Understanding SWR (the entire story explained)

Taking the mystery and mystique out of standing wave ratio.

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It seems that one of the most mysterious parameters often talked about in the world of Amateur Radio is Standing Wave Ratio (SWR). On-the-air discussions are frequently heard regarding the relentless pursuit of achieving the coveted 1:1 SWR at any cost. *But is there a point beyond which further reductions of SWR have little or no effect?* This paper will help to understand SWR basics, how it impacts station performance, and levels that warrant remedial action.

Table 1
SWR & Radiated Power (Includes Effects of Coax Loss on Reflections)

	With 0.5 dB Coax Loss			With 1.0 dB Coax Loss		
*Meter SWR	*Antenna SWR	Power (%) Radiated	Loss (dB)	*Antenna SWR	Power (%) Radiated	Loss (dB)
1.00	1.00	89.1	0.500	1.00	79.4	1.000
1.10	1.11	89.1	0.502	1.13	79.3	1.006
1.20	1.22	88.9	0.507	1.26	79.0	1.021
1.30	1.34	88.7	0.519	1.39	78.6	1.043
1.40	1.46	88.5	0.532	1.53	78.1	1.073
1.50	1.58	88.2	0.547	1.67	77.5	1.106
1.60	1.70	87.8	0.564	1.89	76.5	1.164
1.70	1.82	87.5	0.581	1.97	76.1	1.187
1.80	1.94	87.1	0.600	2.12	75.3	1.230
1.90	2.07	86.7	0.622	2.28	74.5	1.278
2.00	2.20	86.2	0.644	2.45	73.6	1.330
2.50	2.85	83.9	0.760	3.43	68.5	1.640
3.00	3.56	81.4	0.892	4.40	63.9	1.942

*Meter is at transceiver. Antenna SWR is at the antenna. Assumes coax length is ½ wavelength.

What is SWR?

SWR is a key parameter related to how much of your transmitter's power is actually radiated. Under ideal conditions, a properly designed antenna installed with appropriate feedline will present a 50 ohm resistive load to the transmitter allowing 100% of the delivered power to be radiated. This represents a perfect 1:1 SWR.

In real life, however, some level of antenna inductance or capacitance typically exists and there may be a deviation from the ideal 50 ohm antenna feedpoint resistance. The resulting mismatch between the antenna and feedline causes power to be reflected back to the transmitter. The level of forward and reflected power determines SWR where:

$$\mathrm{SWR} = \frac{1+\sqrt{P_r/P_f}}{1-\sqrt{P_r/P_f}}.$$

where Pr = reflected power
Pf = forward power

Effects of High SWR

Excess SWR can result in high voltages along the transmission line due to reflections. It can also cause RFI (radio frequency interference) in your shack, distorted transmission audio, and damage to your transmission line, related components, or your transceiver. Most modern transceivers employ protection to reduce output power when SWR is excessive. High SWR may also coincide with non-resonant operation of an antenna and a degradation of radiation pattern.

Does low SWR Confirm Maximum Radiated Power?

No You can replace your antenna with a 50 ohm dummy load and achieve perfect SWR with little or no radiation.

Why Keep SWR in Check?

Keeping SWR at reasonable levels will avoid the mentioned deleterious effects while allowing your transceiver to safely deliver maximum power to the antenna. This keeps your equipment happy and operating within recommended parameters.

When is SWR Too High?

Modern transceivers are designed to typically accommodate transmission lines exhibiting an SWR of 2:1 or less. Many have built-in auto-tuners capable of cleaning up SWR's of 3:1 or slightly beyond.

Your antenna should typically exhibit a low SWR at the center of your operating frequency range and not exceed these limits at the upper and lower ends of that range.

THE INTERESTING PART

Is All Reflected Power Lost?

Absolutely not In fact, with short runs of low loss transmission line, the reflections bounce back and forth between the transmitter and the antenna and ***most of the power is radiated regardless of the level of SWR!*** Keep in mind, however, the deleterious effects previously mentioned as high levels of SWR can result in degraded performance or damage your equipment.

So where is Power Lost?

