D.A. Hammood
Dept. of Computer Techniques Eng., Electrical Eng. Technical College, Middle Technical University, Baghdad, Iraq
alsaady_dalal@yahoo.com

Received on: 18/10/2015
Accepted on: 29/12/2016

Design and Simulation of Microstrip Bandpass Filter with Regular Slots

Abstract- *This paper presents new microstrip slotted patch resonator bandpass filter with two transmission zeros of output frequency response around design frequency. The proposed filter uses dual-mode (doubly tuned) patch microstrip resonator with regular slots. It has a small surface area and narrower frequency response as compared with single-mode resonators. The filter is simulated by Microwave office 2015 software package at a center frequency of 2.009 GHz. The adopted substrate constant and thickness specification are 10.8 and 1.27 mm, respectively using RT/ Duroid 6010.8 material. Simulation results show that the suggested filter presents interesting frequency responses in addition to smallness properties due its high dielectric constant selection and its miniature surface area. These features represent the appealing features of the latest wireless applications.*

Keywords-*Microstrip dual-mode filter, slotted patch resonator, compacted bandpass filter.*

How to cite this article: D.A. Hammood, "Design and Simulation of Microstrip Bandpass Filter with Regular Slots" *Engineering and Technology Journal*, Vol. 1, Part a, No. 1, pp. 24-28, 2017.

1. Introduction

Network synthesis schemes can be implemented to construct a proficient bandpass filter (BPF) design with intended electrical requirements. The consequential electrical network characteristically has ideal lumped-element resonators that are not realistic for frequencies equal or higher than 1GHz. For this reason, an extra progression in the of microwave BPFs expansion is how to reach to ideal resonator designs in distributed transmission lines. On the other hand, distributed resonators do not operate as their ideal lumped-element compliments as they possess spurious harmonic resonances and inadequate unloaded quality factor. Even though almost microwave BPFs are considered at its operating band frequency of the involved resonators, harmonic band frequencies are approximately existing at integer multiples of the first passband. Although a huge number of BPFs devices can be constructed using a variety of coupling schemes [1], the demanding frequency performance of the resonator can as well be utilized to design superior BPFs as in those with higher stopbands or manifold passbands. It is principally valid for distributed resonators since there is generally several control degrees on their frequency responses. The frequency behavior of resonators can be simply deformed by diverse changes in their structures. For instance, to reallocate spurious harmonics outwards [2], set up extra rejection band levels [3, 4] or to cause a controllable second passband [5, 6]. A dual-mode resonator is an EM structure with the intention of effectively supporting dual modes of resonance that are interrelated to each other without any harmonic relation. For the 2-D resonator configurations, the resonant frequencies can be initiated from the length and width of the resonator structures. However, for upper frequencies, there is a possibility for resonant frequencies to be initiated from the conductive trace thickness. On the other hand, not every resonance can be straightforwardly tuned. For instance, the resonant frequency tuning by conductor thickness can merely be changed by changing the trace thickness, which is unfeasible. When *M* coupled resonators are needed to assemble an *M*th-order bandpass filter, only *M*/2 dual-mode resonators will be needed for the same filter configuration. This is because that every one of the dual-mode resonator behaves as a double coupled resonator. This stands for prospective compactness.

Also, each dual-mode filter has likelihood to lessen all losses, including insertion and conductor losses. A microstrip BPF design using dual-mode triangular loop resonator is reported in [7]. The filter has been designed at 10.0 GHz resonant frequency and 8% fractional bandwidth. Its response has single real frequency transmission zero and single imaginary frequency zero in passband region. Transversal microstrip BPF has been reported in [8]. The proposed filter has compact size designed at 2.0 GHz resonant frequency. Also, its frequency response has suppressed spurious responses.

A new microstrip square loop dual-mode BPF based on capacitively stepped-impedance resonator (CSIR) is presented in [9]. The presented filter has an interesting frequency response designed at 0.9 GHz operating frequency with spurious responses isolations. In [10], new hairpin line BPF using via ground holes has been designed at 2.0 GHz operating frequency. The presented filter in this study has narrow band frequency response using microstrip technology.

A compact microstrip BPF based on hexagonal open-loop resonators and an E-shaped stub loading has been reported in [11]. An E-shaped stub loading decreases the big-order mode frequency of the single-mode hexagonal open-loop resonator. The resultant filter has a small size with suitable frequency responses.

