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Design of Dual Mode SIR Band pass Filter for Wireless Communication Applications

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Abstract*: *In this paper, a new design of microstrip dual-mode bandpass filter using stepped impedance resonators (SIRs) is introduced. The filter consists of a two coupled SIR resonators with a 50 ohm impedance port. The presented dual-mode filter works at 2.4 GHz and 2.89 GHz for industrial, scientific and medical (ISM), closed circuit television (CCTV) and wireless local area networks (WLANs). The filter is designed and simulated using commercial electromagnetic simulator CST microwave studio 2009. The return losses of the filter at the operating frequencies are -32.469 dB and -26.18 dB respectively. The filter shows good insertion losses of 0.37 and 0.24 dB within the operating bands and a good out-of- band rejection more than 25 dB.

Keywrods*: *Dual-mode filter, stepped-impedance resonators, wireless local area network

I. INTRODUCTION

In recent years, the wireless communication systems, such as the mobile communication systems (CDMA, GSM, WCDMA, TD-SCDMA), wireless code-division multiple-access (WCDMA), and especially in the newly developed wireless local-area networks (WLANs) for IEEE 802.11b and IEEE 802.11g standards operate in the unlicensed industrial-scientific medical (ISM) 2.4 GHz band and products of IEEE 802.11a operate in the ISM 5.7 GHz band [1], the short-range communication systems (Bluetooth, UWB), provide convenient communication services in modern society. Compact equipments that support multi-mode wireless systems are very attractive and will be widely used in the future [2].

Besides high selectivity, low passband insertion loss, simple designed implementation, the necessary requirement of bandpass filters for wireless communication systems is wide stopband characteristics and a compact size this is important in modern wireless communication systems. Bandpass filter (BPF) plays an important role in the communication devices. It can be designed as a multiple mode circuit [3].

Dual-mode resonators have highly desirable features for the bandpass (BPF) design, such as size miniaturization, low radiation loss and ease of design because transmission-line theory and design tools can easily be implemented. The dual-mode microstrip filters are very important in miniaturization techniques due to their high gained performance and it can be used as a double circuit in single structure as compared to single mode bandpass filter designs when two degenerate modes are coupled to each other by suitable perturbation excitation [4].

A dual-mode resonator can be employed as a double tuned circuit. Thus, the number of resonators required for a given degree of filter is reduced to half, resulting in a compact filter configuration [5].

SIR can be defined as a TEM or quasi-TEM mode resonators composed of more than two transmission lines with different characteristic impedance [6].

SIR filters are built with several line sections of non uniform widths coupled together with common input and output [3] .Those resonators can be realized using multi-mode or single mode resonator. The second passband in the frequency response of dual mode resonator is actually a harmonic response of the dual-mode resonators, and it can be adjusted by the structural parameters of the SIR [5].

When designed at a low microwave frequency, filter may require a large circuit area or footprint. To overcome this problem and to best exploit a multilayer circuit technology, a new concept of folded resonator, can be deployed for miniaturizing filters. [6]

On the other hand, the dual-mode microstrip resonators in the microwave literature are fed by a pair of orthogonal feed lines arranged at 90˚ (or 270˚) in order to produce the two degenerate modes and coupling them to each other. However, the orthogonal feed lines may not be physically suitable for all microwave networks. Instead, the feed lines oriented along a straight line can be utilized as an alternative solution. In other words, dual-mode microstrip filters may be fed by a pair of feed lines arranged at 180˚ geometrically, along a straight line [8].

In this paper, a dual-mode bandpass filter is proposed by cascading two folded SIRs for wireless communication applications. The dimension and structure of the filter are designed and optimized using commercial EM simulator CST microwave studio 2009.

II. DUAL MODE STEPPED IMPEDANCE RESONATOR

As shown in Fig. 1(a), the basic structure of half-wavelength SIR consists of two lines of different characteristic impedances Z1 and Z2 and electrical lengths $\theta 1$ and $\theta 2$.it constructed by cascading a long-length ($2\Theta_1$) at low-impedance section (Z_1) in the center and in the two sides connected with the short-length (Θ_2) at high -impedance section (Z_2) [9].