As the forward power traverses the coax and the reflections bounce back and forth between antenna and transmitter, power is lost as heat dissipated primarily in the resistive and dielectric components of the coax. High SWR means higher reflected power and hence, higher losses since the power has to make more trips up and down the coax.

The Effects of Coax Loss

An SWR chart will indicate with a 1:1 match that 100% of the power reaching the end of your feedline is delivered to the antenna and none is reflected.

In reality, *100% of your transmitter's power never reaches the antenna since all transmission lines have finite levels of loss depending on their quality.* And, the loss impacts the reflections as well and can make your SWR appear better that what it actually is.

Measure SWR at the Antenna

for an accurate assessment of feedline to antenna match (see Figure 1). This

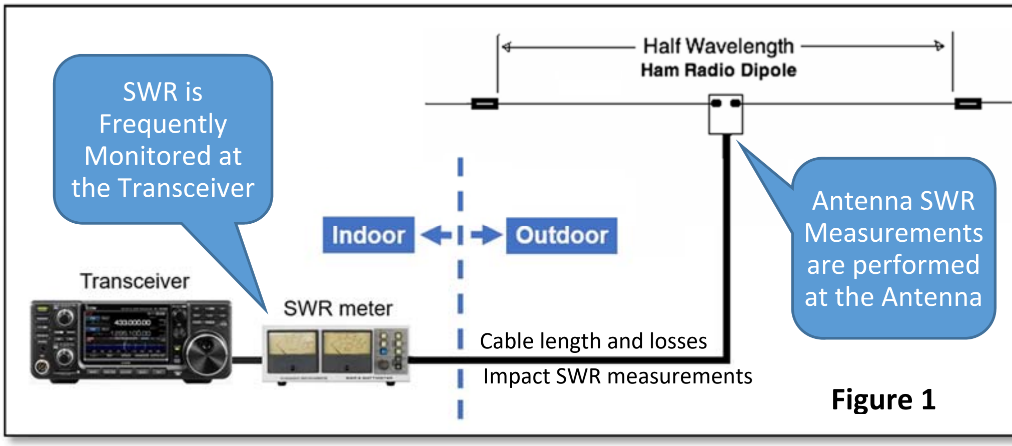

Figure 1

avoids the effects of transmission line loss which can seriously impact measurements. It also eliminates errors introduced by cable length since accurate antenna SWR readings can only be achieved at cable lengths which are a multiple of one-half wavelength.

This is an interesting point, since, if you are trimming an antenna based on meter readings at the transmitter you are adjusting your antenna/coax system, not just the antenna!

And Now the Real World

If SWR Measurements at the Antenna are Not Feasible and you can't control the length of the feedline (which would certainly be a challenge with a multi-band antenna), the primary object remains the same - ***confirming a sufficiently low SWR is presented to the transmitter allowing it to safely operate at full power***. In this case we simply understand the readings do not necessarily accurately depict antenna SWR.

Table 1 shows radiated power based on SWR values at the transceiver with transmission lines having realistic one-way (matched) coax losses of 0.5 and 1.0 dB. SWR at the antenna is derived based on cable loss.

As you can see in both cases, ***even with SWR levels of 3:1 the reduced performance contributed by SWR is less than 1 dB where degradation would likely be unperceivable.***

Many amateur radio operators spend hours working on their HF antennas to reduce SWR from 1.8:1 down to 1:5:1 or better not realizing the improved performance would be negligible. At VHF and UHF frequencies the situation is different and matching becomes more critical to conserve every microvolt of signal to overcome the receiver's noise floor.

Is that the Whole Story?

Not really. When long and lossy transmission lines are involved, a strange situation can occur where SWR measures fine at your transceiver but in fact is *horrible* at the antenna. For example, with an SWR at the transmitter of 2:1 and a 4.5 dB cable loss, the SWR at the antenna would actually be about 32:1.

Wow! Why the difference? Because as mentioned earlier, cable loss also impacts the reflections reaching your SWR meter. And that 4.5 dB loss is a whopper!

73, WB9LIB

Ref: Understanding SWR by Example, Darrin Walraven, K5DVW (ARRL Archive)