Bob's TechTalk #40
by Bob Eckweiler, AF6C

The "L-Matching Network (Part I of II)

The Basics

Introduction:
Often when working with high frequencies you need to match two impedances. For example, you have just built a 10.1 MHz vertical with lots of quarter-wave ground radials and you want to feed it with 50 ohm coax. The antenna, at resonance, measures 36 ohms with no reactive component, as it should. If you connect the coax directly to the vertical you get an SWR of about 1.4 to 1. Not too bad, but you are a perfectionist and would like to see the SWR lower. The solution is to build an "L" Matching Network. Figure 1 shows a completed matching network that will produce a 1:1 SWR match at 10.1 MHz. Ideally this circuit is lossless and even in real world terms the losses are tiny, mostly from the DC resistance of the coil.

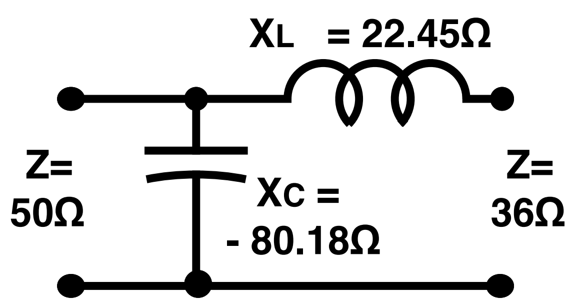

Fig. 1 "L-Network" to Match 50Ω and 36Ω. At 10.1 MHz: C = 196 pF & L = 0.354 μH

Here are some questions we'll answer in this and a future column:

★ Why is it called an "L–Network"?

★ What are some of the uses of the "L-Network"?

★ How does an "L-Network" match?

★ How do I choose the component values?

★ What are the pros and cons of the "L-Network"?

Today we are going to answer the first three questions. The concept of the "L-Network" is easy to understand if you have a basic understanding of AC impedance. You might want to reread Bob's TechTalk # 27: ***Impedance – (Part I of X).***

Why the "L"?:
Why is it called an "L-Network"? Looking at Figure 1, the coil and capacitor are in an "L" configuration with one reactive component in parallel and the other in series with the input/output.

What the "L"?:
The "L-Network" is low loss at HF frequencies making it very efficient and handles high power well. It is bi-directional and can be used to match an impedance to a higher or lower impedance just by swapping the input and output. Design calculations are simple and component values reasonable for low to moderate matching ranges. It can also act as either a high-pass or low-pass filter for attenuating unwanted signals. The "L-Network" is the building block for the more complex "PI Network" and "T-Network" often used in tube RF-amplifiers and antenna tuners respectively. It is also a feature of some antenna matching schemes, especially the beta match.

How the "L"?:
The "L–Network" is based on a simple phenomena of impedance; *At a given frequency an impedance composed of a resistance and reactance in parallel may be replaced by an equivalent resistance and reactance in series*

(and vice versa) without any change in the operation of the circuit.

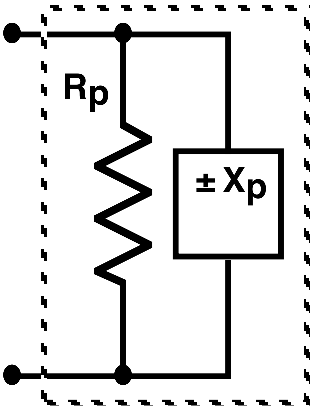

Fig. 2a - Resistance (Rp) in parallel with reactance (Xp)

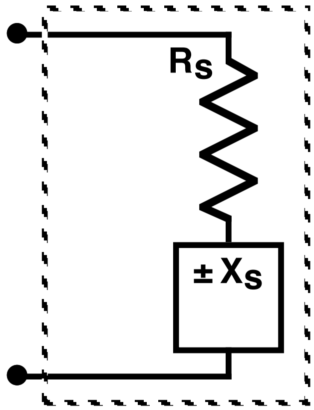

Fig. 2b - Resistance (Rs) in series with reactance (Xs)

