Novel Microstrip low pass Filter Based on Complementary Split-Ring resonators

Hanane Nasraoui, Ahmed Mouhsen, Jamal El Aoufi, Mohamed Taouzari

***Abstract*— Many researchers have introduced various metamaterial structures such as spiral resonator, split ring resonator, complementary split ring resonators, omega, S structures etc., in recent years in that category. The advantage of metamaterial is its compact size with ability to provide improved performance. This paper propose a comparison between a classical Chebyshev microstrip low pass filter with a new design a microstrip low pass filter based complementary split ring resonator (CSRR).the proposed filter has reduced the filter size by 40 %.**

***Index Terms*— split ring resonator, complementary split ring resonators, metamaterials, Chebyshev microstrip filter.**

I. INTRODUCTION

A miniature size better performing low pass filters are of great demand in the applications of microwave circuits.

Recently metamaterials play important role in the performance improvement [1] of microstrip components such as antennas, filters etc...

These Metamaterials were first introduced by Veselago in 1967[2], they are artificial Structures which exhibit negative permittivity, permeability and negative refractive index which is not found in the readily available materials[3]. In the year 1999, Professor John Brian Pendry proposed his design of Thin-Wire (TW) structure that exhibits the negative value of permittivity and the Split Ring Resonator (SRR) with a negative permeability, µ value.[4][5] Following this interesting discovery, Doctor Albert Smith from Duke University combined the two structures and became the first to fabricate the metamaterial [6], it has been shown that negative permittivity can also be generated by means of a resonant element, namely the complementary split ring resonator (CSRR) introduced by Falcone et al. in 2004 [7].

These resonators can be considered as quasi- lumped elements and are, therefore, also very interesting for the miniaturization of planar microwave devices such as filters and diplexers, or for improving their performances.

This paper presents a miniaturized microstrip low pass filter designed using complementary split ring resonator (CSRR) use of complementary split ring resonator (CSRR) results in a significant size reduction of the filter comparing with classical Chebyshev microstrip low pass filter.

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II. DESIGN CHEBYSHEV LOW PASS FILTER

The design of low pass filters involves two main steps [8]. The first one is to select an appropriate low pass prototype [9]. 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 filter, which are usually normalized to make a source impedance go=1 and a cut-off frequency fc =2.5, are then transformed to the L-C elements for the desired cut-off frequency and the desired cut-off frequency and the desired source impedance, which is normally 50 ohms for microstrip filters[10]. The next main step in the design of microstrip low pass filters [11-12] is to find an appropriate microstrip realization that approximates the lumped element filter.

The specifications for the filter under consideration are:
Relative Dielectric Constant, ϵr = 4.4
Cut-off frequency, fc = 2.5GHz
Height of substrate, h = 1.6 mm
Zo= 50 Ω
Ωc= 1

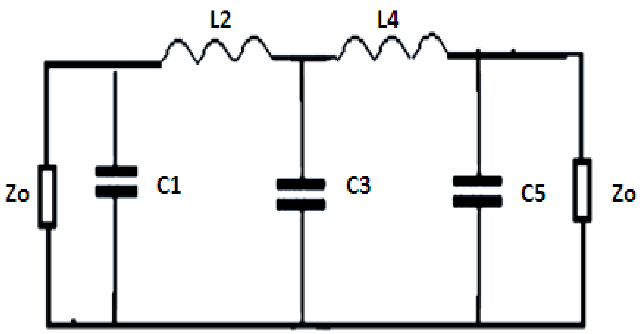

Figure1. Low pass prototype network with five components.

Chebyshev equations to determine the values of the components of low pass filter:

$$Li = (Z_o / g_o)(W_c / 2pf_c)g_i$$
$$Ci = (g_o / Z_o)(W_c / 2pf_c)g_i$$

In a second step must transpose the localized elements, real element, in our case with microstrip lines. For this, the width of the W line is fixed and the value of Er is entered, then the tool determines Line Calc εeff and the characteristic impedance Zc and then calculated the lengths of line selfs and capacitors with the following formulas:

$$l = \frac{L' \ 3.10^8}{Z_c' \ \sqrt{e_{eff}}}$$

$$l = \frac{C' \ Z_c' \ 3.10^8}{\sqrt{e_{eff}}}$$

With:
L: value of the inductance
C: value of the capacitor

TABLE I

Dimensions for a stepped-impedance low pass filters (for n=5)

composant	W(mm)	Zc(Ω)	ε_{eff}	L(mm)
C1=0.98662 pF	4	42,001	3.436	6.7
L2 =2.9491 nH	1	85.91	3.057	5.87
C3=1.6991 pF	10	21.7	3.77	5.89
L4=2.9491 nH	1	85.91	3.057	5.87
C5= 0.98662pF	4	42.001	3.436	6.7

Dimensional view of microstrip stepped impedance low pass filters (for n=5) in Figure 2.

