A New Compact Microstrip Bandpass Filter Based on Stepped Impedance Concentric Square Loop Resonators

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Abstract— In this paper , a new dual mode microstrip bandpass filter has been presented for the requirements of modern wireless communication systems. The filter has been built from double concentrated square loop resonators; each resonator is based on applying step impedance resonator generator on each side of closed resonator. The projected bandpass filter has been designed using a substrate with a dielectric constant of 10.8 and thickness of 1.27mm at 2.43 GHz center frequency . This filter has compact size and narrow band response which are the prerequisites of mobile wireless communication systems. The performance of filter has been studied using Microwave office software package, which is extensively implemented in microwave research and industry. The output results showed that this filter possesses very good frequency responses and high selectivity as well as blocked 2nd harmonic in out of band regions.

Keywords — Narrowband filter, dual mode bandpass filter, double concentric square loop resonators ,step impedance resonator,2nd harmonic suppression

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1 INTRODUCTION

IN present wireless communication scenario, the development of new network signal processing algorithms and pioneering hardware devices is fundamental to sustain the rapidly growing expansion of new and sophisticated services. In particular, modern microwave architectures have to satisfy more and more stringent requirements concerning their performances, together with a general criterion of compactness and easy integration with other systems in the field of the microwave pass-band filters, which play a fundamental role in many applications [1].Basically, communication is process of transmission information from transmitter to receiver . The microstrip filter is either of suitable components that are using on the receiver and transmitter of microwave communication system [2] .It is located at the part of ending transmitter and also in the beginning of receiver. The resonators can be classified into planar resonators and non-planar resonators. The planar resonators are commonly achieved by using microstrip technology. Microstrip line resonators are related to highly planar resonators. The microstrip resonator line has big advantages to decrease the size of the resonator. One of most adopted methods to miniaturize the microstrip line resonator is meandering the microstrip resonator. The open loop meandered microstrip line resonator is less than $\lambda_{g0}/8$ by $\lambda_{g0}/8$, where λ_{g0} is the guided wavelength at resonant frequency [3]. For more resonator miniaturization using meandering the microstrip line, the microstrip line must have too narrow line. However, generally, this will reduce the quality factor of the resonator as the line becomes narrower. This problem has been solved by using High Temperature Superconducting (HTS) materials but the cooling requirements eliminate the miniaturization advantage. On the other hand, non-planar resonators possess relatively bigger quality factor as compared to planar resonators. These non-planar resonators are bulky, however, they are used by the wireless systems where the electrical performances are more important and necessary than the size of the filter. For instance, the waveguide cavity filters have been used in many applications of cellular base stations and satellite transponders [4].

J. S. Hong, and M. J. Lancaster[5], developed a type of dual-mode high selectivity and narrowband microstrip bandpass filters constructed from a meander loop resonator for compactness purposes. This filter was designed at center frequency of 1.58 GHz and a 2.5% bandwidth. A. Görür, Ceyhun Karpuz, and Mustafa Akpinar [6] , used degenerate modes of a dual-mode microstrip square loop resonator to develop dual-mode microstrip bandpass filter with capacitively loaded open-loop arms. This bandpass filter has been designed at the center frequency of 1.603 GHz and a 0.75% bandwidth. The proposed filter has a miniaturization percentage of about 59% at the resonant frequency, as compared to dual-mode microstrip patch, cross-slotted patch, ring resonator and square loop bandpass filters.C.Lugo and J.

Papapolymerou [7] , suggested dual-mode microstrip triangular loop resonator bandpass filter (BPF) design. The filter has frequency responses with single real finite frequency transmission zero and single imaginary finite frequency transmission zero on each side of the passband.

