Design of Stepped Impedance Low Pass Filter Using Defected Ground Structure

R. P. S. Kushwah[a] and R. N. Baral[b*]
[a]GD SATCOM Technologies Inc., Microwave Antenna Products,
1500 Prodelin Drive, Newton, North Carolina 28658 USA
[b]Department of Electronics & Communication Engineering,
IMS Engineering College, Ghaziabad, 201009 India.
*r_n_baral@yahoo.co.in

Abstract

This work presents design and analysis of a low pass filter using a coupled coplanar stripline structure and coplanar strip with defected ground structure. The proposed ninth order stepped impedance low pass filter has a cut-off frequency of 1.8GHz. Subsequently the microstrip filter is fabricated on glass 'Epoxy' substrate and a very good agreement has been observed between the experimental results and simulated data. The proposed design is based on the calculation of parameters from traditional high–low impedance methods.

Keywords - Coplanar Stripline (CPS), Defected Ground Structure (DGS), Low Pass Filters, Microstrip, IE3D.

Introduction

The CPS as a transmission medium holds a great deal of potential in the emerging wireless communications system and in the design of low-cost planar microwave circuits such as filters, mixers, and antennas (Shen *et al*., 2001). A CPS on a dielectric substrate consists of two parallel metallic strips, generally of equal width W, separated by a narrow slot of width S. In this transmission line, the electric fields extend across the slot and the magnetic field lines surround the strip conductors. DGS filters using high–low impedance techniques have also been designed DGS improve the filter performance and obtained sharp cut-off above the cut off frequency but this do not give a way to reduce size of filters (Chen *et al*., 1997). The proposed design is based on the calculation of parameters from conventional high–low impedance methods and simulated using moments method software tool. Subsequently the microstrip filter is fabricated on glass 'Epoxy' and a very good agreement has been found between the experimental results and simulated data.

The work is based on ninth order stepped impedance low pass filter which consists of high and low impedances (Williams, 1992). Method of analysis begins with the calculation of inductive and capacitive stubs with the help of traditional high–low filter design (McLean *et al*., 1992). A 9th order stepped impedance low pass filter with -10dB cutoff frequency at 1.8 GHz and attenuation of 0.1 dB in pass band with port impedance 50 Ω is analyze using the substrate of dielectric constant 4.4, thickness 1.6mm. Prototype and real value so find inductances and capacitance are calculated using (Pozar, 2000).

Design and Analysis of Stepped Impedance Low Pass Filter

Stepped-impedance low-pass filter are presented in this paper which make use of patterning of both sides of the microstrip substrate. Conventional stepped-impedance low pass filters (SI-LPF) consist of a cascading of electrically short high and low impedance sections to approximate the corresponding ladder LC lumped circuit prototype (Mathaei *et al*., 1980; Bozzeti *et al*., 2003; Huang *et al*., 2005). In this contribution we propose a LPF implementation that retains the simplicity of the stepped-impedance structure. The method is based on the implementation of the constituent filter elements by combining microstrip and CPS technologies.