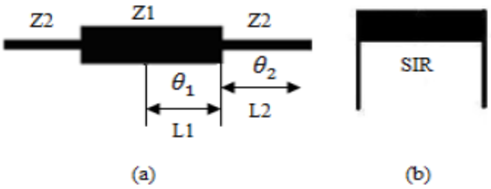

Figure.(1) Electrical and dimensional parameters of a resonator, (a) Stepped impedance resonator (SIR), (b) Example of folded SIR structure.

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Using a folded stepped impedance resonator, source load (input-output) coupling can easily be applied to introduce transmission zeros in the stopband as shown Fig. 1(b) [9].
The resonance conditions can be obtained from one of them since the half-wavelength SIR is symmetrical [10]. The impedance of the resonator can be calculated as expression:

$$Z_{in} = jZ_2 \frac{Z_1 \tan\theta_1 + Z_2 \tan\theta_2}{Z_1 - Z_2 \tan\theta_1 \tan\theta_2} \quad (1)$$

According to the above equation, the resonance appears when *Z*in is infinite, namely the denominator is equal to zero. As a result, the following expression can be obtained as the resonance condition:

$$\frac{Z_2}{Z_1} = \tan(\theta_1)\tan(\theta_2) = R_z \quad (2)$$

Where *R*z is the impedance ratio. In expression (2), we can see that the resonance conditions are determined by $\theta 1$, $\theta 2$ and *R*z. It can adjust these three factors to obtain the resonance that we required, and a dual mode filter can be designed by using SIR. [1]
In most practical application, we often chose $\Theta_1 = \Theta_2$. In this situation ,the first spurious resonance occurs at

$$\tan\theta_{s1} = \infty \quad (3)$$

θ_{s1} is the electrical length for the first spurious frequency *f*s1.
The ratio *U* of the electrical length [9].

$$U = \theta_2(\theta_1 + \theta_2) \quad (4)$$

Note that the ratio of the physical lengths differs from that of the electrical lengths because the effective dielectric constants are different for the two lines. Where

$$\theta = \beta l \quad (5)$$

Where *l* is the physical length of the microstrip. Thus, $\theta=\pi$ when $l = \frac{\lambda_g}{2}$ .This is called half wavelength microstrip line and using in this design [1].
From (2) the resonant frequencies of an SIR can be tuned by changing the value of R_z and the lengths of the high-Z and low-Z segments.
In this paper, to design a good WLAN filter, the first spurious frequency must be avoided at 2.4 GHz.

III. DESIGN AND CONFIGURATION OF DUAL-MODE STEPPED IMPEDANCE BPF

A two-pole microstrip BPF composed of symmetrical two half wavelength SIR are coupled to 50Ω input/output capacitive coupling feeding lines as shown in figure (2)(a).
Substrate having a thickness of 1.5 mm and a relative dielectric constant of 4.4. The resultant dual-mode microstrip filter has a total size dimension 33.625 mm×24 mm. The dimension of the filter shown in fig.(2)(b) are given as: L1 = 7.06125mm, L2 =8.8 mm, L3 = 3.3625 mm, L4 =6.725 mm, W1 = 2.8 mm, W2 = 0.8966 mm, W3 = 1.00875 mm, W4 = 1.2 mm, W5 = 0.7 mm, W6=1.33 mm, S = 0.224 mm.

