The Radio Hotel – Reflected Reflections -- November 2014

What occurs when an Antenna Tuner is placed in the transmission line –TL at some point? What happens to the reflected power that is sent back towards the transmitter from the mis-matched antenna load? Is it lost, is it absorbed, is it radiated…. just what happens? The answers to these questions lies in the organized confluence of complementary impedances, phasing and wave mechanics. There is much more detail than TRH has space to deal with, but I can give you the cursory, 20,000 foot perspective.

An Antenna Tuner, aka Matching Network – MN, is a variable RF transformer that matches the impedance (toward the load) seen at its' output, to the impedance (toward the xmitter) seen at its' input. When matched, you get the maximum amount of power transferred. In the RF world this match is called a "conjugate match", which is 1) making the R values of these two impedances equal; and 2) providing the complement of the imaginary, or j term, in the impedances. For example: if Zout=150 +j50 ohms then the MN provides the complement of 150 –j50 ohms -- mathematically called the "complex conjugate". Hence the name for the match: conjugate match. This complex conjugate matching causes a "maximum power transfer condition". (Google "Conjugate Match" and "Maximum Power Transfer Theorem").

This matching can be accomplished using many network types; the choice is dependent on where the network is applied. At the antenna, you can have Gamma matches, Hairpins, stubs, etc. If it is located within the TL, you can have L, T, and Pi…networks (named after the shape the network elements take in the schematic). These networks are what are inside those "tuners" from MFJ, Palstar, LDG, SGC, etc.

The MN, by setting up this complementary impedance match, also produces complementary wave mechanics and wave phase interactions that cause the reflected waves coming back from the antenna to be "re-reflected" at the MN and then to add, in phase, with the forward going waves continuously traveling toward the antenna from the transmitter. These "reflected reflections" create a "circulating current" of forward and reflected voltage and current waves on the TL. (For a complete (in depth) explanation of this process, Google "Another look at Reflections K6MHE" go to page 24 and read section Reflection Mechanics of Stub Matching – Walt Maxwell explains this process in intimate detail.)

Simple proof that all of the reflected power is truly re-reflected is the observation that the SWR on the TL, from the load to the MN, is something greater than 1:1, but from the MN to the rig it is 1:1, a matched condition. When the SWR is 1:1 there is no reflected power. Zero, Zip, Nada! All power input from the transmitter (except for TL and MN loss) is transferred to the antenna system. The term "reflection gain" is used by Maxwell for this situation where reflected power is added to the forward power, creating, literally, a higher forward power level to the antenna than what the transmitter outputs.

Summary. What does all of this mean to us Hams? First, it shows us that our antennas, TL-feed lines and MN-matching networks are indeed a "closed system" where one change affects the whole system, etc. Second, now that we know that all the power is re-reflected and eventually makes it to the antenna to be radiated and the only losses are the matched TL losses and the minimal MN losses, then the thing to concentrate on is to lessen the TL losses and the MN losses by using lower loss coax/feedline and a more efficient MN.

If everything is implemented properly, the losses incurred will be minimal and you will get maximum power out to the antenna and stronger signals into your receiver. Coax can be used, as it is convenient, but when dealing with multi-band antennas or unmatched antennas on tuned feeders, then it is best to use open wire line or ladder line to lower the loss. The SWR might be higher, as these balanced feedlines run characteristic impedances of 400 ohms and up, but the overall losses incurred will be lower than with coax.

For this series, we started out 6 months ago defining SWR and ended up this month discussing the results of complementary wave mechanics on the TL. A lot of RF thru the proverbial RF bridge (HI). I hope you go back and reread the past 6 columns in order to make sense of what is happening on your TL and understand why it all works as it does and why in the end we get Reflected Reflections. Enjoy – Rick – W5RH

*The purpose of **The Radio Hotel** is to give you a practical kickstart into exploring the workings of antenna systems. It is a series, so go back and read the previous columns to get the whole picture, as one month relies on the previous month's information . Google the buzz words and find out what they mean. Read up on antenna system theory to see how it all works together. You will be glad you did.*