What Does Your SWR Cost You?

Basic Amateur Radio: Wondering whether to spend a fine day with the YL or with your antenna? This article may help you decide.

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No doubt most of us have heard someone tell a story similar to this at a local ham gathering: "I put up a new antenna for 40 meters and it doesn't work. I cut it to exactly 65.69 feet,[1] according to the formula for a dipole, but my SWR bridge reads 3:1!"

For some reason, a good many hams believe that a "high SWR" is a terrible thing, indicative of some serious antenna malfunction. Not long ago there was an excellent series in *QST* entitled "Another Look at Reflections" by M. Walter Maxwell.[2] Those interested in a detailed theoretical discussion should refer to that series. The purpose of this article is to show how to determine the amount of signal you are losing because of your SWR — and more important, whether it is worth bothering about.

Power Loss

There is only one way that power can be wasted in a properly balanced antenna system, and that is in the form of heat.[3] Power may be dissipated in the transmitter output circuit or Transmatch, in the conductors and dielectric of the transmission line, in the antenna conductors, and in objects surrounding the antenna, including the earth and grounding system. All the rest will get radiated. There's simply nowhere else it can go!

Standing waves on a transmission line cause an increase in the amount of power dissipated in the line. In the extreme, power may also be dissipated in the tuning network circuitry, but this rarely occurs if the network is designed to handle a high SWR at the power level being used. A high SWR on a transmission line will *not* appreciably increase radiation from the line.

Table 1 shows the loss of the two kinds of transmission line most often used by hams, in decibels per 100 feet, under perfectly matched conditions (1:1 SWR).[4] It is assumed that the line has not deteriorated because of age or adverse environment; in such cases the loss will be greater than indicated.[5]

As an example, suppose we have 65 feet of RG-58/U feeding an antenna on 21 MHz. The matched-line loss at this frequency is approximately 2.0 dB per 100 feet. To obtain the figure for 65 feet, simply multiply 2.0 by 0.65, giving 1.3 dB. Of course, odds are that we will *not* have a perfect match between the line and the antenna. This figure, 1.3 dB, is nevertheless important for determining the additional loss caused by a mismatch.

Determining the SWR

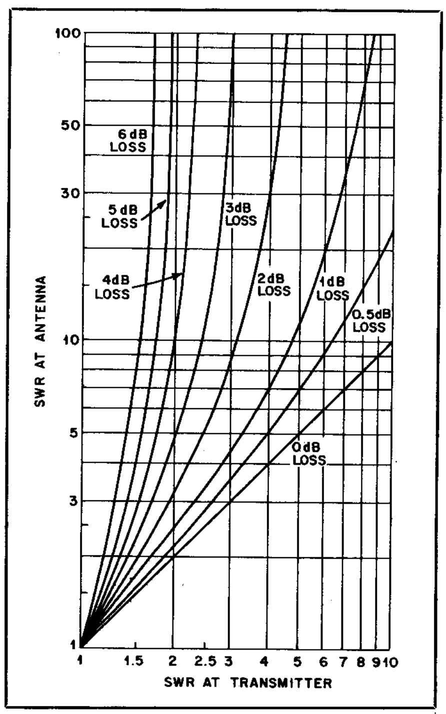
When measuring SWR, one will most likely take the reading at the transmitter output. To get a true reading, however, it should be measured at the point where the feed line is connected to the antenna. Because of line loss, we will see more "forward power" at the transmitter than at the antenna, and also less "reflected power" at the transmitter than at the antenna. These two factors combine to give us a false reading at the transmitter —

Table 1

Approximate matched-line loss in dB per 100 feet for the two most commonly used types of coaxial transmission line.

Coax Type	*Frequency (MHz)* 1.8	3.5	7	14	21	28
RG-8/U	0.2	0.3	0.5	0.7	0.8	1.0
RG-58/U	0.5	0.7	1.0	1.5	2.0	2.3

Fig. 1 — SWR at input end of transmission line vs. SWR at load end for various values of matched-line loss.



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[1]Notes appear on page 20.

the true SWR is higher than this reading. The greater the matched-line loss, the larger the discrepancy. Fig. 1 is a correction graph which will tell you the true SWR if you know the matched-line loss and the SWR as measured at the transmitter.[6] This is certainly more convenient than climbing up to the antenna feed point with an SWR bridge, especially if this point is suspended in midair!