A new BPF using dual-mode hexagonal loop resonator and a step impedance open-end stub perturbation has been presented in [12].The interior angles of the hexagonal geometry of this filter are large compared with square and rectangle counterparts that lead to superior smallness in the microstrip circuits. This filter is miniature and straightforward to be fabricated as well as useful for many wireless systems.

BPFs that are relied on dual-mode ring resonator have been designed as compact devices as stated in [13]. The smallness has been done by deforming the ring trace to a spiral arrangement. The output frequency results have wide passband with dual degenerate modes. This wide passband feature has been achieved by physically powerful I/O coupling using an impedance transformer for external quality factor matching with the filter bandwidth. In this research article, compact doubly tuned microstrip bandpass filter has been designed. It uses a miniature patch resonator with regular slots as an effective EM component. The output S11 and S21 curves of the proposed device are reasonable. Furthermore, it has a narrow band response that can be functional in wireless systems.

2. Dual-mode Filter Design

The essential theory for a patch resonator filter modeling is the required properties of the whole categories of resonant modes. At present, the design of microwave patch filters mostly focuses on dual-mode (doubly tuned circuits) process. Nevertheless, the upper modes have not enough practical realizations. At this time, patch microstrip resonators [14, 15] hold the vast attention of microwave circuit manufacturers for fabricating new microwave devices and enhancing the output frequency responses. A microstrip doubly tuned resonator classically has planar or two-dimensional (2-D) symmetry and it is not the only square in shape for all intents and purposes. Figure 1 illustrates divergent microstrip doubly tuned resonators, where *D* on top of all resonators in this figure points to its regular dimension, and λ_{go} stands for the guided wavelength at its specified resonance. A miniature patch or slit as induction and coupling element has been placed to each resonator at the angle 45° from its dual orthogonal I/O ports as shown in Figure 1.

The electrical requirements of any filter commonly comprise the resonant frequency, bandwidth, insertion loss, return loss and required stopband levels.

The proposed filter has been designed for the operating frequency of 2.009 GHz using a dielectric constant of 10.8 and thickness of 1.27 mm and conductor thickness of 35 µm. The guided wavelength (λ_{go}) is evaluated by [14,15]:

$$\lambda_{go} = \frac{c}{f_0\sqrt{\varepsilon_{eff}}} \qquad (1)$$

Where c stands for light speed, f_0 is center frequency and ε_{eff} is effective substrate value that can be determined from [14,15]:

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

Where ε_r stands for relative substrate constant, *W* is conductor width and *H* represents substrate thickness. The modeled slotted patch filter has illustrated in Figure 2. The perturbation square patch side length (d) is 1.4 mm while the gap (g) among slotted patch resonator and I/O feeds is 0.4 mm. The dimensions of X, Y and Z are 6 mm, 18 mm and 2 mm respectively.

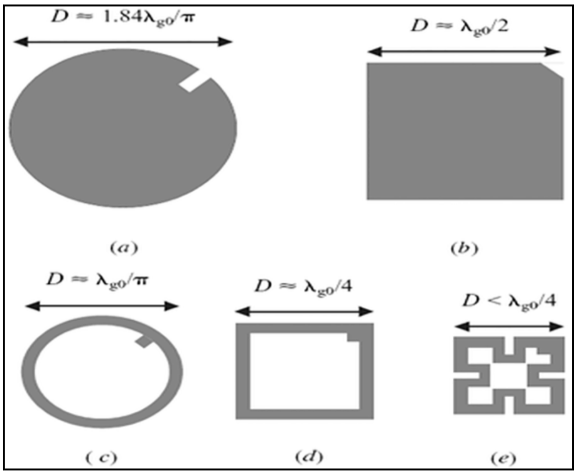

Figure 1: Dual-mode microstrip resonators

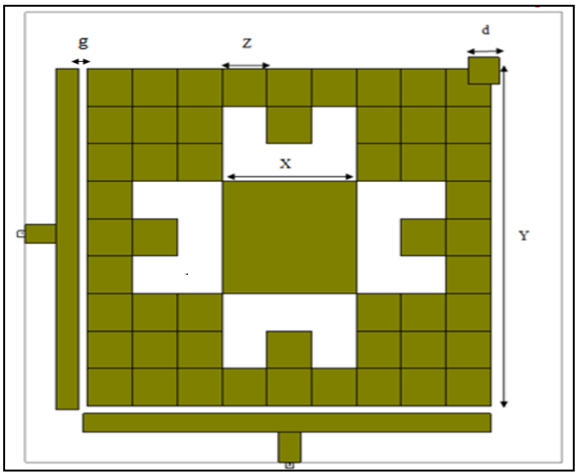

Figure 2: The designed slotted patch filter

The slot nature of the presented patch resonator stands for active perturbation effect to the electromagnetic equilibrium of the resonator configuration. Hence, the electromagnetic distributions of the degenerated modes are going to be no longer orthogonal and combined to each other.

