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Optimizing the Performance of Harmonic Attenuation Stubs

A quarter-wave (0.25 λ) shorted stub makes an effective high-power harmonic-reduction filter. It attenuates the harmonic by putting a very low resistance at the point of insertion in the line between an amplifier and the antenna for that particular frequency. The placement of the stub in the feed line from the transmitter output to the antenna can have a dramatic effect on stub effectiveness.

Usually we see the plots of such stubs taken with a network analyzer in a 50 Ω system. Attenuation can be 20 to 30 dB or greater for RG-213 in the HF bands. When the same stub is inserted randomly into an antenna system, however, the resulting attenuation can be higher or lower; it will depend upon the impedance at the point at which the stub is connected to the line between amplifier and antenna.

Most tube-type linear amplifiers have an LC matching network between the PA and the antenna. Solid-state amplifiers have low-pass or band-pass LC filters in the output circuit. These networks are designed to have 50 Ω output impedance at the operating frequency, but they almost always present a pure reactance at the second and higher harmonics. Some networks are capacitive, and some are inductive, ranging from a few ohms of reactance to several thousand ohms. Since the usual problem is to null a second harmonic, we will focus on that.

The circuit load impedance also can vary widely. For example, a triband beam driven on 20 meters will have a 10-meter impedance close to 50 Ω, but at the harmonics, a monoband antenna can present almost *any* impedance, depending upon matching method.

In a network analyzer the source and load impedances are both 50 Ω resistive. When checking a stub with a network analyzer, the driving impedance is the parallel equivalent of source and load. When a stub is placed in a real station somewhere between the amplifier and antenna, the impedance at that point determines how well the stub will work. When this is higher than 25 Ω at the stub null frequency, the attenuation provided will also be higher than that measured with the network analyzer. Conversely, when the system impedance is low at the connection point, the stub may only provide a few dB of attenuation — substantially less than expected.

We can measure the impedance at the stub insertion point by removing the stub and connecting a meter in its place. A simple one-port instrument such as the MFJ-259B or similar will work. If we measure something like 25 Ω or more at the null frequency, the stub will be doing a reasonable job and no further action is needed.

If we measure a low impedance, we can improve the performance of the stub by moving the connection point. Since the amplifier line and antenna line are connected at this point, we cannot tell which is causing the low impedance. By disconnecting the cable to the amplifier and the cable to the antenna, we can measure each by itself. If the impedance looking into either cable at that point in the line measures greater than 25 Ω, leave it alone. If the other presents a low impedance again at the harmonic, it can easily be increased by adding a short length of transmission line before reconnecting the T and the stub.

An example circuit and some circuit analysis can show what can happen (see Figure 1). On the left side is an analog of a power amplifier with a Pi-L network output circuit. The Pi-L is designed for 2000 Ω to 50 Ω. W1 connects the amplifier output to the T connector, which has a single stub, W3, attached. The output of the T goes through W2 to the antenna. The output is tuned to 14 MHz. The stub is a quarter-wave shorted line cut for 14 MHz. The antenna is simulated by a tuned circuit at 14 MHz in parallel with a 50 Ω load.

The impedance at the T looking toward the amplifier has maximum and minimum values that depend upon the length of W1. The same is true looking through W2 toward the antenna. For these particular values used in the simulation, the values come out to be

W1: Max = 5.5K Ω/Min = 5 Ω

W2: Max = 135 Ω/Min = 18 Ω

The circuit simulation was run under four conditions to determine the net stub attenuation:

