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Enhancement of the Performance of BPF on a Single Unit Cell Metamaterial Substrate

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Abstract: The metamaterial unit cell is composed of split ring resonator (SRR) or complementary split ring resonator (CSRR). This structure recently has been widely used in various microwave devices. Good performance and size miniaturization of various microwave devices are achieved using SSR and CSRR. An enhancement features; roll-off, return loss and phase linearity, have been improved by combining a complementary split ring resonator single unit cell with Chebyshev conventional band bass filter (BPF). Reflection coefficient of 15dB, roll-off -6dB/0.037 GHZ and linearity in the phase characteristics have been achieved in the simulation results.

Key words: Complementary Split Ring Resonator (CSRR), Band Pass Filter (BPF), Roll-Off, Phase Linearity.

INTRODUCTION

In the last decade, the metamaterials subject is at its infancy (V. G. Veselago, 1968). Many researchers proposed different types of resonator on metamaterials design, using spilt ring resonator (SRR) and the complementary split ring resonator (CSRR) (J.B. Pendry *et al*.,1999),(D.R. Smith *et al*.,2000) and (G.V. Eleftheriades *et al*.,2005). CSRR and SRR are broadly employed in a planar structure for offering negative permeability (μ) and permittivity (ε) (J.B. Pendry *et al*., 1999). These resonators had a small size comparing with its wavelength at resonance frequency, for that it's namely sub-wavelength resonators (J.B. Pendry *et al*., 1999) and ,(D.R. Smith *et al*.,2000). The second harmonic response of the band pass filter was eliminated (S.S. Karthikeyan *et al*, 2009) using complementary single split ring resonator (CSSRR). The rejection of high performance local area network (HiperLAN) interference within the spectrum band of band pass filter by combining it with CSRR was proposed by (Abid Ali *et al*., 2008). The combination of CSRR etched close to the short circuit stub of the band pass filter was investigated by (J. Bonache *et al*., 2005) in which the out-of-band was improved and the spurious frequency of band pass filter was eliminated. Further, the bandwidth of the band pass filter was improved by adjusting the geometrical dimensions of the CSRR (H. Bahrami *et al*., 2007) . Level rejection and spurious frequency suppression through integrating CSRR with the structure of the conventional band pass filter was achieved by (Abid Ali *et al*., 2009) . In addition, Chebyshev band pass filter in conventional type was used and exhibits very low performance parameters in terms of roll-off, return loss and phase linearity (J.-S. Hong *et al*., 2011) . However, all the proposed previous studies have improved either one or two of band pass filter performance parameters. So far, in this work three important performance parameters: roll-off, return loss and phase linearity are improved by combining the single unit cell of a CSRR with a conventional filter with no change in BPF size with less complexity.

Methodology:

Chebyshev band pass filter with five pole short-circuit stubs is selected according to the parametric geometry shown in Table 1. A central frequency of f_o=2GHz, ripple in the pass band of 0.1 dB and fractional bandwidth of 0.5 and the impedance of feed line is equivalent to 50Ω are used. The substrate (Rogers RO3010) type with 0.635mm thickness (h) and the ε=10.2 dielectric constant is used as shown in Fig. 1a. A single unit cell CSRR resonator with outer ring dimension of 7X7 mm, spacing between inner and outer ring s= 0.4mm, ring width d= 0.4mm and the split gap g=0.5mm was used as shown in Fig. 1b. The CSRR unit cell is etched on the ground plan of the substrate of the central stub of the band pass filter. The computer simulation technology (CST) software was used.

