A Novel Periodic CPW UWB Low Pass Filter With Large Rejected Band

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Abstract. In this paper, we present a new UWB CPW low pass filter structure by using periodic elements. The originality of this work is to develop a neFigure 4 showsw UWB LPF structure which is compact, miniature, and easy for fabrication. The validated LPF is a compact planar filter easy to associate with others microwave planar circuits, having a large band pass and a large rejection band. The final circuit is simulated and optimized by using the electromagnetic solver ADS (Advanced Design System). After many series of optimizations, we have validated the final circuit into simulation by using different optimization methods taking into account a high density of meshing in order to cover the whole circuit. The simulated LPF circuit shows good results in term of matching input impedance and insertion loss with a cut-off frequency of 6.5GHz. The entire area of the proposed LPF is 16x40 mm^2.

.**Keywords:** CPW, UWB, LPF, Periodic Structure.

1 Introduction

Periodic structures of different types have always been a field of interest for researchers. They are actually used in many applications in the microwave and millimeter-wave regime [1]. The periodic structures have been used to fabricate high-performance filters, to perform harmonic tuning in power amplifiers, to suppress superior's harmonic and to enlarge the band pass [2-5]. Coplanar Waveguide (CPW) structures are one of the important subjects for the miniaturization of microwave integrated circuits (MICs). Due to uniplanar structure, low dispersion effect and simple fabrication process, CPW are used more than microstrip structures in the planar technology filter applications [6]. Harmonic-suppressed and wide stop-band properties have been highly demanded in millimeter systems to reject the spurious responses caused by nonlinear devices, such as high power amplifiers, mixers, and oscillators, etc Different approaches can be used to reach this goal like employing a periodic structure [7-8] or a Defected Ground Structure (DGS) [9], many research activities have been performed in order to apply it to microwave LPF circuits [10].

Many techniques can be used to implement such filters like stepped-impedance, coupled line, using coupled resonators, periodic structures and others. In order to design a planar filter many steps can be followed. Firstly, we can start by designing a low pass filter prototype using Butterworth, Chebyshev approximations [11]. The prototype g-values are scaled (demoralized) to the desire filter termination resistance and cut-off frequency as follow:

$$L = \frac{gR}{\omega} \quad (1)$$

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$$C = \frac{g}{\omega R\prime} \quad (2)$$

High pass, band pass and stop-band can be obtained by applying an L-C transformation on low pass filter [12].

The next step is use the Richards' transformation, which allows the inductors and capacitors of a lumped-element filter to be replaced with short-circuited and open-circuited transmission line stubs as depicted in **Figure 1.**

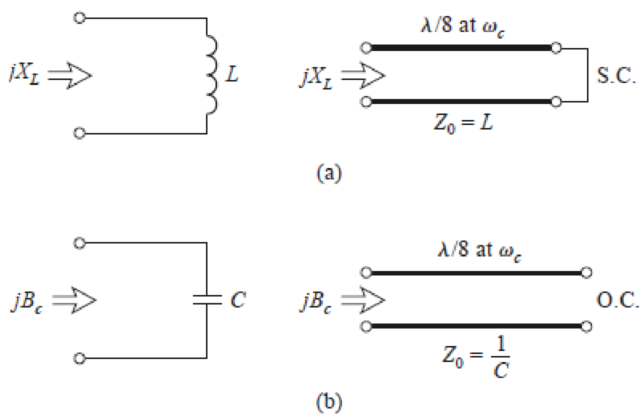


Fig.1. Richards' transformation. (a) For an inductor to a short-circuited stub. (b) For a capacitor to an open-circuited stub.

The transformation

$$\Omega = \tan \beta l = \tan \frac{\omega l}{\vartheta_p} \quad (3)$$

Map ω plane to Ω plane. if we replace the frequency variable with ω, we can write the reactance of an inductor as:

$$jX_L = j\Omega L = jL \tan \beta l \quad (4)$$

$$jB_c = j\Omega C = jC \tan \beta l \quad (5)$$

In addition to these, kuroda identities can be very useful in making the implementation of Richard's transformations more practicable. We can use Kuroda's Identities [13] to:

- Physically separate transmission line stubs.
- Transform series stubs into shunt stubs.
- Change impractical characteristic impedances into more realizable ones.