3. Performance Evaluation

Dual degenerate mode microstrip filter employing slotted square patch resonator has been simulated by Microwave Office 2015 EM software package. The filter structure is depicted in Figure 2. The consequent S11 and S21 curves of the filter have been depicted in Figure 3. It is apparent from this graph that there are two transmission zeros that correspond to band stop levels. Dual transmission poles at 2.0025 and 2.015 in -3dB passband region can be observed distinctly. Regarding S12 curve, they have the same response of S21 curve since the filter design has self-similarity.

Table 1 explains the dimensions of the designed filter with other main filter response parameters. This filter has a narrow band frequency response which is usually a big goal in wireless systems to cause the filter able to prevent the interfering signals working in the neighboring bands. Furthermore, it has a reasonable return loss and insertion loss magnitudes to be applied in many wireless systems.

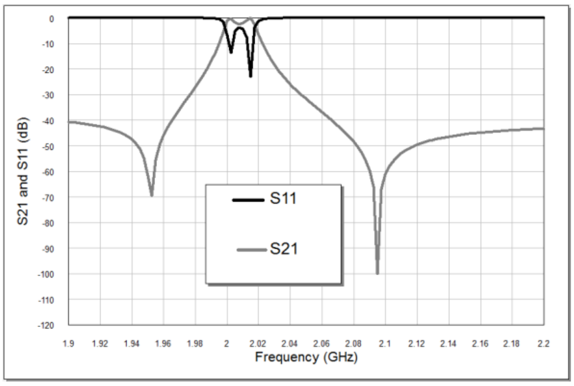

Figure 3: In-band frequency responses for the projected microstrip filter

Table 1: The area and simulation result parameters of the proposed filter

Filter Dimensions and Parameters	Magnitude
Occupied Area, mm^2	384.12
Band-rejection levels	-69 (left) -100 (right)
The Highest S_{11} (dB) in Pass-band region	23
Insertion Loss(dB)	2.11
Bandwidth(MHz)	20

Figure 4 describes the dual-mode conventional patch BPF layout. The slit or slotting operation in the conventional patch reduces its elemental frequency. This is attributed to the square slit approach that enlarges the current path length and shift decreasingly the resonance frequency and transmission zeros as it is perceptible from S21 responses depicted in Figure 5. The elemental frequency of conventional BPF has been decreased by geometrical slitting the classical patch resonator from 3.05 GHz to 2 GHz without external dimensions change.

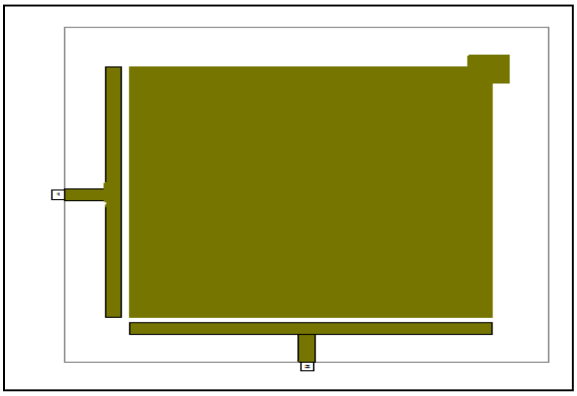

Figure 4: The classical dual-mode patch BPF

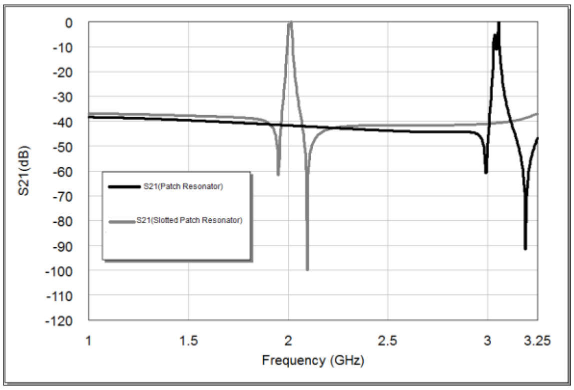

Figure 5: Output S21 curves of microstrip BPFs; with and without uniform slots at 2.0 and 3.05 GHz respectively