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Table 1: The parametric geometry of band-pass filter based on (9)

i	W_i(mm)	$\lambda_{gi}/4$(mm)	$W_{i,i+1}$(mm)	$\lambda_{gi,i+1}/4$(mm)
1	1.61	13.67	0.97	14.03
2	4	13.07	1.1	13.97
3	3.93	13.03	1.1	13.97
4	4	13.07	0.97	14.03
5	1.61	13.67		

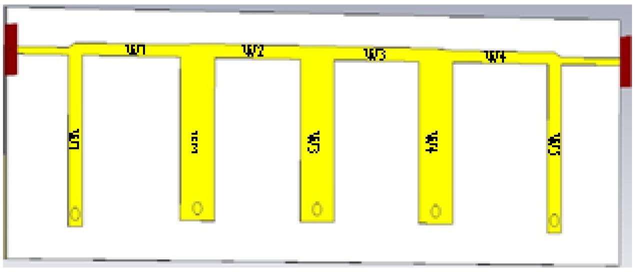

Fig. 1a: Chebyshev BPF short circuit stub

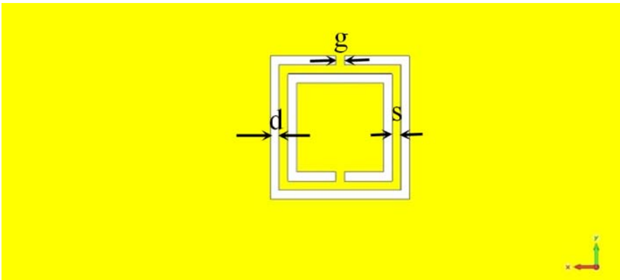

Fig.1b: a single unit cell CSRR etched on ground plane of BPF

Simulated Results:

A Chebyshev band-pass BPF filter with complementary split ring resonator CSRR engraved in the ground plane was combined on a Rogers RT/Duroid 3010 (ε_r=10.2 , thickness h=0.635mm). A new structure which represented by the combination between BPF and CSRR is depicted in Fig.1a and Fig.1b, respectively. The scattering parameters of the conventional BPF were accomplished using computer simulation technology CST as shown in Fig.2. Roll-off of -6dB/0.058 GHz, return loss of 10dB and distorted phase characteristics are achieved as shown in Fig.3. The scattering parameters of the new proposed structure, BPF and a single unit cell CSRR, were carried out using CST simulator are illustrated in Fig.4. Results obtained were better than the results presented by (J.-S. Hong *et al*., 2011). It can be noticed from the results that the return loss is improved to be 15 dB as compared to the 10 dB in conventional BPF due to the matching between the two resonance frequencies of both the BPF and CSRR unit cell. In addition, a high coupling is achieved due to the proper location of the unit cell and as results the roll-off of -6dB/0.037 GHz and the phase linearity characteristics are improved as shown in Fig. 5. For the phase linearity, it is observed that within the pass band, the BPF on metamaterial exhibits very high linearity within the pass band. However, this is not the case with normal substrate. As it is observed near the far end of the pass band, the non-linearity is very large, which can affect the level of distortion of the desired signal through this filter.

Conclusion:

In this paper, the transmission characteristics of band-pass filter is studied. The effect of combined complementary split ring resonators with band-pass filter structure has been presented. Roll-off about$-6\text{dB}/0.037$ GHZ, 15 dB less of return loss and good linearity are achieved comparing to conventional structure due to two important reasons; a good matching between the resonance frequencies of both the BPF and CSRR unit cell, and a high coupling by putting the CSRR in the prober place.. In addition, the proposed structure exhibits no increase in size and less complexity in the structure.