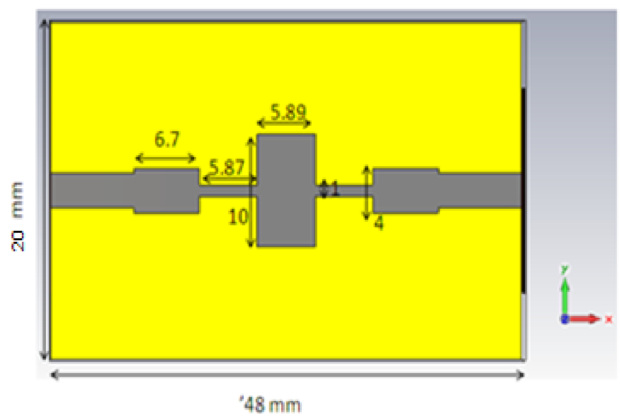

Figure.2 Layout of a 5-pole, stepped- impedance Microstrip lowpass filter on a substrate with εr= 4.4 and h = 1.6 mm at 2.5GHz frequency.

The Simulated filter as shown in Figure 3 and 4of low pass filters for n=5. From the graph it is clear that the cut-off frequency is found to be 2.5 GHz.

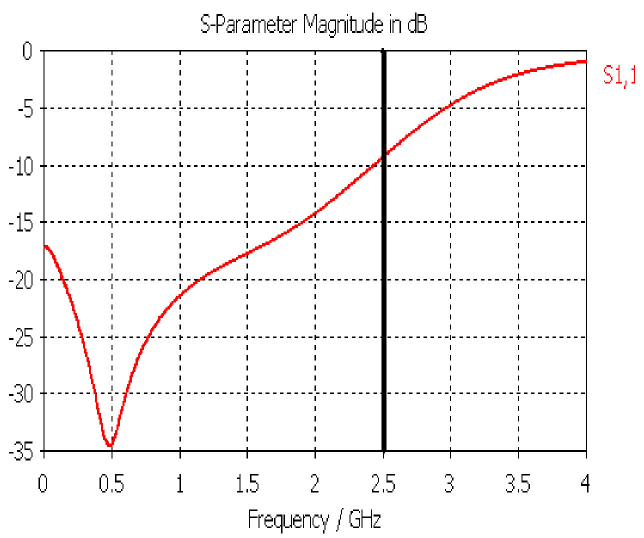

Figure3. Simulated S11 results of the stepped- impedance Microstrip low pass filter

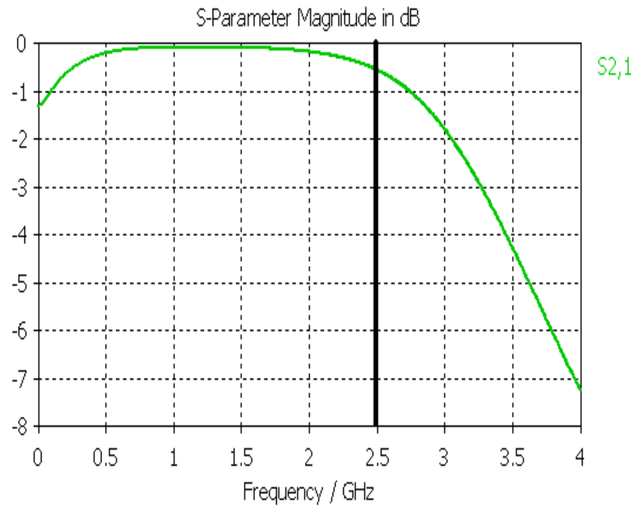

Figure4. Simulated S21 results of the stepped- impedance Microstrip low pass filter

III. Design and Simulation Results of the New Design a Microstrip Low Pass Filter with Complementary Split Ring Resonator (CSRR):

The SRR was originally proposed by Pendry in 1999, and is the metamaterial resonator having the negative permeability [13]. The SRR structure is formed by two concentric metallic rings with a split on opposite sides. This behaves as an LC resonator with distributed inductance and capacitance that can be excited by a time-varying external magnetic field component of normal direction of the resonator [14]. This resonator is electrically small LC resonator with a high quality factor. Based on the Babinet principle and the duality concept, the CSRR is the negative images of SRR, and the basic mechanism is the same to both resonators except for excited axial electric field. With adjustment of the size and geometric parameters of the CSRR, the resonant frequency can be easily tuned to the desired value. Figure 6 shows the geometry and dimensions of the finalized design CSRR. The CSRR based filters proposed in this study are planar structures, implemented in microstrip technology, a new design methodology to achieve the desired frequency responses and reduce size of the filter [15].

Dimensional view of the new design of microstrip low pass filter with complementary split ring resonator (CSRR) is shown in the Figure 5.

