Reflections on standing waves

BY DAN ROACH

One of those parameters that we all jabber about frequently in the transmission game is Standing Wave Ratio, or SWR. It's a pity that there's so much misunderstanding surrounding an essentially simple concept.

Your transmitter is connected to your antenna, or load, with a length of transmission line. Transmission line theory tells us that in an ideal, lossless world, if all three of these items are perfectly matched (at 50 ohms, or whatever), then all of the RF energy leaving the transmitter will arrive at the antenna and be radiated from there. In the real world, there will be some slight attenuation from the transmission line, and some of the energy that does make it to the antenna will be reflected back to the transmitter by slight impedance mismatch.

The phase difference between the forward-going, incident wave and the reflected wave varies along the line, but is constant at any point on the line. This is where the expression "Standing Waves" comes from—although the waves actually travel along the line, the voltage nodes appear to be stationary.

Where the voltages of the incident and reflected waves are in phase, there is a maximum, and where they are out of phase a minimum. The Voltage Standing Wave Ratio, or VSWR, is the ratio of the magnitude of the maximum voltage on the line to the minimum. There is also a Current Standing Wave Ratio, which will have the identical value, so clearly the V in VSWR is not needed and we can simplify our expression to SWR without giving up anything. (The continued popularity of that V in VSWR is another one of the great mysteries of our age.)

A perfect load would result in an SWR of 1.00; an open circuit or a short at the end of the line will give us an SWR near infinity (there is some attenuation that keeps us from getting all the way there).

An alternate expression we don't use much in broadcasting, perhaps to our own misfortune, is Reflection Coefficient, which is simply the ratio of the reflected wave voltage to the forward wave voltage. A perfect match gives a reflection coefficient of 0; a short-circuit load has a coefficient of -1.0, and an open circuit's coefficient is +1.0. Conceptually, this is a little simpler to grasp than SWR. But it amounts to the same thing.

Next comes the very popular, but perhaps overused, expression of Return Loss. If we take 20 times the logarithm of the ratio of the magnitudes of the reflected voltage and the forward voltage, we end up with a number in decibels that represents the power "lost" in the load between the incident and reflected waves.

One of my favourite textbooks describes this whole concept as "silly". Nevertheless, it remains popular, probably because we all know how much engineers love to express things (all things, really) in dB. But when we get right down to it, a low value of return loss means the same thing as a high value of SWR—trouble coming up ahead, fast!

Those high SWR values mean that the peak RF voltage at "nodes" on the line, where the forward and reflected voltages add in phase, will be high. As the waves bounce back and forth repeatedly between source and load, that voltage can become very high. If it exceeds the dielectric breakdown voltage of the line, arcing will ensue. That Teflon insulation will break down to carbon and now we have a short. The short gives us another point of high reflections, and so the cycle continues back towards the transmitter.

Aside from the transmission line damage, the transmitter doesn't care much for the mismatch either. Again, peak voltages and currents are suddenly much higher than planned for and will stress the amplifier's components. Even if the parts aren't overstressed to the point of failure, efficiency drops and temperatures rise. At broadcast power levels, something generally has to give pretty quickly. Which is why so much attention has gone into SWR detection and power foldback from manufacturers!

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