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Design and Development of Harmonics Free Microstrip Band-Stop Resonator Using Complementary Split Ring Resonator

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Abstract: A harmonics rejected microstrip narrowband band-stop resonator using complementary split ring resonator (CSRR) structure is presented in this paper. The proposed harmonics rejected band-stop resonators are first derived from the conventional one with lumped parallel LC resonators. Secondly this lumped resonator is converted as a distributed band-stop resonator. The harmonic rejection ability of this distributed band-stop resonator is improved by embedding CSRR in its ground plane. The proposed design has the advantage of harmonic rejection ability as well as simple to fabricate. Hence the proposed design can be used in harmonics free narrow band transceivers to avoid design complexity. To verify the performance of the proposed design, distributed band-stop resonators are realized using microstrip technology. The experimental results show that in comparison with conventional one which one is not having CSRRs, it has a wide stop-band with high attenuation in the second and third harmonic frequencies and acceptable band-stop frequency response in the fundamental frequency also. The measured and simulated results are in good agreement. Hence, the proposed resonator will be an ideal candidate in future harmonics free narrowband communication systems.

Key words: Resonator, filters, harmonics rejection, complementary split ring resonator, transceiver, stop band, narrow band, microstrip.

INTRODUCTION

The pursuit of microwave components with admirable characteristics, such as short design cycle, planar structure, easy integration, miniature size and good harmonic rejection ability have become dominant trends in the field of research. Numerous techniques and structures have been proposed to fulfill those requirement applications. The microstrip band-stop resonators have been widely used in wireless microwave and millimeter wave narrow band transceiver applications. The parallel resonators are the basic building block of RF filters and oscillators. One major drawback of this type of resonator is, however, the spurious response at twice the fundamental passband frequency $2f_o$, yielding poor stopband performance and asymmetric passband response (Cohn, 1958). Over the past decade, numerous techniques have been proposed to overcome such drawback. The traditional parallel coupled line filter structure was modified for additional capacitive coupling between stages, which effectively introduces transmission zeros at the spurious frequency band (Chang and Itoh, 1991). The wiggly line filter structure in make use of continuous strip width variations to modulate the wave impedances so that the spurious responses at $2f_o$ can be suppressed (Lopetegi *et al*., 2001). In order to improve the harmonic rejection characteristic, the periodic square grooves (Kim *et al*., 2004) and the periodically nonuniform line structures were applied to coupled microstrip lines (Sun and Zhu, 2005). Although effective in improving the spurious stopband response, the meandered structure using coupled Schiffman sections and the fractal shaped structure using Koch shape coupled lines structures invariably possess certain disadvantages. Most notably is the lack of accurate closed-form analysis that can be employed to guide optimal design. As a consequence, circuit and/or electromagnetic (EM) simulation inevitably became an integral part of the design flows (Wang *et al*., 2005; Kim *et al*., 2009). Other disadvantages are the requirement of special fabrication processing steps or special installation requirement and difficulty in practical implementation (Velazquez *et al*., 2004).Systems based on microwave technology have on increasing impact in civil and consumer society. Modern communication systems such as satellite communications, RADAR, wireless systems and portable wireless devices require more and more multiband applications and a better use of the electromagnetic spectrum. This requires the use of microwave filters with characteristics like design multiband operation, sharp transition slopes and different transfer functions. In particular the use of microwave filters with transmission zeros at certain frequencies are very convenient in these conditions. Multiple techniques and methodologies are available for designing microwave filters. Recent contributions of microwave filters have been focused on the synthesis and

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design of elliptic or quasi-elliptic filters for channel separation or multiband structures (Mokhtaari *et al*., 2006; Macchiarella and Tamiazzo, 2005).

Due to the increasing demand for dual band and narrowband operation in modern RF systems, band-pass filters (BPF) and band-stop filters (BSF) have become an essential component. In the past, a variety of BPFs with improved electrical performance and geometrical features has been investigated. These BSFs is known to have attractive features such as simpler design, easier to manufacture, lower cost, compact size and lower insertion loss (Hong *et al*., 2007; Wolfe, 1972; Hong and Lancaster, 1995; Fork *et al*., 2006). Hence the main concern is about the design of band-stop as well as band-stop responses. To implement the compact communication systems, an alternative approach to coping with the good band pass response as well as band rejection characteristics. However, to achieve high quality factor (Q) to improve the frequency selectivity of the BPF, in the order of the filter must be higher. This increases the size of the communication system and insertion loss. So, this paper presents compact implementations in microstrip technology for the harmonic rejection purpose. For practical implementation, the band-stop resonators employed are ($\lambda/2$) and (λ) microstrip printed lines. The simple combination of open-ended and shunt stubs are used for the easier fabrication. As compared to previous works, the proposed structure achieves better performance with harmonic rejection. The proposed narrowband band-stop resonator has been simulated, fabricated and measured. The measured results are in good agreement with the simulated results. The structure of the paper is organized as follows. Section 2 explains proposed band-stop resonator design. In section 3, the experimental verification of the proposed resonator is discussed. Simulation and measured results are presented in section 4. Section 5 concludes paper.

