INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY,
VOL.11, NO.1, JANUARY 2016

A Novel Configuration of a Miniature Microstrip Low Pass Filter

F. Benriad[1*], J. Zbitou[2], B. Abboud[1], H. Bennis[2], A. Tribak[3], A. Mediavilla[4]

[1] LITEN Laboratory, FST of Settat Hassan 1[ST] University, Morocco
[2] LMEET Laboratory, FPK/FST of Settat Hassan 1[ST] University, Morocco
[3] Microwave group, INPT Rabat, Morocco
[4] DICOM Laboratory, University of Cantabria Santander, Spain
E-mail: faridabenriad@gmail.com

Abstract*- In this paper, we will present the design and the fabrication of a new configuration of a microstrip low pass filter. The originality of this work is that the final proposed filter is miniature and presents good performances in term of insertion loss around -0.15dB and it has a wide stopband until 7 GHz. The design of such filter is based on the use of optimization and tuning methods integrated into two electromagnetic solvers ADS and CST-MWS. After the fabrication, the final LPF structure is tested which give a good agreement between simulation results for the both solvers and measurement responses. The proposed filter has a cutoff frequency of 2.33 GHz which makes it suitable for many standards like DCS "Digital communication system", and UMTS "Universal Mobile Telecommunications System" bands. The final circuit presents an area of 20x20mm^2.

***Index Terms*- DCS, ISM, low pass filter, microstrip, planar filters.**

I. INTRODUCTION

The filters are one of the primary and important components of a microwave system, especially in wireless and mobile communication systems. Low pass filter must be included at the transmitting end and the receiving side of the system to get desired spectrum. A filter is a two-port network used to control the frequency response at a certain point in an RF or microwave system by providing transmission at frequencies within the passband of the filter and attenuation in the stopband of the filter. When designing a planar filter, miniature dimensions of the circuit are desired. To do so, we can use many techniques by applying for example fractal theory to the filter, which enable to create longer current lines on a smaller surface [1-2]. Another technique used, is the insertion of etched slots in the ground plane (called defected ground structure, DGS) which can create an equivalent parallel resonant circuit permitting the miniaturization of the final circuit [3]. Also, the combination between DGS concept and a fractal approach for the design of a compact low pass filter can reduce significantly the dimensions [4]. Designing microwave planar filters demand to have a high selectivity and low insertion loss for the transmission frequency band [5-13]. In the same time, a special attention must be given to the achievement of wide attenuated bands for low-pass filters. One of the most popular approaches for the achievement of LPF is based on the alternate cascade of high and low-impedance transmission-line segments. By consequent, we should use a large number of sections to produce a significant signal attenuation levels in the rejected band. In this work, we will introduce a new compact miniature microstrip LPF topology with low insertion loss and a large attenuated stopband, the achievement of such circuit is obtained by using tuning and optimization methods.

II. DESIGN PROCEDURES

Compact low-pass filter designs with a sharp attenuation response are challenging. Most classical approaches used for filter synthesis are Butterworth or Chebyshev types, but they require a high-order design to achieve a good selectivity near the passband. TEM structures of stripline and microstrip lines are ideal for LPFs [14]. A waveguide LPF is not possible because

INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY,
VOL.11, NO.1, JANUARY 2016

waveguides have low cutoff frequencies. The design of a microwave LPF closely follows the idealized lumped-element circuit. Fig.1 [14] presents the relationship between a microwave lowpass filter and a low-frequency lowpass filter prototype. Where high-impedance transmission line can be replaced by a series inductance. A short section of a low-impedance transmission line can be replaced by a shunt capacitor.

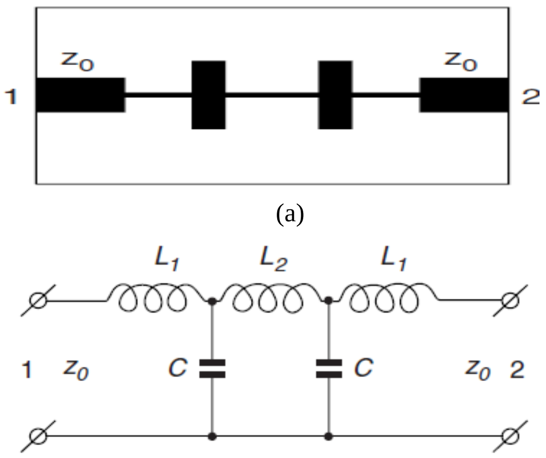


Fig.1. Stepped impedance microstrip LPF: layout of 5th order filter (a); equivalent circuit (b)

