Dual-Mode Microstrip Open-Loop Resonators and Filters

A report submitted towards the progress of project

by

Venkata Varunbabu Mannam

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RF & Microwave Engineering

Under the guidance of

Dr. Arijit De & Prof. Subrata Sanyal

Department of Electronics and Electrical Communication Engineering

Indian Institute of Technology Kharagpur

Kharagpur-721302, West Bengal, India

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ABSTRACT

A compact dual-mode microstrip open-loop resonator is presented for the design of compact, sharp-rejection and narrowband bandpass filter (BPF). The different characteristics of the dual-mode microstrip open-loop resonator are observed using full-wave electromagnetic simulations. From the simulation it is explained that two operating modes (even and odd modes) exist within a single dual-mode resonator. These two modes (currents are mutually exclusive in nature) do not couple each other and a finite transmission zero inherently associated with the even mode. Variation of parameters of dual-mode resonator loading element leads to asymmetric frequency response used for filter design. Multiple sections of resonator give the sharp rejection after the passband. Higher order filters are designed using non resonating nodes of the dual-mode resonator. The proposed geometry is simulated on two different substrates corresponding results are presented.

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1. Introduction

Microstrip filters have found wide applications in many RF/microwave circuits and systems [1]. In general, microstrip bandpass filters may be designed using single or dual-mode resonators. Dual-mode microstrip resonators are attractive because each dual-mode resonator can be used as a doubly tuned resonant circuit and, therefore, the number of resonators required for a given degree of filter is reduced by half, resulting in a compact filter configuration.

Today communication system requires mainly low insertion loss and high selectivity. Waveguide Cavities or dielectric resonator loaded cavities provides low insertion loss but leads to increment in size, weight and cost. For compact size planar structure is the better alternative, but leads to High conductor losses which are reduced by HTS materials. Open loop resonators are used for cross coupling filter design with compact size.

Types of open loop resonators:

1. Square loop
2. Circular ring
3. Circular disk
4. Square patches
5. Triangular patches.

In this paper, we present an investigation of a new type of miniature microstrip dual-mode resonator for filter applications. The proposed new dual-mode resonator is developed from a single-mode (operated) open-loop resonator [3]. The open-loop resonator is well known for its flexibility to design cross-coupled resonator filters, as well as its compact size, which amounts to $\lambda/8$ by $\lambda/8$, where λ is the guided wavelength at the fundamental resonant frequency. It will be shown that the proposed dual-mode open-loop resonator has a size that is the same as the single-mode open-loop resonator. Here we will show that the dual-mode open-loop resonator has some distinct characteristics, which are different from that of the conventional dual-mode loop resonator.

2. Design specifications

Design a narrow bandpass filter with low insertion loss and higher selectivity at upper side of the passband.

Filter specifications:

Center Frequency = 2GHz

Pass band: 1.95GHz to 2.05GHz, (i.e. Bandwidth = 100MHz)

Upper passband side selectivity = -70dB from 2.05GHz to 2.10GHz

Return loss is more than -15dB over the pass band.

Selected Substrates:

TMM10->dielectric constant 9.2, loss tangent 0.0022 and substrate height is 1.27mm on stripline configuration.

TFG ->dielectric constant 2.5, loss tangent 0.0009 and substrate height is 3.175mm on stripline configuration.

3. Single-mode open-loop resonator

When frequency selectivity and bandpass loss are considered to be the important filtering properties, then the optimum filters are those exhibiting ripple in both passband and stopband. Such a filter response can be realized using filter5 with cross couplings between nonadjacent resonators. These cross couplings give a number of alternative paths which a signal may take between the input and output ports. Depending on the phasing of the signals, the multipath effect may cause attenuation poles at finite frequencies or group delay flattening, or even both simultaneously. Usually Semi open configuration and inhomogeneous dielectric medium of coupling structure, leads to characterize the coupling in terms of its resonant mode splitting.

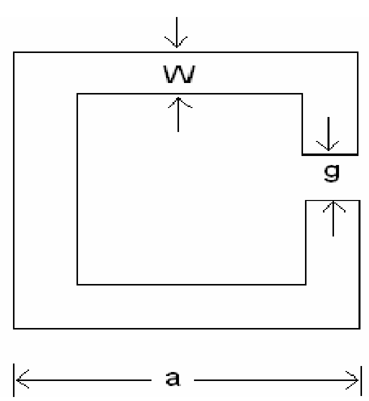

Figure1. Single-mode open-loop square resonator [1]

One difficulty in realizing the cross-coupled microwave filters in the planar structures is to identify and control the required electric and magnetic couplings for the nonadjacent resonators. Several new cross-coupled planar filter structures have been proposed recently, including the microstrip dual-mode filters. Different orientation of identical microstrip open loop resonators are separated by‘s’ and offset by‘d’ leads to coupling structure. Three types of coupling takes place Electric coupling, Magnetic coupling and Mixed coupling.

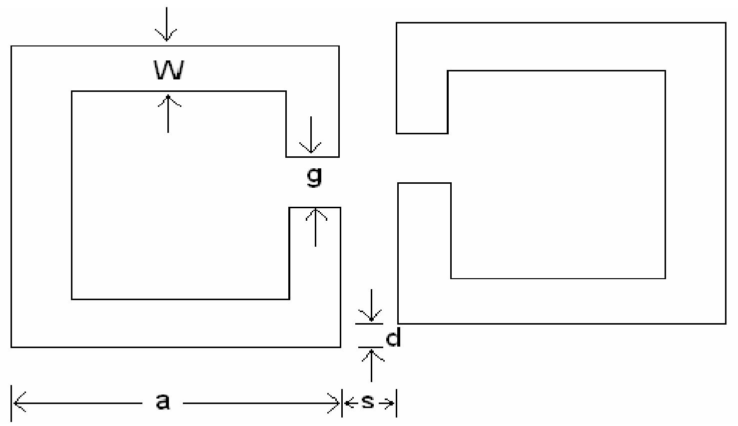

Figure2. Electrical coupling between two single-mode resonators [1].