Y. X. Wang, B.-Z. Wang, and J. Wang[8] ,presented new dual-mode microstrip BPF with wide stop-band .This filter uses square loop resonator with tree shaped patches placed to all four internal corners of the loop. The splitting mode is realized by making a small cut at 45° offset from its dual orthogonal modes.This microstrip BPF has a wide stop-band especially in the first spurious resonance frequency. The center frequency can be tuned. Moreover, the designed filter has a more compactness as compared with conventional dual mode bandpass filters at the similar central frequency. M. Zhou,et.al[9] , proposed compact dual mode microstrip bandpass filter based on resonator-embedded structure. Dual transmission zeros are placed to enhance the selectivity of the filter. In addition, source-load capacitive coupling is submitted to form a transmission zero above the passband. The filter is designed on 2.28 GHz with 300 MHz bandwidth. The filter size is smaller than $0.21\lambda_{g0}\times 0.25\lambda_{g0}$.

D. Bukuru ,et.al [10] , developed a miniaturized microstrip bandpass filter based on a rectangular dual spiral resonator (DSR). The rectangular DSR bandpass filter is centered at 3.65 GHz to suit for WirelessLAN (IEEE802.11y) application. The proposed filter offers transmission zero at the high side of out-of-band response.

The proposed microstrip bandpass filter in this paper has been constructed from double concentrated square loop resonators; each resonator is based on applying step impedance resonator generator on each side of closed square loop resonator.This bandpass filter has small size and narrow band response which are very remarkable properties of mobile wireless communication systems.

2 STEP IMPEDANCE RESONATOR

Stepped impedance resonator (SIR) is a TEM or quasi TEM mode transmission line resonator that consists of two or more lines with different characteristic impedance. SIR is a non-uniform transmission line, which were used in the filter design either for miniaturization purposes [11], or shift the spurious passband to the higher frequency, or to suppress the harmonic frequencies .The SIR employed in this paper was shown in Fig. 1, it is made of two transmission line sections with two different characteristic impedances Z_1 and Z_2 with corresponding electrical lengths **x** and **y**, respectively. The input admittance that viewed from an open end can be calculated by [12] :

$$Y_{in} = \frac{2\,j\,Y_2\,(K\,K_1 + K_2)(K - K_1\,K_2)}{K(1-K_1^2)(1-K_2^2) - 2(1-K^2)K_1\,K_2} \qquad (3)$$

Where $K_1 = \tan(x/2)$, $K_2 = \tan(y)$ and $K = Z_2 / Z_1$.

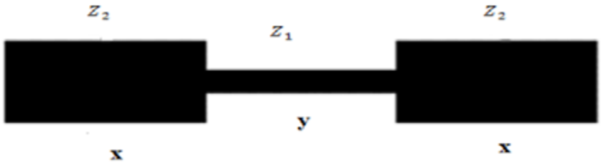

Fig.1 Schematic of the employed two-sections step impedance resonator (SIR).

3 FILTER DESIGN

Dual concentric square loop resonators with applied SIR , have been designed at a frequency of 2.43 GHz. It has been presumed that the filter structure has been etched using a substrate with a relative dielectric constant of 10.8 and a substrate thickness of 1.27 mm. The outer resonator dimensions have been found to be 13×13 mm² with *w*= 1 mm, x =4.75 mm, y =3.5 mm and r=0.5 mm .

The inner resonator has taken as whole dimensions of 9.25× 9.25 mm² with *w*= 1 mm, x =3.25 mm,y=2.75 mm and r=0.5 mm .The perturbation square patch side length (d) is 1 mm while the gap between I/O feeders and external resonator (g) is 0.5 mm . Fig.2 shows the corresponding bandpass filter design. The guided wavelength at the design frequency is calculated by (λ_{g0}) [1,13]:

$$\lambda_{g0} = \frac{c}{f\sqrt{\varepsilon_e}} \qquad (4)$$

and

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \cdot \frac{1}{\sqrt{1 + \frac{12H}{W}}} \qquad (5)$$

Where ε_e is effective dielectric coefficient and *c* is speed of light .