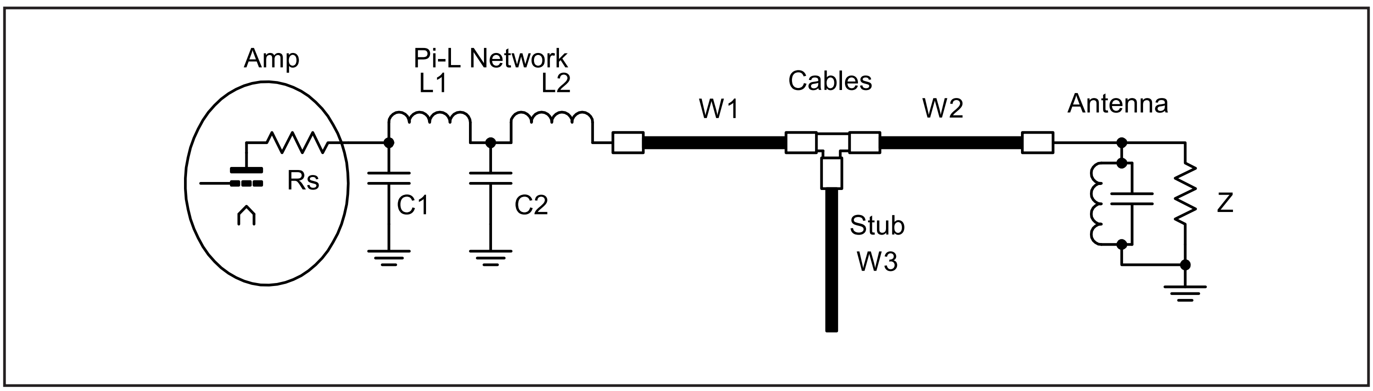

Figure 1 — An analog of a power amplifier with a Pi-L output circuit designed for 2000 Ω to 50 Ω is on the left. W1 connects the amplifier output to the T connector, with stub W3 attached. The output, tuned to 14 MHz, goes through W2 to the antenna. The stub is a quarter-wave shorted line cut to 14 MHz. A tuned circuit at 14 MHz in parallel with a 50 Ω load simulates the antenna.

W1 Max, W2 Max: Net attenuation = 51.1 dB

W1 Max, W2 Min: Net attenuation = 34.4 dB

W1 Min, W2 Max: Net attenuation = 6.4 dB

W1 Min, W2Min: Net attenuation = 6.2 dB

In order to arrive at these results, analysis under each of the four conditions was run twice — once with the stub in place, and once without the stub. The attenuation at 28 MHz with the stub was subtracted from the attenuation without the stub.

The results show a wide variation in the attenuation added by the stub. When the impedance at the stub insertion point is very low, the stub is not very effective. When it's high, the stub can be more effective than indicated by network analyzer measurements.

While we would not complain if our stub produced *more* than 50 dB second-harmonic attenuation — or even 34 dB — it would hardly be worth it to attain only 6 dB. Remember this is only an example, and results can vary a great deal from those shown. The point here is that we must make some simple measurements to be sure the stub is working well.

To prepare for the measurement we must first tune the amplifier for normal operation, and then remove the driver cable from the amplifier, so there is no possibility of RF. Next, activate the PTT to connect the amplifier tank circuit to the antenna output cable.

Now, let's say we remove the stub and measure a low impedance at the connection point. We then separate the cables from the transmitter and to the antenna. We know we will have to alter one or both of the cable lengths, and, because we are dealing with an existing installation, we will only consider adding cable, not removing it. We measure the impedance looking into the transmitter cable, and we read a low value — something lower than 25 Ω to 50 Ω at the stub null frequency. Now we increase the frequency a small amount and observe the direction of change. If the impedance goes *up* we can try adding about 0.125 λ of cable at the null frequency and then re-measure the impedance. It should be higher. If the impedance goes *down* as we sweep the frequency up a bit, we can try adding 0.375 λ of cable.

This method should be used on the antenna cable as well, if it measures a low impedance. If the station uses a pair of stubs, the same method may be used while leaving the coupling line between stubs in place. Before replacing the stub, it is a good idea to make the measurements again.

Thanks to N3RR, whose questions prompted me to look into this issue, and to NØAX for editing help.