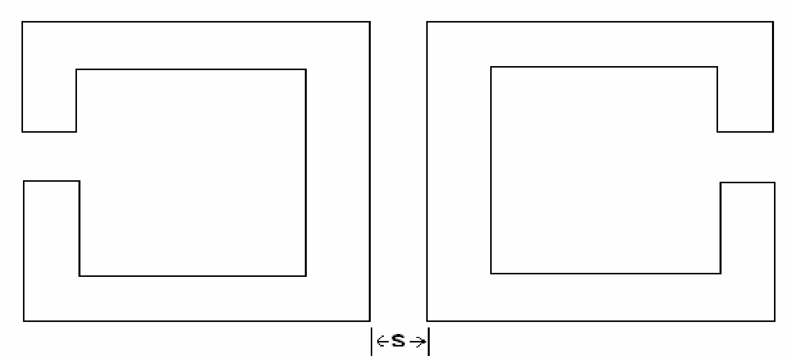

Figure3. Magnetic coupling of single-mode resonators separated by distance‘s’ [1].

Figure4. Mixed coupling of single-mode resonators separated by distance‘s’ [1].

4. Dual-mode open-loop resonator

Each single-mode resonator is equal to an LC circuit, which produces a pole at the resonance frequency. But in order to design a filter with sharp rejection no of single-mode resonators are to be connected in cascade structures and this leads to increase in size of the filter. Each Dual mode resonator is a doubly tuned resonant circuit. So no of resonators for a given degree of filter is reduces by half. Here proposed design has the same size as single mode resonator with the help of *loading element* leads to compact in size. A loading element with a variable parameter 'W' is tapped from inside onto the open loop.

Characteristics:

Change of width of loading element 'W' leads to mode splitting. Two modes exists odd mode and even mode. The resonance frequency which is not affected by change of width of loading element is called odd-mode. The resonance frequency which is affected by change of width of loading element is called even-mode.

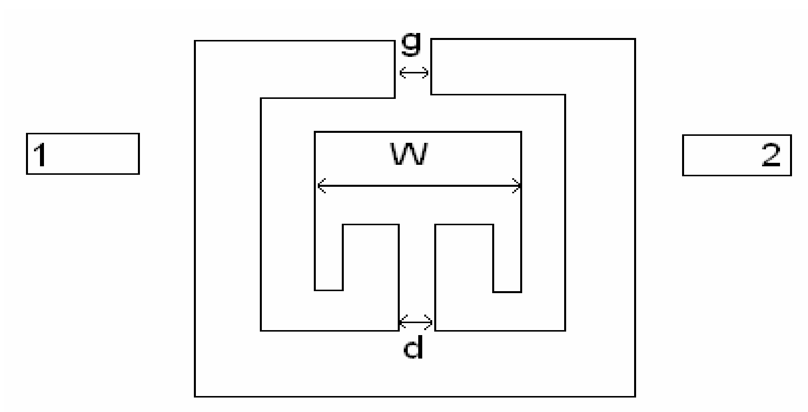

Figure5. Dual mode open-loop square resonator [2].

Here the effect of the loading element is shown in figure below with different W values on the microstrip dual mode open-loop square resonator on TMM10 substrate having dielectric constant of 10.8 with substrate height of 1.27mm.

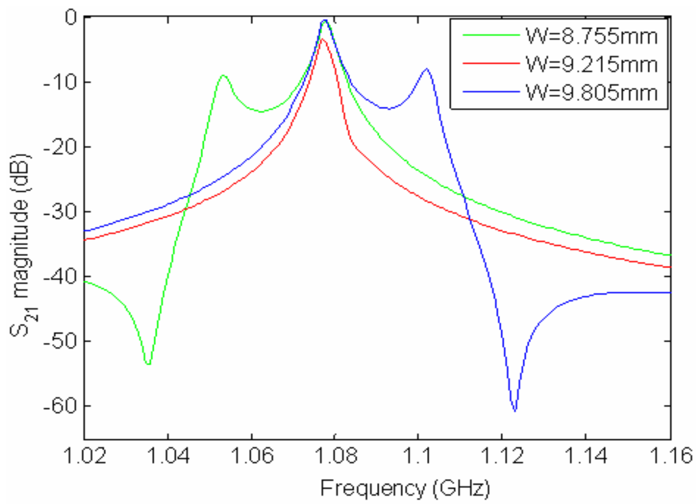

Figure6. Modal resonant characteristics of the proposed dual-mode microstrip open-loop resonator for g=0.9 mm and d=1.1 mm.

Odd mode exhibits the same characteristics that of single mode resonator, since in the odd mode at the tapping point its short circuit. So the loading element does not contribute any coupling here. Hence the odd mode resonance frequency is dependent only on square open-loop parameters (i.e. length of resonator (a), width of resonator (w) and gap of open loop (g)). But in the even mode it causes the resonant frequency with varying the width of loading element (‘W’), and width of tapping element (d). Diagrams shows here the variation of even mode resonant frequency with ‘W’and‘d’.