2. *Design Of Proposed Resonator:*

Band-stop resonators provide the resonance frequencies at nf_o, where n is the integer number; f_o is the center frequency of the resonator. Figure 1 depict a short and open ended transmission line resonators with a length of $L=\lambda_g/2$, respectively. Here λ_g is the guided wavelength at the fundamental resonant frequency. In order to suppress the second and third order harmonics, CSRR structures are incorporated on the band-stop resonator design.

Structures that are complementary to double split rings were designed and produced by applying the Babinet principle to the split ring resonators (SRR). In this way structures with apertures in metal surface are obtained and these CSRRs create negative ε instead of negative μ in a narrow range near the resonance frequency. In microstrip technology, left handed Meta material structures exhibiting a band stop behavior can be implemented by etching CSRRs in the ground plane, underneath the conductor strip, and along the series capacitive gaps. The gaps provide a negative value of the effective permeability up to certain frequency that depends on gap dimensions and separation. The negative ε structure has been obtained by loading a microstrip line with CSRR particles as shown in figure (1). There are many different parameters that affect resonance frequency of CSRR, most dominant being the permittivity of the substrate and length of the band-stop frequency. The anti-resonance frequency is inversely proportional to the length of the resonator and is directly proportional to the split gap of the resonator. Also, the equivalent circuit of the CSRR is similar to the parallel *LC* resonant circuit as shown in figure 2. This structure rejects the second harmonics of the fundamental frequency range due to increasing the effective inductance of a transmission line.

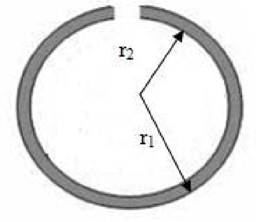


Fig. 1: Microstrip loaded CSRR

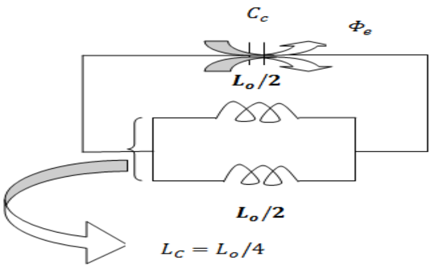


Fig. 2: Equivalent circuit of CSRR

The microstrip narrow band band-stop resonator is realized and CSRR structure is embedded in the ground plane. The layouts of the microstrip band-stop resonators with and without CSRR are shown in figure 3 and 4. The dimensions of the CSRR structures are calculated from the band-stop frequencies. The optimized design parameters of the band-stop resonators are given in Table 1.

Fig. 3: Layout of the band-stop resonator without CSRR

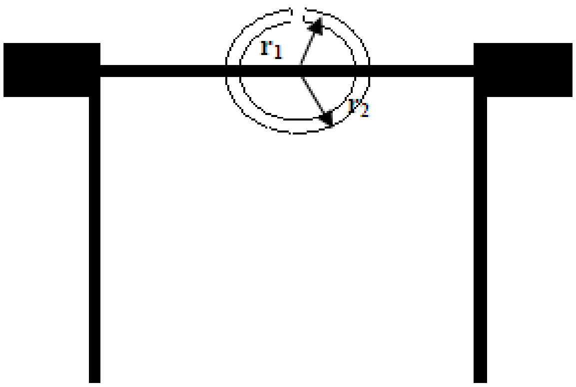


Fig. 4: Layout of the band-stop resonator with CSRR

Table 1: The dimensions of the proposed design

Design	Microstrip line		CSRR		
	Length (mm)	Width (mm)	Radius (mm)		Width (mm)
			r_1	r_2	
Band-stop resonator with CSRR	19.00	0.600	2.871	4.109	0.861

Fabrication:

To validate the feasibility of the proposed designs, a band-stop resonator with and without CSRR was designed and fabricated on an FR-4 substrate with a thickness of 1.6mm, dielectric constant of 4.5, and loss tangent of 0.00027. The centre frequency of the pass-band is set to 2.45GHz. The operating bands are designed to be centered at the frequency of 2.45GHz and stop-bands frequencies are centered at second and third harmonics of fundamental frequency. The simulation is done in Agilent ADS software. The photographs of the fabricated resonators are shown in figures 5 and 6. It occupies a circuit size of 2.5×1.6cm^2.

RESULTS AND DISCUSSION

The simulated and measured results are illustrated in figures 7 and 8. The *S* parameter measurement of the fabricated prototype models has been carried out using Agilent N5230A PNA series vector network analyzer. As expected, pass-band has transmission zeros which will be helpful to improve the selectivity of the band-stop resonator. The return loss and insertion loss at f_o, $2f_o$ and $3f_o$ are given in Table 2. Both the insertion and return losses are mainly contributed from the dielectric and conductor losses. In addition, it is observed from the figures 7 and 8 the proposed design rejects the second order harmonics. Also it is clearly indicates, the proposed resonators band rejection ability is better than the traditional resonator which one is not having CSRR.

