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A Novel CPW Low Cost Lowpass Filter Integrating Periodic Structures

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ABSTRACT

In this work, we propose a novel design of a planar CPW lowpass “LPF” filter based on the use of periodic structures. The periodic cells are formed from a rectangular slot repeated periodically. The originality of this work is to develop a new LPF structure which is simple, low cost for fabrication and easy to associate with others microwave planar circuits. The proposed and validated LPF is a compact planar filter structure. The final circuit is simulated and optimized by using two electromagnetic solvers, advanced design system (ADS) and high frequency structural simulator (HFSS). After many series of optimization we have validated the final circuit into simulation by using optimization methods integrated into the both solvers, taking into account a high density of meshing in order to cover the whole circuit. The fabricated LPF circuit shows good agreement between simulation and measurement results in term of matching input impedance and insertion loss with a cut-off frequency of 1.25GHz. The entire area of the proposed LPF is 35x31 mm^2.

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1. INTRODUCTION

Lowpass filters (LPFs) have been widely used in RF and microwave applications [1]-[8]. LPFs based on CPW technology have been studied and exploited extensively as a key block in modern communication system as the technologies of satellite systems, mobile communications, etc. Compact design, low insertion in the passband and sharp rejection in the stop band are required.

In this paper, we propose a novel lowpass filter based on CPW technology [9]-[12] with suppression of superiors response. The new LPF is compact and have miniature dimensions. The suggested filter provides an attenuation of -44.70dB in the rejection band. To design such circuit we can find many techniques like the stepped impedance [13], open stubs [14], lumped element [15], etc.

To design such LPF circuit, we have used the technique of insertion of periodic structure. In this work, we have used the rectangular slot as the periodic *structure; the dimensions of this cell were optimized into simulation.

The following sections will present the different steps followed to design and to simulate the proposed lowpass filter, and at the end a comparison between simulation and measurement results is discussed.

2. DESIGN PROCEDURE

Firstly, we have designed a 50 Ohm CPW line designed by using the following equations [16]:

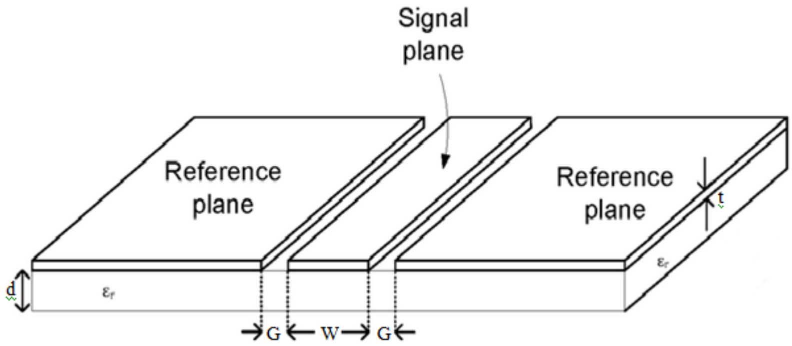


Figure 1. Coplanar waveguide (CPW) line [16]

There are four geometric parameters: the Gap G, the conductor width W, metal thickness t and the substrate thickness d. The characteristic impedance and the effective permittivity are given approximatly below: Effective permittivity

$$\varepsilon_{re} = \frac{\varepsilon_r+1}{2}\left\{\tanh\left[0.775\ln\left(\frac{d}{G}\right)+1.75\right]+\frac{kG}{d}\left[0.04-0.7k+0.01(1-0.1\varepsilon_r)(0.25+k)\right]\right\} \quad (1)$$

where:

$$k = \frac{W}{W+2G}$$

Characteristic Impedance

$$Z_0 = \frac{30\pi}{\sqrt{\varepsilon_{re}}}\frac{K'(k)}{K(k)} \quad (2)$$

where K(k) is a complete elliptical function of the first kind. We have

$$k' = \sqrt{1-k^2}\ ;\ K'(k) = K(k') \quad (3)$$

and

$$\frac{K(k)}{K'(k)} = \left[\frac{1}{\pi}\ln\left(2\frac{1+\sqrt{k'}}{1-\sqrt{k'}}\right)\right] \qquad \text{if} \quad 0 < k < 0.707 \quad (4)$$

$$\left[\frac{1}{\pi}\ln\left(2\frac{1+\sqrt{k}}{1-\sqrt{k}}\right)\right]^{-1} \qquad \text{if} \quad 0.707 < k < 1 \quad (5)$$

The CPW offeres many advantages, which include the following:

- It can work to extremely high frequencies (100 GHz or more).
- Good circuit isolation can be achieved using a CPW. Many examples of high-isolation RF switches have used a grounded CPW to get 60 dB isolation or more.