If the length ℓ of a high-impedance section is less than λ/8. Where the electrical lengths of the inductor sections to be calculated as [15]:

$$\beta\,\ell = \frac{L\,R_0}{Z_h} \quad \text{(inductor)} \qquad (1)$$

and the electrical length of the capacitor sections as [15]:

$$\beta\,\ell = \frac{C\,Z_\ell}{R_0} \quad \text{(capacitor)} \qquad (2)$$

Where R_0 is the filter impedance and L and C are the normalized element values. And the actual values of Z_h and Z_ℓ are usually set to the highest and lowest characteristic impedance that can be practically fabricated.

After the validation of the filter based on the lumped elements we can pass to microstrip configuration by the last adequate transformation. But not always simple to achieve a LPF having sharp stopband, therefore, this work will describe the design of compact low pass filter based on optimization and tuning methods.

The proposed LPF is mounted on an FR4 substrate characterized by a thickness of 1.6 mm, a relative electric constant of 4.4, a loss tangent of 0.025 and a conductor thickness of 35 µm.
After many series of optimization we have validated the structure shown in Fig.2.

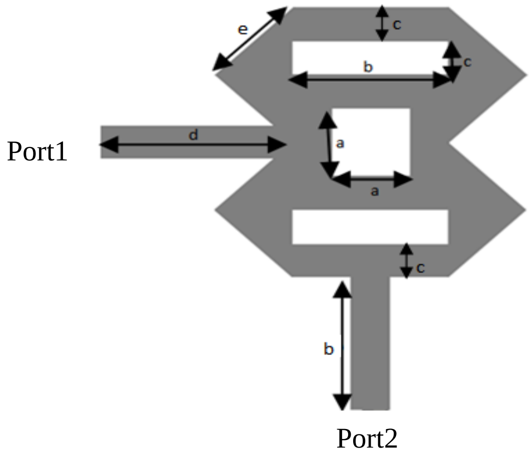


Fig.2. The configuration of the proposed LPF including the optimized parameters

The dimensions of each part of the proposed low pass filter are listed in Table 1:

Table 1: Dimensions of the filter in mm

a	b	c	d	e
2	4	1	5	2,82

Firstly, this LPF structure was validated into simulation by using Momentum which is a 2D electromagnetic solver integrated in ADS, the simulation of such circuit has taken into account a high density of meshing to cover the whole circuit. After that and before passing to fabrication, we have launched a comparison between ADS and another 3D electromagnetic solver which is CST-MWS. As presented in

INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY,
VOL.11, NO.1, JANUARY 2016

Fig.3, we have nearly the same results with the same behavior of the LPF.

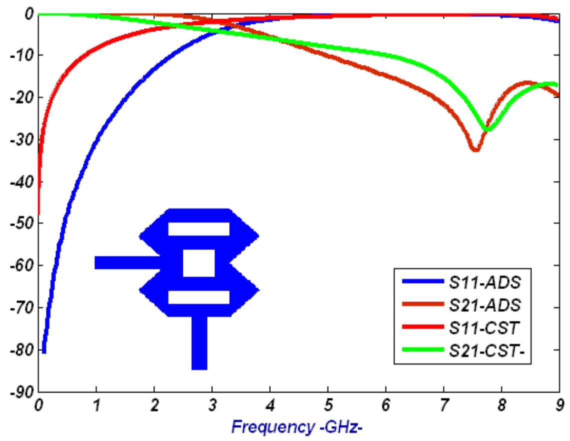
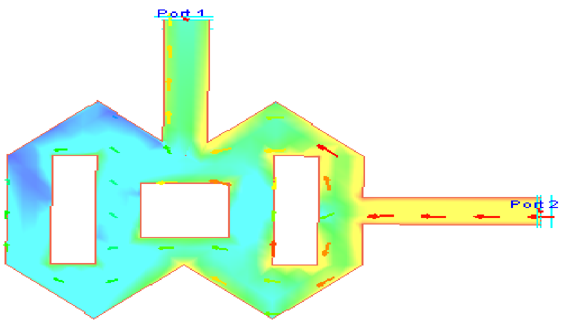
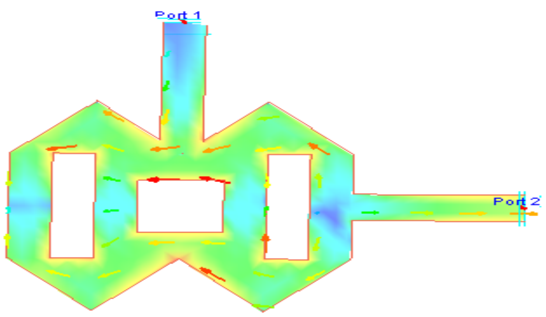


