This wave is best as a ripple – VSWR

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Photo 1. The two units at the top represent the sort of run-of-the-mill VSWR/Power meters that you might see in many amateurs' shacks. The box at front is a homebrew milliwatt RF power meter.

Measuring Voltage Standing Wave Ratio (VSWR) on antennas and feedlines is one of the most common and frequent tests amateurs perform, typically carried out with the sort of equipment seen in Photo 1. The equipment in Photo 1 illustrates the sort of run-of-the-mill meters

The most common and frequent test amateurs perform with equipment shown in Photo 1, is the Voltage Standing Wave Ratio (VSWR) measurement on their antennas. In many instances, the V is dropped, and the term becomes plain old SWR.

The SWR value is expressed as figures such as 2:1, 5:1, etc. This is a numerical ratio and has no units. When there is a perfect impedance match between a transmitter and the load (generally, an antenna), the SWR will be 1:1. But when there is a complete mismatch with a short or open circuit, the SWR value is infinity-to-1.

We all do it. We all accept it. But, do we really know what we are doing? Hopefully this article will shed some light on the wave that should be a ripple.

Impedance matching

When connecting an antenna to a radio (transmitter or receiver) there are three components, and their associated connections, to be considered in the match.

1. Transmitter (and receiver)
2. Transmission Line
3. Antenna

To achieve maximum power transfer from the transmitter to the airwaves, the output of the transmitter is designed to match the input impedance of the transmission line. The transmission line's impedance must match the input (feedpoint) impedance of the antenna.

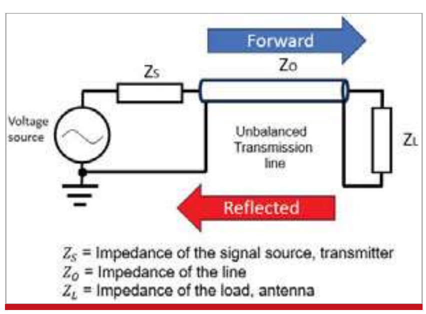

Figure 1. The 'workings' of unbalanced transmission line, such as coaxial cable.

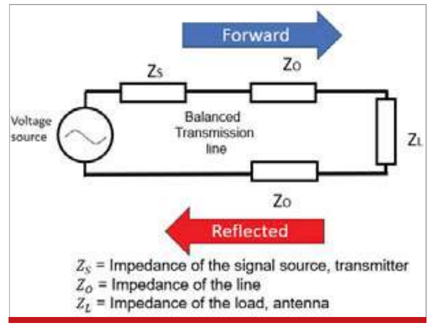

Figure 2. The 'workings' of balanced transmission line, such as 'ladder line' or open wire feedline.

Looking at **Figures 1** and **2**, if $Z_S = Z_0 = Z_L$, a matched condition exists. Attach an oscilloscope to the signal source (at left) emitting a simple carrier wave, the signal on the oscilloscope would be a perfect carrier wave. All the power is transmitted to the antenna.

Any mismatches and a portion of the signal from the transmitter is reflected to the transmitter, just like an echo in a bare room. If this reflection is a wave, this is not good. A ripple is OK. The comparison of this reflected wave is called the SWR.

An antenna is generally a complex load, with both resistance and reactance. In this article, for simplicity, I am only addressing the antennas' impedance as Z_L.

SWR

A definition for SWR I found is this:

> *"SWR is a measure of impedance matching of loads to the characteristic impedance of a transmission line. Impedance mismatches result in standing waves along the transmission line, and SWR is defined as the ratio of the partial standing wave's amplitude at an antinode (maximum) to the amplitude at a node (minimum) along the line."*

That is a mouthful. Simply, it means – measure the high, measure the low, and compare.

SWR meters are passive instruments that measure forward and reflected voltage in a transmission line. As the examples in Photo 1 show, the SWR scale often include a power scale in Watts.

Impact

The reason a standing wave is not good is that as the reflected wave from any mismatch adds and subtracts to the forward wave, producing a standing wave. The

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forward and reflected waves are moving up and down along the transmission line. As the waves come into phase, the voltages add, and at that point are maximum (antinode). As the waves go out of phase, the voltages subtract, and are at minimum (node).

Figure 3 illustrates how the waves moving in and out of phase can become produce a large standing. For example, an SWR of 1.2:1 means the peak voltage is 1.2 times the minimum voltage along that line.

