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Designing of Dual Mode Band Pass Filter Using Square Patch Resonator

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Abstract: This Paper presents a methodology for the design of microwave band pass filter using square patch resonator. The 3D simulator ADS Momentum is used for the layout design. The performance of the filter is evaluated by method of momentum. This methodology figure out the design of dual mode filters using square resonator. The technique developed in this work results in filter with low loss, high power handling capability and good level of miniaturization. Dual mode filter is developed using square resonator presenting two poles in the pass band with centre frequency at 2.4 GHz and fractional bandwidth 13%. Maximum insertion loss of this filter is less than 1 dB and minimum return loss is 18 dB. The results show agood agreement with the study theory.

Keywords: ADS Momentum, Square Resonator, Dual Mode Filter, Miniaturization

1. INTRODUCTION

Filters and Microwave systems are essential part of the modern telecommunication for transmitting and receiving communication signals. Filter attenuates unwanted signals and only passes the information carrying signals. In recent decades, there is a great expansion of communication systems carrying audio, video or data signals. In this flourishing field, there has always been a dire need of filters with low cost, small size, minimum loss and ease of fabrication. So there are continuous effort towards the miniaturization and ease of integration in cellular and satellite communication. Recent advances in computational tools for Computer Aided Design (CAD) simulators have revolutionized the design of microwave filters, allowing the design of new topologies. The focus of this paperIs to achieve these characteristics using planer resonators. Various types of planer filters has been developed using dimensional resonator in (Gorur, 2002) (Hong, and Lancaster, 1999) (Saavedrd, 2001) (Hong, and Lancaster, 1995) patch resonators are also employed in designing of band pass or band stop filter in (Tan, 2002) (Zhu, *et al.,* 2005) (Hong, and LI, 2004) Patch filters exhibit low losses and high power handling capability.Although patch resonator suffer losses due to radiations as compared to one dimensional resonator. The filters can be designed using single mode (Hong and Lancaster, 2000) or dual mode resonators (Wolff, 1972). Single mode resonator contains one pole in its pass band region and multi mode filters presents multiple poles in pass band. Multi mode filter has an attractive feature of small size and compact design as compared to single mode filter. This paper focused on the design of planar multimode patch resonator filter.

2. BACKGROUND

A physical structure that resonates at certain frequency is named as resonator. Resonators can be treated as planer waveguide cavity with upper and lower conducting walls surrounded by magnetic walls (Overfelt, and White, 1986) (Wolff, and Knoppik, 1974) A balanced band pass filter with transmission zeros and UWB band pass filter also proposed by authors in (Zheng, *et al.*,2016) (Janković, *et al.*,2016) One of the important applications of resonator is in filters. There are various technologies available to design resonators like planer, dielectric, waveguide, etc. these resonators may be in the shape of circular, triangular, square, etc.

In planer filters dielectric is sandwiched between two metal layers. The major parameters that determine the dimensions of the filter are dielectric constant, thickness of the dielectric and the metal layer. Metal conductivity and dielectric loss tangent effect the insertion loss in filter response. Planer filters are fabricated on the upper metal layer, and this layer is grounded through metal via to the bottom layer. There are two categories of the planer filter, one dimensional and two dimensional. The first category includes micro strip filters made from stepped impedance resonator SIR. This paper deals with the second type, two dimensional filters. Unlike the micro strip filters that are based on transmission lines, patch filters are builtwith two dimensional geometries. The complete analysis of patch filter is based on the electromagnetic field pattern.

In Patch resonators, the applied energy splits among different resonant modes where each mode

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operates at a particular frequency. The lowest frequency of the first mode is termed as fundamental modal frequency. Resonators with regular geometry may present two modes that have same resonant frequency but different electromagnetic field pattern. These modes are called degenerate modes, one exhibiting an even mode and other as odd mode. There may be more than one degenerate mode within the same resonator. Patch resonators are like waveguide cavity having perfect electric walls at the top and bottom that is surrounded by perfect magnetic walls. Therefore transverse magnetic field pattern exists in such resonators. In TM mode, no magnetic field present along the direction of propagation that is Z axis paper.

3. THE PROPOSED FILTER DESIGN ETHODOLOGY

A. Filter Specification

Filter specifications are defined before initiating the paper. Major specifications include centre frequency, bandwidth, insertion loss, return loss and rejection level of harmonics. Among these characteristics, centre frequency is the vital parameter to progress in right way. Other parameters are approximated while inserting slot during optimization.

B. Determinations Of The Resonator Dimensions

Simple and accurate mathematical expressions are used to determine the effective length of the square and circular resonator.

In case of rectangular resonator effective side length is given by (Zhu, *et al.*, 2005) $L_{ef} = L + 2|\Delta L|$

Where

$$\Delta L = 0.412\left[\frac{\varepsilon_{ef} + {}^{0.3L}/_{h} + 0.264}{\varepsilon_{ef} - {}^{0.258L}/_{h} + 0.8}\right]$$

ε_{ef} is the effective dielectric constant of the resonator

L is the length of the disk

H is the substrate thickness

L_{ef} is the effective length of the square side

The dimensions of the resonator are calculated in such a way that the filter resonate at frequency 20% above the centre frequency.

