Analysis and Design of a Miniaturized Low Pass Filter in Suspended Microstrip Structure

Alicia Casanueva, Elena Zubizarreta, Oscar González, Ana Grande, Enrique Villa
Dpto. Ingeniería de Comunicaciones, Universidad de Cantabria. SPAIN
Tel: +34-42-201492, Fax: +34-42-201488, E-mail: alicia@dicom.unican.es

***Abstract*— This project is intended to build a suspended microstrip low pass filter with a pass band till 3 GHz. Harmonic filters are invaluable for removing unwanted higher-order harmonic signals from microwave multipliers and mixers in receiver designs, among other applications. Although a variety of filter configurations have been developed to reduce the level of harmonic signals, the authors investigated two varieties of low-pass filter designed for to improve harmonic suppression. In this article, the stop-band characteristics of an asymmetrical step suspended microstrip structure are studied and its application to a low pass filter is proposed. The equivalent circuit model of the unit defected suspended microstrip structure is used to explain the stop-band characteristic at a certain frequency and the parameters of the circuit model are extracted from EM simulation and circuit theory. Two types of three-pole low pass filters and a type of five-pole low pass filter are proposed and optimized as applications. The measured results on the low pass filter are in good agreement with the simulated ones.**

Keywords-component; Index Terms—Low pass filter, suspended substrate, harmonic suppression.

I. Introduction

The investigation of the use of ultra-wideband (UWB) has been one of the most controversial technologies of modern times. Its applications can be seen in diverse areas such as local area networks, position location searching, advanced imaging of the human body, etc. Traditionally, microstrip filters suffer from spurious responses located at twice the fundamental frequency. Harmonic filters are invaluable for removing unwanted higher-order harmonic signals from microwave multipliers and mixers in receiver designs, among other applications. Although a variety of filter configurations have been developed to reduce the level of harmonic signals [2-6], the authors investigated two varieties of low-pass filter designed for good harmonic suppression. A technique to design low pass filters (LPFs) using asymmetrical stepped microstrip structures has been proposed already by [1]. In this paper, another structure and scheme are employed to improve harmonic suppression. The suspended microstrip line is known to be a versatile transmission medium for millimeter -wave frequencies. In addition to low loss (compared to the more commonly used microstrip, [7-9]) it also offers the option of fabricating double-sided circuits.

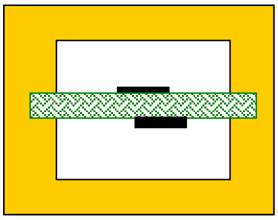


Figure 1. Suspended microstrip transmission line

One of the reasons why it is not universally adopted is the necessity of a channel matching the circuit, which necessitates time-consuming machining processes. This is particularly serious if the circuit contains many T or cross-junctions. However if the entire circuit fits in a single straight channel, as for example a low-pass filter using alternating high and low impedance lines, then the inherent advantages of the suspended configuration become significant.

In this work, a model of a simple suspended microstrip low pass filter (LPF) is designed, analyzed and, built, which consists of the asymmetrical microstrip step discontinuity circuit and low-impedance transmission line.

Based on EM simulation results, a circuit model of the LPF is established and the lumped elements of this model are extracted according to circuit theory. The stop-band effect of the presented LPF can be explained by employing the extracted parameters and circuit theory. In order to show the effectiveness of the proposed scheme, two types of three-pole low pass filters and a five-pole low pass filter (LPF) are designed asymmetrical microstrip step discontinuity circuit and low-impedance transmission line to improve their stop-band characteristics. The proposed low pass filter has the advantages of compact size, low insertion loss and harmonic suppression. The results measured on the LPF agree well with the simulation.

II. ASYMMETRICAL MICROSTRIP STEP DISCONTINUITY: CIRCUIT MODEL

The equivalent circuit model of the asymmetrical step discontinuity is shown in the following figures.

