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ASK THE EXPERTS

Matching Network Design Formulas

This month's note was inspired by the article in this issue, "Practical Estimation of Losses in Tee Network Antenna Tuning Units," by Dr. Perry Wheless. It is a review of a simple design technique for Tee networks, plus two simple transmission line matching tricks.

For a Tee network (Figure 1), the easiest way to obtain a solution for the *L* and *C* values is to use a 90-degree phase shift network. In this case, the reactance magnitude of all three elements is the same, but only when matching to resistive loads ($X_{\text{load}} = 0$):

$$X_a = -X_b = X_c = \sqrt{R_{\text{source}} \times R_{\text{load}}}$$

For example, to match a 50-ohm source to an antenna or device load of 100 ohms, the reactance of the elements is ±70.7 ohms. For the lowpass configuration used in the Wheless article (series inductors and shunt capacitor), operating at 1 MHz—in the middle of the AM/MW broadcast band, the two inductors will be 11.25 µH and the capacitor to ground between them will be 2.25 nF.

The next step is to expand the design process to handle a reactive load. As Wheless explains, X_{load} can be subtracted from X_c, resulting in a new X'_c, leaving a "purely resistive" R_{load}:

$$X'_c = X_c - X_{\text{load}}$$

If we modify the above example to have a load impedance of 100 +*j*100 ohms, X_a and X_b remain unchanged, and we can calculate a new X'_c:

$$X'_c = 70.7 - 100 = -29.3 \text{ ohms}$$

Note that this component is no longer an inductor, but a capacitor, with a value of 5.43 nF at 1 MHz.

Also note the special case where $X_c = X_{\text{load}}$. In this case, $X'_c = 0$ and the network is reduced to just two components. This feature can be used with more complex calculations to obtain 2-element matching networks for other transformations. These calculations use other phase shifts or Q_L values, depending on which parameter is used in the design equations.

The above Tee network design procedure is as simple as can be found. Any four-function calculator with a square root key can be used to compute the element values using the above equations above, plus these formulas for inductance and capacitance:

$$L = X_L/2\pi f \quad \text{and} \quad C = 1/(2\pi f X_C)$$

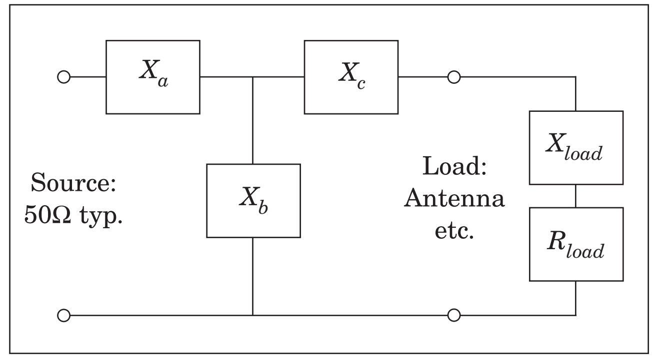

Figure 1 · Tee network topology.

Simple Transmission Line Matching

Analogous to the simplified Tee network example, there are some transmission line topologies that lend themselves to quick calculation. In Wheless' article, the λ/4 transformer section was noted:

$$R_{\text{line}} = \sqrt{R_{\text{source}} \times R_{\text{load}}}$$

The similarity to the simplified formula for a Tee network is unmistakable, illustrating that the 90-degree Tee network is electrically equivalent to a λ/4 transmission line.

Another transmission line "trick" allows easy transformation from one standard line impedance to another. Two 0.08λ (29-degree) line sections, one at the source impedance, the other at the load impedance, create the desired impedance transformation (Figure 2).

Transmission lines at various impedances may be relatively easy to implement in microstrip, but at lower frequencies, coaxial lines are readily available only in a few impedance values, most commonly 50 and 75 ohms. Other impedances are available from some manufacturers, but usually at higher cost and with limited availability of sizes and materials.

For both techniques, it is possible to parallel transmission lines to obtain lower impedances, which permits a wider range of transformations—e.g. two 50-ohm lines to make a 25-ohm line, two 75-ohm lines for a 37.5-ohm line, or one of each impedance for a 30-ohm line—plus other multiple-line combinations.

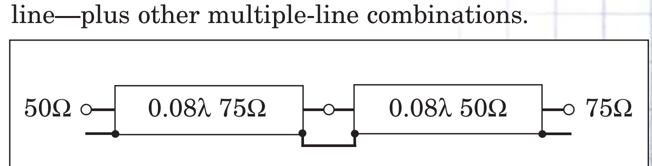

Figure 2 · Simple 50 to 75 ohm transformation.