**SWR: What it is and What it is Not**

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By

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Before getting into the nuts and bolts of Standing Wave Ratio (SWR), we need to understand some of the terminology involved with the concept. Specifically, resistance, impedance, reactance, and resonance. Some of these terms sound like they mean basically the same thing, however, the differences are highly significant. Finally, electronic components behave differently when used in DC circuits versus when they are used in AC circuits. In amateur radio, our radio frequency (RF) signals are AC in nature and at frequencies measured in kilohertz (KHz), megahertz (MHz), and gigahertz (GHz). The most common bands of operation measured in megahertz.

***Direct Current Voltage:*** usually abbreviated as DC. DC voltage is where the neither increases or decreases, but stays at a constant level. This is the type of voltage we get from batteries or power supplies that turn wall outlet voltage (AC) into DC.

***Alternating Current Voltage:***usually abbreviated as AC. AC voltage is where voltage is fluctuating from some negative value to a positive value and at a particular rate of doing so. This is the type of voltage supplied to homes from the power company. Typically, 120 volts alternating at a frequency of 60 Hz.

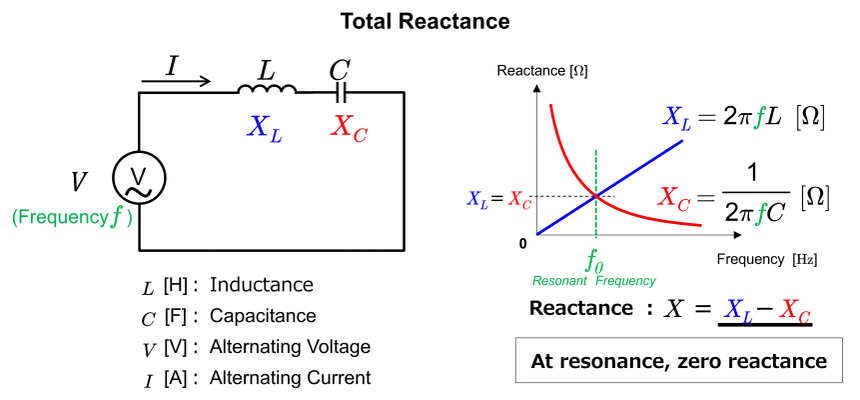
***Resistance:*** In basic electronics one of the first concepts we learn about is the relationship between voltage (V), current (I), and resistance (R), and these are usually presented in circuits where the voltage is direct current (DC). One of the key formulas we learn that relates these three properties is Ohm’s Law: V=IR. In a DC circuit, resistance is the opposition to the flow of electrons in the circuit. Perhaps the most common electronic component for resistance is the resistor. Resistors tend to offer the same level of resistance regardless of whether the circuit is DC or AC.

***Reactance:*** When moving into the world of AC, components, particularly inductors (L) and capacitors (C) also begin to offer opposition to the flow of electrons, however, the intensity of opposition is dependent upon the frequency. Inductors offer greater opposition as the frequency goes up, whereas capacitors offer less opposition as the frequency goes up. Reactance uses the letter X and Inductive reactance () is the labeled X sub L. Capacitive reactance () is labeled X sub C.

***Impedance:*** In an AC circuit impedance is the overall opposition to the flow of electrons. It is the bundling of resistance and reactance together. It should be noted that impedance is actually a complex number: R ± jX, where R is the resistance value in the real number domain, and X is the reactance in the imaginary number domain. Reactance is in that domain due to how voltage and current are separated as they flow through inductors and capacitors.

***Resonance:*** (from Merriam-Webster) b(1): a vibration of large amplitude in a mechanical or electrical system caused by a relatively small periodic stimulus of the same or nearly the same period as the natural vibration period of the system.

In an antenna system, resonance has two places where it can be applied. 1) The point where both the inductive reactance and the capacitive reactance are equal and therefore cancel each other. 2) An antenna may be “tuned” to be resonant on a particular frequency. For example, an end-fed half-wave dipole might have its radiating element cut to be a half-wave at the mid band region of 40 meters. It is resonant for 40 meters, and because of harmonics, it is also resonant at 20 and 15 meters, and with an added cap (100pF), resonate for 10 meters.



***Voltage Standing Wave Ratio (VSWR or just SWR)***

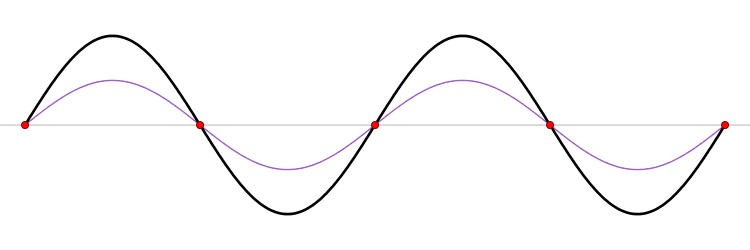
***SWR and what it is not:***

The value given by the SWR measurement is ***NOT*** an indication of how effective the actual antenna is at radiating RF energy. A great example of this is hooking up a dummy load to the output of the transmitter. Since the dummy load has an impedance of 50 ohms and that matches the transmitter output impedance of 50 ohms, we have a 1 to 1 SWR. However, the dummy load does not radiate the RF energy dumped into it as anything other than heat! This is mentioned here because many of us invest in so-called antenna tuners that let us impedance match our radios to our antenna systems. The nomenclature of “antenna tuner” gives us the illusion that we are tuning our antennas. No antenna tuning takes place at all. The next section explains what is actually being tuned.