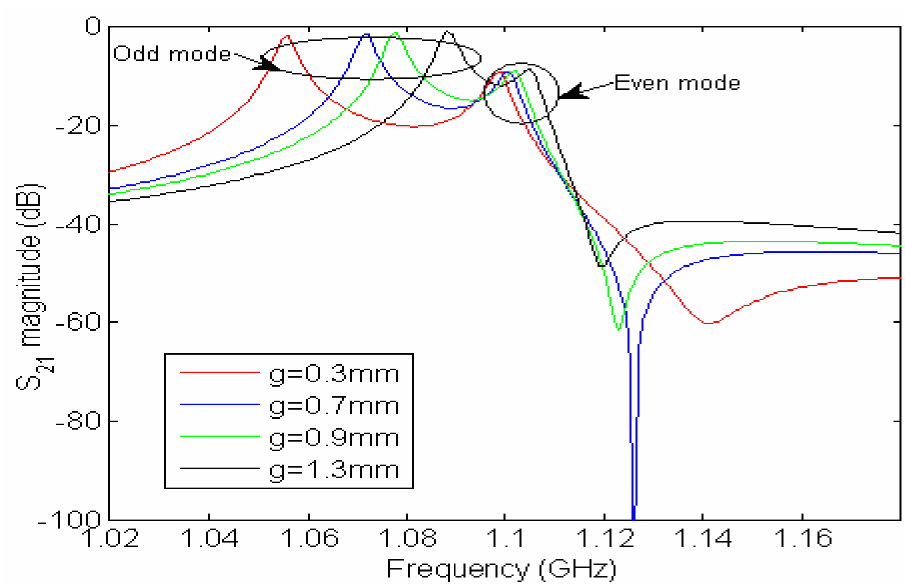

Figure7. g-dependance of modal resonant characteristics of the proposed dual-mode microstrip open-loop resonator for W = 9.805 mm and d = 1.1 mm.

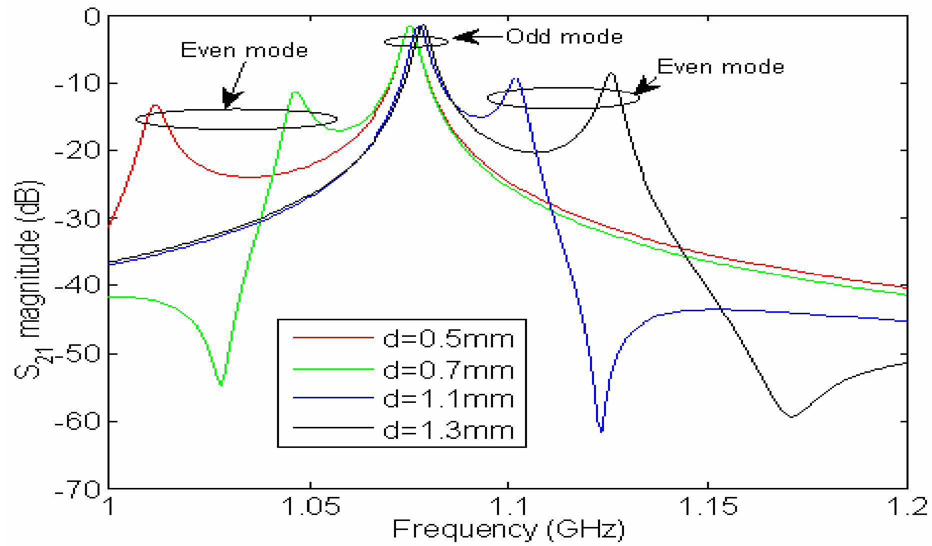

Figure7. d-dependance of modal resonant characteristics of the proposed dual-mode microstrip open-loop resonator for W = 9.805 mm and g = 0.9 mm.

To excite the resonator, weakly coupled ports are used. For a single value of ‘W’ the two modes exhibits same resonance frequency. As ‘W’ increases/decreases, the two modes split. Smaller ‘W’, shifts resonance frequency of even mode to right. Larger ‘W’, shifts resonance frequency of even mode to left. Due to short circuit at tapped point no charge or current in the odd mode case in the loading element, and maximum current in the even mode case in loading element. There is a finite frequency transmission zero as the modes split. Transmission zero is on right side if even mode frequency is more than odd mode frequency and on left side if odd mode frequency is more than even mode frequency.

Properties of dual-mode resonator:

The transmission zero is related to the even mode case only. There are 2 properties of dual-mode resonator.

1. It exhibits a transmission zero for filter design of asymmetric response.

2. Two modes are not coupled to each other even after they split.

From the theory of asynchronous tuned coupled resonator, two split mode frequencies are equal to two self resonant frequencies and no coupling between these two resonators. To find these separate frequencies response place a magnetic/electric wall along the line of symmetry leads to two self resonant frequencies. To design a filter one need to allocate the modal frequencies in the passband.

5. Filter Design procedure using dual-mode resonator:

For the given substrate find the guided wavelength using center frequency of the required filter. Here side of square open-loop resonator is one eighth of guided wavelength. Then adjust the gap such that it odd mode resonance frequency is equal to the given center frequency. Size of the loading element controls the capacitive loading, so as to change the even mode resonance frequency. Using ‘W’and‘d’ place the even mode resonance frequency in the passband so as the transmission zero is in the stopband. Place no of sections to get sharp roll-off. Give the coupled-line coupling for the ports instead of tapered line coupling.

6. Results

For the TMM10 material on the stripline design with single, double and four sections connected using non resonating nodes and using coupled line coupling.

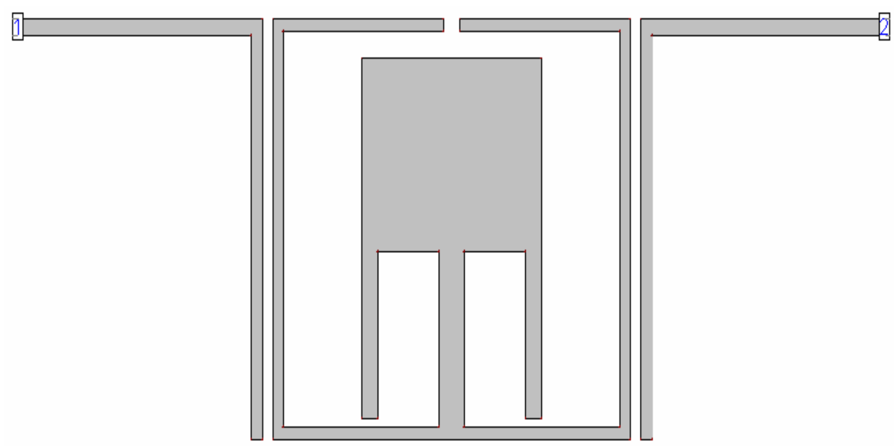

Figure8. Single section open loop resonator strip line design on TMM10 substrate [2].

