Common Mistakes (and How to Avoid Them) in Impedance Matching Network Synthesis

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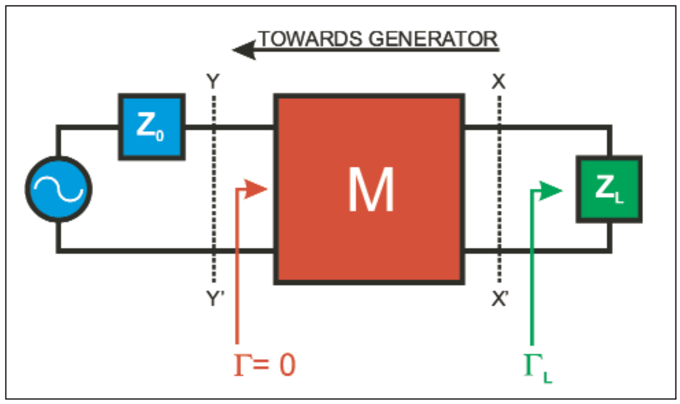
Frequently, students or those new to impedance matching will synthesize the wrong matching network when applying textbook methods to real designs, such as the small-signal transistor amplifier. The two problems which manifest themselves most often are whether to start with the reflection coefficient or the conjugate reflection coefficient (i.e., where to start on the Smith chart), and whether to move towards the generator (load-to-source) or towards the load (source-to-load).

Unfortunately, many popular microwave textbooks fail to point out these small subtleties. The goal of this article is to provide a simple and consistent method of setting up the correct matching network synthesis problem.



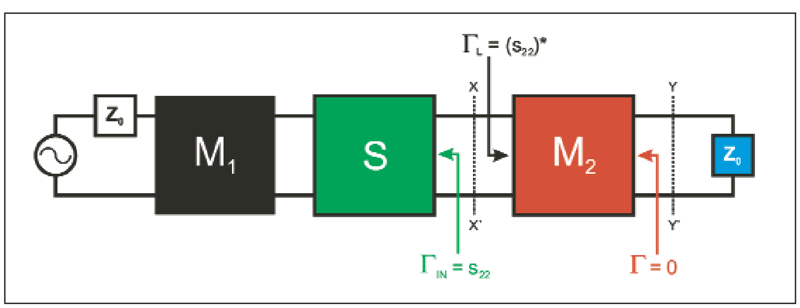
▲ **Figure 1. Textbook matching problem: Load-to-source matching.**

Consider the standard textbook impedance matching network design problem (Figure 1). The student is presented with a load impedance Z_L and is asked to synthesize the matching network M, which matches the load impedance Z_L to the generator impedance Z_0.

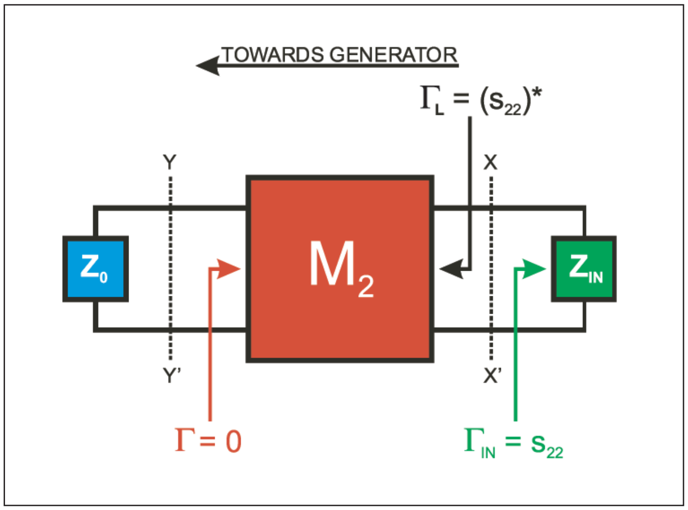
For this article, the color blue has been intentionally mapped to the "generator" impedance (port Y–Y'), red to the matching network and green to the "load" impedance (port X–X'). These correspond to movement on the Smith chart.

The problem can easily be solved by plotting the "load" reflection coefficient Γ_L, using a single-stub tuner or other matching network and keeping in mind that one should always move on the WTG (wavelengths towards generator) scale on the Smith chart when using distributed elements. Moving toward the "generator" on the Smith chart is analogous to moving to the left on the circuit schematic as indicated.

Now, consider the practical design of an output matching network M_2 for a small-signal unilateral transistor amplifier (Figure 2). Here, the



▲ **Figure 2. Design of an output matching network for a small-signal unilateral transistor amplifier.**



▲ **Figure 3. Matching the load impedance Z_{IN} to the generator impedance Z_0.**

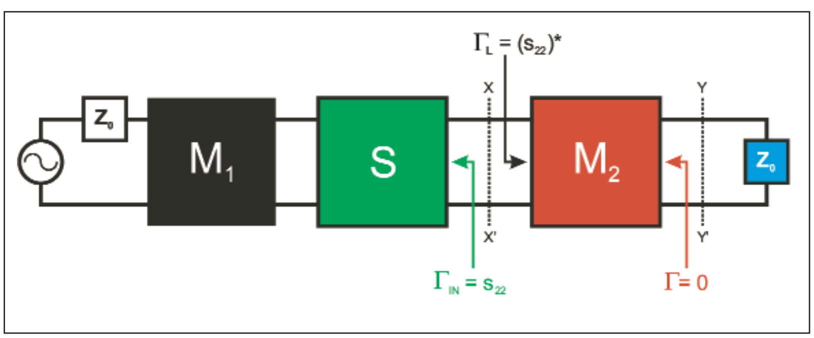
appropriate direction to move on the Smith chart is less trivial.

The student is asked to provide a conjugate matching network such that $\Gamma_L = (\Gamma_{IN})^*$. At this point, confusion can arise: which way is "towards the generator"? Should Γ_L or $(\Gamma_L)^*$ be plotted? The student might even be inclined to follow the textbook method presented in the first example by plotting Γ_L on the Smith chart and moving towards the generator impedance (of the whole system). Clearly, there is room for error if one is not careful. One should also keep in mind that Smith chart software packages can be set up differently — some work from source-to-load, some from load-to-source, and their placement of matching elements can be different as well.

One good method for avoiding these pitfalls is to redraw the network so that it resembles the textbook example given in Figure 1. In Figure 3, the output network of Figure 2 has been redrawn such that moving "towards the generator" is to the left in both Figure 1 and Figure 3.

Further visual simplification is achieved by representing the output impedance of the transistor with load Z_{IN}. Note the similarity to Figure 1 and that the "load" reflection coefficient is Γ_{IN}, not Γ_L. In Figure 1, we would say we are going to match the "load" impedance Z_L to the "generator" impedance Z_0. In Figure 3, we would say that we are going to match the "load" impedance Z_{IN} to the "generator" impedance Z_0. In Figure 3, we are *not* matching Γ_L to the generator impedance.

The original problem of Figure 2 has been effectively redrawn in terms of the classic textbook impedance matching problem (Figure 1), and the solution can be found using the matching network of the student's choice. For clarity, Figure 3 is inserted back into the original network transistor amplifier (Figure 4).



▲ **Figure 4. Network transistor amplifier with Figure 3 inserted.**

Conclusion

When presented with impedance matching problems, mistakes can be avoided by redrawing the network carefully in a form that is consistent with textbook approaches to matching, thus avoiding confusion with the direction of movement and the appropriate starting location on the Smith chart. Furthermore, when using software tools for matching, be sure to understand how the software works in terms of direction and element placement. ■

References

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