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DESIGN SPLIT RING RESONATORS ON MICROWAVE LOW PASS FILTERS

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ABSTRACT

Stepped Impedance microwave low pass filter design using conventional structure and split ring resonators (SRRs) structure is presented in this paper. The conventional stepped impedance low pass filter with cutoff frequency 1.9GHz is proposed and low impedance line in conventional design replaced by split ring resonator (SRR) to get compact, low insertion loss(IL), sharp cutoff, and high selectivity LPF. The multi ring SRR offers the possibility of designing multi-band filters with a small size and simple structure. These new filter designs have better results compared to conventional counterpart. The simulated results indicate that a flat pass band achieve without ripples, corresponding to number of rings of SRR structure. The circuit was simulated using IE3D simulator and the Flame Retardant 4 (FR-4) substrate with dielectric constant ε_r = 4.4 were used as a core material in this design.

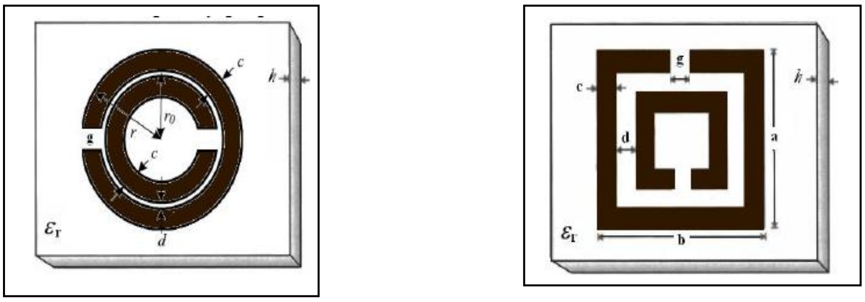
Keywords: Low Pass, Resonators, Split Ring, Stepped Impedance, Selectivity.

I. INTRODUCTION

For different applications, different filters are available in microwave wireless systems. The miniaturization of filters is one of the challenges of the present and the future for microwave communication devices. Low pass filters (LPFs) are often an important component in RF circuits and microwave communication systems. Conventional filter design methods such as stepped impedance and open stub suffering from poor skirt characteristics and spurious pass band [1-3], however these structures have a gradual cutoff response which is not sharp. Therefore, the rejection characteristics have limitations in such traditional LPFs. By adding new sections, there is increasing in the pass-band insertion loss and also limitation can be improved. However, this increasing does increase the size of overall structure. In order to overcome from these problems there has been an increasing interest for the use of metamaterial structures such as SRRs or other structures [4] in the development of compact microwave components using printed circuit boards and MMIC technologies [5-9].So. Metamaterial filters at high frequencies are the best studied for microwave wireless where miniaturization of filters leading to reduction in size, light weight and low cost.

Metamaterials are artificially synthesized materials which produce attractive physical properties unavailable in the conventional materials [10] .It can exhibit exotic negative refractive index, inverse Snell's law and reversed

Doppler effects. The dimensions of metamaterial inclusion are small compared to the wave length at the resonance.Split ring resonator was the first particle proposed for the implementation of Metamaterial [11]. In fact, to achieve a negative effective permeability in a certain frequency range, the metamaterial can be designed based on split ring resonators (SRRs) or similar geometries [12]. To construct miniaturized microwave circuits, these structures have been widely described as basic resonators. Using SRRs, the miniaturization can be realized by taking advantage of the well-known sub wavelength effect of these structures. In particular, split ring resonator (SRR) can be used as a basic particle for the design of stopband negative permeability structure. The SRR structures shown in Fig. 1 are used to obtain a negative value of effective permeability over a desired frequency range. This negative permeability can prevent wave propagation at resonant frequency.