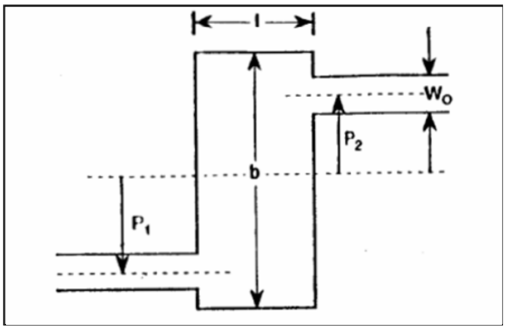
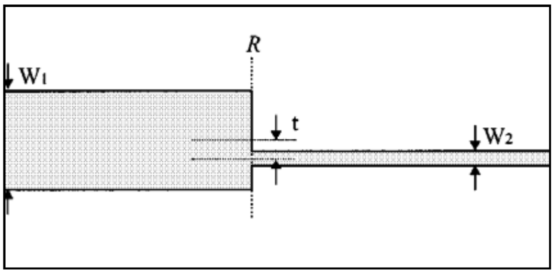
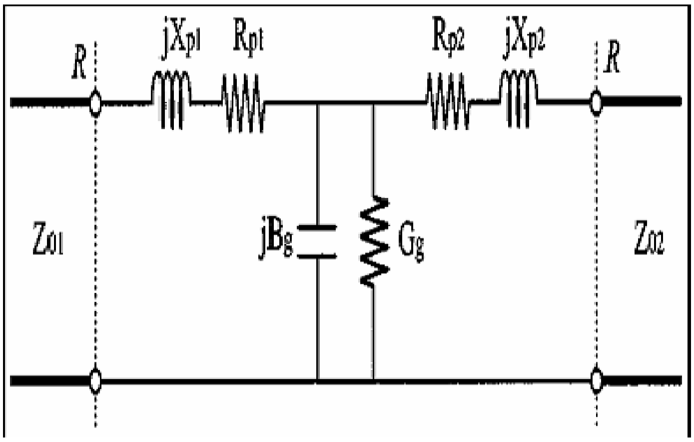


Figure 2. Asymmetrical microstrip step discontinuity

Fig. 2 shows the geometry of a suspended microstrip discontinuity, whose two feed lines are transversely aligned by an offset distance.



(a)



(b)

Figure 3.a. Asymmetrical step discontinuity. Figure 3.b. Dynamic T-type circuit model.

Fig.3 depicts the geometry of a microstrip step discontinuity, whose two feed lines present different strip widths and also transversely aligned by an offset distance (t) at the step location (R). Early work based on static assumption [10]–[11] suggested that the symmetrical counterpart with t=0, could be expressed as a lossless equivalent T-type lumped-circuit network with a single shunt capacitance and two series inductances. As frequency increases, however, the static model has to be modified into a dynamic T-type circuit model that can account for all potential effects around the step discontinuity such as high-order modes, frequency dispersion, and radiation loss. Fig. 3.b illustrates the complete circuit model with a shunt capacitive admittance and two series inductive impedances which demonstrate electrical properties of this step discontinuity without any hypothesis in theory [12].

III. SKETCH OF THE SUSPENDED MICROSTRIP LOW PASS FILTER (LPF)

Fig. 4 depicts the geometry of the one of the filters analyzed.

