Reflection and Bandwidth Limits for Exponentially Tapered Transmission Lines

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In this paper, relationships for the parameters of an exponentially tapered transmission line section needed to match a given load to a real input impedance subject to practical constraints on realizable ranges of characteristic impedance are derived. Attention is paid to the overall length of the matching section (including its minimum value) as well as to its bandwidth.

There are a number of transmission-line section techniques for impedance matching. The quarter-wave transformer uses a single uniform transmission line with a characteristic impedance equal to the geometric mean of the input and the real load impedance. The two discontinuities along with the $\lambda/4$ section of transmission line create an ideal match ($\rho_0 = 0$) at a single frequency, and perform well within some associated bandwidth. Shorter transmission line matching networks can be designed by using additional sections of line with different characteristic impedances and the associated discontinuities, for example, the two-stage designs proposed by B. A. Bramham (Electron. Eng., 33, 42-44, 1961) and by G. Chen and M. Hamid (Int. J. Electron., 63, 911-920, 1987). These transmission line matching networks can be made arbitrarily short if large impedance changes are allowed. However, practical application of these kinds of matching networks will be impacted by parasitics from the abrupt impedance changes.

The goal of this paper is to investigate the use of an exponentially-tapered transmission line section allowing for discontinuities in characteristic impedance at the input and load ends of the taper. A mathematical derivation has been carried out for the reflection coefficient, allowing for easy design of the tapered section with one degree of freedom. This analytical model is validated using a finite-element analysis that accounts for all parasitics associated with the impedance discontinuities. For practical application, the impact from these parasitics is reduced by a re-tuning process. The performance of the re-tuned designs is then compared to other common transmission line matching networks. Consideration is given to the bandwidth, physical length, and manufacturing practicality of the matching circuits.

It is found that the exponential taper can be used to create an impedance transforming network with a significantly shorter length than quarter-wave or Bramham transformers at a given frequency at the expense of some reduction in bandwidth.