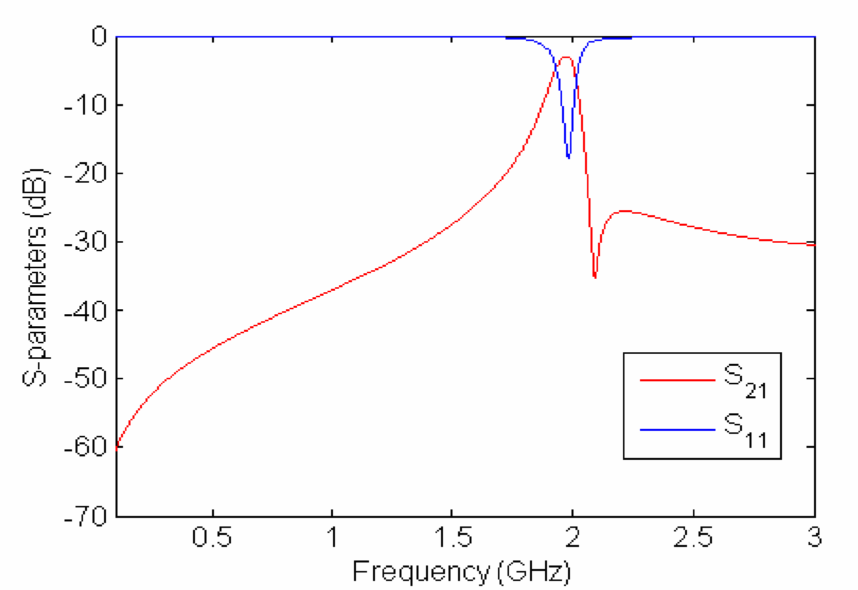

Figure9. Frequency response of single section open-loop resonator on TMM10 substrate.

Double section:

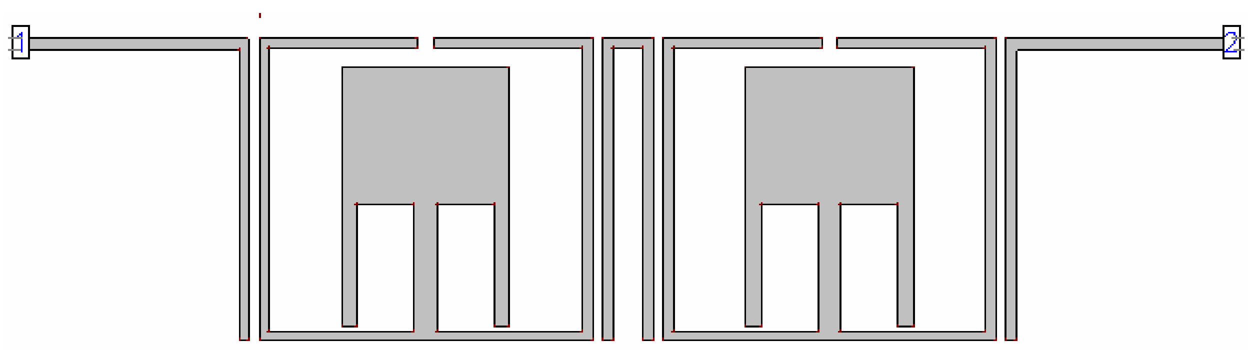

Figure10. Open loop resonator strip line design on TMM10 substrate for double section.

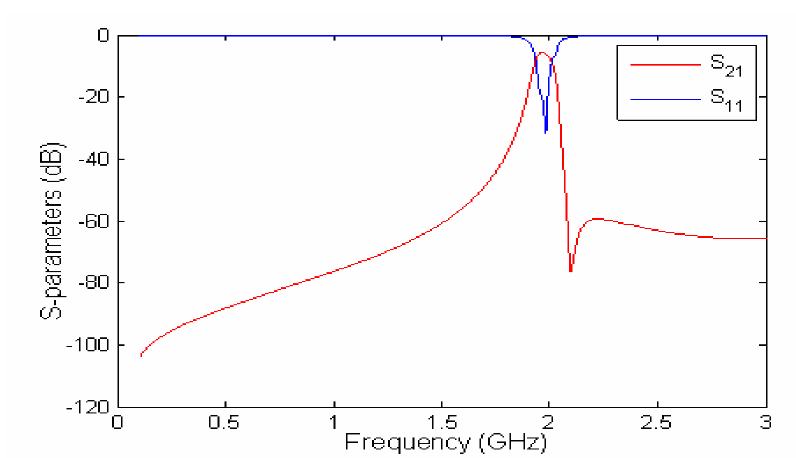

Figure11. Frequency response of double section open-loop resonator on TMM10 substrate.