Figure 2a and 2b appear the same to an attached circuit. For any values of Rp and Xp, values can be calculated for Rs and Xs that make the circuits appear the same. Xp and Xs can be either an inductance (positive) or a capacitance (negative), but they must be the

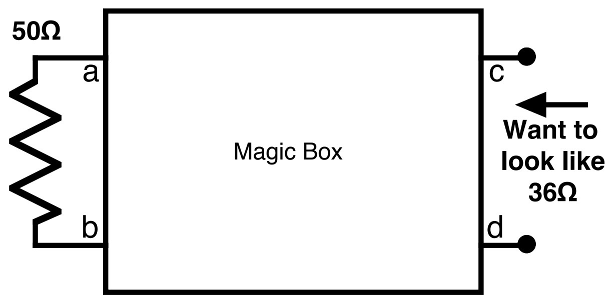

Fig. 3a

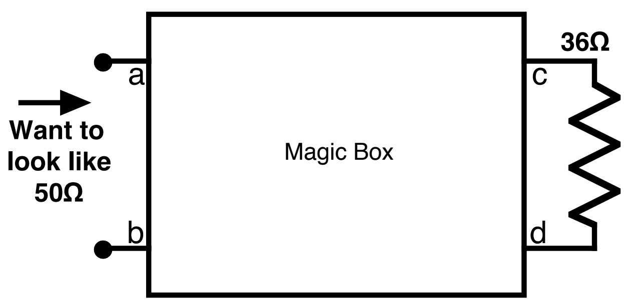

Fig. 3b

same. Rp must always be larger than Rs. This ability to be able to switch between series and parallel impedances forms the basis for the "L–Network". The astute will notice that since reactive components change value with frequency, this equality is frequency dependent!

Let's go back to our vertical antenna matching problem. What we need is a magic box has two sets of terminals. When 50 ohms is connected across terminals a-b, terminals c-d looks like 36 ohms; and conversely when 36 ohms is connected across terminals c-d, terminals a-b looks like 50 ohms. Figures 3a and 3b show this magic box and what we want the impedances at the terminals to appear as.

Inside the magic box add a reactance across the the higher of the two resistance values;

