Compact Single-Layer Planar Wideband 180° Balun Networks

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1. Introduction

Baluns are frequently used in microwave networks connecting balanced circuits to unbalanced ones such as mixers, amplifiers and antenna feed networks. In many instances, space for the circuit layout is not a concern since only one or two components are involved. In this paper, we evaluate a number of 180° baluns to investigate their suitability for use as compact element feeds for a broadband wide angle scan array. The balun should have a bandwidth of 80 - 90%, phase deviation of ±5°, amplitude imbalance of < 0.5 dB and input match < -13 dB. Typical broadband elements used in antenna arrays that required two anti-phase inputs are bow-tie and dual probe-fed patch radiators. Because of the wide scan requirement, element spacing is approximately 0.50 wavelength at the highest frequency of operation. This restricts the planar area available for the balun implementation to a half wavelength square. Further, to maintain a low profile implementation of the array, the feed network should be placed in a single layer backing and orthogonal to the array.

Seven different networks have been evaluated. The most appropriate in the form of a parallel connection of double Schiffman coupled lines with matching lines is chosen for implementation. Plots of the measurements of this circuit are given below and they show that the network meets all of the requirements.

2. Differential Phase Shifters

The typical implementation of a wideband balun has a Wilkinson or in-line hybrid power divider with two or three sections to provide two equal in-phase output signals. A single section divider does not have the required bandwidth. To provide the 180° phase difference, a phase shifter is connected to one output port and a reference line is connected to the other output port as shown in Fig. 8.

Seven different phase shifter networks, taken from the literature, are analyzed for their performance characteristics using circuit analysis and even-odd mode decomposition. The line lengths and line impedances used are shown in the circuit diagram. The input match of the phase shifter and its differential phase with respect to the reference line are plotted beside the circuit representation as shown in Figs. 1 to 7. The performance computations are done at VHF/UHF band for ease of network implementation.

These networks have appeared in the literature [1-4]. All-pass networks consisting only of Schiffman coupled line pairs have the bandwidth but is difficult to realize on printed circuit boards due to the narrow gaps resulting from the tight coupling required. Band-pass networks, consisting of transmission lines, short-circuited and open-circuited stubs [5], do not have the required bandwidth. Bandwidth of such networks is less than an octave. A combination of all-pass and band-pass networks however meets the requirements. The port match and phase shift of the Schiffman coupled line degrades substantially when the even mode phase velocity differs from that of the odd mode.

This occurs in the microstrip format. Hence a stripline implementation of the network or at least the coupled line section is necessary for the present requirement.

Network #5 [3, 5] is the simplest, consisting only of open and short-circuited λ/8 stubs and a half-wave line section, and can be implemented on microstrip. It has about 54% bandwidth and does not meet the requirements. Networks #1 [1] and #7 [2] consisting of a single coupled line with open and shorted stubs and line sections have broader bandwidths with #1 performing better than #7. Only networks #2, 3, 4 and 6 with at least two coupled line sections meet the requirements. Of these, network #4 is the most compact and would likely fit into the allowable space below the array element. The phase shifter of network #4 has a parallel connection of 2 coupled line sections in between two matching line sections. One of the coupled line sections is grounded.

3. Balun With Double Schiffman

The balun, consisting of Network #4 and a 2-section power divider, is implemented in stripline using two 0.10 inch thick substrate boards (Rogers R/T Duroid 6006 dk=6.15) screwed together. The matching line impedance and the even and odd mode coupled line impedances shown in Fig. 4 are the optimized values to achieve 90% bandwidth. A picture of the etched balun circuit is shown in Fig. 8. The measured port match and port isolation are plotted in Fig. 9. The worst-case port isolation is better than 20 dB while the input port reflection coefficient is less than -13 dB. The phase deviation from 180° is less than ± 6° across the band as shown in Fig. 10. The amplitude imbalance is less than 0.5 dB as seen in Fig. 11.

4. Conclusion

A compact 180° balun network with 90% bandwidth, ± 6° phase deviation and 0.5 dB amplitude imbalance has been successfully demonstrated.