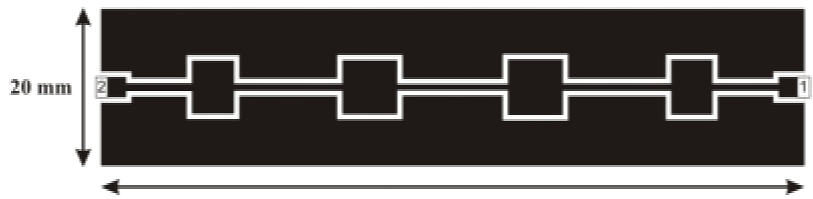

Figure 1(a): Layout of the final filter design

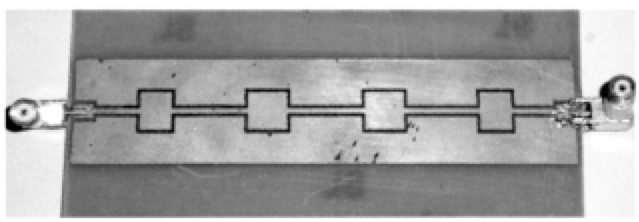

Figure 1(b): Photograph of the fabricated microstrip filter

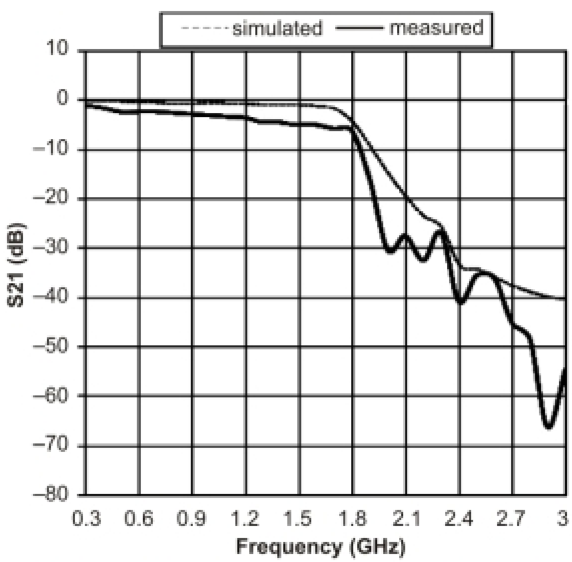

Figure 2(a): Variation of S21 with frequency

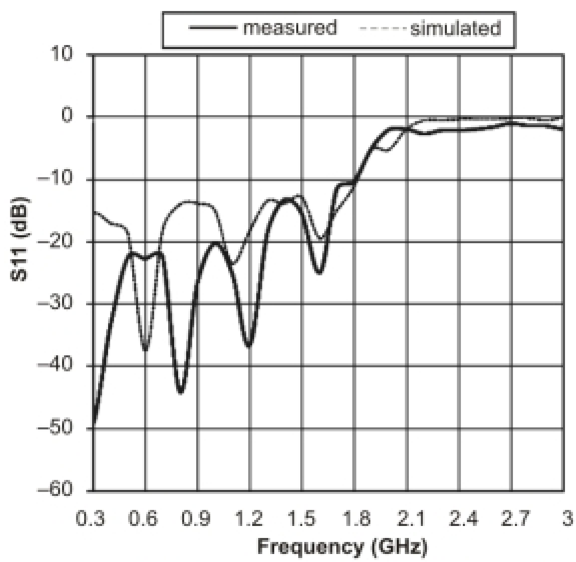

Figure 2(b): Variation of S11 with frequency

The layout of the final filter design with all the determined dimensions is illustrated in Figure 4. The filter is quite compact, with a substrate size of 1.6 mm. The EM simulated performance of the filter is shown in Figure 1(a) and fabricated geometry in figure 1(b). Filter is physically implemented on FR-4 'Glass/Epoxy' substrate using conventional fabrication process the comparison plots for transmission coefficient and reflection coefficient of both simulate and measured results are shown in figure 2(a) and 2(b) respectively.

Microstrip LPF with Defected Ground Structure

The microstrip coplanar filter is subsequently simulated using IE3D commercial tool. The simulated transmission co-efficient response is not sharp and the attenuation loss is 10 dB is 1.8 GHz, for the first transmission zero. The stop band cut-off rate is nearly 10dB/GHz. To improve the frequency response, periodic ring structure is being etched out in the metallic ground plane of the coplanar microstrip filter. The layout of the modified filter is shown in figure 3.