Fig.3. CST and ADS simulation results comparison

The designed filter has a cutoff frequency of 2.4 GHz with an important rejected band. To study the current distributions, Fig.4 depicts the current flow for two different frequencies. The first one is in the bandwidth at 1.75 GHz and the second one in the attenuated band at 7.8 GHz.



(a)



(b)

Fig.4. The current distribution of the proposed LPF: (a) at 1.75 GHz and (b) at 7.8 GHz

In order to obtain the desired frequency response of the low pass filter, several parametric studies were achieved. Fig.5 shows the evolution of the S-parameters of the proposed filter versus the variation of the critical geometric parameter *a*.

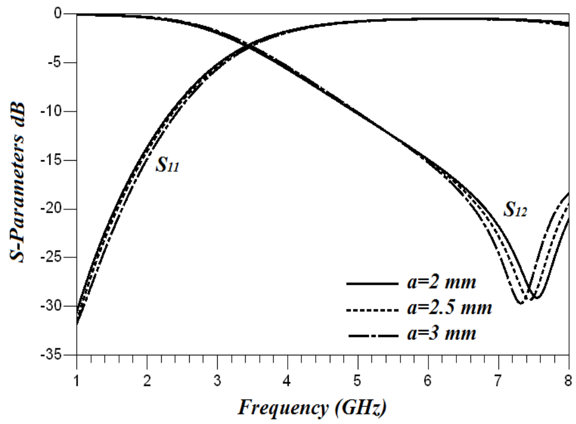


Fig.5. Frequency response of the proposed low pass filter under different values of the geometrical parameter *a*

As can be seen, the variation of this parameter has no effect on the location of cut-off frequency and the passband bandwidth. In fact, the periphery of the proposed outside resonator is kept unchanged, thus the cut-off frequency is not affected. In return, changing the value of the parameter *a* from 2 mm to 3 mm will decrease the frequency of the transmission zero and enhance its attenuation. Therefore, controlling the position and the attenuation of this transmission zero can enlarge the attenuation band and suppress the spurious resonant frequencies. Consequently, from these studies, we can conclude that the periphery of the outside resonator can control the cut-off frequency and passband bandwidth, while the width of the inside square resonator can control the attenuation and location of the transmission zeros and by the way the width of the attenuation band.

III. FABRICATED DEVICE AND MEASUREMENT

The designed LPF was fabricated by using LPKF machine and tested using an R&S VNA. As shown in Fig.6, the fabricated filter having a volume of 20x20x1.6 mm^3.

Fig.6. Photograph of the fabricated LPF

As illustrated in Fig.7, the test of the LPF shows that we have a good agreement between simulation and measurement in term of return loss and insertion loss. The final circuit is validated with a low insertion loss around -0.15dB and a wide frequency band for the attenuated band. As we can see the level of attenuation in the stopband is reaching 7 GHz.

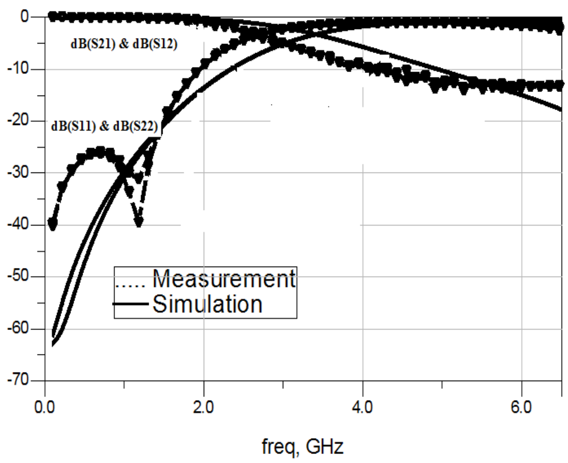


Fig.7. Simulation and measurement results comparison for the proposed LPF

The final circuit is compact miniature and low cost, it can be used for many wireless applications, the achieved cutoff frequency makes the LPF suitable for GSM, DCS and UMTS applications.