References

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[4] S.Y. Eom, S.I. Jeon, J.S. Chae, J.G. Yook, “Broadband 180° bit phase shifter using a new switched network”, IEEE MTT-S International Microwave Symposium Digest, Vol. 1, pp. 39-42, 2003.

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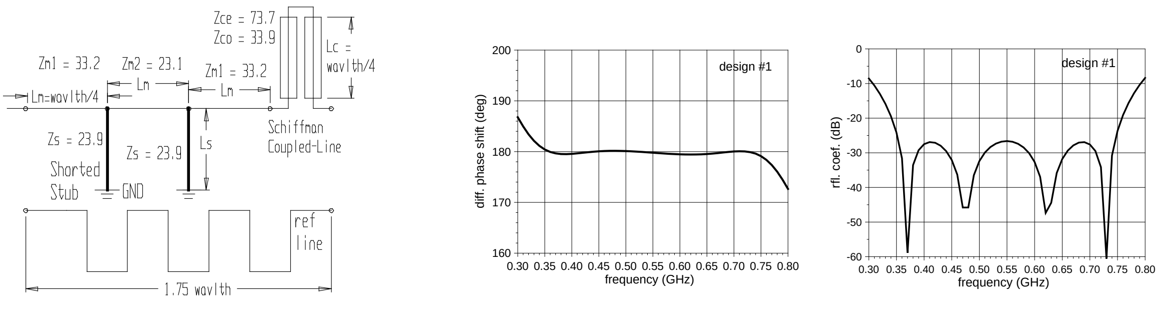

Fig. 1: Balun network #1 circuit and performance.

