, page 91.
4. *Electronics Data Book, ARRL, pages 82-84.*

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