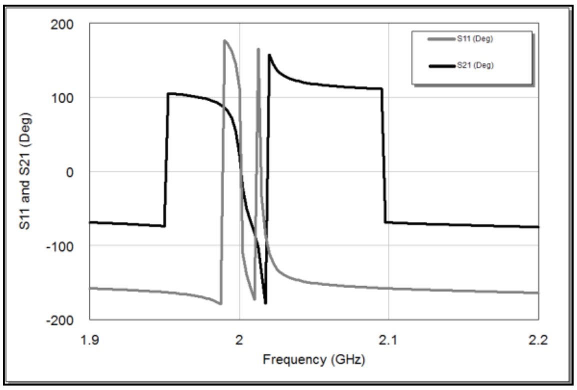

Figure 6: Output S21and S11 phase response curves of the designed filter

Figure 6 gives an idea about the scattering phase response of the modeled filter for S11 and S21 parameters respectively.

The surface current density simulation results at 2 GHz (in the pass-band) and 2.2 GHz (in the stop-band), have been demonstrated in Figures 7 and 8 respectively which take the shape of adopted slotted patch bandpass filter. These responses are achieved using Sonnet EM simulator. In these figures, the red color is a sign of the upper limit of coupling whereas the blue color explains the minimum one. The largest values of surface current intensity are visible at 2.0 GHz design frequency. The minimum current intensities are noticeable at 2.2 GHz in stop-band locations. Therefore, the weakest coupling can be detected easily, that represents big evidence that the projected filter is not being induced enough and, for that reason, offers a physically influential rejection, unlike pass-band region.

From Table 2, the suggested filter in this study has mostly better electrical specifications and miniature area as compared to the reported research works in [8] and [10] at the same design frequency of 2.0 GHz. This is because the proposed filter in this study has low insertion loss magnitude and smaller than [10], that stands for an important feature to integrate the filter within various communication devices as well as it has the lowest (narrowest) bandwidth magnitude that is a big objective in communication system to prevent interference among signals in adjacent bands. Also, it has reasonable return loss magnitude and higher than reported filter in [8] which means theoretically that proposed filter under simulation test has good quality to be adopted since it has return loss greater than 20 dB.

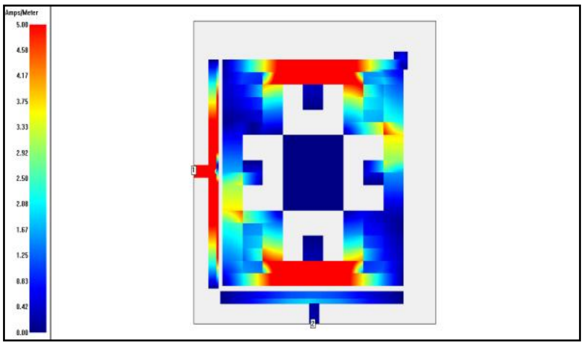

Figure 7. Current intensity distributions of the projected filter at 2 GHz

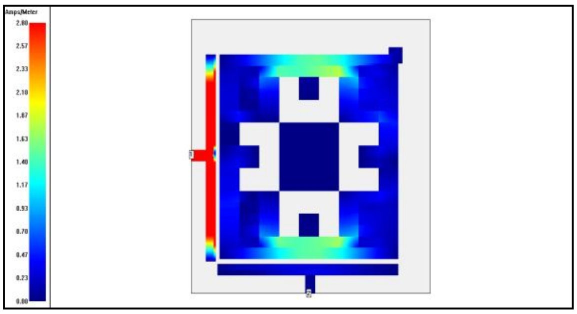

Figure 8 Current intensity distributions of the projected filter at 2.2 GHz

Table 2: Comparative results between this work and reported BPFs in [8] and [10] at 2.0 GHz operating frequency

BPF Specifications	This Work	[8]	[10]
S21 at center frequency (dB)	2.11	1.1	2.343
Highest S11 within pass-band region (dB)	23	22	26.455
Bandwidth(MHz)	20	100	26.4

4. Conclusion

In this research article, a new narrow doubly tuned bandpass filter has been presented as a miniature device for mobile communication systems. In this context, this bandpass filter structure has been produced by applying regular geometrical slots on the classical square patch resonator.