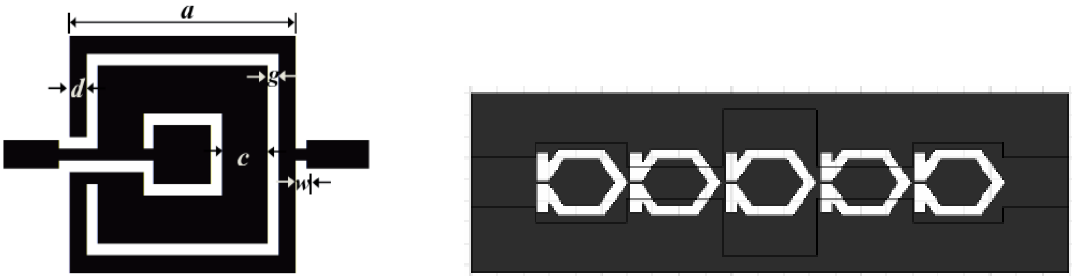


(a) (b)

Figure1: Unit cell SRR topology a) Circle shape, b) Square shape. The relevant dimensions are indicated.

There are many research papers related to the Metamaterial based LPFs, through using different structures such as CSRRs, Complementary hexagonal-omega structures, open complementary split ring resonators (OCSRRs), Hilbert-shaped complementary ring resonator (H-CRR) and dumbbell defected ground structures (DGSs). Few papers are reviewed as follows;

The low pass filter can be designed by using two cascaded stages of OCSRR. This low pass filter have narrow rejection bandwidth, therefore tapered dumbbell shaped DGS section is placed under the OCSRR to enhance the bandwidth. The cutoff frequency of this lowpass filter is 1.09 GHz. And the rejection bandwidth of the filter covers the entire ultra wide band spectrum [13]. Complimentary hexagonal-omega structures are used to design compact, low insertion loss, lowpass filter with sharp cutoff. It has been designed for improvement of selectivity based on negative property of complimentary hex-omega structure for both permeability and permittivity. By properly designing and loading the hexagonal omega structures in the ground plane of microstrip line not only improve the roll -off of the low pass filter, but also reduced the filter size. The simulated results indicate that the proposed filter achieves a flat pass-band with no ripples as well as better selectivity, corresponding to the five unit cells hex-omega structures Fig. 2 shows the schematic of OCSRR and hex-omega structures printed on the microstrip line.



(a) (b)

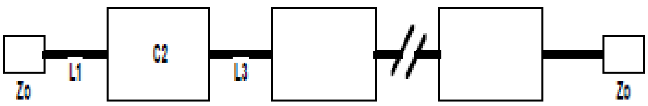
Figure 2: Layout of a) OCSRR b) Complimentary Hex-omega structures.

The major benefits from this work are to get low insertion loss, flattest pass band response, high selectivity, sharp cutoff performance and size reduction. In this paper, stepped impedance microwave low pass filters are presented. The cut off frequency of the conventional LPF design is 1.9GHz. The other designs of LPFs based on Metamaterial property by using multi ring SRR structures. The multi band resonator is composed of a number N of different concertic split rings. The N- ring generates N different resonance frequencies and engenders a magnetic resonance for each frequency.In fact , the value of each resonance response can be adjusted by varying the geometrical parameters of each ring resonator and also changing the design parameters. Here compared the conventional structure to the multi band SRR structures. As a proof of the concept , three filters are designed and simulated for three different cases (for N= 1,2 and 3). All presented filters are simulated by using IE3D and implemented on the Flame Retardant 4 (FR-4) substrate. This substrate has a dielectric constant ε_r = 4.4, loss tangent tan δ = 0.02, substrate height h = 1.6mm and thickness of microstrip conductor t = 0.035mm.

II. DESIGN METHODOLOGY

2.1 Conventional Stepped Impedance LPF Structure

In Fig.3, the general structure of stepped impedance lowpass filter is shown, which uses a cascaded structure of alternating high and low impedance transmission lines. The high impedance line act as series inductor whereas low impedance line act as shunt capacitor. The design of low pass filters involves two main steps. The first one is to select an appropriate low pass prototype. The choice of the type of response, including Pass band ripple and the number of reactive elements will depend on the required specifications. The element values of the low pass prototype filters, which are usually normalized to make a source impedance go = 1 and a cutoff frequency Ωc = 1.0, are then transformed to the L-C elements for the desired cutoff frequency and the desired source impedance, which is normally 50 ohms for microstrip filters. The next main step in the design of microstrip low pass filters is to find an appropriate micro strip realization that approximates the lumped element filter. The element values for the low pass prototype with Chebyshev response at pass band ripple factor L_{AR}= 0.1 dB, characteristic impedance source/load Zo = 50 ohms, are taken from normalized values g_i i.e. g_1, g_2, g_3, $g_{4......}$, $g_{n.}$ whereas the value of $g_0 = g_4 = 1$, $g_1 = g_3 = 1.0316$, g_2= 1.1474 for n = 3.