4-sections dual mode resonator:

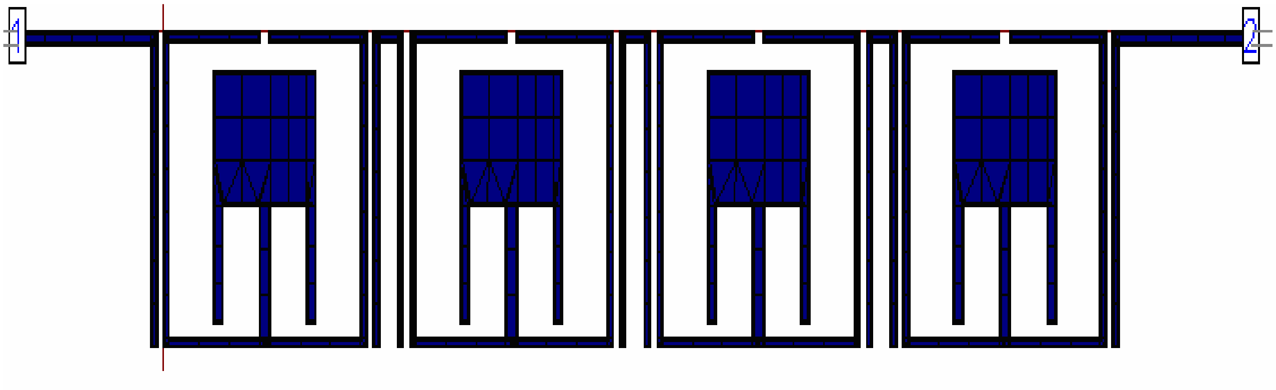

Figure12. Open loop resonator strip line design on TMM10 substrate for quadra section.

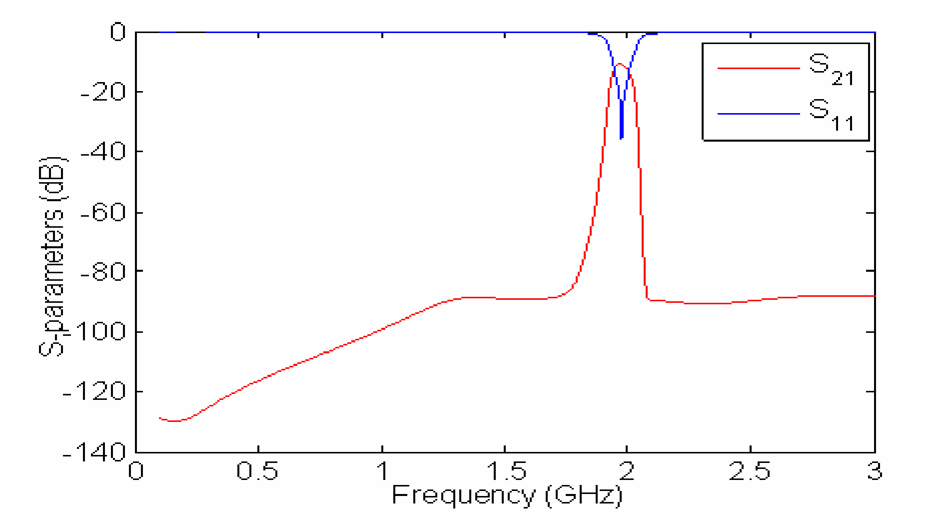

Figure13. Frequency response of four-section open-loop resonator on TMM10 substrate.

Discussions:

From the figure 13, Insertion loss in pass band at f=1.97 GHz value is -11.07 dB.

Frequency band separation between the pass band and stop band

At f=2.05 GHz is -52.87 dB.

At f=2.10 GHz is -92.20 dB.

At f=2.08 GHz is -98.80 dB.

87 dB isolation is achieved between 1.97 GHz and 2.08GHz.

40.6 dB isolation is achieved between 2.05 GHz and 2.10GHz.

The filter roll-off rate = 790 dB/GHz on the upper side of the pass band.

Return loss in pass band better than -18 dB

Upper Band Rejection- insertion loss >-80 dB from 2.08 GHz to 3 GHz.

Design on TFG Substrate:

For the TFG material on the stripline design with single, double and four sections of dual mode open-loop resonator are connecting using non resonating nodes with coupled line coupling.

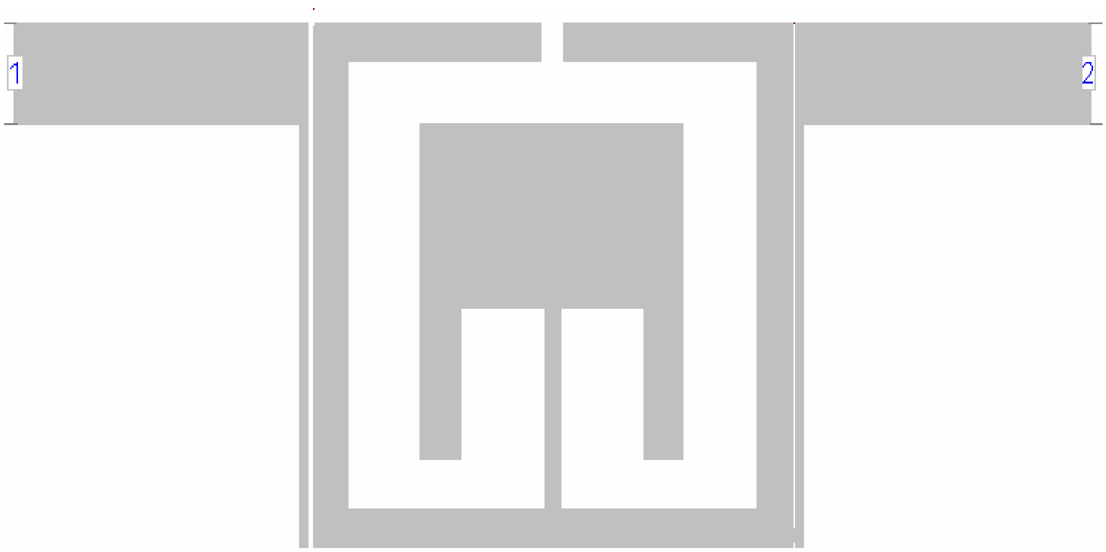

Figure14. Single section open loop resonator strip line design on TFG substrate [2].