Suppose the 21-MHz installation previously mentioned gives us an SWR reading of 2:1 at the station. Using Fig. 1, we see that the true SWR is about 2.8:1 (this involves some interpolation but extreme accuracy is not essential). That sounds pretty bad, doesn't it? At 21 MHz, using RG-58/U, it must be horrible, right? Well, let's see!

How Much Does It Cost?

Now that we know the true SWR, we're almost ready for the final step. But first it is important to understand one thing: If the additional loss caused by standing waves amounts to less than 1 dB, then from a practical standpoint there is no SWR loss at all. Never mind that 1 dB represents 20 percent of the power! A decibel happens to be the smallest change in signal strength that a listener can detect if he is expecting it. Any change of lesser magnitude is inconsequential.

We use Fig. 2 to determine the loss caused by the line SWR. Since the matched-line loss is 1.3 dB and the true SWR is 2.8:1, less than 0.6 dB additional loss results from the mismatch. This amount is negligible!

The *overall* feed-line loss (the sum of the matched-line loss and the SWR loss) in this system is 1.3 dB + 0.6 dB, or 1.9 dB. If we replace the RG-58/U cable with an equal length of RG-8/U, the overall loss will be approximately 0.8 dB, as the reader is invited to verify. Whether or not this gain of 1.1 dB, which is a just-detectable improvement, is worth the expense is up to the control op to decide.

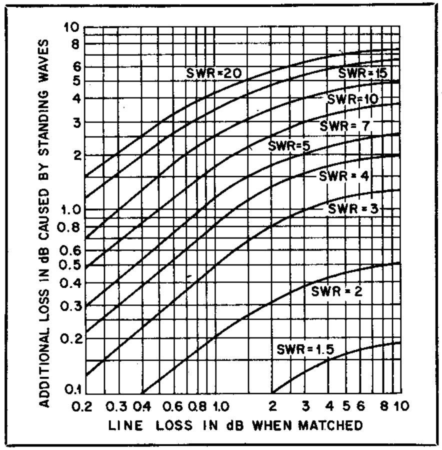

Fig. 2 — Increase in line loss because of standing waves (SWR measured at the load). To determine SWR loss, first determine the matched-line loss for the piece of line in question. Locate this point on the horizontal axis and move up to the curve corresponding to the actual SWR as measured at the antenna. The corresponding value on the vertical axis gives the additional loss in decibels caused by the standing waves.

Some rather surprising facts can be gathered using Table 1 and Figs. 1 and 2. Suppose for instance we are using 50 feet of RG-8/U at 3.5 MHz. How large an SWR, as measured at the transmitter, can be tolerated if one desires to keep the SWR loss to less than 1 dB? Believe it or not, the answer is 9:1! In fact, if you cut an 80-meter dipole for the center of the band, it can be used from 3.5 to 4.0 MHz without significant SWR loss, even with a fairly long feed line.

In closing, it should be mentioned that most modern commercially manufactured equipment is designed to operate with an SWR of 2:1 or less. There is a good reason for this limitation: A high SWR can cause large currents or voltages to appear in the transmitter output network. Under certain conditions there may be sufficient current to cause heat damage to the output coil, or enough voltage to arc across the loading capacitors. Usually the mismatch will render it impossible to obtain enough output for either of these things to happen. But it's a good idea to use a Transmatch under high-SWR conditions (even though it won't reduce feed-line mismatch loss) to keep your transmitter happy and your sleep free from nightmares. QST

Notes

[1] Feet may be converted to meters by multiplying by 0.3048.

[2] *QST*, April, June, August and October 1973, April and December 1974, and August 1976.

[3] With improper balance the line may radiate some power. Depending on the particular installation, this may or may not be considered "wasted."

[4] Additional data for these and other kinds of transmission lines can be found in *The ARRL Antenna Book* and *The Radio Amateur's Handbook*.

[5] A method of testing old coax for matched-line loss was given by L. A. Cholewski, "Some Amateur Applications of the Smith Chart," *QST*, January 1960, p. 28. It also appears in the 1966-1972 editions of the *Handbook*.

[6] *The ARRL Antenna Book*, 1974, pp. 82-83.