Brass Tacks

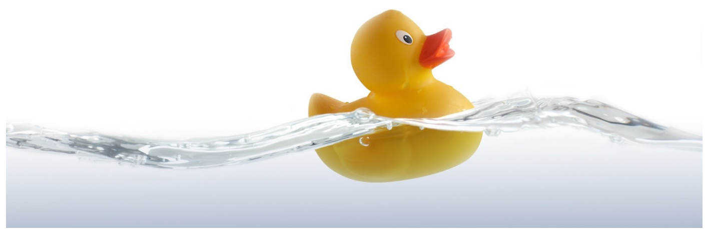
An in-depth look at a radio-related topic

What is SWR, and does it affect my rubber duck?

One night while relaxing in your tub, you reach for the faucet, when something catches your eye. A drop of water falls from your hand onto the still surface of your warm bath. You watch as the drop disrupts your once-smooth pond, causing small waves to move out in concentric circles from its point of impact.

Then, as you curiously continue watching, you see the tiny waves crash into the sides of your tub. Amazingly, those waves ***reflect*** back toward your drop, and with the same speed and frequency as when it hit the wall. Suddenly, the light bulb turns on, and you realize that you're looking at an example of SWR in action, assuming you're not the one who reached over and switched on the electric bulb.

Enter the duck



To see this better, you reach for your rubber duck (no, not ***that*** kind, ***this*** kind), and set it on the tub water. This time you make a bigger wave with, say, your leg. But you notice some inconsistencies, like if you place your duck multiples of exactly one-half wave-length (3 wavelengths, 3 ½ wavelengths, etc.) from the tub wall, it simply sits in place, assuming a small enough duck. But when you place it at non-half quarter-multiples of a wavelength (3 ¼ wavelengths, 3 ¾ wavelengths, etc.) from the tub wall, the little rubber duck actually bobs up and down, and at nearly twice the height as the wave started by your leg. Say it with me: ***fascinating***.

Standing waves

The waves you see reflected off the tub wall dance in concert with the ones that project out from ground zero, and they seem for a moment to rise and fall in place. These dancing circles, caused by the constructive and destructive collisions of crests, are called ***standing waves***. And the height of the largest wave caused by constructive interference compared with that of the smallest wave from destructive interference is called the ***standing wave ratio***, or SWR.

Let's take it a step further. Suppose you reach over and pick up your sponge or washcloth, and place it in the water right against the tub wall where you saw the waves hit, part of it above sea level and part of it submerged. Now repeat the first water drop experiment, only without your rubber (or whatever it's made of) duck. What you see now is that all or most of the waves your drop makes move out toward the sponge, but don't return to the point of impact. In other words, the sponge ***absorbed*** nearly all of the energy that was carried by the waves, so that almost none was reflected.

Cause for reflection

As you can imagine, the interaction between your radio and its antenna system works pretty much the same way, give or take. When you press your PTT (push-to-talk) button, your radio sends out radio-frequency current through a wire to your antenna, which converts the electricity to radio waves, in hopes that these waves will reach the antenna of a radio station located

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continued

on a distant shore. Your goal is to have ***all*** of the electrical energy sent out from your radio converted to radio waves.

Turns out that a scientist (Moritz von Jacobi) creeping around in a damp castle in Transylvania came up with what's known as the ***Maximum Power Transfer Theorem***, which essentially states that, in order for the maximum amount of power to get transmitted through our antenna system, its impedance must match the impedance of the transmitter. (To be more exact, maximum power transfer occurs if the load impedance is equal to the complex conjugate of the source impedance.)

Now, you *know* what impedance your transmitter presents, right? 50 ohms, or more descriptively, 50 + j0 ohms. So that means you want your antenna system to also present 50 ohms, but that's not always easy, especially if its impedance actually changes as you raise or lower your antenna, alter antenna geometry (length, diameter, separation, etc., of its elements,) or you breathe backwards. ***The SWR of your antenna system, therefore, is the relationship (match) between the antenna system impedance and the source impedance.***

SWR consequences

Ok, so what if not 100% of your radio's power gets transmitted out through your antenna? Is that really so bad? Let's take a look. If your HT is rated at 5 watts (P_f), and your antenna measures an SWR of 2:1, then according to the equation below, the reflected power (P_r) will be 0.56 watts, meaning 4.44 watts made it to the antenna. That means 0.56 watts was actually returned to your radio, and its output (final) transistor will experience a total of 5 + 0.56 = 5.56 watts. Can your little HT handle that 560 mW backlash? Probably. What about an SWR of 3:1? That's 6.25 watts, still do-able. 4:1? 6.8 watts. Not good, but the HT can likely handle that without a hiccup.

$$\frac{P_r}{P_f} = \left(\frac{SWR - 1}{SWR + 1}\right)^2$$

How about your 100-watt HF rig? If its antenna system measures an SWR of 2:1, then 11 watts will return to the transmitter final transistors, cresting at 100 + 11 = 111 watts. Can it handle that? Maybe, but your radio will get warm. At an SWR of 3:1, that's 125 watts...your finals are in jeopardy. 4:1? 136 watts at your transmitter, which will likely fry your poor little investment.

What it all means to you

In short, the SWR of your antenna system measures how well matched its impedance is, to that of your radio. So, the closer your antenna system is to 50 ohms (in other words, the closer your SWR is to 1.0:1), the less power is reflected back to your radio to heat it up.

Finally, a perfect (1.0:1) SWR does not mean your antenna system will actually work as an antenna. After all, a dummy load is perfectly matched to your radio, and so has an SWR of 1.0:1, but is a very poor antenna. Your rubber duck (ok, the one that came with your HT) is not quite a dummy load, but it's a very ***inefficient*** antenna. The difference between the perfectly matched dummy load and a well-matched antenna system is the subject for another day.

— Noji Ratzlaff, KNØJI