What Tuners Do

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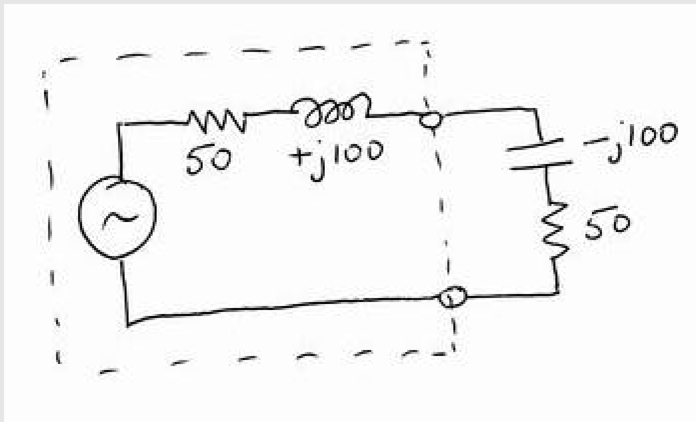
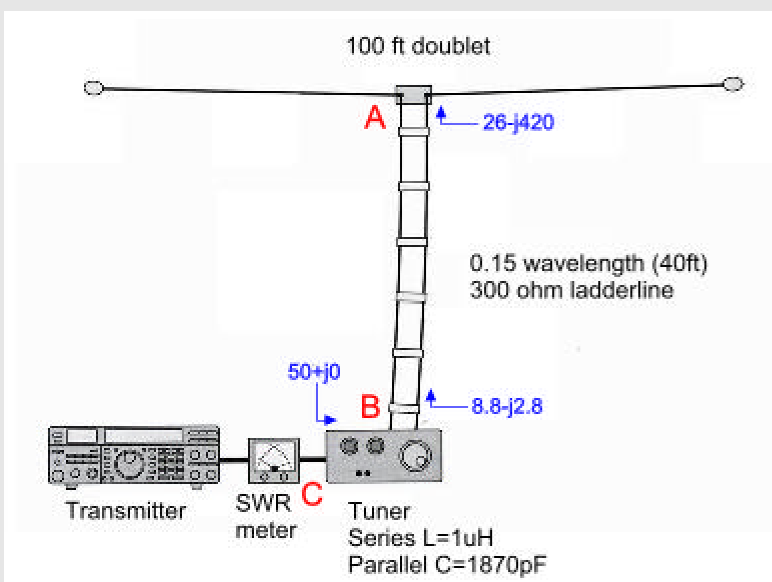


Follow the discussions on any Internet Ham Radio forum and it wont be long before someone comments that: "A tuner in the shack can't affect the match at a remote antenna feedpoint", or: "A tuner simply 'fools' the radio into thinking it is matched". On this page I'll show that both these statements are incorrect!

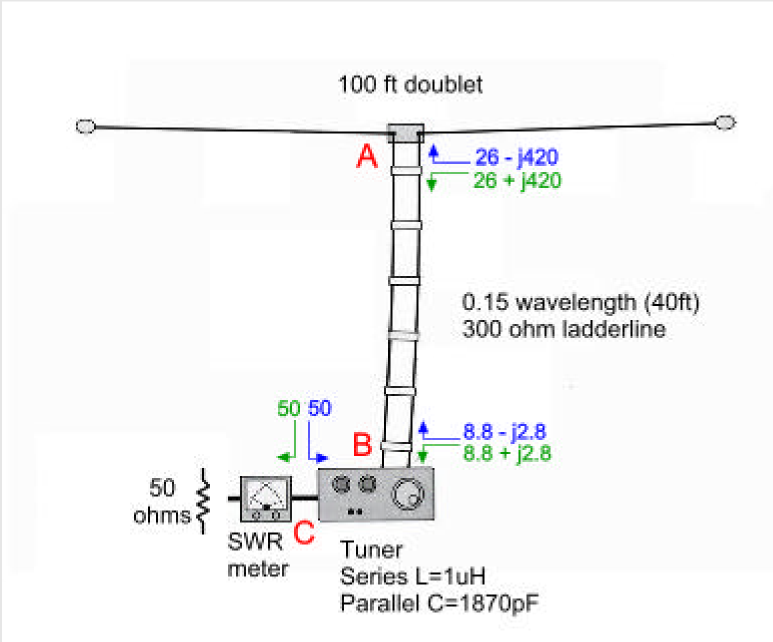
Firstly we need to understand something about "conjugate matching". I guess most folk are familiar with the "Maximum Power Transfer" theorem which says that if a source has a source resistance of R we can extract the maximum power from it if we provide a load of resistance R. Perhaps less well known is how the theorem applies when the source impedance is a combination of resistance and reactance instead of being purely resistive.