IV. CONCLUSION

This paper has presented the different steps followed to achieve a microstrip miniature LPF. The fabricated circuit presents good performances with a low insertion loss in the bandwidth and large attenuated stopband. Which permit to use it for high frequencies until 7 GHz with an important level of rejection. The validation of this circuit has followed many steps and series of optimization by using different methods integrated into electromagnetic solvers. The final LPF configuration is simple compact which avoid using standard approaches as stepped-impedance or others which increase the dimensions of the filters. The different techniques and steps followed can be exploited to match the same LPF to another frequency bands looking for other applications.

ACKNOWLEDGMENT

We have to thank Mr. Angel Mediavilla Director of DICOM Laboratory of the Cantabria University in Santander Spain, for allowing us to use all the equipments and electromagnetic solvers available in his laboratory.

REFERENCES

[1] Campos, A.L.P.S., De Oloveira, E.E., and Da Fonseca Silva, P.H.: “Design of miniaturized frequency selective surfaces using Minkowski island fractal”, *J. Microw. Optoelectron. Electromagn*, Vol. 9, No. 1, pp. 43–49, Appl. 2010.

[2] Kim, I.K., Kingsley, N., Morton, M., Bairavasubrama-Nian, R., Papapolymerou, J., Tentzeris, M.M., and Yook, J.G.: “Fractal shaped microstrip coupled line band pass filters for suppression of 2ND harmonic”, *IEEE Trans. Microw. Theory Tech.*, Vol. 53, No. 9, pp. 2943–2948, 2005.

[3] Vágner, P.: “Microstrip filters using defected ground structure”, Doctoral thesis, Brno University of Technology, 2008

[4] M. Kufa and Z. Raida “Lowpass filter with reduced fractal defected ground structure”, *Electronics Letters*, Vol. 49, No. 3, 31st January 2013.

[5] C. Hunter, L. Billonnet, B. Jarry, and P. Guillon, “Microwave filters—Applications and

INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY,

VOL.11, NO.1, JANUARY 2016

technology", *IEEE Trans. Microw. Theory Techn.*, Vol. 50, No. 3, pp. 794–805, Mar. 2002.

[6] J.-S. Hong and M. J. Lancaster, *Microstrip Filters for RF/Microwave Applications*. New York, NY, USA: Wiley, 2001.

[7] S. Y. Huang and Y. H. Lee, "Compact U-shaped dual planar EBG microstrip low-pass filter", *IEEE Trans. Microw. Theory Techn.*, Vol. 53, No. 12, pp. 3799–3805, Dec. 2005.

[8] M. K. Mandal and S. Sanyal, "A novel defected ground structure for planar circuits", *IEEE Microw. Wireless Compon. Lett.*, Vol. 16, No. 2, pp. 600–602, Feb. 2006.

[9] M. K. Mandal, P. Mondal, S. Sanyal, and A. Chakrabarty, "Low insertion- loss, sharp-rejection and compact microstrip low-pass filters", *IEEE Microw.Wireless Compon. Lett.*, Vol. 16, No. 11, pp. 93–95, Nov. 2006.

[10] A. Balalem, A. R. Ali, J. Machac, and A. Omar, "Quasi-elliptic microstrip low-pass filters using an interdigital DGS slot", *IEEE Microw. Wireless Compon. Lett.*, Vol. 17, No. 8, pp. 586–588, Aug. 2007.

[11] F. Aznar, A. Vélez, J. Bonache, J. Menés, and F. Martín, "Compact lowpass filters with very sharp transition bands based on open complementary split ring resonators", *Electron. Lett.*, Vol. 45, No. 6, pp. 316–317, Mar. 2009.

[12] W. H. Tu and K. Chang, "Compact microstrip low-pass filter with sharp-rejection", *IEEE Microw. Wireless Compon. Lett.*, Vol. 15, No. 6, pp. 404–406, Jun. 2005.

[13] V. K. Velidi and S. Sanyal, "Sharp roll-off lowpass filter with wide stopband using stub-loaded coupled-line hairpin unit", *IEEE Microw. Wireless Compon. Lett.*, Vol. 21, No. 6, pp. 301–303, Jun. 2011.

[14] Leo G. Maloratsky "RF and Microwave Integrated Circuits Passive Components and Control Devices", Library of Congress Cataloging-in-Publication Data.

[15] David M. Pozar, *Microwave Engineering*, Fourth Edition 2012, JohnWiley & Sons, Inc.