In general, the filter synthesis isn't always possible; therefore we can achieve new filter structures by using optimization methods. In this paper, we have used the optimization methods to achieve a novel LPF based on the coplanar waveguide (CPW) with improving the insertion loss and stop-band performances.

2 Design procedure

To develop this novel structure, we have done a bibliography study, in order to have an idea about the different shapes and techniques used for such design. By consequent, we have started our work taking into account the study done in [14]. The filter design is started by passing from a simple CPW line, in which we have inserted octagonal shape as shown in **Figure 2.**

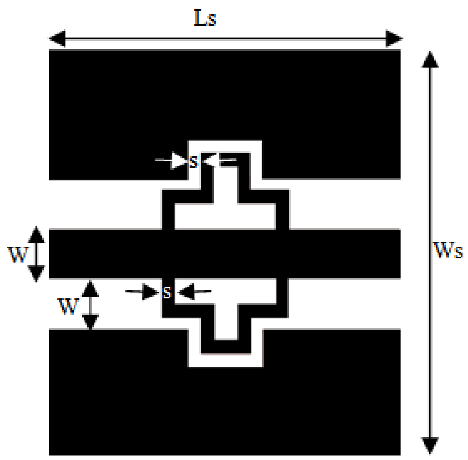


Fig.2. The geometry of the CPW (Ws=16mm, Ls=14mm, s=0.5mm et W =2mm).

The simulation results of this filter structure are depicted in **Figure 3**.

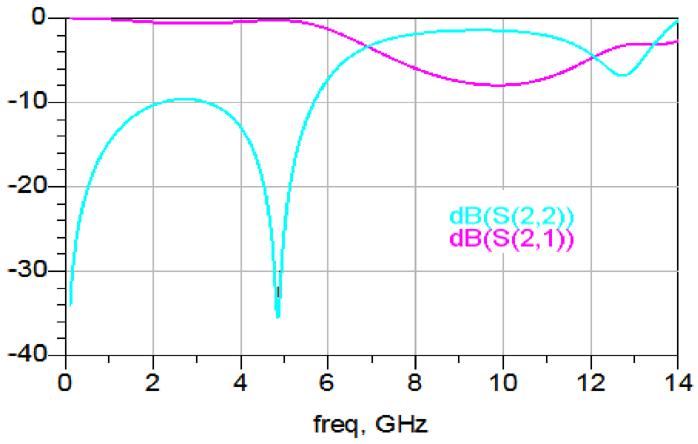


Fig.3. The S-parameters of the simulated CPW line versus frequency.

The Figure 3 shows the simulation results of the structure with one cell, as we can conclude, we have obtained a low pass filter behavior with a cutoff frequency equal to 6.77 GHz correspending to a reflection coeffecient around -10dB in the whole bandwidth with an insertion loss less than -0.5dB. In order to enhance the rejection band characteristics we have done another study based on the technique of the use of the periodic structure. The number of unit cell and the distance between cells influence the rejection band characteristics (Aytouna et al., 2015).

After many series of simulation using optimization methods integrated in ADS, we have validated into simulation the proposed CPW LPF presented in **Figure 4**. The final proposed CPW LPF structure contains 4 cells which gave the good performances.

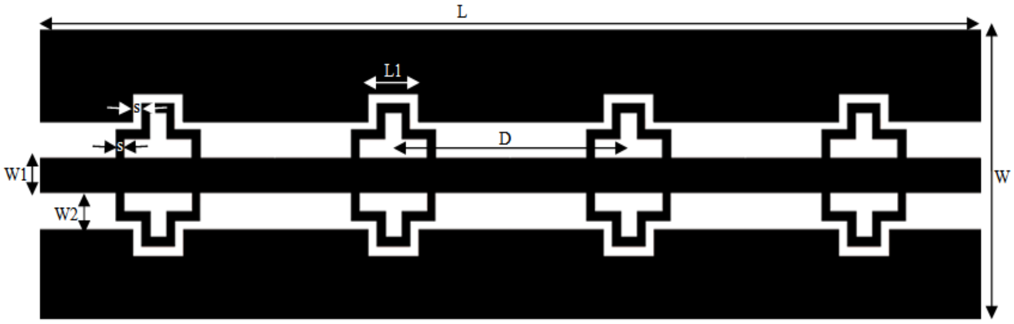


Fig.4. The topology of the proposed LPF.

