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Narrow Band Bandpass Filter using CSRR with Harmonic Rejection

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Abstract: *A coupled line narrowband filter with second harmonic suppression is presented. A Novel narrow bandpass filter with sharp rejection at the lower frequency is proposed using open loop resonator. The stopband characteristics of complementary circular split ring resonator (CSRR) are studied and designed to suppress the second harmonic frequency. CSRR loaded with the proposed filter for harmonic suppression is demonstrated. The CSRR is optimized to create the required bandstop characteristics without affecting the desired bandpass frequency. The proposed CSRR configuration provides a harmonic suppression at 2.8 GHz and open loop resonator resonates at 1.5 GHz to bandpass the desired frequency. Results are compared with the full wave simulation analysis and presented.*
Keywords: *Complementary circular split ring resonator; openloop resonator; harmonic suppression.*

I. Introduction

The RF filter design has got more attention since decades, the two factors i.e. the limited electromagnetic spectrum and the out of band which leads to system noise and harmonics present in the filter. These factors degrade the performance of the communication system The above two major issues have forced the researchers to focus on the design principle of RF filter to develop with sharp rejection, harmonic suppression, compactness and better performance, which is always the center of attraction to built any filter. Microstrip trisection filter with different resonator shapes, such as open-loop resonators can produce asymmetric frequency responses with an attenuation pole of finite frequency on either side of the passband. A three-pole bandpass filter with an attenuation pole of finite frequency on the lower side of the passband [1], which has provided very low insertion loss and sharp rejection at the lower side of the passband. The designers have got a new area with the invention of Metamaterials, are artificially engineered materials which display negative permeability and permittivity over a certain range of frequency [2]. Since realization of such materials was difficult at that time, there was very little progress in this field. A breakthrough on realization of such materials was given by [3] demonstrating a well established collective excitation of metals called plasmons, at a lower frequency than visible and near UV, exhibit negative permittivity. Microstructures built from non-magnetic conducting sheets show an effective permeability. An array of interspaced circular concentric rings and thin wire could exhibit the metamaterial property in the microwave frequencies [4]. The ring has a gap between them and hence was called as Split Ring Resonator (SRR). We know that the lumped equivalent circuit of the SRR is an LC circuit. The various forms of SRR and complementary split ring resonator (CSRR) and their equivalent circuits are given in detail [5]. The transmission line equivalent of metamaterials is given in [6]. A new idea of OSRR which allows for series connection along a microstrip line[7-9]. In this paper the combination of this two types of filter structures where a coupled line microstrip trisection filter has designed to have a higher selectivity on the lower side of the passband with complementary split ring resonator for harmonic suppression.

II. Filter Design

In this section, we present the design and simulation of a bandpass filter with centre frequency of 1.5 GHz and fractional bandwidth of 3.3%. RT Duroid 6010 commercial PCB substrate of relative dielectric permittivity 10.2 and thickness of 1.27 mm is used. A third order filter has been chosen in order to achieve better rejection in the out of band region. The proposed three-pole microstrip trisection filter has attenuation pole of finite frequency on the lower side of the passband so that the selectivity on this side is higher than that on the upper side. It has the dimension of L=16 mm, B=7 mm, g=1.4 mm, G=1.8 mm, W=0.4 mm, S=0.7 mm. Fig.1. represents the top view of the microstrip open loop resonator filter. Frequency response of coupled line filter is shown in Fig.4, it shows the second harmonic of the filter about -3 dB at 2.8 GHz with high rejection in lower cut off of about -50 dB at 1.4 GHz . In order to suppress the second harmonic of the filter at 2.8 GHz, CSRR is designed.