The sketch above shows just such a situation, where the source has an impedance of 50+j100. Without working through a complete mathematical proof we can see intuitively that for maximum power transfer the reactance of the source needs to be "cancelled" by an equal-but-opposite reactance in the load, and that the resistive components must still be equal. In other words if the source impedance is R+jX the load impedance needs to be R-jX; we then say that we have a "conjugate match".



Let's see how this works out in a practical antenna system.

The diagram above illustrates a 100ft doublet antenna being center-fed with 0.15? of 300O ladderline from an L-network tuner. To keep things simple we'll assume that the ladderline and tuner have negligible losses. Let's separate the ladderline from the antenna at point A and connect an analyzer across the antenna feedpoint; according to EZNEC we'll measure an impedance of about 26-j420 at a frequency of 3.5MHz. Now reconnect the ladderline to the antenna, but disconnect the other end of the line from the output of the tuner at point B. Connect an analyzer across the ladderline terminals and we'll measure an impedance of about 8.8-j2.8 - the ladderline has transformed the antenna feedpoint impedance (26-j420) into something quite different.
It is true that whatever we do with the tuner we cannot affect these two impedances nor, therefore, the VSWR on the ladderline; however the tuner can affect the impedance seen looking into the tuner at point C. A series inductance of 1uH and a shunt capacitance of 1870pF will transform the tuner's 8.8-j2.8 load impedance at point B into 50+j0 at point C creating an ideal load for the transmitter. So far so good - no surprises!



Now let's replace the transmitter with a 50O resistor to represent its specified load impedance, and repeat the measurements, but this time measuring the impedances looking back towards the transmitter rather than towards the antenna; in other words we're measuring source impedances rather than load impedances. Oh - and be sure not to alter the tuner settings!

If we disconnect the cable from the input of the tuner and measure the impedance looking back towards the SWR meter, we will of course measure 50+j0 or 50-j0 - they're the same thing. Reconnect the cable. Now separate the ladderline from the output of the tuner at point B and connect the analyzer across the tuner terminals we'll measure an impedance, which is 50O, modified by the tuner components. In fact we'll measure 8.8+j2.8. Reconnect the ladderline to the output of the tuner. Now separate the ladderline from the antenna at point A and connect the analyzer across the ladderline terminals. The length of ladderline will transform the 8.8+j2.8 impedance we measured previously into a new impedance of 26+j420.

So, to summarize, at points A, B and C we have measured load and source impedances of:

A: 50+j0 & 50-j0

B: 8.8-j2.8 & 8.8+j2.8

C: 26-j420 & 26+j420

That should look familiar! At each of the points the tuner has created a conjugate match **even at the remote antenna feedpoint!**

At points A & B the tuner can't affect the load impedance, but it can affect the source impedance; conversely at C it can't affect the source impedance but it can affect the load impedance. In fact we could break open the ladderline at any point along its length and we would measure conjugate source and load impedances looking in the two directions.

Another way of looking at the issue is to ask how we are going to easily transfer power into an antenna, which has such a high capacitive reactance; after all, a tuner can do nothing about changing that impedance. The answer is that we need to create a source impedance with a similar high inductive reactance. The combined action of the tuner and the ladderline transforms the source impedance of the transmitter into a value that will allow power to flow more readily into the antenna.

Please don't misunderstand, the 300O surge impedance of the ladderline is still mis-terminated at the antenna, and it still has a high VSWR on it, the tuner hasn't changed that; but it has changed the steady-state system match at the antenna feedpoint, they are different things!

Also, please note that the source impedance of a typical “real-life” transmitter may be significantly different from 50O; however, if the tuner is adjusted to provide a 50O load for the transmitter, there will be a conjugate match throughout the system if the transmitter is removed and replaced by a 50O resistor across the tuner input terminals.

So the next time someone tells you that a tuner doesn't alter the antenna's impedance, agree with them; but point out that it does alter the source impedance at the feedpoint so that the specified transmitter output power gets transferred. **Yes, the tuner really does affect the matching at the remote antenna feedpoint!**