Using *TLW* to Design Impedance Matching Networks

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There are many devices available to amateurs that will measure the complex impedance at the end of a transmission line. For example: the MFJ 269, the LP-100A wattmeter, the AIM4170, any vector network analyzer (VNA), etc. Given an impedance in the series format R + *j*X, the software *TLW* by Dean Straw, N6BV, distributed with the *ARRL Antenna Book,* can determine the components required to match it.

Let us go through some examples to see how we can use *TLW*. We can use some of the values shown in the table for a 100-foot center fed dipole. (See the supplemental article "Multiband Operation with Open-Wire Line" for more about this type of antenna system.) Suppose we would like to use the antenna on 3.8 MHz. First of all, we should be feeding it with 450-Ω line as the losses are excessive with RG-213. After we open *TLW*, for Cable Type we select 450-ohm Window Ladder Line. Set the length to 100 feet. Next we enter the impedance value from **Table 1**, 37.5 – *j*354 Ω. Other settings are: Frequency = 3.8, Source = Normal and select Load.

Table 1
Modeled Data for a 100-ft Flat-Top Antenna

Freq (MHz)	*Antenna Impedance (Ω)*	*Input VSWR RG-213 Coax*	*Loss of 100 ft RG-213 Coax (dB)*	*Loss of 100 ft 450- Ω Line (dB)*	*Max Voltage RG-213 Coax at 1500 W*	*Max Voltage 450- Ω Line at 1500 W*
1.8	4.18 –*j* 1590	33.7	26.0	8.8	1507	10950
3.8	37.5 –*j* 354	16.7	5.7	0.5	1177	3231
7.1	447 +*j* 956	12.3	5.9	0.2	985	2001
10.1	2010 –*j* 2970	12.1	10.1	0.6	967	2911
14.1	87.6 –*j* 156	4.6	2.4	0.3	587	1747
18.1	1800 +*j* 1470	7.7	6.8	0.3	753	1600
21.1	461 –*j* 1250	4.6	3.2	0.1	585	828
24.9	155 +*j* 150	3.6	2.6	0.2	516	1328
28.4	2590 +*j* 772	6.7	9.4	0.5	703	1950

These values were computed using version 3 of the antenna modeling program, *EZNEC* (**www.eznec.com**). Antenna impedance computed using 499 segments and with the Real Ground model.

At the bottom of the screen things have been happening. We see the SWR at the line input is 16.97, the loss is 0.461 dB and the impedance at the line input is 171.02 – j1000.26 Ω.

Now we can look at the various impedance matching designs. There are four Network Types available. We can select them one at a time and compare some characteristics as shown in **Table 2**.

Table 2
Conditions for Different Matching Networks

	Loss	*Cap Voltage*	*Coil Current*
High-Pass L	8.9%	4039V	8.2A
Low-Pass L	5.8%	4125V	5.5A
Low-Pass Pi	33.9%	3457V	31.6A
High-Pass Tee	14.2%	5926V	8.9A

The Low-Pass L network has the lowest loss and would be preferable due to that alone. But, the capacitor voltage is very high and requires a physically large part. Maybe there is something we can do about that. Select Volt/Current and press Graph. Note that with 100 feet of transmission line we are close to a voltage maximum at the transmitter end. Also note there is about 60 feet between the current and voltage maximums. If we add some transmission line, we can move the voltage minimum to the end of the line. It looks like the voltage maximum is about 15 feet down the line, so if we add 60 – 15 = 45 feet we should have a voltage minimum at the line input. Re-plot the Volt/Current graph with 145 feet of line and verify. Now let us look at the various networks again.

Table 3
Conditions with Additional Line Added

	Loss	*Cap Voltage*	*Coil Current*
High-Pass L	0.6%	298V	5.5A
Low-Pass L	0.6%	387V	7.7A
Low-Pass Pi	0.8%	387V	7.9A
High-Pass Tee	15.1%	4237V	12.6A

What an amazing difference for a few cents worth of 450 Ω line. Note the losses are way down in the tuner and the voltages are quite low. Capacitors rated about twice the peak voltage listed voltage should be adequate. Either the Low Pass or High Pass L network will work fine.

Note that the values required in an actual antenna may vary from these calculated values due to different ground parameters or surrounding objects. These numbers are a good starting point, however.

TLW can also be used to design networks for high impedances such as plate tank circuits. Let's try an example. First, select User Defined Transmission Line. In the resulting table set Enter Attenuation to 0.000 and Enter X0 to 0.000. Then press Compute X0. This will remove some residual reactance in the software that occurs even when the transmission line length is set to zero. Close the parameter window. Now set the transmission line length to 0.

Suppose we want to design an amplifier's Pi-network tank circuit to match a 2000-Ω plate output impedance to 50 Ω at 21.1 MHz. In the Resistance/Reactance box, select Input and then input 2000 Ω resistance and 0 Ω reactance. Press Tuner , then select Low-Pass Pi Network. In the Default Values window the Pi-Network Output Capacitor, pF will be the main tuning capacitor. Input a value such as 50 pF for a starting point. Generate the tuner. In the resulting screen, note the effective Q (Eff Q) is 14.8. Most often a Q or 12 would be used. (Pi network design for amplifiers is discussed in the **RF Power Amplifiers** chapter.) To reduce the effective Q, reduce the output capacitance and rerun the example. About 40 pF gives the desired results in this case.

The same result can be had by changing from Load to Input in the opening screen. The value for Output Stray Capacitance, pF value is a reminder not to forget the strays, but this value does not change the computed circuit.