(a)

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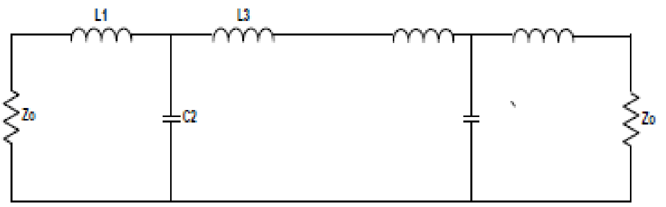


(b)

Figure 3: Circuit Structure of Low Pass Filter with Stepped Impedance.

The filter design steps are as follows:

1. Determine the number of sections from the specification characteristics for microstrip parameters.

   Filter Specifications:

   Relative Dielectric Constant, $\epsilon_r = 4.4$

   Height of substrate, h = 1.6 mm

   Loss tangent $\tan \delta = 0.02$

   Source/ Load Impedance Z_o=50 Ω

   Normalized Frequency $\Omega_c = 1$

2. Determine the values of the prototype elements to realize the specifications. Also we have taken the element value for low pass filters for n=3

$$L_i = (Z_o/g_o)\ (\Omega_c/2\pi f_c)\ g_i$$

1

$$C_i = (g_o/Z_o)\ (\Omega_c/2\pi f_c)\ g_i$$

2

3. Detemine the physical lengths of the high- impedance and low-impedance lines for low pass filters.

$$l_L = \lambda_{gl}/2\pi\ \mathrm{Sin}^{-1}(\omega_c L_i / Z_{OL})$$

3

$$l_C = \lambda_{gc}/2\pi\ \mathrm{Sin}^{-1}(\omega_c C_i\ Zoc)$$

4

4. The relevant design parameters of microstrip lines, which are determined using formulas in [14], are listed in Table 1.

Table 1 Dimensions For A Stepped-Impedance Low Pass Filter

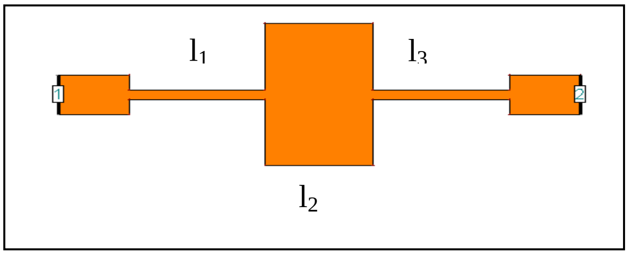
S.No.	Dimensions and Values		
	Microstrip line width in mm	***Characteristics Impedance in ohm***	***Effective dielectric constant***
1.	W_C=11.10, W_O=3.059, W_L=0.71	Z_{OC} = 20, Z_O = 50, Z_{OL} = 100	$(\varepsilon re)_C$ = 3.79, $(\varepsilon re)_O$ = 3. 381, $(\varepsilon re)_L$ = 3.05

5. The overall results came from equations (1) – (4) are listed in Table 2.

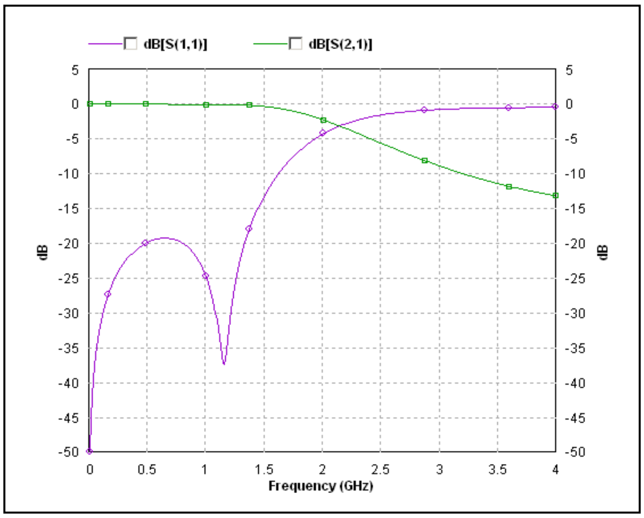
Table 2 Design Parameters of Stepped Impedance Lpf

L1 =L3 (H)	C2 (nF)	Physical length (mm)		Guided wavelength
4.33 X 10-9	1.923	l_L	l_C	85.883
		7.80	6.16	

A layout of conventional microstrip LPF is shown in Fig. 4 (a). The simulated transmission (S_{21}) and reflection (S_{11}) parameters as frequency response for conventional LPF is shown in Fig. 3 (b). It is obtained by simulation using IE3D Simulator.