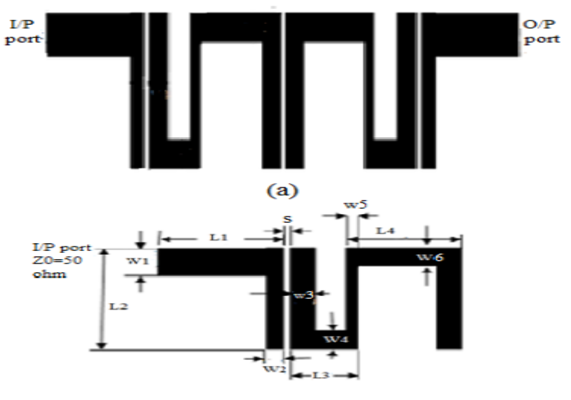

Figure (2) Filter structure (a) BPF Filter Structure (b) Filter dimensions.

Each SIR is equivalent to an LC resonant circuit, and they have capacitive coupling due to the capacitive reactance of the input and output feed lines as shown in figure (3).

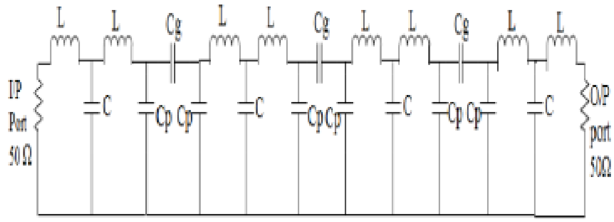

Figure (3). The Equivalent circuit of proposed filter

IV. RESULTS

The frequency response obtained from an EM simulation of the proposed BPF is shown in Fig. (4).There is two resonance frequencies within the band, they can be observed at 2.46 GHz and 2.89 GHz with a return loss of -32.469 dB and -26.18 dB, respectively. The center frequency is about 2.47 GHz and has a maximally fractional bandwidth FBW of 19.69% using a full-wave EM simulator.

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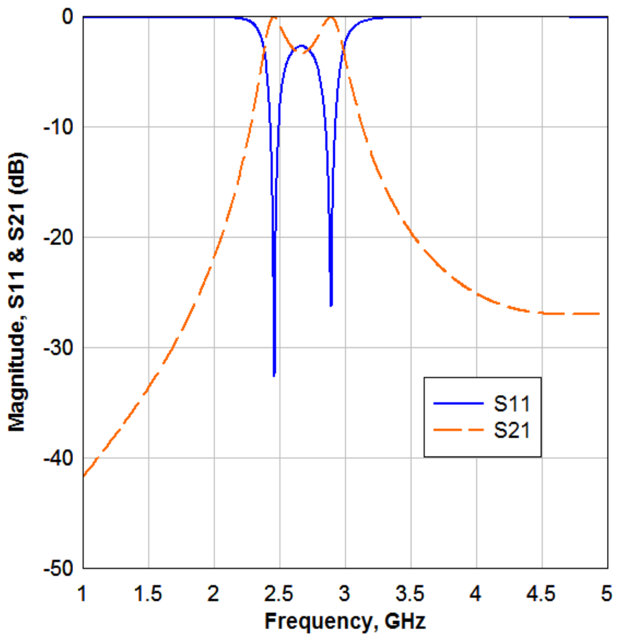
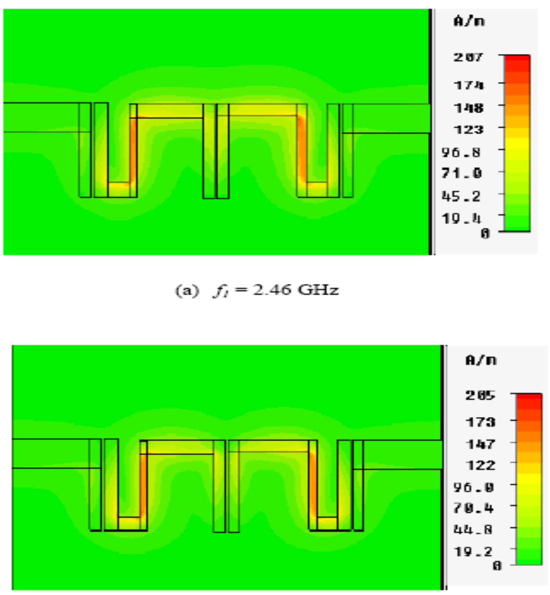


Figure (4). Return and insertion loss responses of the proposed BPF filter.