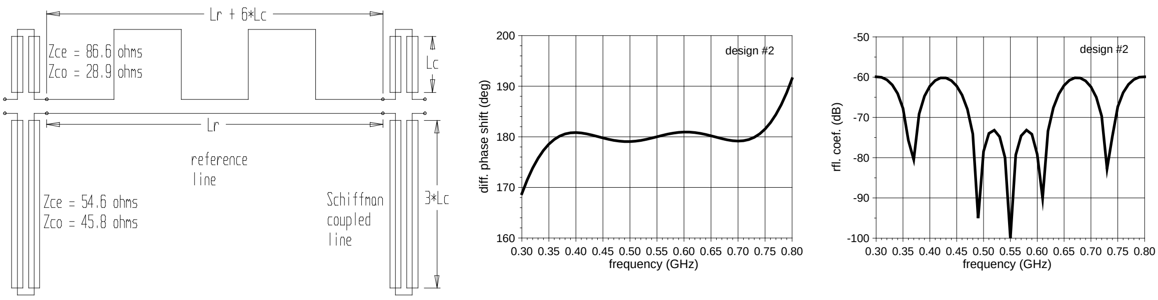

Fig. 2: Balun network #2 circuit and performance

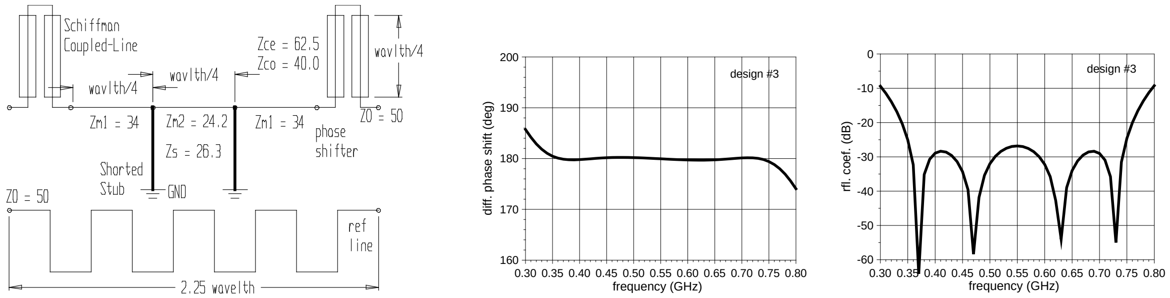

Fig. 3: Balun network #3 circuit and performance

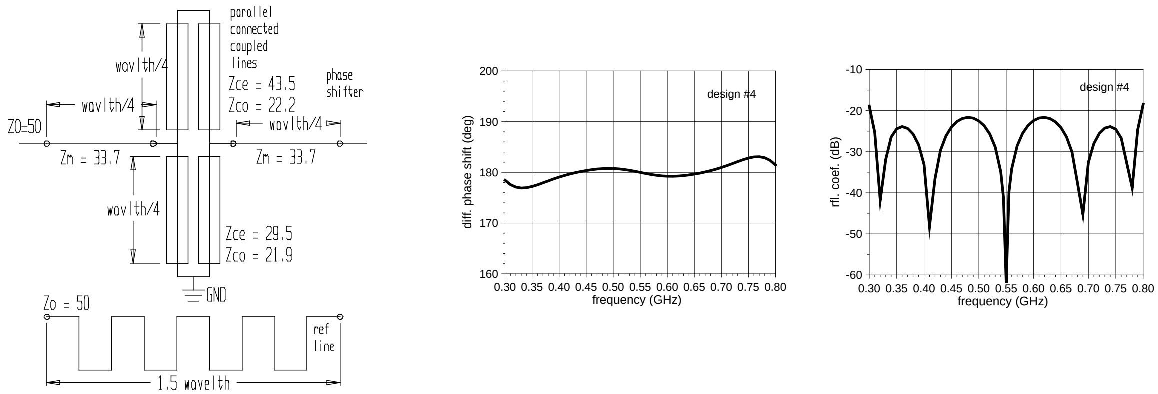

Fig. 4: Balun network #4 circuit and performance

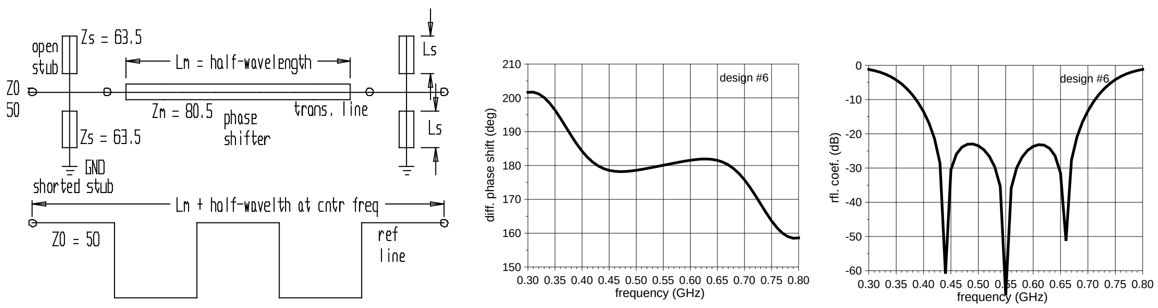

Fig. 5: Balun network #5 circuit and performance

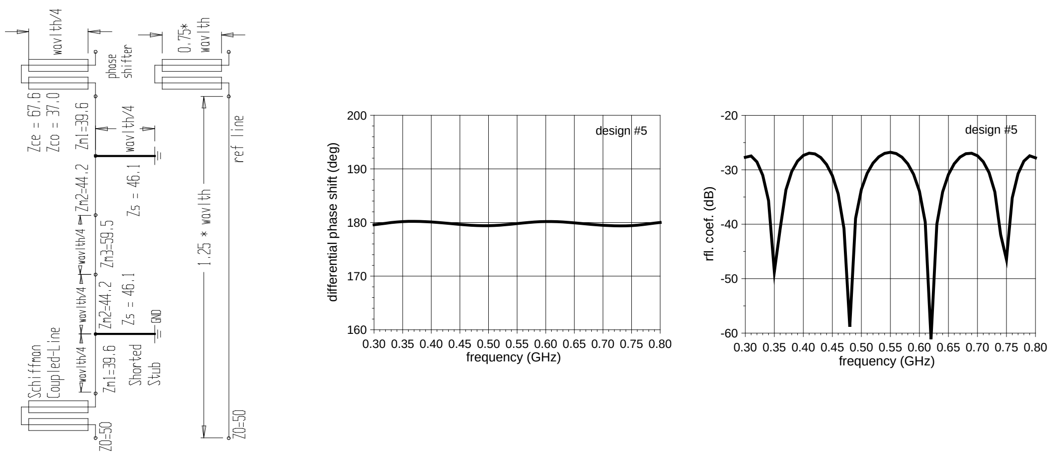

Fig. 6: Balun network #6 circuit and performance

