Finite Element Analysis and Design of Dual mode band pass filter

Jaimon Yohannan\textsuperscript{1}, K. Vasudevan\textsuperscript{2} and Mathew K T\textsuperscript{3}

\textsuperscript{1}Department of Electronics, Cochin University of Science & Technology, Kochi, Kerala, India
\textsuperscript{1}e-mail-jaimonyohannan@yahoo.com
\textsuperscript{2}email-vasudevan@cusat.ac.in, \textsuperscript{3}email-ktm@cusat.ac.in

Abstract

A novel dual-mode band pass filter composed of a micro strip square loop resonator was designed and fabricated. The filter was simulated using Finite element method and experimental S-parameter measurement was done using a network analyzer. The use of square resonators facilitates the realisation of dual mode designs and elliptic functions and self equalised planar filter designs.

1. Introduction

Implementation of planar microwave filters is often achieved using microstrip and stripline fabrication techniques. Microstrip is formed by etching a circuit pattern on one side of two metal layers separated by a dielectric substrate. The unetched side serves as a ground plane. Single mode planar filters, however, are of limited utility for most high performance microwave applications due to their typically high insertion loss and their impracticality for filter passbands of less than 5 \%. These filters have the drawbacks of relatively large size and high cost. A dual mode planar filter is provided comprising substantially planar, substantially square resonating rings having a pair of orthogonal resonating paths for conducting two modes of electromagnetic signals.

In this field of application microstrip dual-mode filtering [1], [2] is an interesting technique. Solutions appeared in the literatures [3], [4] demonstrated the validity of this approach and its appreciable superiority in comparison with conventional planar techniques (coupled lines, hairpin etc.). Miniaturized high performance narrowband microwave band pass filters are highly desirable for the next generation of satellite and mobile communications systems. To meet this demand, it seems that the dual-mode micro strip filter is one of the prospective candidates. This paper proposes a dual-mode micro strip square loop resonator for the design of compact microwave band pass filters. The Simulated electric field vector, magnetic field vector and vector $J$ of dual mode band pass filter are presented. A band pass filter composed of a proposed dual-mode micro strip square loop resonator was designed and fabricated.

2. Dual Mode Microstrip Square Loop Resonator Filter

In Fig. 1 the layout of a planar elliptic dual mode band depicted. A square loop consisting of four identical arms forms a basic resonator. The in-out coupling, the direct coupling and the cross-coupling between non-adjacent resonators are provided by proper interconnecting microstrip lines. A dual mode planar filter comprising planar square resonating ring, having a pair of orthogonal resonating paths for conducting two modes of electromagnetic signals. A small rectangular patch is attached to an inner corner of the loop for exciting and coupling a pair of degenerate modes (having the same propagation constant) to form a dual-mode resonator.

The dual-mode micro strip filter is composed of dual-mode micro strip resonators which are usually in the form of a ring, a disk or a square patch. These micro strip resonators can be treated as waveguide cavities with magnetic walls on the sides. The fields within the cavities can be expanded by the $TM_{2\text{-even}}$ modes, where $z$ is perpendicular to the ground plane. Thus, the resonators may also be referred to as 2-D resonators since a resonance can occur in either of two orthogonal co-ordinates. The circuit surface area needed to accommodate ring, disk and square patch resonators
may be estimated by, \( S_{\text{ring}} \approx \left( \frac{\lambda_{g0}}{\pi} \right)^2 \), \( S_{\text{disk}} \approx \left( \frac{1.84\lambda_{g0}}{\pi} \right)^2 \) and \( S_{\text{patch}} \approx \left( \frac{\lambda_{g0}}{2} \right)^2 \) respectively, where \( \lambda_{g0} \) is the guided wavelength at resonant frequency \( f_0 \), in the associated resonators. It is felt that these sizes are still too large for the design of high performance multi pole filters, especially at lower microwave frequency bands, such as L, S or C bands, which are used by many satellite and mobile communications systems. From an equivalent transmission line model for the proposed square loop resonator, it can be shown that the first resonance occurs when \( \frac{(a + b)}{2} = \frac{\lambda_{g0}}{4} \). The surface area occupied by the square loop resonator may be estimated by \( S_{\text{loop}} \approx \left( \frac{\lambda_{g0}}{4} \right)^2 \) if \((a - b)/2 << a\). Therefore, it is desirable to develop new types of dual-mode micro strip resonators not only for offering alternative designs but also for miniaturizing filters. This condition is easily satisfied at a lower frequency band. Thus, it can be seen that the square loop resonator requires the smallest circuit size compared to other 2-D resonators. The estimated size reduction has been confirmed by our experiments. This size reduction, more than 25% against the ring and more than 50% against the disk square patch resonators, can be significant, especially for those circuits and systems where the size reduction is important.