C. Disruption Of Regular Geometry

The major step in the design of multimode filter is theanalysis of disruption in the regular geometry of the resonator. Through this analysis, it is observed whether the central frequency is achieved or not by chosen topology. The disturbance can be in the form of slots, cuts or a combination of geometries. Perturbations are introduced in such a way that the overall symmetry of the resonator on the feed lines remain constant.

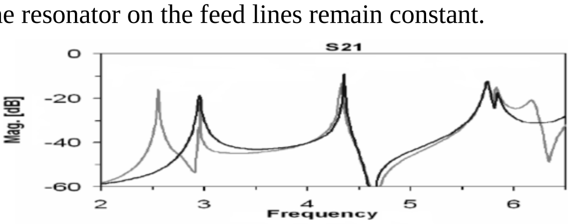
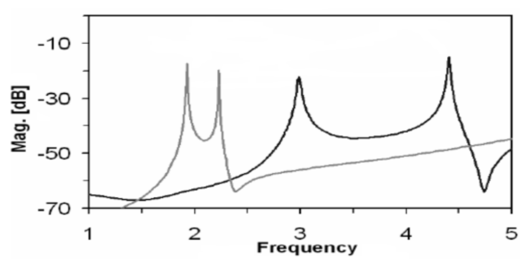


Fig. 9. Resonant Frequencies with and without perturbation, when input lines are at the edge of resonators

In the above structure, all the modes present in the resonator are excited because feed lines are positioned at edges where non-zero electric field exists. When a perturbation is inserted in the middle of the resonator, the dominant mode frequency is reduced.

Dual mode patch filter is formed by inserting four identical slots, which results in reducing both the fundamental frequency and the 2nd mode frequency generating a pass band.



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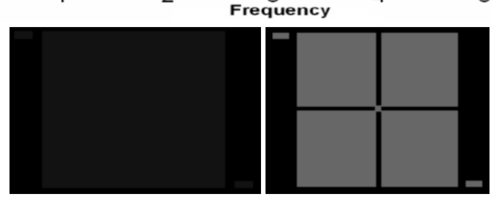

Fig.10. Resonanat frequencies with inserting flour slots at quadrature.

The band width of the filter depends on the gap between the resonant modes exited and the location of the input/output ports. The disturbance inserted in the resonator is analyzed in term of its length, width and position. After a series of simulation, a correct choice of the perturbation is made.

4. DUAL MODE BAND PASS FILTER USING SQUARE RESONATOR

A. Filter Specifications

- Centre frequency 2.4 GHz
- Bandwidth 200MHz
- Fractional bandwidth 13%
- Maximum Insertion loss 1dB
- Minimum Return loss 18dB

B. Analysis Of Resonator

Square geometry of the resonator is selected for this 2-pole band pass filter. The substrate used is Roger3010 with dielectric constant 10.2 and thickness 25 mil. A series of simulations is performed by keeping the width of slots constant but varying their lengths.

The results are recorded by altering each slot length individually. It is observed that resonant frequency of $TM_{0,1,0}$ is not affected by the changing the slots A, A' lengths. On the other side, resonant frequency of $TM_{1,0,0}$ practically remains constant with variations in the lengths of B & B'.