The optimized parameters are presented in **Table 1**.

Table 1. Dimensions of the proposed CPW LPF structure.

Parameters	Values (mm)
W	16
W1	2
W2	2
L	40
L1	3
D	9
S	0.5

This CPW LPF is printed on an FR4 substrate with a thickness of 1.6mm, a dielectric permittivity $\varepsilon_r = 4.4$ and loss tangent $\tan\delta = 0.025$.

Figure 5 illustrates the S parameters of the proposed filter.

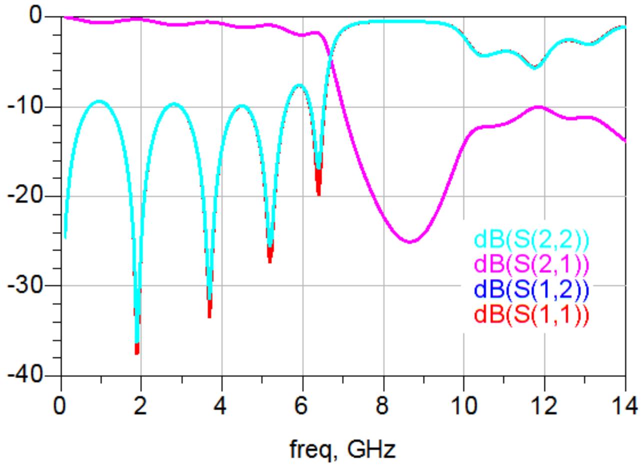


Fig.5. S-parameters versus frequency of the designed CPW LPF

As depicted in **Figure 5** we have obtained good results in term of insertion loss around -0.8dB, a cutoff frequency of 6.77 GHz and a good rejection until 15GHz. These results are due to the insertion of periodic structures.

To show the effect of the variation of the distance and the number of cells, we have conducted a series of simulations based on two parameters:

2.1 Effect of the number of cells

The first study is done by fixing the distance between cells at 9 mm. **Figure 6** and **Figure 7** illustrate the S-parameters versus frequency of the designed LPF by changing the number of cells.

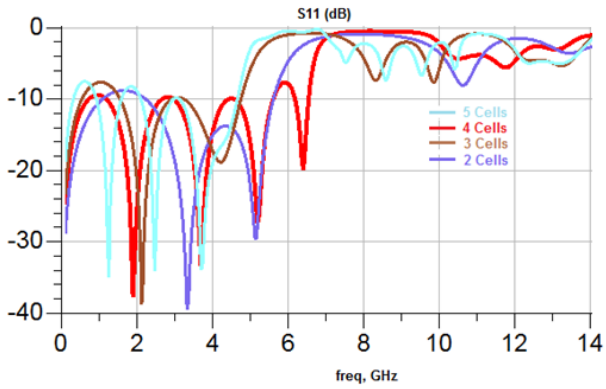


Fig.6. S11 parameter versus frequency for different number of cells of the proposed LPF.

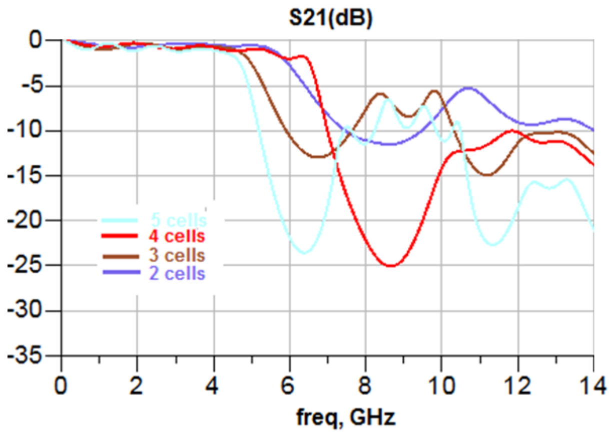


Fig.7. S21 parameter versus frequency for different number of cells of the proposed LPF.