As shown in the result, insertion loss within the band at the resonance frequencies is 0.37 and 0.24 dB respectively. The filter shows a good out of the band rejection for more than 25 dB in band frequencies demonstrate that the filter gets a good selectivity.

Fig. 5 (a) and (b) shows the surface current distribution at the designed frequencies. It is shown that the modes in the frequency 2.46 GHz and 2.89 GHz simulated with CST.

Current distributions of the dual-mode resonator current shown that the locations of the higher and the lower density regions of Mode-I (f_1) and Mode-II (f_2) are very closely coupled.



(a) $f_1 = 2.46$ GHz

(b) $f_2 = 2.89$ GHz

Figure (5). Surface current distribution, (a) $f_1 = 2.46$ and (b) $f_2 = 2.89$ GHz

The effect of varying the dimension of w5 on the dual frequency response of the proposed bandpass filter is shown in Figure (6) (a) and (b).

From Fig. 6, it can be seen clearly, that the width of the w_5 can tune the lower edge of the WLAN band of the proposed filter between 2.26 and 2.46 GHz, as the width of parameter w5is decreased gradually between 0.2, 0.4 and 0.6 mm. Fig. 7 shows that the lowest insertion loss and higher out-of-band rejection levels are affected by changing the width w5 and more than -30 dB out-of-band rejection can be obtained.

V. CONCLUSION

In this paper, a new dual-mode Microstrip stepped impedance resonator is introduced. The filter has a response at - 3 dB fractional bandwidths of 19.69% of the center frequency at 2.46 GHz with an acceptable return and insertion losses, and covers the required band for ISM, CCTV, and WLANs.

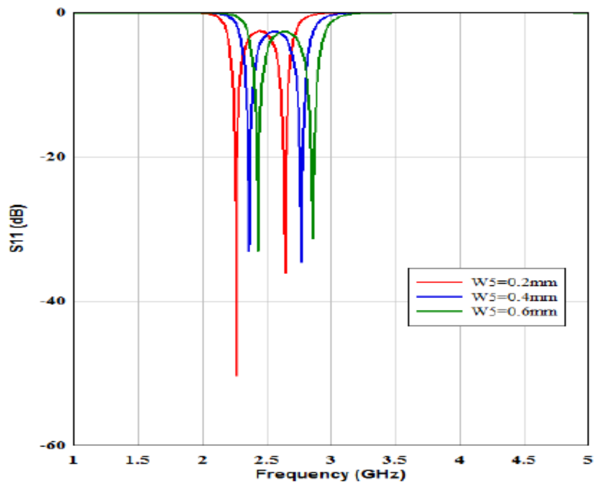


Figure (6).The effect of varying width of W5 on the return loss response of the proposed filter.

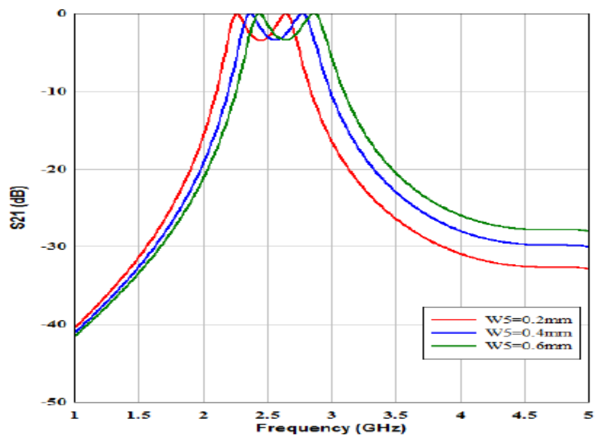


Figure (7).The effect of varying width of W5 on the insertion loss response of the proposed filter.

The proposed filter has the advantages of simple structure, compact size and good selectivity. It shows that with the new coupling structure, the filter has good passband performance, good selectivity, and good out- of the-band rejection properties.

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