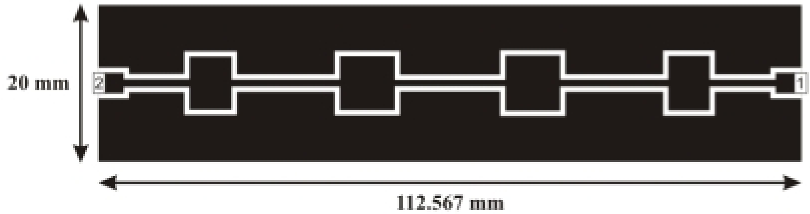

Figure 3(a): Upper layer

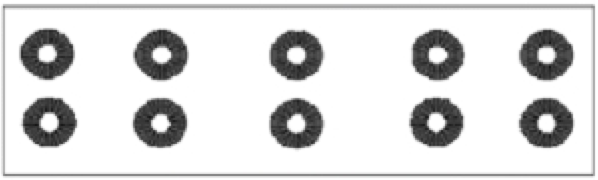

Figure 3(b): Ground layer

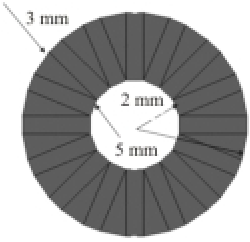

Figure 3(c): Layout and dimension of ring

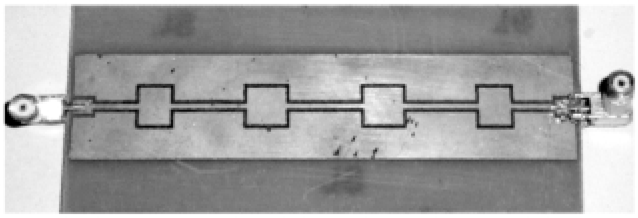

Figure 4(a): Upper layer of the CPS filter

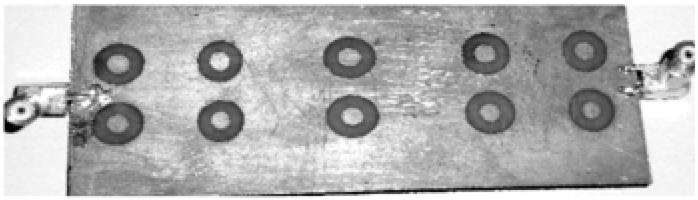

Figure 4(b): Lower layer of the CPS filter

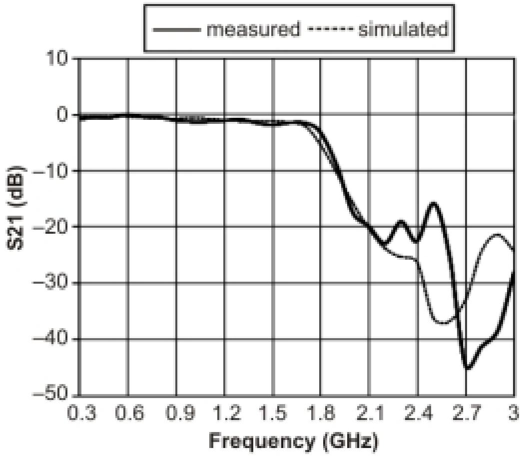

Figure 5(a): Variation of S21 with frequency

Filter is physically implemented on FR-4 "Glass/Epoxy" substrate using conventional fabrication process the comparison plots for transmission coefficient and reflection coefficient of both simulate and measured results are shown in figure 5(a)-(b). The objective of the following study is to prove the dependence of the equivalent circuit elements (capacitance and inductance) on the surface current distribution. As shown in Fig. 5(c). The current is distributed throughout the whole structure. Therefore any change in the length of the meander arm strongly affects the magnetic field distribution and hence the surface current.