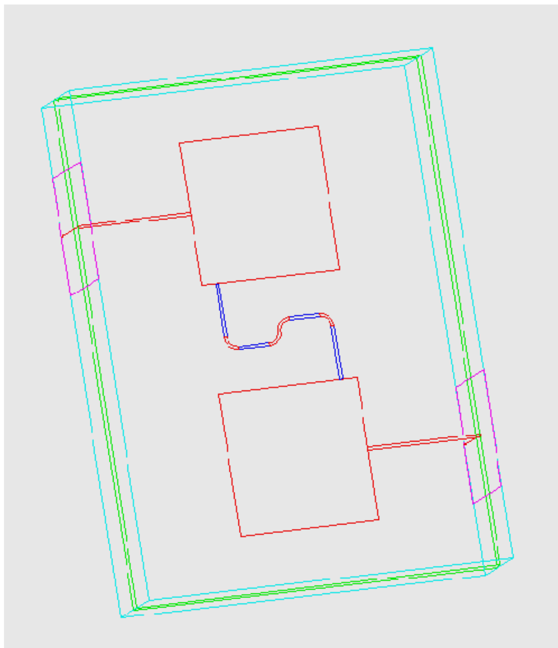


Figure 4. Geometrical structure of the low pass filter in suspended microstrip line.

The high impedance value is nearly 200 ohms and the low one close to 15 ohms.

The low pass filters have been designed, analyzed and being manufactured using a substrate with a thickness h=0.020” and ε_r=3.38. The height of the suspended substrate is $h_{suspended}$= 1.5 mm.

IV. THEORETICAL CHARACTERIZATION: AGILENT´S EMDS FIELD SIMULATIONS

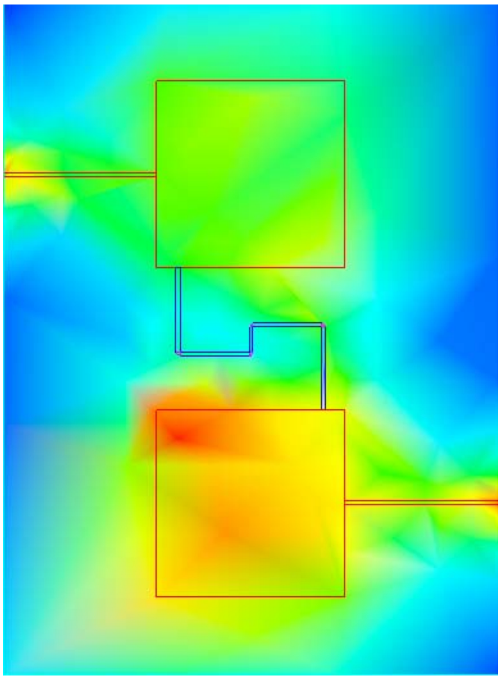


Figure 5. Electric field at 3 GHz.

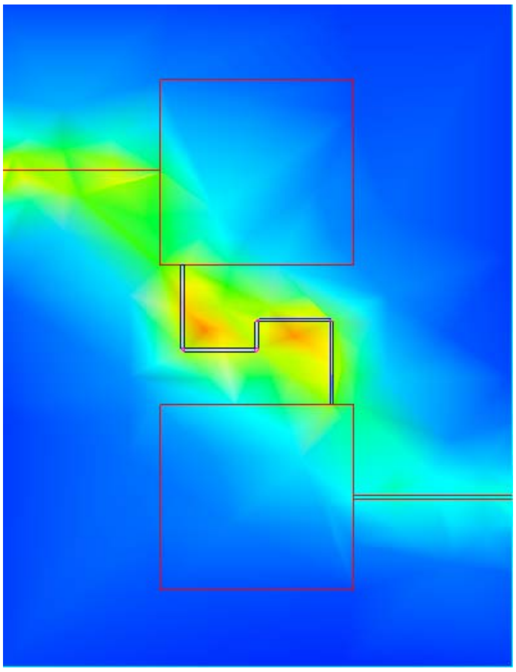


Figure 6. Magnetic field at 3 GHz.

Fig. 5 and Fig. 6 show the theoretical characterization: by using the electromagnetic simulator AGILENT´S at 3 GHz for one of the filters analyzed.