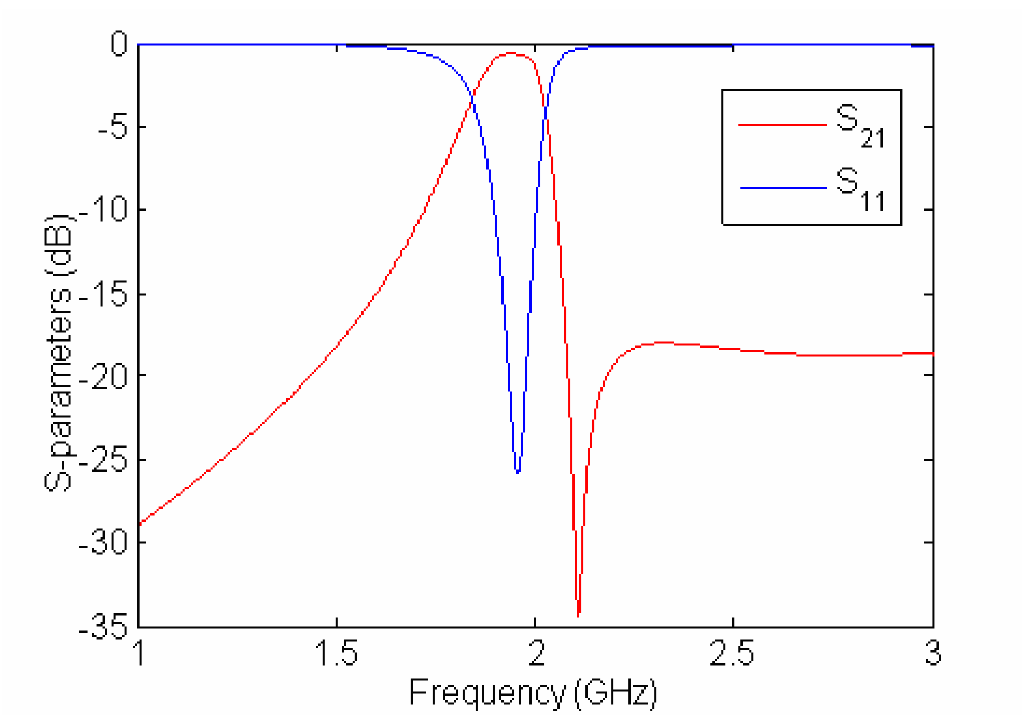

Figure15. Frequency response of single section open-loop resonator on TFG substrate.

Double section:

Figure16. Double section open-loop resonator using stripline design on TFG substrate.

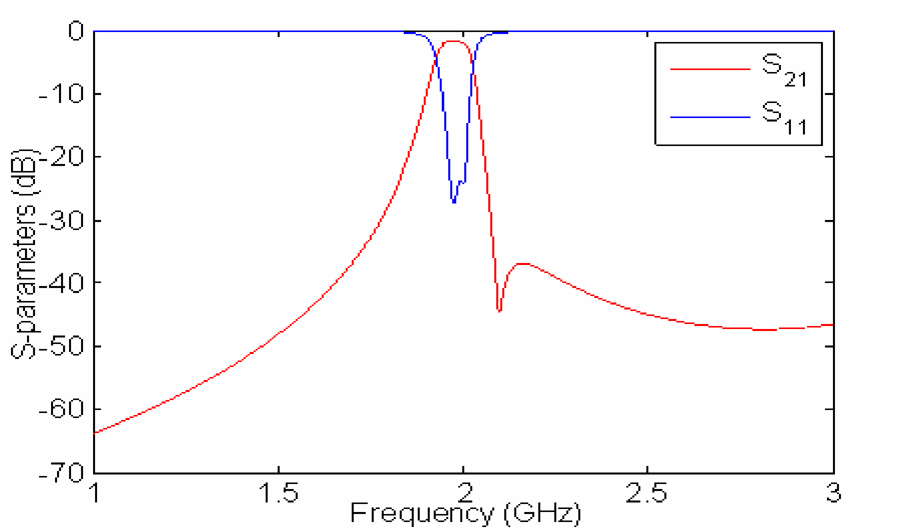

Figure17. Frequency response of double section open-loop resonator on TFG substrate.

4-section open-loop resonator:

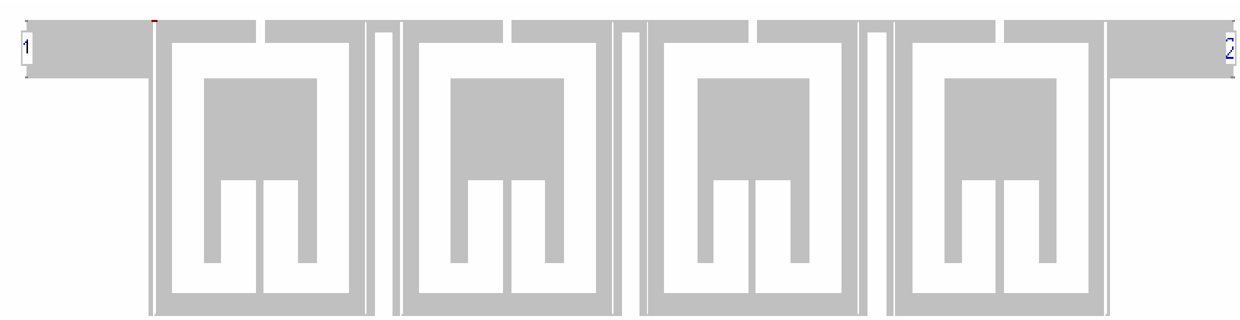

Figure18. Four section open loop resonator strip line design on TFG substrate.

