# Design of Wideband Impedance Transformers



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Although design methods of wideband impedance transformers are known, in some cases there can be limitations on the implementation. A practical limitation is the availability of the required characteristic impedance levels, particularly in antenna array feed structures. For example, practical ranges of characteristic impedance levels of microstrip lines are around 30-200 Ω. Lines with characteristic impedances lower than 30 Ω are impractically wide, and impedance levels higher than 200 Ω are usually beyond the capabilities for accurate production. Published results concerning the radiation loss of the feed-line segments limits the range even to 100-200 Ω [1]. In the following examples we have assumed that a 60-180 Ω range is realizable.

If the source impedance is low, and the required characteristic impedance of the first line segment is smaller than the realizable range, then the characteristic impedance of the first line is set to be the minimum realizable impedance. The impedance of the source transferred by that line segment is calculated. If the calculated value is in the realizable range, then the rest of the line segments are determined by the general techniques, accepting the transferred impedance as the source impedance of the network to be designed. If it is not in the acceptable range, then the second line segment is set to the maximum realizable characteristic impedance. The overall design can be obtained by applying this algorithm successively. A similar approach can be adopted for high source impedances (or high/low load impedances).

Therefore, transformers with theoretical bandwidths of $1:P$ transformers may not be achieved in feed network designs when the realizable impedance bandwidth is narrow, and the characteristic impedance range limitation is a restriction for the bandwidth of the $1:P$ transformer at the final stage. Wideband impedance transformations require lines with characteristic impedances in the range between the source and the load impedances. If both $ZA/P$ and $ZA$ are in the realizable range, well-known wideband matching synthesis techniques can be used. Otherwise, quarter-wavelength impedance transformers can be used. Nevertheless, the bandwidth decreases as the incoherent impedance mismatch levels (as defined in [2]) increase in the structure. It is obvious that there may be considerable reflection, which implies that the structure's bandwidth is inherently narrow. If all line segments in the feed structure are incoherently matched, then the final impedance transformer will also probably be composed of incoherently matched line segments.

As an example of wideband transformation, consider the design of a 1:8 impedance transformer (25 Ω to 200 Ω) using four line segments. It is assumed that the realizable range of characteristic impedances is 60 Ω to 180 Ω. Maximally flat response implies the following characteristic impedances: 28.49 Ω, 48.63 Ω, 109.53 Ω, 178.32 Ω. However, the first two lines are not realizable. Therefore, the first line segment will be set to 60 Ω, the minimum realizable characteristic impedance. The transferred impedance of 25 Ω on this line is 144 Ω. The remaining three line sections will be determined by the design of a 144:200 transformer. The frequency-bandwidth limitation of the 60 Ω line dominates the rest of the structure. A 144 Ω:200 Ω maximally flat transformer can be obtained by these line impedances: 150.04 Ω, 169.73 Ω, 191.98 Ω. Both structures transform 25 Ω to 200 Ω, and the bandwidth comparison is given in Figure 1. As can be seen from this figure, when the impedance range is limited, a 20 dB match bandwidth becomes about one-fifth of the unlimited case.

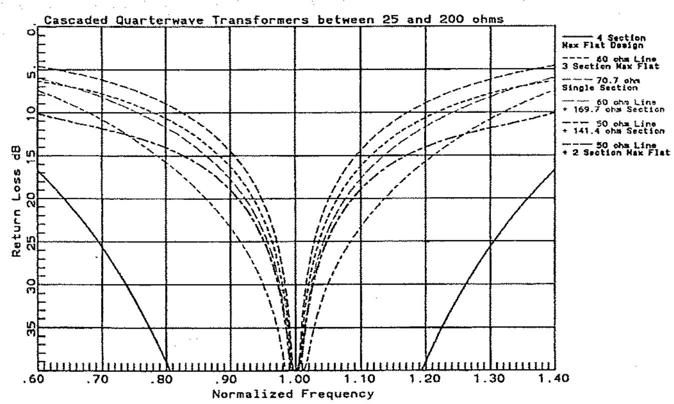


**Figure 1. The frequency response of cascaded quarter-wave transformers between 25 Ω and 200 Ω. —— Four-section maximally flat design; - - - - 60 Ω line, three sections, maximally flat; – – – – 70.7 Ω, single section; — — — — 60 Ω line + 169.7 ohm section; - - - - - 50 Ω line + 141.4 Ω section; — - — - — 50 Ω line + two sections maximally flat.**

## References

1. E. Levine, G. Malamud, S. Shtrikman, and D. Treves, "A Study of Microstrip Array Antennas with the Feed Network," *IEEE Transactions on Antennas and Propagation*, **AP-37**, April 1989, pp. 426-434.

2. S. Demir and C. Toker, "Optimum Design of Feed Structures for high *G/T* Passive and Active Antenna Arrays," *IEEE Transactions on Antennas and Propagation*, **AP-47**, March 1999, pp. 443-452.

## Editor's Comments

I added a few curves to Figure 1 to compare this design to other possibilities. A single-section transformer of 70.7 Ω between 25 Ω and 200 Ω produces a transformer with a smaller bandwidth, but it shows that adding a three-section maximally flat transformer after a 60 Ω transformer section does not significantly increase the bandwidth. It is interesting that adding a single transformer section after the 60 Ω line gives a greater bandwidth than the design followed with three sections. Because 60 Ω is close to the single-line solution, it limits the bandwidth. If we use a 50 Ω fist line instead, then the bandwidth increases. As the first line impedance approaches the two-section maximally flat design with a 42 Ω line for its first transformer, the bandwidth increases. Adding a two-section transformer after the 50 Ω line decreases the bandwidth compared to a single-section design. The author presents an interesting approach to design, which must account for the limited impedance levels for a transformer. We must think beyond the obvious design.

### Ideas for Antenna Designer's Notebook

Ideas are needed for future issues of the Antenna Designer's Notebook. Please send your suggestions to Tom Milligan and they will be considered for publication as quickly as possible. Topics can include antenna design tips, equations, nomographs, or shortcuts, as well as ideas to improve or facilitate measurements.



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