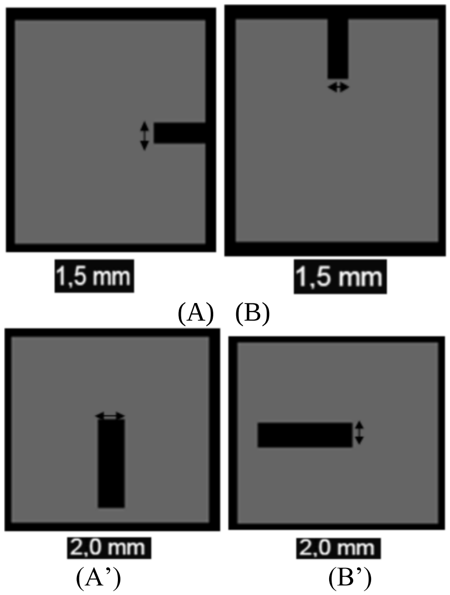

Fig. 11. Combination of different slots used to approximate the results

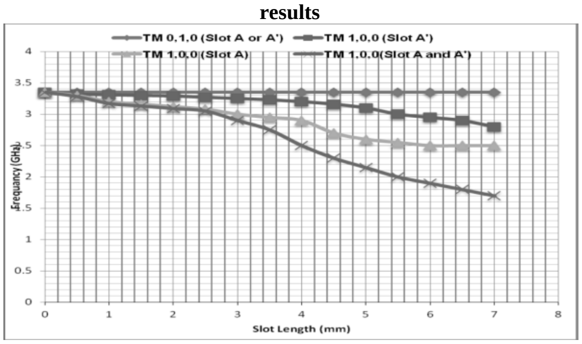

Fig.12. Effect of slot pair A, A' on the resonant frequencies

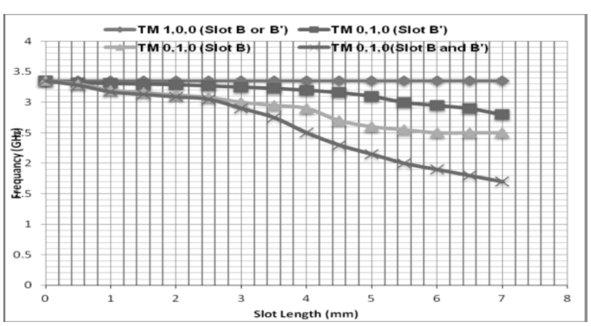

Fig. 13. Effect of slot pair B, B' on the resonant frequencies

C. Effect Of Perturbations

From the above graphs, it is observed that the frequency of mode $TM_{0,1,0}$ remains constant to variation in A, A' but its resonant frequency decreases with increase in the length of B, B' slot. The same analogy applied to the mode $TM_{1,0,0}$ that practically remains almost same for B and B' but increasing length of A, A' results in decreasing its resonant frequency. A good combination of the slots A, A' and B, B' leads to the required approximation. When the length of A is 4mm, it is observed that $TM_{1,0,0}$ modal frequency resonate at 2.9 GHz, reduced by 0.45 GHz from its original frequency. Similarly for A' at the length of 7mm, the $TM_{1,0,0}$ modal frequency decreases by 0.55 GHz and now resonate at 2.8GHz. A combination of A, A' 4mm, 7mm respectively generates (0.45+0.55)1GHz frequency reduction and diminished the initially estimated resonant frequency 3.55GHz to required central frequency 2.4 GHz. Moreover, the frequency difference of 100 MHzis achieved, that is a reasonable value. The same analogy is applied in the choice of B and B.

D. EM Simulations

Initial design is simulated by using A, B slots 4mm long, 1.5 mm wide and A', B' 7mm long and 2mm wide. The input and output lines are directly coupled to the resonator. Its layout structure and simulated graph is shown in **(Fig. 14)**.

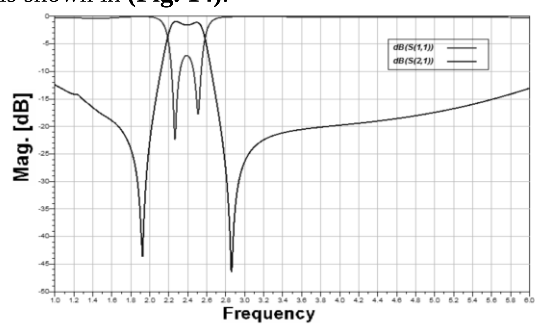

Fig. 14. Band Pass filter response using square resonator without optimization.

Fig. 15. Filter Layout, input lines directly coupled to the resonator.

The above simulation shows that there is a centre frequency of 2.4 GHz with maximum insertion loss 2.4 dB and minimum return loss of 7 dB. This is not according to filter specifications, so some modification are introduced in the circuit by cutting its edges in the form square of 1.1x1.1mm dimension and inserting another slot of 3mm long,0.7mm wide along the diagonal between A' and B.' The new layout structure and its simulation results are mentioned below.

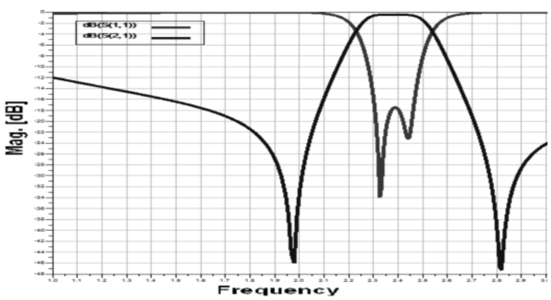

Fig. 16. Band pass filter response using Square resonator with optimization

Fig. 17. Filter Optimized Layout

The simulation seems to be optimised. Its central frequency is 2.4GHz; bandwidth is 200 MHz, Maximum Insertion loss is less then 1dB, and minimum return loss is 18 dB.

E. Performance Evaluation

The above figure shows the simulated results of two pole band pass filter. There is a good agreement between the simulated results and the filter specifications. There are two transmission zeros in the pass band, with centre frequency 2.4 GHz. Maximum insertion loss is 1 dB and the return loss is 18 dB. The fractional bandwidth is better then 13%. The reduction in the area of this dual mode filter is 50% smaller then single mode filter, which is a remarkable level of miniaturization.

5. CONCLUSION

It can be inferred that a miniaturized microwave band pass filter with patch resonator is successfully developed that presents low losses, and high power handling capability. Theoretical concepts and ADS Momentum tool is used in analyzing the field pattern of the square resonator. The filters designed showed that proposed methodology has wide application in the design of narrow band and wideband filters.

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