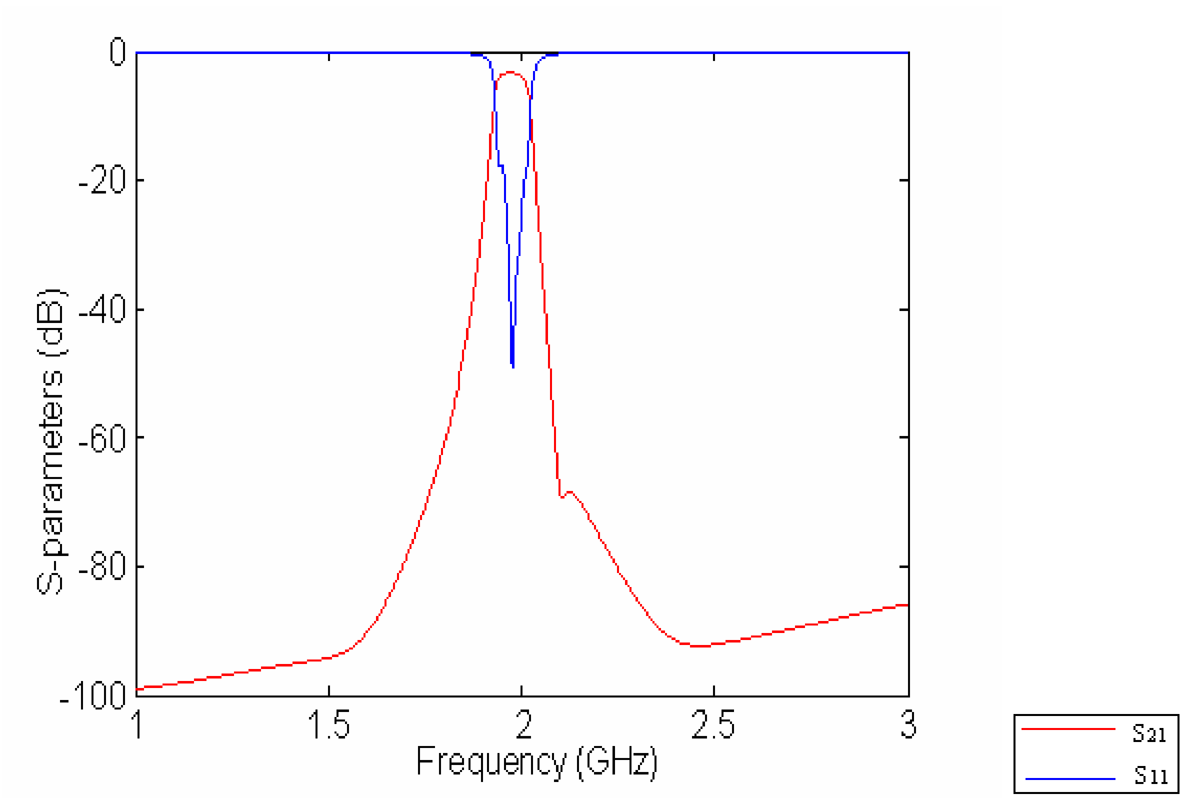

Figure19. Frequency response of four-section open-loop resonator on TFG substrate.

Discussions:

From the figure 19, Insertion loss in pass band is at f=2 GHz value -3.82 dB.

Frequency band separation between the pass band and stop band

At f=2.05 GHz is -29.26 dB.

At f=2.10 GHz is -66.41 dB.

At f=2.11 GHz is -73.36 dB.

70dB isolation is achieved between 2.00 GHz and 2.11GHz.

37.1dB isolation is achieved between 2.05 GHz and 2.10GHz.

The filter roll-off rate = 636 dB/GHz on the upper side of the pass band.

Return loss in pass band is more than -18dB.

Passband frequencies f1=1.95 GHz and f2= 2.02GHz.

Upper Band Rejection is insertion loss >=-70 dB from 2.11 GHz to 3 GHz.

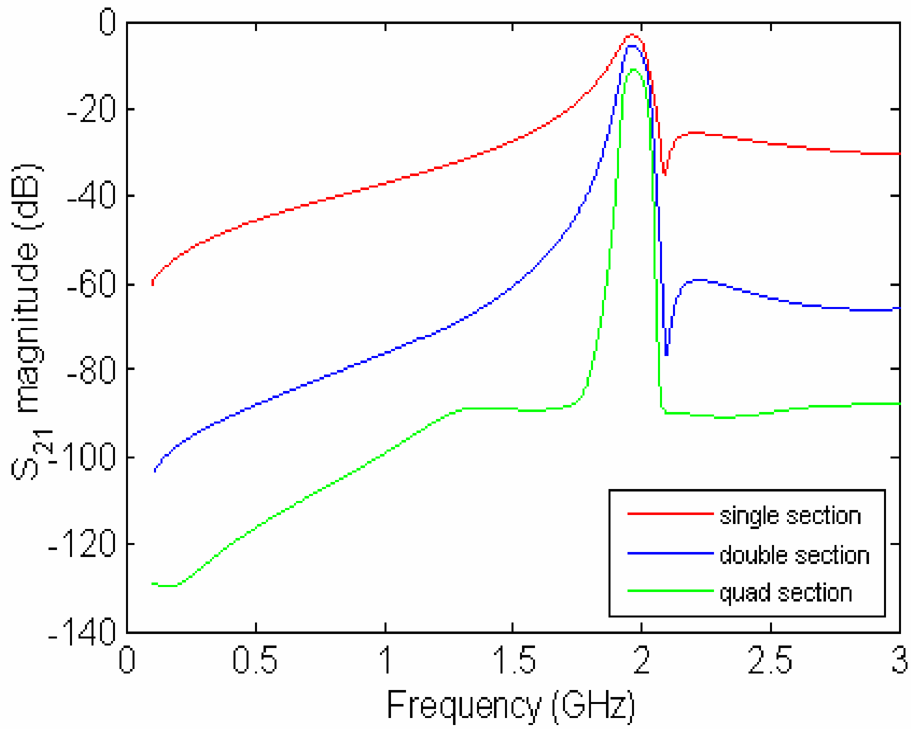

Figure20. Frequency response of single, double and four-section open-loop resonator on TMM10 substrate.