(a)

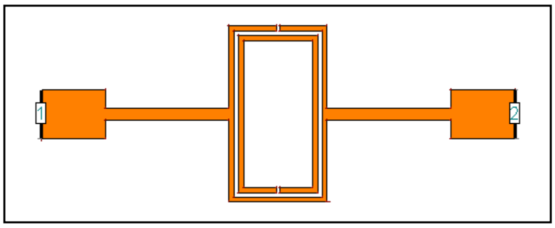


(b)

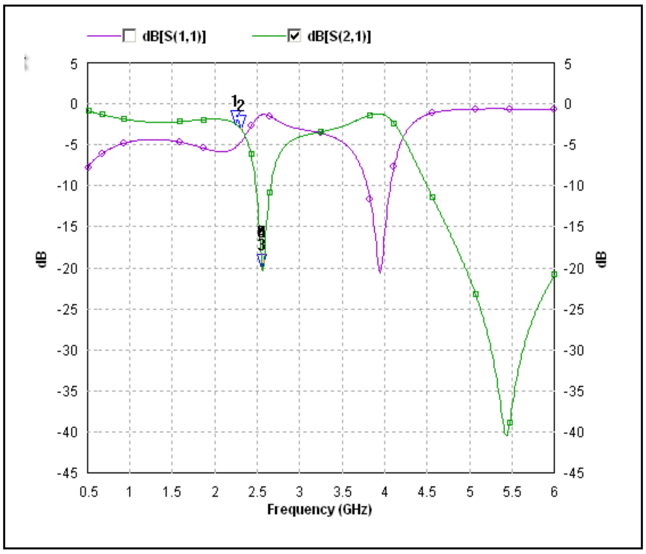
Figure 4: Conventional Stepped Impedance Microwave LPF, (a) Layout (Dimensions in mm), (b) S_{21} and S_{11} Frequency Response (Design 1)

2.2 Improvement of Stepped Impedance LPF design

The equivalent circuit of an SRR shown in figure 1(b) is replaced instead of shunt capacitor in the equivalent circuit of conventional design to get better results such as sharp roll- off response. The double split rings are rectangular copper with a thickness of 0.035 and the geometric parameters (a, b, and c) are 11.10 mm, 6.16 mm and 0.3 mm respectively.The gap between the inner and outer rings (d) is 0.2 mm, and each of the splits in the inner and outer rings has the same width (g) of 0.3 mm.



(a)



(b)

Figure 5: LPF Contains Rectangular SRR , (a) Layout (b) S21 and S11 Frequency Response (Design 2).

III. RESULTS AND DISCUSSION

To get good electrical performance of the present filters, the design parameters were tuned and optimized using IE3D software. The layout of filters with its simulation results are shown in figures 5 .It is observed that the roll off rate of LPF becomes sharper and there is better matching in the pass band with the SRR structure than the conventional structure.The response of the conventional LPF showsa low pass characteristics with a 3 dB cut off frequency of 1.9 GHz. The insertion loss reaches to -13.19 dB and return loss -37.43 dB. It can be seen that the scattering parameters for the LPF incorporating SRR particles, at 2.54GHz insertion loss reaches to -18.49dB and at 3.9 GHz, return loss -20.509 dB.

IV. CONCLUSION

This paper proposed a conventional design of stepped impedance microwave low pass filter with a cutoff frequency of 1.9 GHz and at least 10 dB insertion loss at 3 GHz (approx.). Other design depending on conventional design using the SRR structure. Through the proper design and loading the rectangular SRR structure instead of shunt capacitor , several merits have been achieved such as ; low insertion loss, sharp cutoff with high selectivity, and expand the bandwidth of pass- band in LPF performance.

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