

### 3.21: Impedance Matching - General Considerations

“Impedance matching” refers to the problem of transforming a particular impedance  $Z_L$  into a modified impedance  $Z_{in}$ . The problem of impedance matching arises because it is not convenient, practical, or desirable to have all devices in a system operate at the same input and output impedances. Here are just a few of the issues:

- It is not convenient or practical to market coaxial cables having characteristic impedance equal to every terminating impedance that might be encountered.
- Different types of antennas operate at different impedances, and the impedance of most antennas vary significantly with frequency.
- Different types of amplifiers operate most effectively at different output impedances. For example, amplifiers operating as current sources operate most effectively with low output impedance, whereas amplifiers operating as voltage sources operate most effectively with high output impedances.
- Independently of the above issue, techniques for the design of transistor amplifiers rely on intentionally *mismatching* impedances; i.e., matching to an impedance different than that which maximizes power transfer or minimizes reflection. In other words, various design goals are met by applying particular impedances to the input and output ports of the transistor.<sup>1</sup>

For all of these reasons, electrical engineers frequently find themselves with the task of transforming a particular impedance  $Z_L$  into a modified impedance  $Z_{in}$ .

The reader is probably already familiar with many approaches to the impedance matching problem that employ discrete components and do not require knowledge of electromagnetics.<sup>2</sup> To list just a few of these approaches: transformers, resistive (lossy) matching, single-reactance matching, and two-reactance (“L” network) matching. However, all of these have limitations. Perhaps the most serious limitations pertain to the performance of discrete components at high frequencies. Here are just a few of the most common problems:

- Practical resistors actually behave as ideal resistors in series with ideal inductors
- Practical capacitors actually behave as ideal capacitors in series with ideal resistors
- Practical inductors behave as ideal inductors in parallel with ideal capacitors, and in series with ideal resistors.

All of this makes the use of discrete components increasingly difficult with increasing frequency.

One possible solution to these types of problems is to more precisely model each component, and then to account for the non-ideal behavior by incorporating the appropriate models in the analysis and design process. Alternatively, one may consider ways to replace particular troublesome components – or, in some cases, all discrete components – with transmission line devices. The latter approach is particularly convenient in circuits implemented on printed circuit boards at frequencies in the UHF band and higher, since the necessary transmission line structures are easy to implement as microstrip lines and are relatively compact since the wavelength is relatively small. However, applications employing transmission lines as components in impedance matching devices can be found at lower frequencies as well.

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1. For a concise introduction to this concept, see Chapter 10 of S.W. Ellingson, *Radio Systems Engineering*, Cambridge Univ. Press, 2016.↩

2. For an overview, see Chapter 9 of S.W. Ellingson, *Radio Systems Engineering*, Cambridge Univ. Press, 2016.↩

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