After the validation into simulation of the 50ohm CPW line in term of return loss and insertion loss, we have conducted a second study to change the behavior of this line and to generate a reject band permitting the achievement of a LPF. The proposed structure is based of the integration of three coupled line associated to the CPW ground plane. So to adjust the bandwidth and the stop band we have inserted an optimized rectangular slot structure repeated along the two coupled lines with the centred line.Therefore, after many steps of optimizations using Momentum integrated in ADS, we have validated into simulation the proposed CPW LPF depicted in Figure 2, the optimized parameters are presented in Table 1.

This filter is mounted on an FR4 substrate having a thickness of 1.6mm, a dielectric permittivity $\varepsilon_r = 4.4$ and loss tangent $\tan\delta = 0.025$.

After this validation, we have conducted another study by using a 3D electromagnetic solver to take into account the dimensions of substrate, by consequent; we have launched the simulation of the same LPF circuit by using HFSS slover.

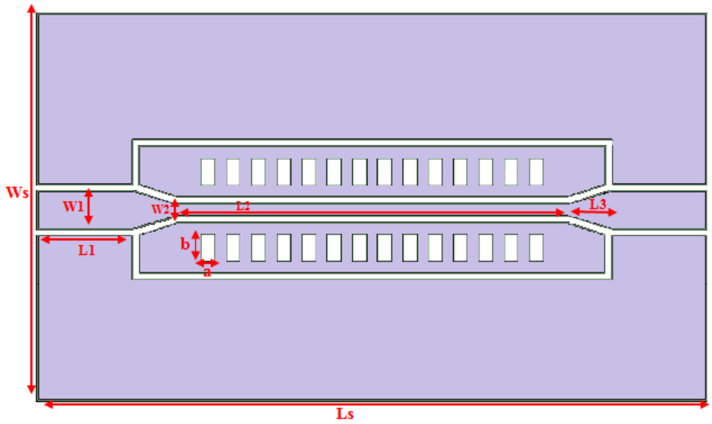


Figure 2. Geometry of the proposed lowpass filter

Table 1. Values of the different parameters of the bandpass filter

Parameters	Values (mm)
Ws	31
Ls	53
W1	3
L1	7.5
W2	1
L2	31
L3	3.5
a	1
b	2

As shown in Figure 3, we have a good agreement between ADS and HFSS. The lowpass filter presents a cut-off frequency equal to 1.25 GHz with a return loss more around -12dB in the whole bandwidth with an insertion loss less than -0.5dB.

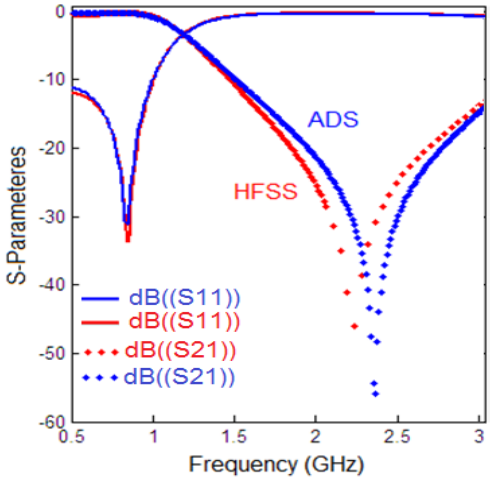
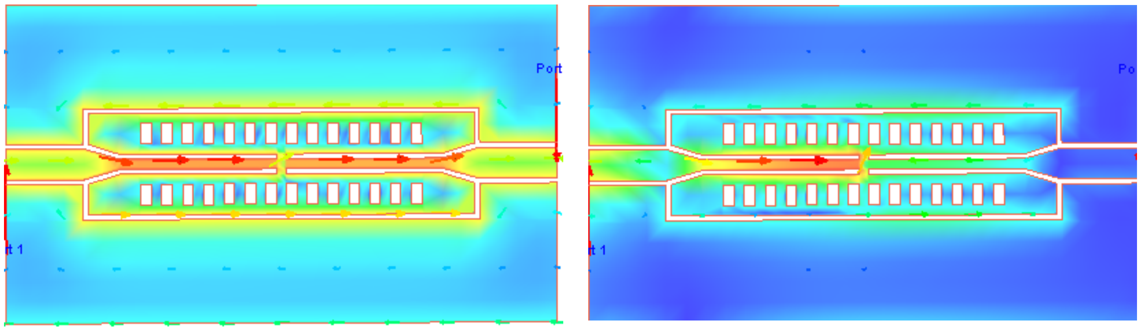