As shown in **Figure 6** and **Figure 7** the use of adequate number of cells in the proposed CPW LPF permits to enlarge the rejection band.

2.2 Effect of the distance between cells D

The second study is done by fixing the number of cells; in this case we have used 4 cells and we have changed the distance D between cells, the different results obtained are presented in **Figure 8** and **Figure 9**.

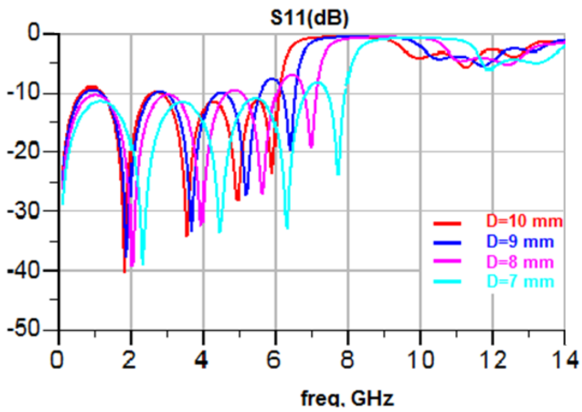


Fig.8. S11 versus frequency for different value of distance between cells of the proposed LPF.

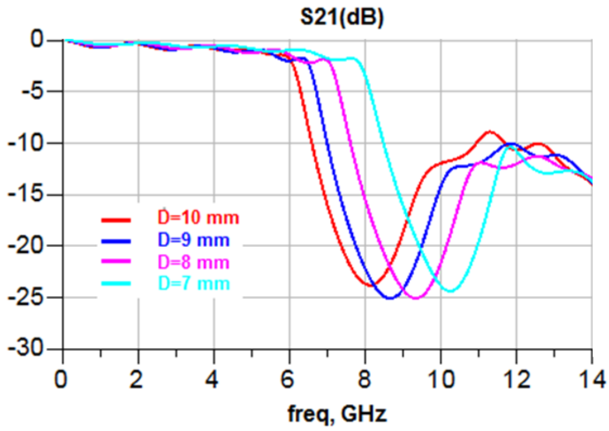
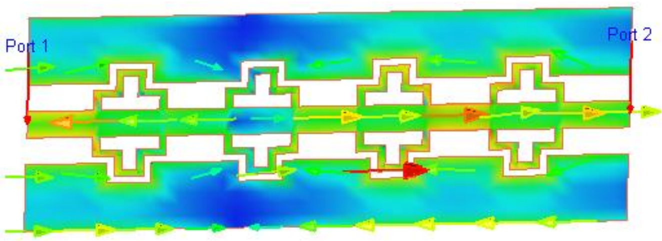
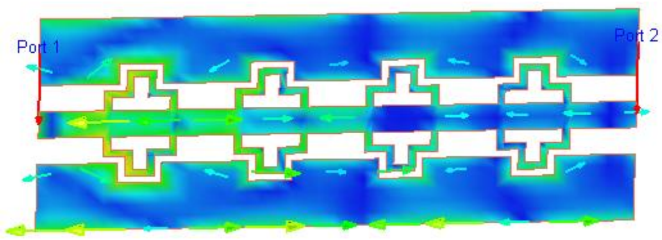


Fig. 9. S21 versus frequency for different distance between cells of the proposed LPF

To show the flow of energy in the band pass and rejected band, we have launched a simulation which confirms the function of the CPW LPF filter. **Figure 10** presents surface current distribution , one in the bandwidth at 2.58 GHz and another one at 10 GHz in the rejected band which validate the frequency bands of the proposed filter.



(a) at 2.58 GHz



(b) at 10 GHz

Fig.10. Presents the current distribution at 2.58 GHz and at 10 GHz

3 Conclusion

This work comes with a new configuration of LPF structure based on the use of CPW technology and periodic structures formed by octagonal shape slots permitting to adjust the bandwidth and to enlarge the rejection band. The design procedures were based on many optimization methods integrated into ADS. The simulation of the LPF was done taking into account a high mesh density to cover the whole circuit. The final proposed filter structure can be used for wireless communications and many other microwave applications. The methodology followed in this study can be used to match the LPF filter to another frequency band.

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