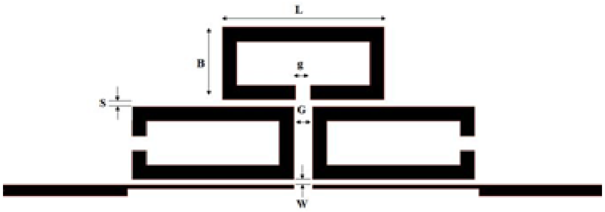

Fig.1. Layout of the microstrip Coupled Line Filter from top view on a 1.27 mm thick substrate with a relative dielectric constant of 10.2, L=16 mm, B=7 mm, g=1.4 mm, G=1.8 mm, W=0.4 mm, S=0.7 mm.

III. CSRR Design

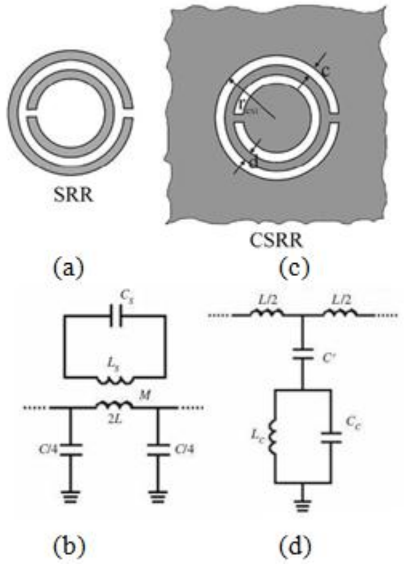

Fig. 2. (a) Topology of the SRR (b) Lumped-element equivalent circuit for the unit cell of the SRR coupled to a transmission line. (c) Topology of the CSRR with its relevant dimensions. Metallization zones are depicted in grey. (d) Lumped-element equivalent circuit of the CSRR coupled to a transmission line.

The sub wavelength resonators used in this paper in order to suppress the harmonic at the RF band are the CSRRs (the dual particle of the SRRs). Fig. 2 shows the basic topologies of both particles and their equivalent circuit models coupled to transmission lines. Essentially, SRRs [Fig. 2(a)] consist of a pair of metal rings etched on a dielectric slab with apertures in opposite sides which can be mainly excited by means of a parallel magnetic field along its axis. Therefore they behave as an *LC* tank (described by *LS* and *CS* parameters) magnetically coupled (by using a mutual inductance, *M)* to the host line [defined by *L* and *C*, Fig. 2(b) [8].

From duality of SRR is based on Babinet's principle, which is established that, the CSRRs [Fig. 2(c)], which are the *negative images* of SRRs, roughly behave as their dual counterparts. Therefore, CSRRs are mainly excited by means of an axial time-varying electric field (magnetic field contribution is relatively minor) [9]. Since the main coupling contribution of these particles is electric, it can be described by means of a coupling capacitance (*C)*. Therefore, an efficient way to achieve stop-band frequency responses is to etch CSRRs in the ground plane of a structure such as a microstrip line (or similar) or even in the conductor strip. The synthesis of the filter is performed by using the *LC* equivalent model of CSRRs (described by *Lc* and *Cc* parameters) coupled by means of a capacitor value *C*, (capacitance of the transmission line) with the host line [Fig. 2(d)]. According to the equivalent circuit model, the zero transmission frequency *fz* of each CSRR coupled to the transmission line is given by

$$f_z = \frac{1}{2\ \sqrt{\ \cdot [\ +\ ]}} \qquad (1)$$

CSRR unit cell structure shown in Fig.3. consists of two circular complementary split ring resonator. The complementary split ring resonator (CSRR) loaded underneath a microstrip coupled line filter provides high rejection. The CSRR is optimized to create the required bandstop characteristics. The parameters describing the

CSRR are: length of the outer circle (s) is 2.8 mm, and inner circle (s') is 2.2 mm, the width of the strip (w) is 0.3 mm, the width of the gap between the inner and outer circles (d) 0.3 mm. The spacing between the CSRR unit cell (D) is 45 mm. Frequency response of CSRR loaded with transmission line is shown in Fig.5, it shows stopband response of about -78 dB at 2.8 GHz and Fig.6 represents the frequency response of coupled line filter with CSRR which provides harmonics suppression of about -58 dB at 2.8 GHz.