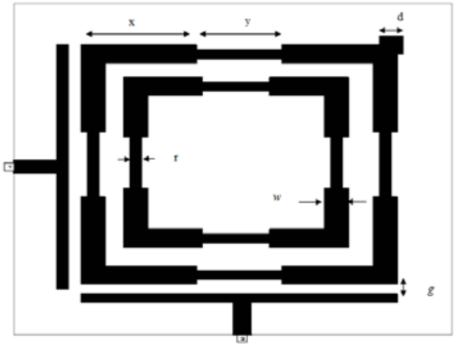

Fig.2 The modeled layout of stepped impedance BPF

Generally in degenerate dual-mode case, the bandpass filter response can be obtained through the excitation of the two degenerate modes by input /output feed lines and adjusting the coupling between the two modes by adding suitable form of perturbation within the resonators. In this paper, small square patch that acts as perturbation effect is applied to proposed filter design, at locations that are assumed at an angle 45^0 offset from its two orthogonal modes. This perturbation can be in the form of a small square patch with a side length d, added to the upper right corner of the conventional square patch as shown in Fig. 2 [1,13] .

4 PERFORMANCE EVALUATION

Filter structure, depicted in Fig.2 has been modeled and investigated at an operating frequency of 2.43 GHz using Microwave Office 2009 electromagnetic simulator from Advanced Wave Research (AWR) Inc. This simulator acts upon electromagnetic analysis using the method of moments (MoM). The simulation results of return loss, S11, and transmission, S21, responses of these filters are shown in Fig. 3. It is understandable, that the resultant bandpass filter based on SIR application on each of concentric square loop resonator presents a quasi-elliptic transmission response with transmission zeros that are asymmetrically situated around the deign frequency near pass-band edges. TABLE I shows results of the modeled filter dimensions as designed for 2.43GHz application with corresponding filter performance parameters. The frequency response of this filter has low insertion loss and good return loss as well as narrow band at -3 dB regions which are very good features in the basics of filter theory.

TABLE I Summary of the calculated and simulation results of the modeled filters

Filter Dimensions and Parameters	Magnitude
Occupied Area, mm^2	196
Band Rejection levels(dB)	-60 (left) -75 (right)
S$_{11}$ (dB)	-29
Insertion Loss(dB)	-0.02
Bandwidth(MHz)	46

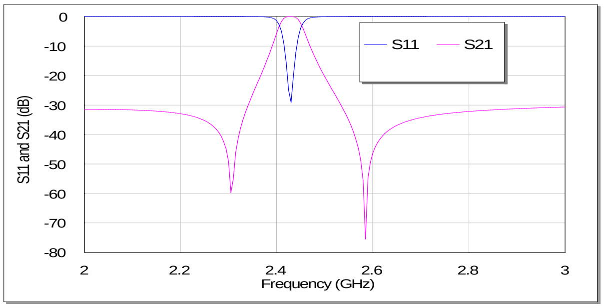

Fig.3 The return loss and transmission responses of BPF depicted in Fig.2 designed for 2.45 GHz

The quantity of coupling effect depends on the side length of perturbation patch in the upper right corner, which influences resonant frequency of output response [1,13]. The edge spacing between resonators and I/O feeders locations, can be used as tuning limitations to increase return loss and decrease insertion loss to optimize frequency response of the filter as good as possible [14]. Fig.4 shows the out-of-band responses of the filters depicted in Fig.2 . It is clear from Fig.4 , the performance response has obvious 2nd harmonic suppression in out of band regions that conventionally appears in the bandpass filter performance .

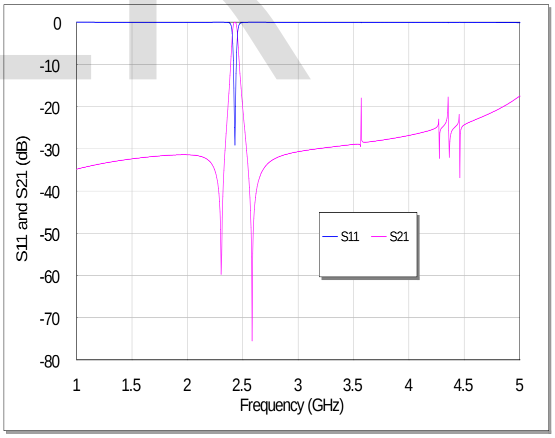

Fig.4 The out-of-band responses of the bandpass filter depicted in Fig.2

Fig.5 shows the scattering parameter simulation results of the proposed filter , where non-linear phase responses for S$_{11}$ and S$_{12}$ with respect to different frequencies can be seen visibly. Also ,the intersection between S11 and S21 responses can be perceived nearby design frequency .