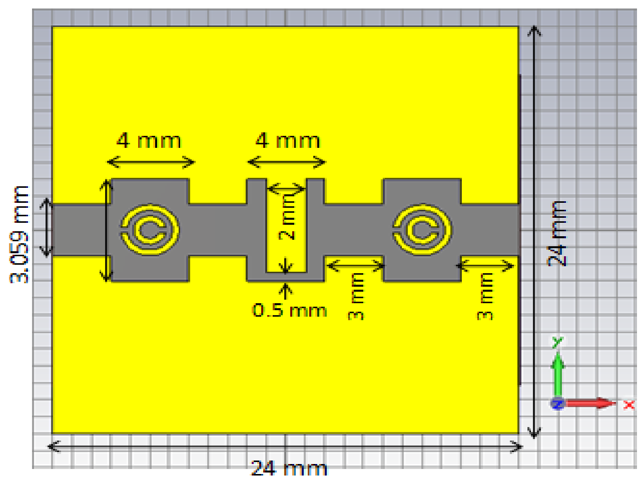

Figure.5: the new design a microstrip low pass filter with complementary split ring resonator (CSRR)

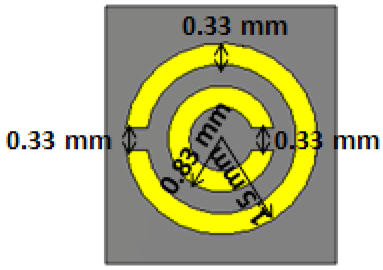

Figure.6: The complementary split ring resonator (CSRR) particle geometry.

The simulations results of Figure 7 and 8 shows a reflection of the coefficient S11 and the transmission S21 of the new design of the microstrip low pass filter with complementary split ring resonator (CSRR).

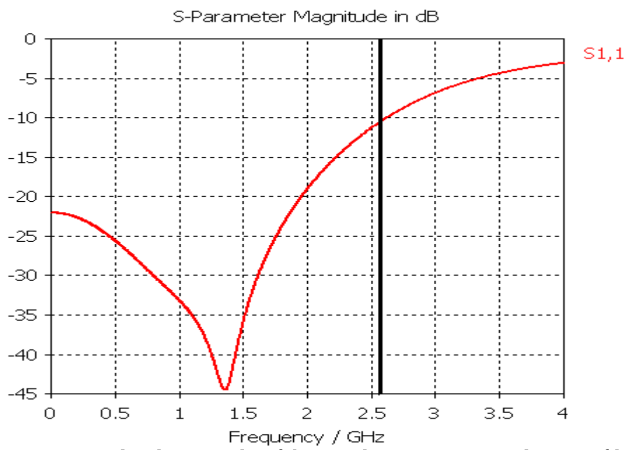

Figure.7: Simulated S11 results of the new design a microstrip low pass filter with complementary split ring resonator (CSRR)

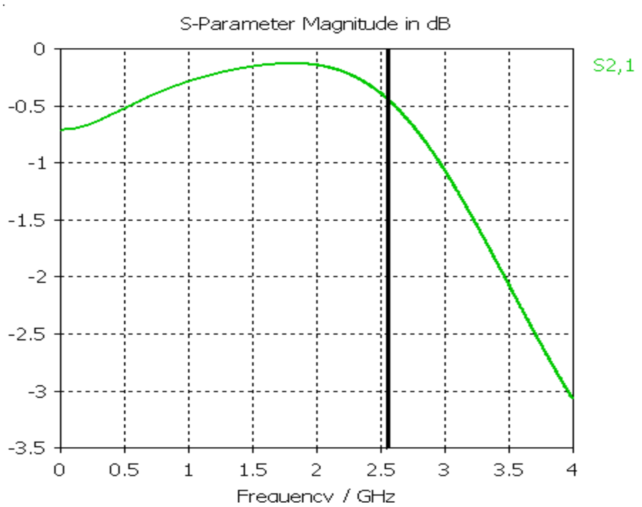

Figure.8: Simulated S21 results of the new design of the microstrip low pass filter with complementary split ring Resonator (CSRR)

Figure 7 and 8 show the results of simulation CSRR with new filter which has an improvement in the coefficients S11 and S21 with respect to the simulation results of the coefficients S11 and S21 as shown in Figures 3 and 4 of the conventional filter, simulation reported by the software simulation Microwave Studio CST.

According to Figure 2, where replaces classical Chebyshev microstrip low pass filter by the new design a microstrip low pass filter with complementary split ring resonator (CSRR) Figure 5 characterized by that the same cut-off frequency fc=2.5 of classical Chebyshev microstrip low pass filter. We can see an improvement reduction in size of new filter by 40% compared to classical filter.

IV. CONCLUSION

This paper proposes a miniaturized microstrip low pass filter by using metamaterial structure, the size and dimensions of the new design of the micro strip low pass filter has been compared to classical Chebyshev micro strip low pass filter. To achieve the miniaturization of the filter's size, we have used a complementary split ring resonator (CSRR) having the negative permeability characteristics. The proposed Filter achieves a 40% size reduction comparison with classical filter.

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