The design and simulation results of the proposed filter have been examined using Microwave Office 2015 simulator with RT/Duroid substrate constant of 10.8 and substrate height of 1.27mm at 2.009 GHz resonant frequency.The proposed filter comprises high-quality S11 and S21 responses as well as very compact size due to its high dielectric constant adoption and small surface area. These characteristics can be adopted in various wireless schemes. Additional future work is to prove the simulated results with fabrication and measurements.

References

[1] J. M. Rasool and S.H. Abdul Razzaq, “Novel model design of compact dual notch-bands of attenuation for bandpass filters,” Engineering and Technology Journal, Vol. 29, No.10, 1955-1961, 2011.

[2] A.A. Noori, “A novel microstrip dual-mode band-pass filter for 2nd Harmonic Suppression,” Engineering and Technology Journal, Vol. 28, No. 11, 2207-2211, 2010.

[3] Y. Ping, and M. Sun, “Dual-band microstrip bandpass filter using stepped-impedance resonators with new coupling schemes,” IEEE Transactions on Microwave Theory and Techniques, Vol. 54, No. 10, 3779-3785, 2006

[4] J-S. Hong, H. Shaman, and Y.-H. Chun, “Dual-Mode Microstrip Open-loop Resonators and Filters,” IEEE Transactions on Microwave Theory and Techniques, Vol. 55, No. 8, 1764-1770, 2007.

[5] A.C. Kundu, and I. Awai, “Control of attenuation pole frequency of a dual-mode microstrip ring resonator bandpass filter,” IEEE Transactions on Microwave Theory and Techniques, Vol. 49, No. 6, 1113-1117, 2001.

[6] J-S. Hong, and M.J. Lancaster, “Realization of quasielliptic function filter using dual-mode microstrip square loop resonators,” Electronic Letters, Vol. 31, No. 24, 2085-2086, 1995.

[7] C. Lugo and J. Papapolymerou, “Bandpass filter design using a microstrip triangular loop resonator with dual-mode operation,” IEEE Microw. Wireless Compon. Letters, Vol. 15, No. 7, 75-477, 2005.

[8] W-W. Choi, K.-W. Tam and R. P. Martins, “A novel microstrip transversal bandpass filter with simultaneous size reduction and spurious responses suppression,” 2005 Asia-Pacific Microwave Conference Proceedings, Vol. 1, 508-511, Suzhou, China, 2005.

[9] S-W. Fok, P. Cheong, and K. -W. Tam, “A novel microstrip square-loop dual-mode bandpass filter with simultaneous size reduction and spurious response suppression,” IEEE Transactions on Microwave theory and Techniques, Vol. 54, No. 5, 2033-2041, 2006.

[10] A. Hasan, and A.E. Nadeem, “Novel microstrip hairpin line narrowband bandpass filter using via ground holes,” Progress In Electromagnetics Research, Vol. 78, 393-419, 2008

[11] X.K. Cheng, J. Xu, M. Zhang, “Miniature dual-mode bandpass filters using hexagonal open-loop resonators with E-shaped stubs loading,” International Symposium on Signals, Systems and Electronics, Vol. 1, 1-3, Nanjing, China, 2010.

[12] J.L. Murmu, G. Singh, and S. Das, “Hexagonal bandpass filter using open end step impedance stub perturbation,” International Conference on Microwave and Photonics (ICMAP), 1-4, Dhanbad, India, 2013.

[13] T-W. Lin, J-T. Kuo, S-C. Tang, S-J. Chung, “Miniaturized dual-mode ring resonator bandpass filter with a wide passband,” IEEE International Wireless Symposium (IWS), 1-3, Shenzhen, China, 2014.

[14] Y.S. Mezaal**, “**New compact microstrip patch antennas: design and simulation results**,”** Indian Journal of Science and Technology, Vol. 9, No. 12, 1-6. 2016.

[15] J.S. Hong and M. J. Lancaster**,** “Microstrip filters for RF/microwave application,” New York, Wiley, 2001.

Author Biography

Dalal A. Hammood has been awarded B.Sc degree in computer engineering and information technology, from the University of Technology, Iraq in 2003 and MSc degree in computer engineering techniques, from the Department of Electrical Engineering Technical College, Middle Technical University, Iraq in 2011. Currently, she is a lecturer at the Department of Electrical Engineering. Her research interests are in the fields of computer networks security, cryptography, artificial intelligence/ artificial neural networks, genetic algorithms and wireless sensor networks. She has six published papers in IEEE conferences in these fields.