Figure 3. S-parameteres versus frequency of the designed filter



f = 1GHz f = 2.5 GHz

Figure 4. Presents the current distribution at 1GHz and at 2.3 GHz

To study the current distribution along this LPF structure, Figure 4 presents two current distribution, one in the bandwidth at 1 GHz and an other at 2.5 GHz in the rejected band which confirm the opration frequency bands of the proposed filter.

3. FABRICATION AND MEASUREMENTS

In this part we will introduce the measurement results of the proposed LPF. As shown in Figure 5, the final CPW filter is fabricated presenting an area of 35x31 mm^2. The test of this circuit is done by using a VNA from R&S assoiciated to 3.5 mm calibration Kit.

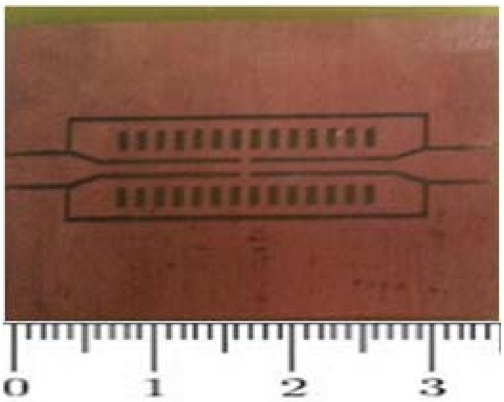


Figure 5. Photograph of te fabricated low pass Filter

As dipected in Figure 6, we have obtained a good agreement between measurement and the both electromagnetic solvers. The fabricated filter presents a cutt-off frequency at -3dB equal to 1.25 GHz, with a good rejection. The insertion loss in the bandwidth is arround – 0.3 dB. The final structure is a low cost, compact, suitable and easy for integration with passive and actif RF circuits, it can be used for several applications of wireless communications.

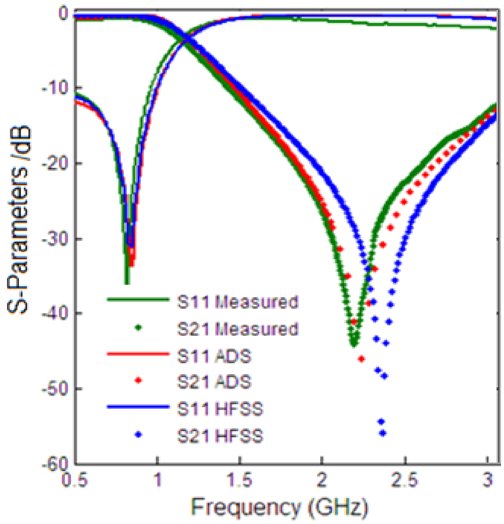


Figure 6. S-parameter of simulation and measurement results of the low pass filter

4. CONCLUSION

This work comes with a new configuration of a planar LPF structure based on the use of CPW technology and periodic structures illustrated in the use of rectangular slots permitting to adjust the bandwidth and the rejection level. The design procedures were based on the use of several optimization methods integrated into ADS and also we have taken into account a high mesh density to cover the whole circuit.The final proposed filter can be used for GSM and others microwave applications handling low levels of power. The methodology followed in this study can be used to match the LPF filter to another frequency band.

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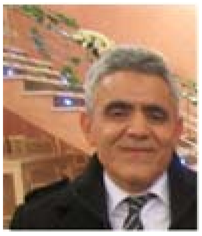

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