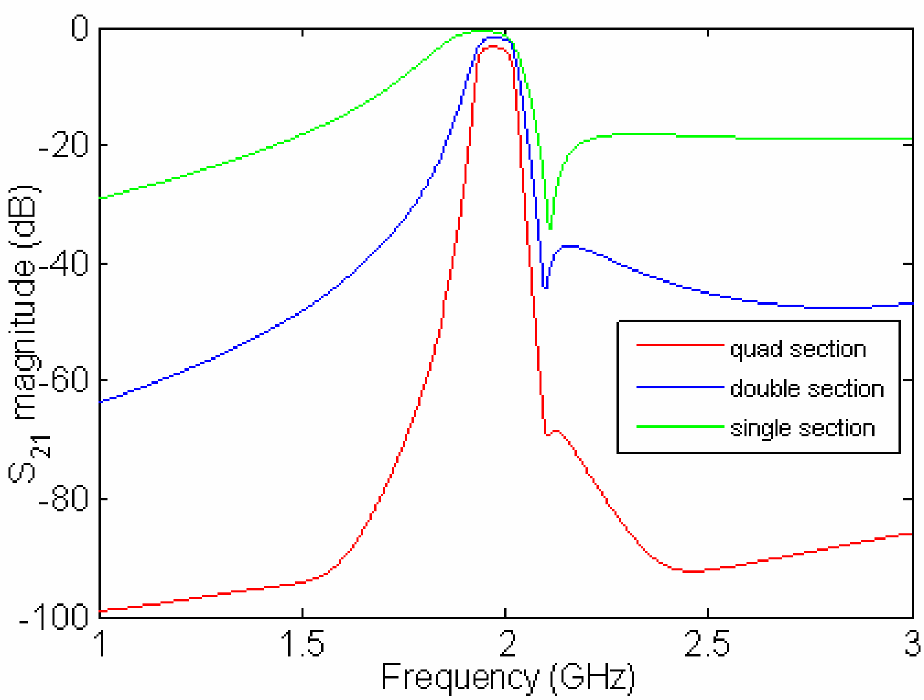

Figure21. Frequency response of single, double and four-section open-loop resonator on TFG substrate.

Comparison of quadra section stripline design on different substrates:

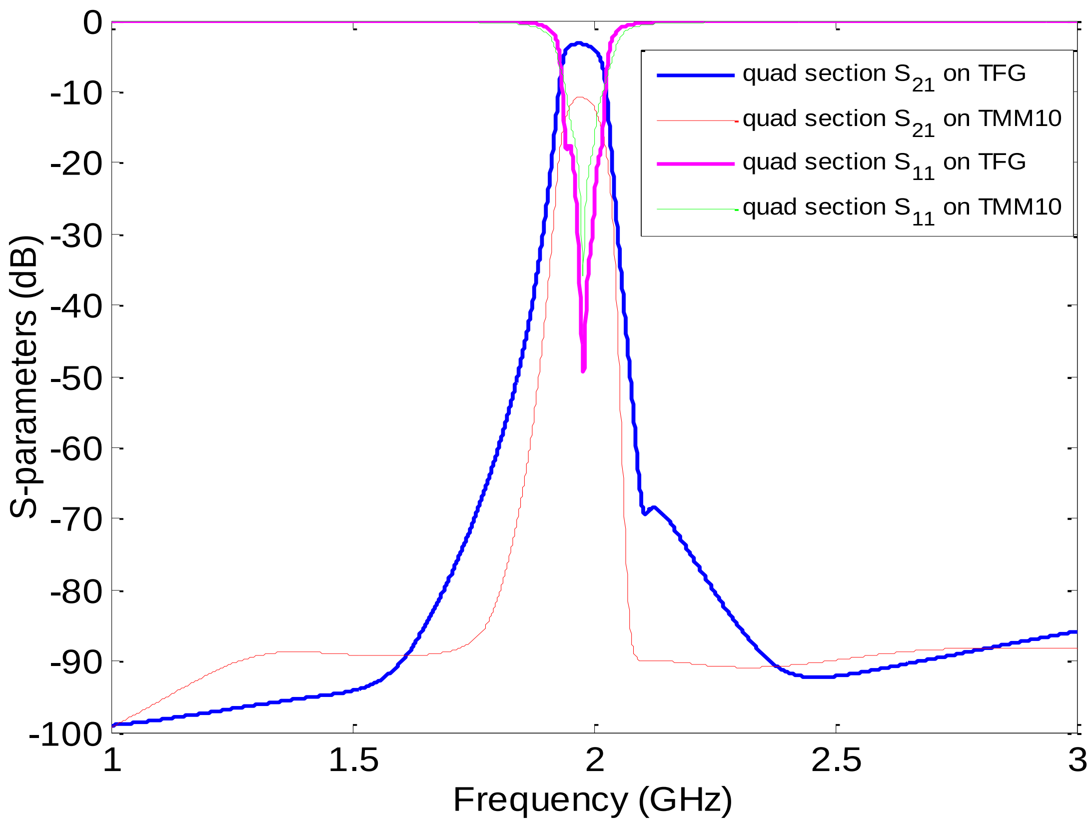

Figure22. Frequency response of 4 section resonator on TFG and TMM10 substrate.

7. Future work:

1. To verify the above results with measured data.
2. Any another structure leads to compact size and produce improved insertion loss in pass-band for the given design problem.

8. Acknowledgement:

I would like to thank Ph.D students Vamsi Krishna Velidi and K.Divyabramham of the Department of Electronics and Electrical Communication Engineering, Indian Institute of Technology Kharagpur, India, for their valuable suggestions.

9. References:

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