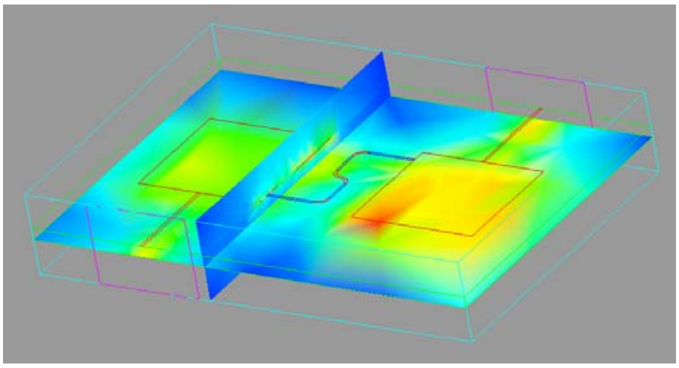


Figure 7. Electric field at 2 GHz.

Fig. 7 shows the theoretical characterization of a modified version of the filter presented in Fig. 5 and 6 by using the electromagnetic simulator AGILENT´S EMDS.

V. SCATTERING PARAMETERS

In figures 8 and 9 the scattering parameters for the designed filters are plotted. Among all the filter responses, it can be observed how the suspended filter with mitered round corners presents the best response.

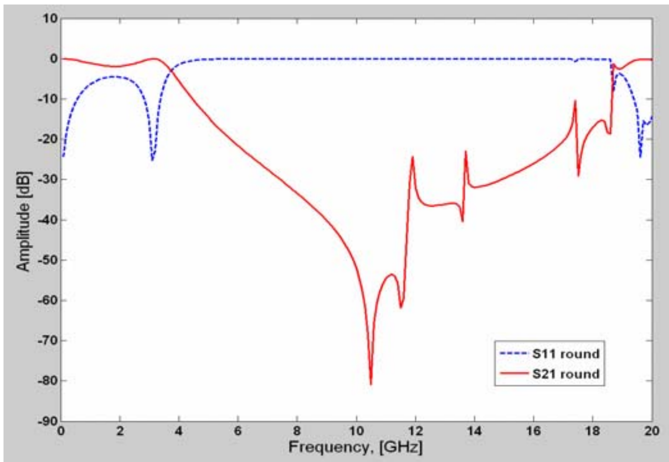


Figure 8. Wideband response of the filter shown in Figure 7

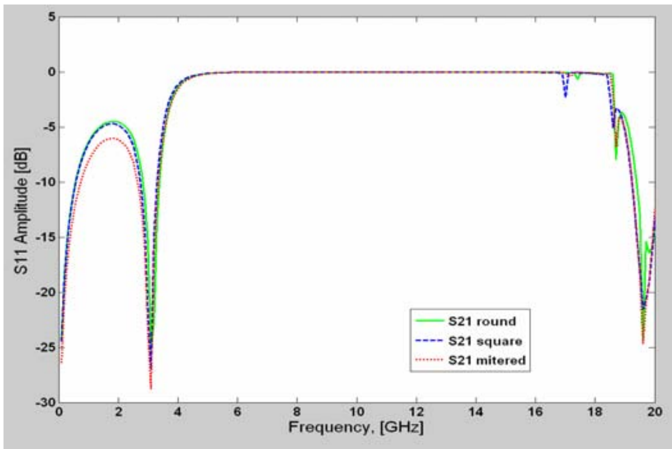


Figure 9. Comparison between different layouts suspended low pass filter

The following figure (Figure 10) shows the results of the simulation, with Agilent’s ADS simulator, and measurement of the same filter shown on Figures 5 and 6, in a microstrip structure, not in suspended substrate.