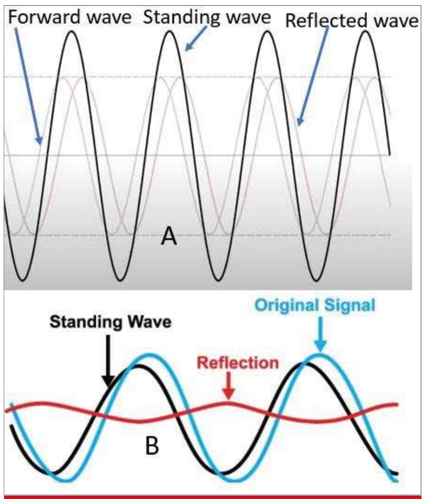

Figure 3. Showing how standing waves are produced.

The wave in **Figure 3A** is an example of an open or short circuit mismatch. The forward and the reflected waves are at the same amplitude. **Figure 3B** is an example of a more moderate mismatch.

Consequences

Some negative side effects of a high VSWR include:

- Transmitter power amplifier (PA) stage(s) can be damaged.
- PA Protection in modern transmitters reduce output power.
- High voltage and current levels can damage transmission lines.
- Delays resulting from reflections can cause distortion in the signal.
- Reduction in signal strength compared to perfectly match system.

Example

Say we have a transmitter delivering a maximum signal voltage on the transmission line of 200 V and a minimum of 100 V. Using the formula below, we get an SWR of 3:1.

$$VSWR = \frac{V_f + V_r}{V_f - V_r} \qquad V_f\text{=Forward voltage} \quad V_r\text{=Reflected voltage}$$
$$= \frac{200 + 100}{200 - 100}$$
$$= \frac{300}{100}$$
$$= 3{:}1 \ \text{Not good}$$

Calculation 1. Calculating VSWR.

Not a great SWR, but looking at **Table 1** we get a better appreciation of what is happening to all that energy.

- The power loss is 25%, equalling 25 W lost. This energy must be dissipated as heat somewhere in the circuit.
- Voltage loss of 50%.

VSWR	% Power Loss	% Voltage Loss	Reflection Coefficient
1:1	0	0	0
1.1:1	0.2	4.7	0.047
1.15:1	0.49	7.0	0.070
1.25:1	1.2	11.1	0.111
1.5:1	4.0	20.0	0.200
1.75:1	7.4	27.3	0.273
1.9:1	9.6	31.6	0.316
2:1	11.1	33.3	0.333
2.5:1	18.2	42.9	0.429
3:1	25.1	50.0	0.500
3.5:1	30.9	55.5	0.555
4:1	36.3	60.0	0.600
4.5:1	40.7	63.6	0.636
5:1	44.7	66.6	0.666
10:1	67.6	81.8	0.818
20:1	81.9	90.5	0.905
100:1	96.2	98	0.980
Infinite	100	100	1.000

* Divide % voltage loss by 100 to obtain p (Reflection Coefficient)

Table 1. Comparisons of VSWR levels.

Limits

- SWR 1.0-1.5: Ideal.
- SWR 1.5 - 1.9: There's room for improvement.
- SWR 2.0 - 2.4: Should not damage your radio with casual use.
- SWR 2.5 - 2.9: Performance decreased.
- SWR 3.0-plus: Could cause damage; will degrade performance.

ATU

Such a simple acronym! When someone throws out the term ATU, they can mean – antenna tuner, or antenna matching unit, impedance matching unit, matchbox, matching network, transmatch, antenna match, antenna tuning unit (ATU!), antenna coupler, or feedline coupler.

The ATU is a passive electronic device, or "network," placed in between the radio transmitter and the transmission line. The ATU does not change the transmission line or the antenna impedance. The ATU only provides the transmitter with the impedance it requires.

Dummy load

A good dummy load is an essential item of equipment in the shack. The dummy load not only dissipates the signal energy when adjusting a transmitter, it is a perfect impedance match to substitute as an antenna load.

Getting a high SWR in your feedline and antenna system and not sure where the mismatch is? Substitute the dummy load for the antenna at the end of the feedline (or feedline sections) to isolate the problem..

Regular checks

Mismatches can occur with components of different impedances or a faulty connector. I had an active antenna in use for some time. After a holiday I checked the SWR and the reading was very high. Water had penetrated the connector and caused corrosion. So, check your VSWR regularly. It taught me a lesson to always have my SWR meter permanently in the equation.

Further reading

While the examples used often refer to the transmitter, SWR affects receivers equally in terms of transmission line degradation and consequential receiver performance.

Information about related factors such as increased losses in coaxial cable due to high SWR, and how such losses can be mitigated with open wire feedline, is available in respected antenna publications by John D Kraus W8JK, William I Orr W6SAI, the ARRL, and RSGB et al.

Have fun and stay safe.

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