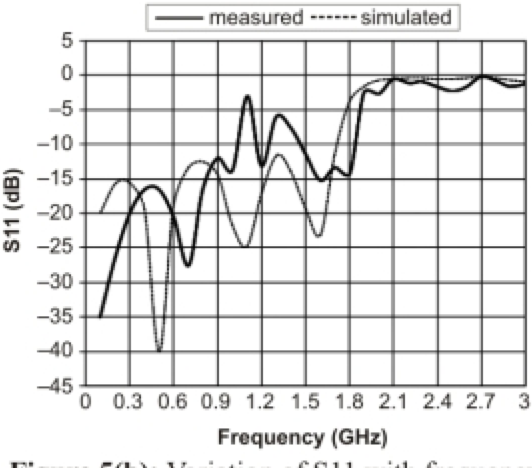

Figure 5(b): Variation of S11 with frequency

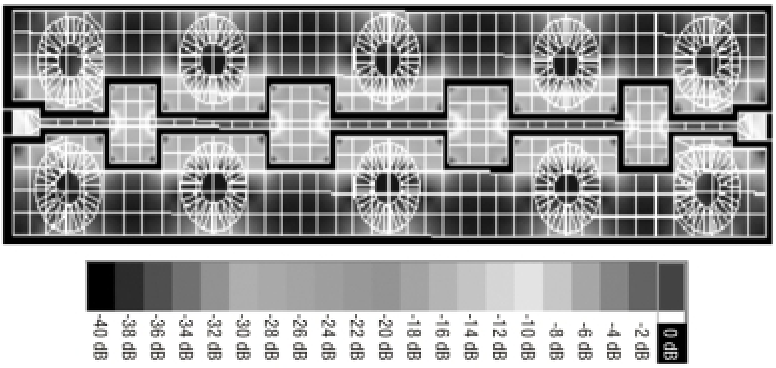

Figure 5(c): Surface current distribution

Conclusions

A design methodology for CPS lowpass filters using CPS discontinuities has been demonstrated. It is evident from the measured results that high-performance filters are possible to design with the added flexibility provided by the CPS configuration. The removed portion in the ground plane increases the shunt capacitance and series inductance, which exhibits sharp cut-off above the cut off frequency.

Acknowledgments

The authors would like to acknowledge, Dr. P. K. Singhal, Professor, Department of Electronics, Madhav Institute of Technology & Science, Gwalior, India, for his valuable suggestion and guidance for this work. Also the authors express their gratitude to authorities of IMS Engineering College, Ghaziabad and GD SATCOM Technologies Inc. for all the help provided.

References

Shen, J., Hong, G., Lancaster, M. J. 2001. Microstrip Filters for RF/ Microwave Applications. John Wiley & Sons Inc., pp. 471.

Chen, E., Stephen, Y., Chou, L. 1997. Characteristics of Coplanar Transmission Lines on Multilayer Substrate: Modeling and Experiments. *IEEE Transactions on Microwave Theory and Techniques*, 45, 939-945.

Williams, F. 1992. Novel Coplanar Stripline: Design, Characterization and Applications. *IEEE Transactions on Microwave Theory and Techniques Symposium*, MTT-S, Digest, pp. 214.

McLean, J.S., Tatsuo, I. 1992. Analysis of a New Configuration of Coplanar Stripline. *IEEE Transactions on Microwave Theory and Techniques*, 40, 772-774.

Pozar, D. M. 2000. Microwave Engineering (2nd Ed.), John Wiley & Sons, New York.

Mathaei, G.L., Young, L., Jones, E., M., T. 1980. Microwave Filter, impedance matching networks and coupling structures, Artech House, Dedham, MA.

Bozzeti, M., D'Orazio, A., Petruzzelli, V., Prudenzano, F., Renna, F. 2003. Tapered photonic bandgap microstrip low pass filter: design and realization, Microwaves, Antenna and Propagation. *IEEE proceedings*, 150(6), 459-462.

Huang, H., Mao, J., Li, Xiao-Chun, Zhengfan, L. 2005. A photonic bandgap microstrip filter based on YBCO superconducting film. *IEEE transactions on Applied Superconductivity*, 15(3), 3827-3830.

IE3D Software Release – 8, Developed by M/s Zeland Software Inc.