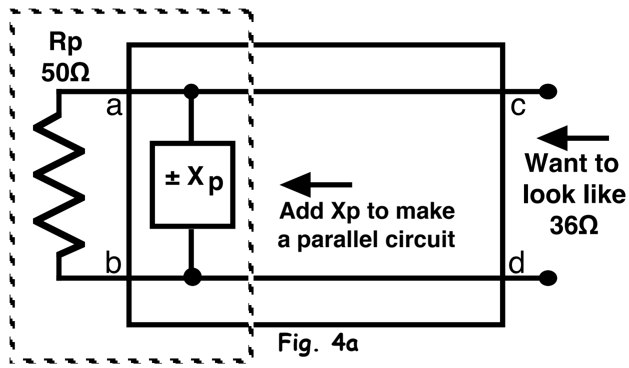

Fig. 4a

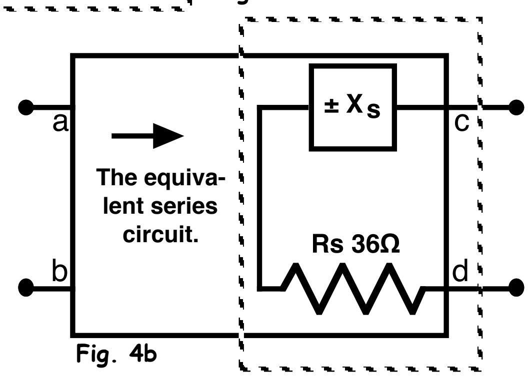

Fig. 4b

in this case across the 50Ω a-b terminals. Call the resistance Rp and the added reactance Xp since they make up a parallel circuit (Figure 4a). This parallel circuit has an equivalent series circuit. What is wanted is an equivalent series circuit that has an Rs value of 36 ohms (Figure 4b). Since Rp and Rs are known, it is a simple matter to calculate the value of the Xp as well as the value of Xs that shows up in series with Rs. Calculating Xp and Xs results in two sets of answers, positive or negative. Thus Xp and Xs may be chosen to either both be inductors (positive) or both be capacitors (negative). If inductors are chosen the "L-Network" acts as a high-pass filter; if capacitors are chosen is acts as a low-pass filter.

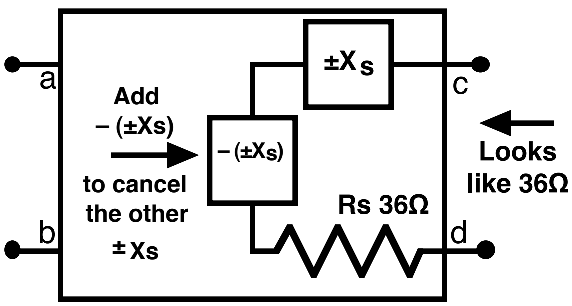

Fig. 5

Looking into terminals c-d in Figure 4b we see the wanted 36 ohms, but there is also a reactance ±Xs in series with the resistance. You cancel this reactance by adding an opposite reactance – (±Xs) in series with ±Xs (Figure 5).

Physically, just two components have been added inside the magic box, Xp and –Xs (Figure 6), one an inductor and one a capacitor. The component values can be calculated for whatever frequency you want the match to occur at using the reactance formulas you learned getting your ham license. Looking back at figure 1 the component values were calculated for 10.1 MHz. The reactance values Xp and Xs are independent of frequency, but the chosen capacitance and inductance must be calculated for whatever frequency the match is desired to be at.

As hinted in the article, the components can either be inductive or capacitive; the choice is yours. Figure 7 performs the identical match as figure 1. However, for most radio work figure 1 is preferred since it acts as a low-pass filter reducing harmonics of the fundamental frequency. However if you want high-pass action, then figure 7 is a better choice.

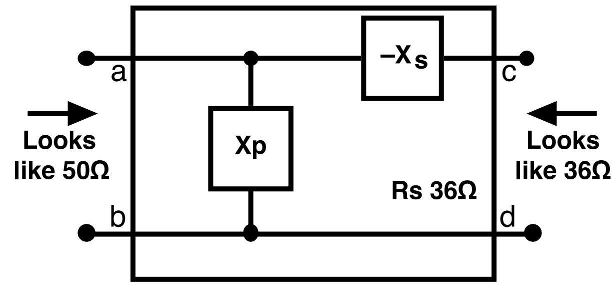

Fig. 6

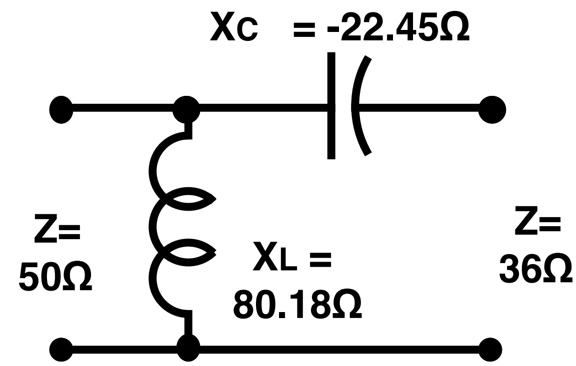

Fig. 7 High-pass "L-Network" version of Fig. 1. At 10.1 MHz: C = 702 pF & L = 1.26 µH

Next month we'll look at the equations used to calculate the needed reactance values; we'll also discuss some of the pros and cons of the L-Network and some caveats when using them.

73, from AF6C

This article is based on the TechTalk article that originally appeared in the February 2010 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.