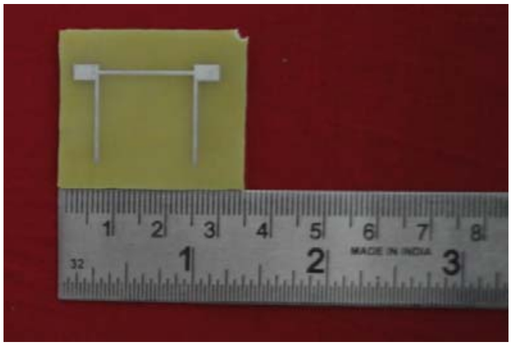
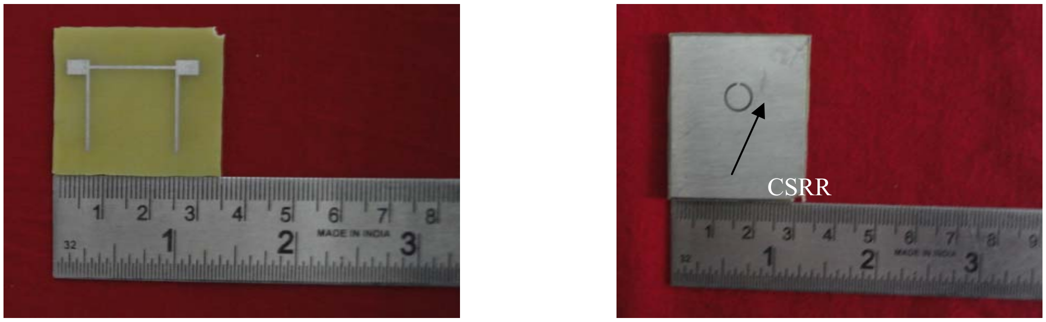


Fig. 5: Fabricated prototype of band-stop resonator without CSRR



(a) Front side

(b) Back side

Fig. 6: Fabricated prototype of band-stop resonator with CSRR

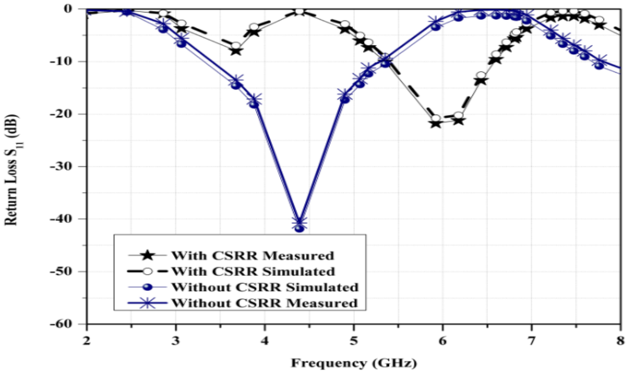


Fig. 7: Return Loss (S_{11})

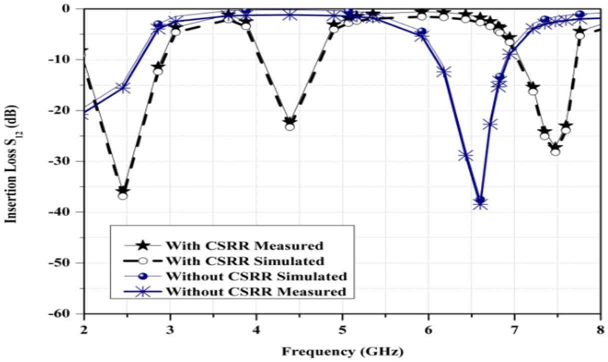


Fig. 8: Insertion Loss (S_{12})

Table 2: Performance comparison

Parameters		S_{11}(dB)		S_{12}(dB)	
		Simulated	Measured	Simulated	Measured
Band-stop resonator without CSRR	f_o	-0.559	-0.409	-14.558	-15.6
	$2f_o$	-17.322	-16.172	-0.318	-1.318
Band-stop resonator with CSRR	f_o	-0.253	-0.198	-35.899	-36.884
	$2f_o$	-3.809	-2.834	-24.795	-23.02

Conclusion:

In this paper, band-stop resonator is designed, simulated, fabricated and tested to operate only at specific frequency 2.45GHz.It is also observed that the proposed designs simulated results are agreed well with the measured one. Traditionally low-pass filter and band-stop filters are used for rejecting unwanted harmonics in narrowband transceivers and multiplexers. So it avoids need of extra components to reject the unwanted harmonics. Hence the proposed design will be an ideal candidate to use in future microwave systems. The results in section IV demonstrate that the proposed band-stop resonator can be successfully employed to implement harmonics free narrow-band communication systems. Moreover, the proposed resonator has a spurious rejection and wide stop-band suppression characteristics. Inherently the proposed design rejects the 3rd harmonics, so we focused only on 2nd harmonic rejection. In future the same technique can be used for the higher order harmonics suppression.

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