3. Dual Mode band pass Filter

To confirm the band pass characteristics and demonstrate the application of the proposed dual-mode micro strip square loop resonator, a two-pole band pass filter is designed and fabricated on a Glass epoxy substrate having a thickness of 1.6 mm and a relative dielectric constant of 4.2. The designed structure is enclosed within a metallic cavity having dimensions length, 82 mm, breadth, 82 mm, height, 25 mm respectively. Figure 2 shows the simulated transmission and return loss of the filter using Ansoft’s HFSS. The first resonance peak at 1.88 GHz, in the transmission plot corresponds to TE\(_{100}\) mode of the rectangular metallic cavity. A higher resonance observed at 2.63 GHz is due to the square microstrip ring. Figure 3 shows the frequency response measured using an Agilent ET 8714 A network analyzer. The measured transmission characteristics show good agreement with simulated results. The electric field vector pattern, magnetic field vector plots and J volume [A/m] vector field distribution of the excited resonant mode was computed using Ansoft’s HFSS and is plotted in figures 4, 5 and 6.

![Figure 1: Layout of the dual mode band pass filter.](image)

![Figure 2: Simulated \( S_{21} \) of dual mode band pass filter.](image)
field intensity plot clearly shows that the fields and current density is maximum along the feeding lines. Here the two poles located in the middle of the left and right arms and the two zeros located in the middle of the top and bottom arms can be distinguished. This mode corresponds to the TM\textsubscript{100} mode in a square patch resonator. If the excitation port is changed to port 2, the field pattern is rotated by 90° for the associated degenerate mode, which corresponds to the TM\textsubscript{010} mode in a square patch resonator. Dual mode band pass filter have 2.36 % band width at 2.619 GHz.

![Graph showing frequency response](image1)

**Figure 3:** shows the measured frequency response of dual transmission and return loss characteristics of dual mode filter.

![Simulated electric field vector](image2)

**Figure 4:** Simulated electric field vector \(E\) of mode band pass filter.

![Simulated magnetic field vector](image3)

**Figure 5:** Simulated magnetic field vector \(H\) of the filter.

![Simulated J volume vector field](image4)

**Figure 6:** Simulated J volume \([A/m]\) vector field distribution of dual mode band pass filter.

The minimum insertion loss is -4.6 dB. The square ring resonator circuits usually suffer from a high insertion loss. This is because simple gap structures at the input and output cannot achieve tight coupling and are sensitive to fabrication tolerance. The loss is also due to the inherent conductor loss. The overall performance of the filter can be further improved by optimizing the design. High out of band isolation is achieved due to locating the input and output ports in two different resonators. This realization can open the door for using high quality microwave filters in applications previously not possible because of high manufacturing cost of the earlier known realizations.
4. Conclusion

A new dual-mode micro strip square loop resonator structure has been reported. Dual mode band pass filter of this type with a 2.36 % band width at 2.619 GHz was designed and fabricated to demonstrate the application for designing miniaturized microwave filters. It is expected that the new dual-mode micro strip square loop resonator will be a very attractive structure for developing compact and high performance microwave band pass filters with fully planar fabrication techniques. This is especially of benefit to monolithic microwave integrated circuits (MMIC’s) and growing microwave superconductive circuits.

5. Acknowledgments

This work was sponsored by Department of Science and Technology, Ministry of Science and Technology, New Delhi, India. The authors thankfully acknowledge the financial support extended through DST SERC fast track project.

6. References