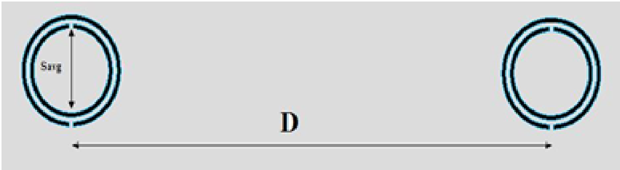

Fig.3. Structure of CSRR at bottom view, D=45 mm, Savg =5.6.

IV. Results

Thus complementary split ring resonator (CSRR) loaded underneath a microstrip coupled line filter Fig.1,& 3 shows the top and bottom views of the simulated structure. The open loop resonator resonates at 1.5 GHz with S11 of about -40dB and S12 less than -1 (-0.77) dB. The filter has been designed with sharp lower cut off of about -50 dB at 1.4 GHz and narrow bandwidth of about 3.3% at -10 dB level. The harmonic created by the filter at 2.8 GHz with S12 is -3 dB has been suppressed to -58 dB by using the CSRR. The simulated coupled line filter using CSRR is characterized using the full wave simulated (ADS Momentum) response.

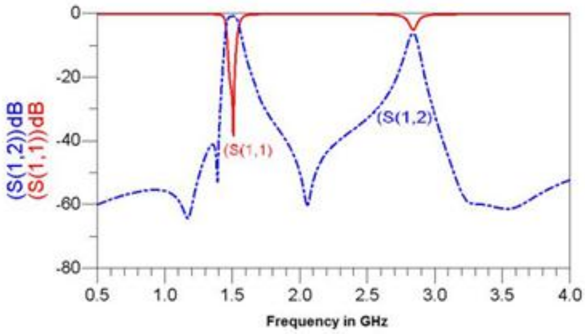

Fig.4. Frequency response of coupled line filter

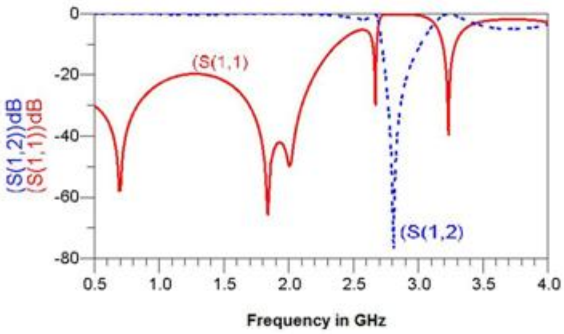

Fig.5. Frequency response of CSRR loaded with transmission line

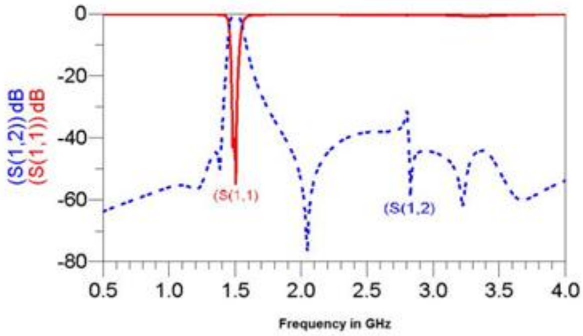

Fig.6. Frequency response of coupled line filter with CSRR

V. Conclusion

In summary a compact, narrow band, coupled line open loop narrowband filter has been designed with Complementary Split Ring Resonator Structure. The simulated result shows second harmonic suppression by means of CSRR loaded with the filter. The design has been carried out by ADS momentum which provides flexibility to the developer and gives base to implement the idea. The CSRR is optimized to create the required bandstop S12 characteristics of about -58 dB rejection at 2.8 GHz without affecting the desired bandpass frequency at 1.5 GHz with S11 -55 dB.

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