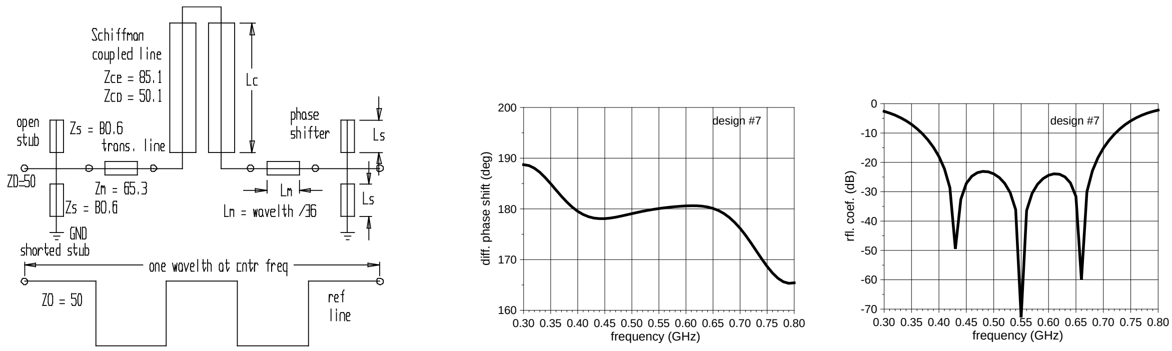

Fig. 7: Balun network #7 circuit and performance

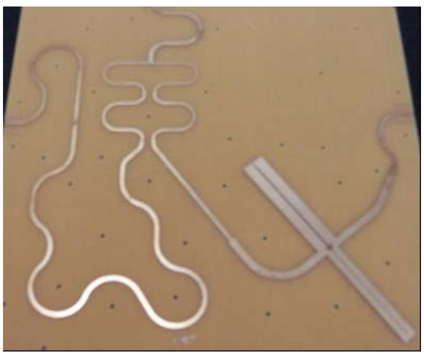

Fig. 8: Etched balun network #4.

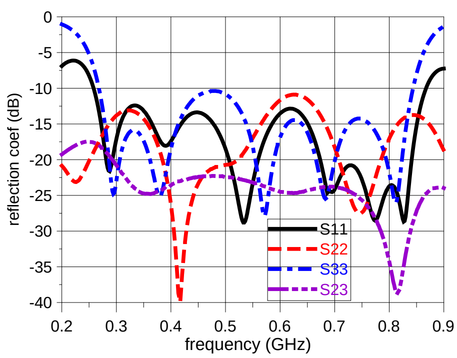

Fig. 9: Measured port match & isolation.

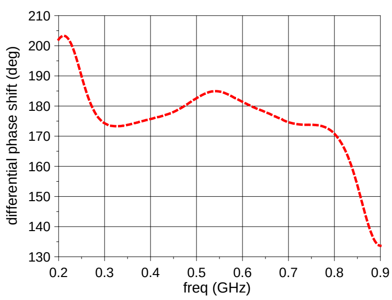

Fig. 10: Measured differential phase shift.

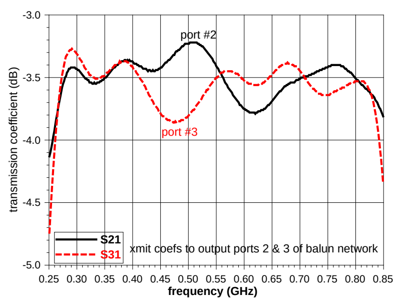

Fig. 11: Measured output port amplitude distributions.