Simulation results for the surface current density at two different frequencies of operation, 2.43 GHz (the center frequency) and 3.3GHz (in the rejectband region), are illustrated in Figs.6 and 7 correspondingly. In these figures, the red color points to the uppermost coupling outcome while the blue color indicates the lowest one.The maximum surface current densities can be noted at the design frequency, which comes from the truth that low losses are present and the desired resonant frequency is within higher excitation condition. In contrast, the lowest current densities can be seen at 3.3 GHz in stopband region . In this case, weakest coupling can be seen, which is given by the fact that proposed bandpass filter is not being induced and, hence, provides a strong rejection in an otherwise passband structure.

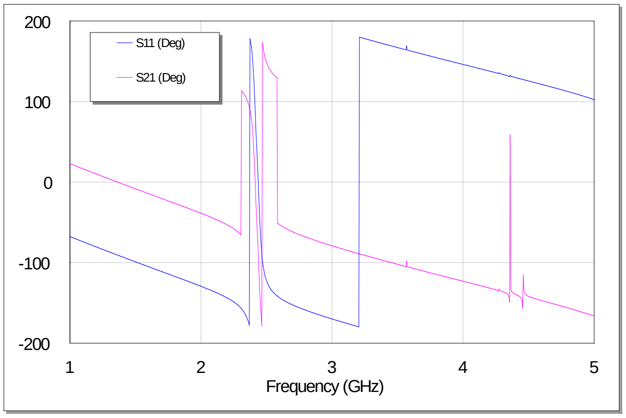

Fig.5 The phase responses of the bandpass filter depicted in Fig.2

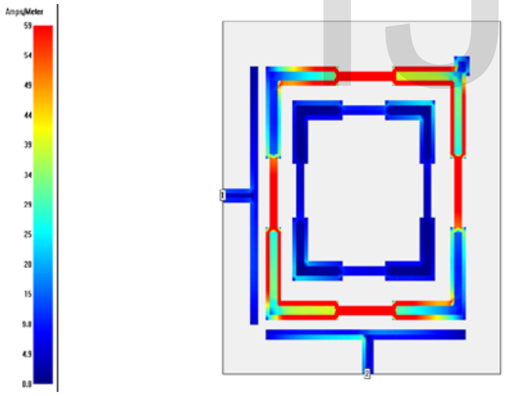

Fig.6 Simulated current density distributions of the proposed BPF at 2.43 GHz

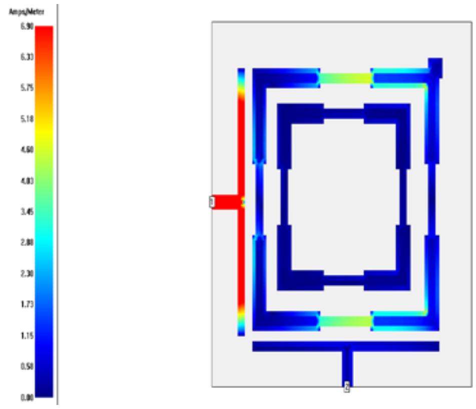

Fig.7 Simulated current density distributions of the proposed BPF at 3.3 GHz

5 CONCLUSION

New narrow band microstrip bandpass filter design by applying SIR generator on each side of square loop resonator has been presented in this paper for first time. The proposed filter structure has been composed of dual concentric microstrip resonators with a dielectric constant of 10.8 and thickness of 1.27mm at 2.43 GHz center frequency. The new filter design has small sizes and good transmission and return loss characteristics with blocked higher harmonics in out of band regions, which are very attractive properties required for current wireless applications.

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