***What is SWR:***

Let’s boil our system down to its three major subsystems: the transmitter or transceiver; the antenna feed line; and the antenna. Today’s transceivers have a fixed output impedance of 50 ohms – nothing to adjust there; it’s fixed. Next comes the feed or transmission line. This system physically connects the radio to the antenna system. While there are several types and configurations of feed lines, perhaps the most common or well-known is coax cable. Typically, the coax cable has an impedance of 50 ohms. However, age, location, and length are a few of the many variables than can affect impedance. Finally, we get to the antenna system itself. It may or may not offer an impedance of 50 ohms. When it comes to antennas, everything affects everything. So, let’s see what happens when we send some RF energy out of our radio into the feedline.

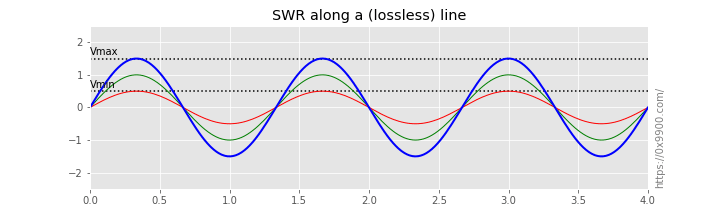
As the RF travels down the feedline, it will likely encounter some impedance beyond what the cable design was meant to offer. The antenna system itself may offer a lot more impedance than 50 ohms and this gets added to the total. Remember that impedance is the combination of resistance, inductive reactance, and capacitive reactance. This additional impedance causes part of the original RF energy to be reflected back toward the transmitter. As it travels back, it combines with the peaks and valleys of the source RF and creates a standing wave. In cases of severe mismatch, the standing wave can have a voltage high enough to fry the transmitter output transistors.



The blue line is the RF travelling to the antenna. The red line is the reflected RF headed back to the transmitter, and the black line is the standing wave that is created by the source and reflected RF combining.

***Measuring SWR:***

SWR is a ratio of the highest voltage reached by the standing wave divided by the lowest voltage reached, . Assume the following condition -



In the diagram above, the is 1.5 and the  is 0.5. This is a 3 to 1 SWR and would be considered by most to be too high for any long-term operation.

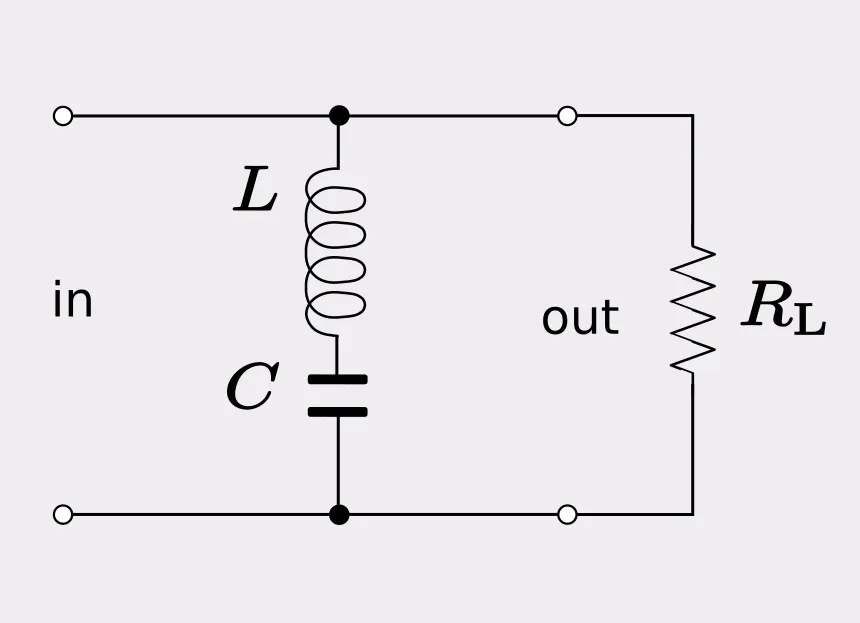
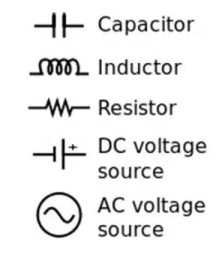
SWR is measured easily by a NanoVNA or antenna analyzer such as the RigExpert. Many of today’s radios have S meters capable of measuring SWR.

***Conclusion:***

Having the feedline and antenna impedance matched means that we are delivering the maximum amount of RF power to the input of the antenna system. Measuring SWR is important because it gives us an indication of how well our feedline and antenna system are impedance matched to our transmitter. A high SWR can indicate a situation where we may damage our radio if we do not fix the system for a better impedance match. At this point, you may be asking, “Where do we draw the line between acceptable and unacceptable SWR?”

The generally accepted rule of thumb is 2:1 and below is acceptable for operation. Even at 2:1, assuming an output of 100 watts, the loss is about 10 watts. Most modern radios also contain circuitry to limit output power if the transmitter senses a high SWR. There is little or no return on investment in struggling to get an SWR of 1.4 down to a 1.3, as the difference will not be noticeable in the real world.

***Some equivalent diagrams.***

Transmission line Antenna system

