HINTS & KINKS

BETTER FEEDLINE-LOSS MEASUREMENTS WITH ANTENNA ANALYZERS

◊ Various publications through the years have shown how the SWR measured on a shorted (or open) feed line can be used to calculate feed line attenuation. One of the claims made in the manual for my SWR analyzer is that it can be used in a similar fashion to measure feedline attenuation. While that claim is technically true, I found that those measurements are only feasible if the feed line has more than 3 dB of attenuation.

The practical concept behind the theory is simple to illustrate. We start with a transmitter feeding 1 W of incident power into a transmission line. That is, FWD = 1 in Eq 1.

If the line is shorted or open at the far end and the line attenuation is zero, 100% of the forward power becomes reflected power, making REF = 1 in Eq 1.

Since FWD = REF, the SWR calculated by the standard formula Eq 1 is infinite. (Actually any value divided by zero is undefined but in electronics, we bend the math rules to make undefined the same as infinity.)

$$\mathrm{SWR} = \frac{1+\sqrt{\dfrac{\mathrm{REF}}{\mathrm{FWD}}}}{1-\sqrt{\dfrac{\mathrm{REF}}{\mathrm{FWD}}}} \qquad \text{[Eq 1]}$$

For similar reasons, if the feed line had infinite attenuation, all of the incident power is attenuated before it can be reflected back to the wattmeter. As a result, REF = 0 in Eq 1, and the measured SWR would be 1:1.

Zero feed line attenuation manifests itself as infinite SWR and infinite feed line attenuation shows up as 1:1 SWR. Any other attenuation values show up as SWR values between 1:1 and 8:1.

As an example, consider that a 1 W transmitter feeds a line with $^1/_2$ dB attenuation. The 1 W forward power is attenuated to 891 mW by the time that it reaches the open end. The 891 mW is reflected at the open end and further reduced by the $^1/_2$ dB attenuation to 794 mW as it travels back to the wattmeter. Using Eq 1, an approximate SWR of 17.4:1 is measured; that is, $^1/_2$ dB correlates to an SWR of 17.4:1. Table 1 shows some correlations between SWR and feed line loss.

Various charts have been created to convert SWR measurements to feed line attenuation. This was a handy method in the days when a wattmeter was a luxury and most hams only owned an SWR meter. (With a wattmeter, attenuation can be calculated directly from FWD and REF. There's no need to calculate SWR.)

Unfortunately, when I tried to use my antenna analyzer for the same measurement, I ran into a significant flaw right at the point where theory meets practice. A 3:1 SWR is the highest usable value calibrated on my antenna analyzer; an SWR of 17.4:1 is beyond the useful range of measurement.

A 3:1 SWR corresponds to a 3 dB feed line loss. Since all of my feed lines are good quality, my feed line loss is less than 1 dB. The SWR measured using my analyzer always fell somewhere between 3:1 and infinity. This made reading and estimating my feed line loss difficult to impossible using my antenna analyzer.

Table 1
Feed Line Loss versus SWR

Loss (dB)	*SWR*
6	1.6:1
3	3.0:1
2	4.4:1
1	8.7:1

Table 2
SWR Equivalent to Several Attenuation Levels

Attenuation (dB)	*Max SWR*
3	3.0:1
4	2.3:1
5	1.9:1
6	1.6:1

Table 3
Actual Line Loss and SWR fro SWR Measured with 4 dB of Attenuation

Line loss (dB)	*SWR + 4 dB*	*SWR (0 dB attenuation)*
3.0	1.50	3.0
2.0	1.67	4.4
1.0	1.92	8.7
0.75	2.0	11.6
0.50	2.1	17.4
0.25	2.2	34.8
0.10	2.3	86.9

My solution is reasonably simple. I happened to find a 4 dB attenuator for 50 Ω line in my junk box. I connected the attenuator to the SWR analyzer and the feed line to the attenuator. If a feedline has zero attenuation, the 4 dB attenuator alone will cause the measured SWR to be approximately 2.3:1. Let's use a 1 W transmitter to prove that the reduction in SWR as measured at the transmitter is true. The 1 W FWD power is reduced by 4 dB to 398 mW when it reaches the open end. That 398 mW is reflected and then as it passes through the attenuator a second time it is reduced by an additional 4 dB to 158 mW before reaching the meter. Again using Eq 1, if FWD = 1 W and REF = 158 mW then SWR = 2.3:1. Any additional feed line loss causes the measured SWR to be reduced to less than 2.3:1 since it further reduces the REF power reaching the wattmeter.

The calculated SWR for some common attenuators and zero feed line loss is included in Table 2.

Now reconsider the original example using the 1 W transmitter connected to an open feedline with $^1/_2$ dB of attenuation. Without the 4 dB attenuator, the SWR measured 17.4:1. The attenuator by itself reduces the measured SWR to 2.3:1. The 4 dB attenuator plus the additional $^1/_2$ dB of feed-line loss reduces the measured SWR to approximately 2.1:1. This value falls within the usable calibration range of my antenna analyzer. Table 3 provides some comparison values.

By measuring the SWR with the line connected through the attenuator, I can now get a much clearer picture of feed line attenuation. Because all of my measurements now fall within the calibrated range of my analyzer, it is now much

Bob Schetgen, KU7G ♦ Senior Assistant Technical Editor ♦ h&k@arrl.org

easier to make reasonably accurate measurements of feed line attenuation.

One final point needs to be mentioned regarding the electrical length of the line being measured. Notice that an open or shorted feed line also acts as a resonant circuit. This phenomenon can affect the accuracy of your measurement. Make your measurement at a frequency where the line acts as an open circuit (maximum impedance).—*Dan Wanchic, WA8VZQ, 1209 13th St N, St Cloud, MN 56303;* **wa8vzq@arrl.net**