

Standing Wave Ratio

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Imagine an infinitely long transmission line. A cable constructed with certain dimensions might look like a 50-ohm resistor. It wouldn't (ideally) dissipate any power, it just travels forever to infinity.

If you cut off that cable at some point and connect a 50-ohm resistor to its end, the whole thing is, to the source, still equivalent to 50 ohms, except that now all the power will be dissipated (warm up) the resistor.

An antenna designed to look like 50 ohms will look the same to the source, except that in this case what looks like power "lost" is really what is radiated out. As far as the transmitter is concerned, it looks the same, since it doesn't "know" what it is that absorbs the energy.

If now there is either a short circuit at the other end, or the opposite, namely an open circuit, there is nothing to absorb energy. So what happens to the energy that merrily traveled down the coax, hoping to be used up either by being radiated out into the world as electromagnetic radiation, or as just plain lowly heat?

Conservation of energy to the rescue: It gets reflected, the same as a sound wave from a wall (a hard brick wall, not one with acoustic tiles, or a blanket hanging on it -- Can you see the analogy?)

And when you have two waves with identical frequency (namely the same one) traveling in opposite direction, you get a "standing wave" (Physics 101 - probably)

So, with a perfect match, no standing wave, with a perfect "UN-match" a total standing wave, and with in-between "mis-matches" an in-between amount of standing waves. The amount of standing waves gives you an idea of how good the match of the load (antenna) is to the characteristic impedance of the transmission line.

No standing waves is also called a "flat" line, because the voltage is the same all along. In this case, the standing wave ratio (SWR) is 1, representing a perfect impedance match. With standing waves the voltage will have "bumps" or antinodes which are 1/2 wavelength apart along the line, and the higher the SWR is, the poorer the match at the load end, and the greater the amount of reflected power.

Now it's time to express this mathematically. We define the reflection coefficient, represented by the symbol Γ . For $\Gamma = 0.5$ the total electric field function (or voltage, if you want to think about it that way) might look like this: $E = \cos(\omega t - \phi) + 0.5 \cos(\omega t + \phi) \text{ [V/m]}$

The standing wave ratio is defined as the ratio of the maximum amplitude of the standing wave to the minimum amplitude. This means that SWR is the ratio of the antinode voltage to the node voltage of the standing wave in the feed line. SWR is also related to the reflection coefficient and, of course, the impedances of the mediums on either side of the boundary, which are usually a transmission line and an antenna.

$$SWR = \frac{E_{max}}{E_{min}} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

For the perfect impedance match situation, $\Gamma = 0$, and $SWR = 1$. This may also be expressed as 1:1. When SWR is expressed as a ratio, the denominator of the ratio is always 1, making life a bit simpler.

An SWR less than 1.5:1 is considered good. An SWR greater than 2:1 is usually unacceptable. Modern radios will shut down over a threshold SWR which is usually slightly larger than 2:1. An unacceptably high SWR signals an antenna system problem. The antenna may not be tuned correctly, or maybe the antenna or feed line is too close to metal. Balanced lines are especially sensitive to being in close proximity with metal—trust me, I found out the hard way!

An SWR meter is an important piece of station equipment. It is especially important to check new antenna systems for SWR to be sure that they are functioning properly. A typical SWR meter only costs \$20 to \$30. It is logical to place one near the transmitter. If you are using an antenna tuner, it will probably include an SWR meter, so you're set.

You are now more than ready to answer the exam questions on SWR! You'll find that they are really quite easy.

Reference:

Stuart Wentworth. *Fundamentals of Electromagnetics*. Hoboken, NJ: Wiley, 2005. pp. 245-246.

Practice Exam Questions on SWR

T8E01

What does standing-wave ratio mean?

- A. The ratio of maximum to minimum inductances on a feed line
- B. The ratio of maximum to minimum capacitances on a feed line
- C. The ratio of maximum to minimum impedances on a feed line
- D. The ratio of maximum to minimum voltages on a feed line

T8E03

What would an SWR of 1:1 indicate about an antenna system?

- A. That the antenna was very effective
- B. That the impedance of the antenna and its transmission line were matched
- C. That the transmission line was radiating
- D. That the antenna was reflecting as much power as it was radiating

T8E04

What does an SWR reading of 4:1 mean?

- A. An impedance match that is too low
- B. An impedance match that is good, but not the best
- C. An impedance mismatch; something may be wrong with the antenna system
- D. An antenna gain of 4

T8A11

What might you connect between your transceiver and an antenna switch connected to several antennas?

- A. A high-pass filter
- B. An SWR meter
- C. A key-click filter
- D. A mixer

Key (order scrambled – check question identifiers):

T8E03 B
T8E04 C
T8A11 B
T8E01 D

Questions from the 2003 NCVEC Element 2 Question Pool. Responses scrambled.