

## SWR by any other name...

By Harold Kinley, C.E.T.

No matter what you call it, SWR, or *standing wave ratio*, is an indication of the degree of match, or mismatch, of load impedance to source impedance. Generally, we use this term to indicate how well the antenna and transmission line are matched to the transmitter output. Other terms, such as forward and reflected power, reflection coefficient and return loss, are used to indicate the degree of match or mismatch as well. How are these terms interrelated? This column will explain that. Because most land mobile radio technicians are more familiar with forward and reflected power measurements, the definitions of the other terms will be based on their relationship to forward and reflected power.

### Forward and reflected power

Those who work in the land mobile radio industry typically use a directional, in-line wattmeter to measure the forward power and the reflected power at the output of a transmitter. The comparison of the forward and reflected power indicates how well the load (transmission line and antenna) is accepting the power being delivered to it by the transmitter. The higher the reflected power, the higher the degree of mismatch and the lower the efficiency of the system. Not only is the mismatch reducing efficiency, but the reflected power also triggers a *foldback protection* circuit that reduces the transmitter output power. Thus, the reflected power has a two-fold effect in reducing system efficiency.

Generally, the experienced technician uses the forward and reflected power measurements to place a *qualitative* value on the antenna system. One doesn't normally think in terms of standing wave ratio, return loss or reflection coefficient. For example, a technician may measure the forward and reflected power at the transmitter output and find that the forward power is 100W and that the reflected power is 2W. This is a high ratio of forward-to-reflected power, and so all seems to be well. The qualitative analysis has been done simply by reading the forward and reflected power and mentally noting that the forward-to-reflected power ratio is high. Forget the *quantitative* analysis, right? Yes, *maybe!*

### Effects of line loss

In the above example, the forward-to-reflected power ratio was 100/2, or 50:1.

Assuming a negligible line loss, this represents an excellent antenna match. However, suppose the line loss is 3dB. The line loss affects the forward power and the reflected power because both must travel the length of the line. Now, again suppose the forward power at the transmitter is 100W. With a 3dB line loss, the forward power at the antenna connection is 50W. Moreover, with a reflected power reading of 2W at the transmitter, the reflected power at the antenna must be 4W. Thus, the forward-to-reflected power at

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*Transmission line loss can mask the true SWR when it is measured at the transmitter vs. measurements at the antenna..*

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the antenna connection is actually 50:4 or 12.5:1—much worse than the 50:1 ratio found at the transmitter output. This illustrates just how transmission line loss can mask the true SWR when it is measured at the transmitter vs. measurements at the antenna. As long as you know the line loss, you can determine the true SWR at the antenna from measurements made at the transmitter. References to the previous example will be made throughout the remainder of this column.

### Return loss

If the forward and reflected power are known, the return loss can be easily determined from the formula:

$$R_l = 10 \log \frac{f}{r}$$

where  $R_l$  is return loss,  $f$  is forward power, and  $r$  is reflected power.

In the example above, the forward power measured at the transmitter was 100W, and the reflected power was 2W for an  $f/r$  ratio of 50:1. The log of 50 is about 1.7. Thus, the return loss is  $10 \times 1.7$ , or 17dB. Remember too, that the forward-to-reflected power ratio at the antenna was 12.5. Because the log of 12.5 is about 1.1, the return loss at the antenna is  $10 \times 1.1$ , or 11dB. Notice that the difference between the return loss at the transmitter and antenna is 6dB—exactly *twice*

the line loss. The general rule can be stated as: *the return loss at the antenna will be reduced from the return loss at the transmitter by a factor of twice the line loss.* It is important to remember that *the higher the return loss, the better the impedance match.*

### SWR

To convert forward and reflected power measurements into an equivalent SWR figure, the following formula is used:

$$S = \frac{1 + \sqrt{\frac{r}{f}}}{1 - \sqrt{\frac{r}{f}}}$$

where  $S$  is SWR,  $r$  is reflected power and  $f$  is forward power.

In the above example, the reflected power at the transmitter is 2W, and the forward power at the transmitter is 100W, so the ratio of  $r/f$  is 2/100 or 0.02. The square root of 0.02 is about 0.14. Thus, the SWR at the transmitter is:

$$S = \frac{1 + 0.14}{1 - 0.14} = \frac{1.14}{0.86} = 1.33$$

The reflected power at the antenna is 4W, and the forward power at the antenna is 50W. The SWR at the antenna is found using the same formula and is approximately equal to 1.79. Again, the line loss masks the true SWR at the antenna as seen from the transmitter end.

### Reflection coefficient

The reflection coefficient can be derived from forward and reflected power measurements by using the following formula:

$$\Gamma = \sqrt{\frac{r}{f}}$$

where  $\Gamma$  represents reflection coefficient,  $r$  is reflected power and  $f$  is forward power.

Using the example at the transmitter, the ratio of  $r/f$  would be 2/100, or 0.02.

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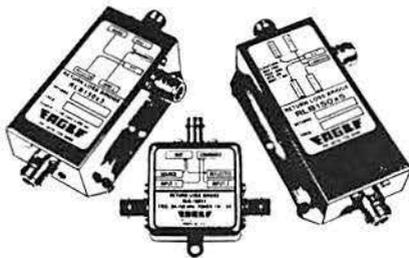
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## Technically speaking

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The square root of 0.02 is approximately equal to 0.14. Thus, the reflection coefficient at the transmitter is 0.14. At the antenna, the ratio of  $r/f$  is 4/50, or 0.08. The square root of 0.08 is approximately equal to 0.28. It is interesting to note that for a line loss of 3dB, the reflection coefficient at the antenna is exactly *twice* the reflection coefficient at the transmitter.

### Transmission loss

*Transmission loss* is a term used to describe just how much the signal power is reduced by a given mismatch, zero being the perfect figure for a *return loss* of  $\infty$ dB, or a *standing wave ratio* of 1:1 or a *reflection coefficient* of 0.0. The transmission loss can be determined from forward and reflected power by using the following formula:

$$T_L = 10 \log \left( 1 - \frac{r}{f} \right)$$

where  $T_L$  is transmission loss,  $r$  is reflected power and  $f$  is forward power.

Using our example, the forward power at the antenna was 50W, and the reflected power was 4W. Thus, the ratio  $r/f$  is 4/50, or 0.08, and  $1 - 0.08 = 0.92$ . The log of 0.92 is approximately equal to 0.036, and  $10 \times 0.036$  is 0.36dB. Therefore, the transmission loss caused by the mismatch at the antenna is 0.36dB.

### Additional line loss

An additional line loss is caused by the standing waves on the line. The net power absorbed or radiated by a load is equal to the forward power minus the reflected power. The loss of the line can be calculated from the net input power minus the net output power. In our example, the net input power was 98W, and the net output power was 46W. Calculating the loss from input to output results in a figure of about 3.28dB. This is 0.28dB more than the loss of the line under normal matched conditions. The additional 0.28dB of loss is caused by the standing waves.

### Summary

No matter what you might call it, the results are the same. A mismatched load will cause degradation in transmission efficiency. However, the actual transmission loss is not as severe as one might expect. Transmission line loss will mask the true SWR that exists at the antenna when measurements are made at the transmitter. By using the formulas presented here you can convert forward and reflected power into any of the other units of measure.

Until next time—*stay tuned!*