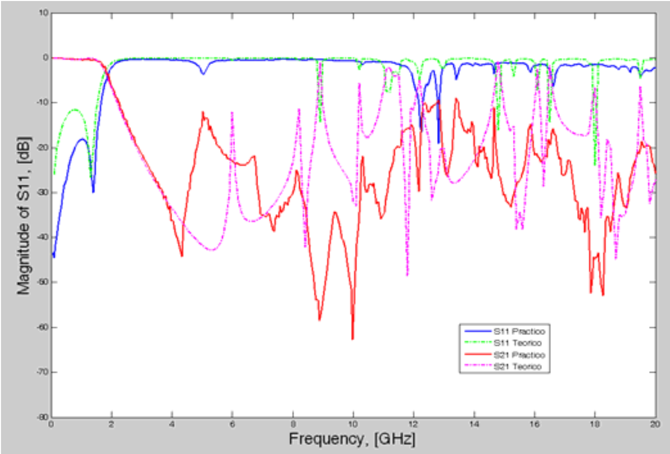


Figure 10. Simulation and measurement of a microstrip LPF

The result of the suspended substrate is a wider bandpass, increasing it from 2 GHz in the not suspended case to nearly 4 GHz.

VI. CONCLUSIONS

In this work, a study of a low past filter based on the suspended microstrip technology is presented. Due to the promising results shown here, the authors strongly believe that a rigorous analysis of such filters must be carried out, including the optimization for high order filters. In the presentation of this work, two improved filters of three and five poles are being manufactured and carefully analyzed.

VII. ACKNOWLEDGMENT

The authors would like to thank the Spanish Ministry of Education and Science (MEC) by the financial support provided through project TEC 2005-07985-C03-01.

REFERENCES

[1] I.-S. Kim and S.-W. Yun, “Compact LPF using asymmetrical microstrip step]discontinuity for harmonic supression”, IEEE Electronics Letters, Vol. 41, No. 16, August 2005.J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] Ahn, D., Park, J.-S., Kim, C.-S., Qian, Y., and Itoh, T.: ‘A design of lowpass filter using the novel microstrip defected ground structure’, IEEE Trans. Microw. Theory Tech., 2001, 49, (1), pp. 86–93.

[3] Hsieh, L.-H., and Chang, K.: ‘Compact elliptic-function low-pass filters using microstrip stepped-impedance hairpin resonators’, IEEE Trans. Microw. Theory Tech., 2003, 51, (1), pp. 193–199.

[4] Lopetegi et al., "New microstrip Wiggly-Line Filters with spurious Pass band suppression," IEEE Trans. MTT, September 2001, pp. 1593-1597.

[5] Myoung and Yook, "Miniaturization and harmonic suppression method of parallel coupled line filters using lumped capacitors and grounding," Electronics Letters, July 2005, pp. 849-851.

[6] Joseph S.Wong, "Microstrip Tapped-Line Filter Design," IEEE Trans. MTT-27, 1979, pp. 44-50.

[7] K.C.Gupta, R.Garg, I.Bahl, P.Bhartia, Microstrip Lines and Slot Lines, Artech House, 1996.

[8] Mª. Borge, A. Casanueva and J. L. García, "Efficient eigenmode analysis for multiconductor and multilayer planar transmission lines: SVD a technique capable solving homogeneous matrix equations without poles", 23rd Europe. Microwave. Conf. 1993, Madrid, Spain, pp. 531-534.

[9] E. Yamashita, B.Y. Wang, K. Atsuki, K.R. Li, “Effects of Sidewall Grooves on Transmission Characteristics of Suspended Striplines”, IEEE Transactions on Microwave Theory and Techniques, Dec.1985, pp.1323 – 1328.

[10] A. Farrar and A. T. Adams, “Matrix methods for microstrip three-dimensional problems,” IEEE Trans. Microwave Theory Tech., vol. MTT-20, pp. 729–733, Aug. 1972.

[11] P. Benedek and P. Silvester, “Equivalent capacitances for microstrip gaps and steps,” IEEE Trans. Microwave Theory Tech., vol. MTT-20, pp. 729–733, Nov. 1972.

[12] Zhu, L., and Wu, K.: ‘Short-open calibration technique for field theory-based parameter extraction of lumped elements of planar integrated circuits’, IEEE Trans. Microw. Theory Tech., 2002, 50, (8),pp. 1861–1869.