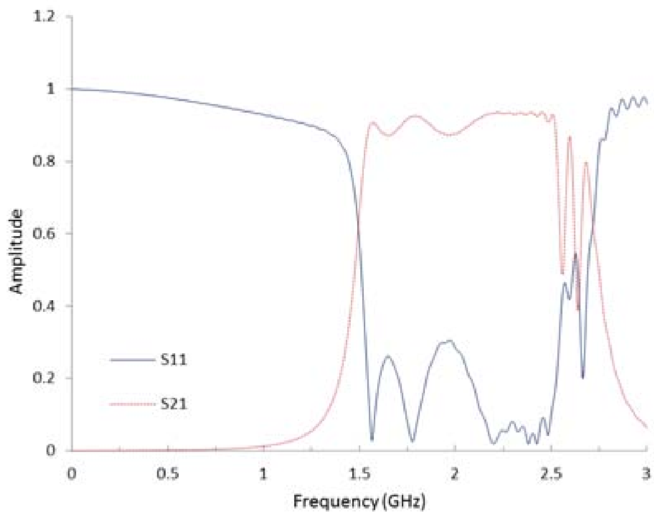

Fig. 2: S-parameters for the conventional

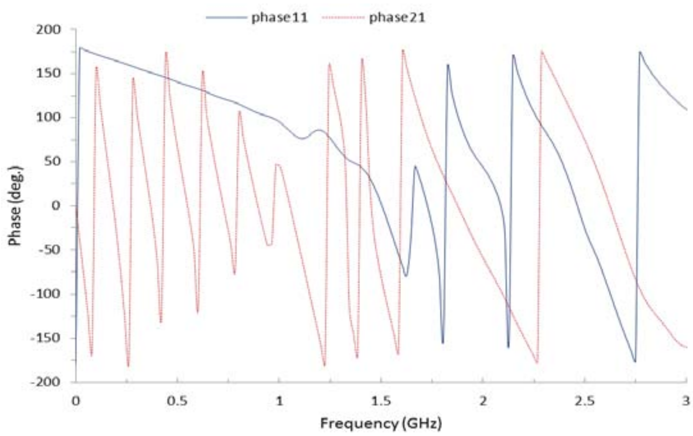

Fig. 3: phase characteristics for the conventional band-pass filter (9)

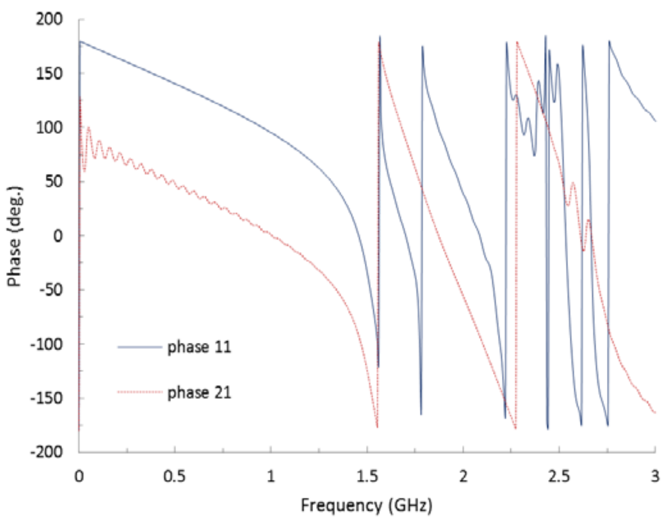

Fig. 4: S-parameters for the metamaterial band-pass filter using a single unit cell

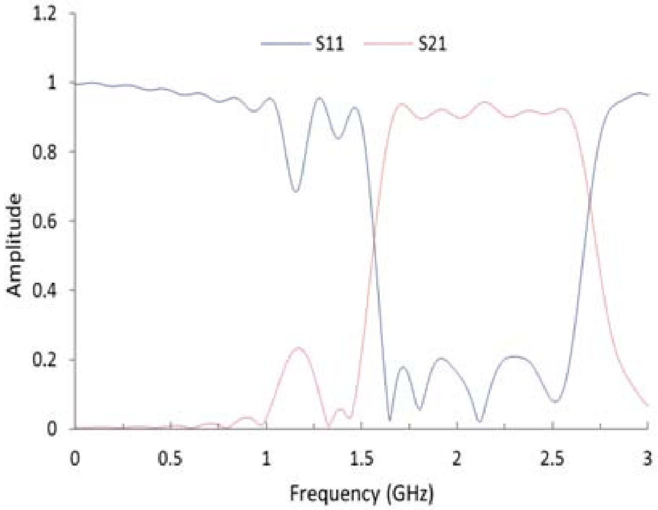

Fig. 5: phase characteristics for the meta-material band-pass filter using a single unit cell

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