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Reconfigurable Band Stop Filter for Bandwidth Control in Imt-Advanced

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ABSTRACT

A novel reconfigurable microstrip band stop filter (BSF) for International Mobile Telecommunication-Advanced (IMT-A) application is proposed in this paper. The propoed square ring microstrip structure with direct coupled feed provides inependent control over frequency and band width. The filter has been designed provide a BW (Bandwidth) variation of 23 MHz to 146 MHz, further square ring reconfigurable filter for seven distinct BW states has been fabricated Which has been experimentally verified. The measured results are in good agreement with simulated results.

Index Terms - Reconfigurable filter, International Mobile Telecommunication-Advanced (IMT-A), Band stop filter, Comb-tooth structure, Bandwidth control

1. INTRODUCTION

The reconfigurable microstrip filters are essential component for transmitter and receiver front end for improving the capability of both current as well as future wireless communication system. The BSFs used now a days are very much useful in minimizing the interferences, by rejecting the suitable portion of the available spectrum.

The research in reconfigurable BSF filter design can be divided into two major directions of, frequency control and bandwidth control. A large number of BSFs have been investigated to control the center frequency. Varactor diode as a tuning technique is reported in [1-3]. These filters provide frequency tuning without BW control. The frequency tuning can also be achieved by ferromagnetic or piezoelectric materials which are controlled by electric signals as discussed in [6-7]. Frequency tuning using magnetic layers which are reactive to the magnetic signals are reported in [8-9]. [10-11] Explains respectively about the use of actuator and DGS for frequency tuning. The main reason behind the center frequency variation is the variation in the transmission line length or electrical length of the filter resonator which is explained in [12]. This has been achieved in continuous way by the help of varactor diodes or in discrete steps by the use of pin diode as explained in [2, 13]. A very less effort has been made on BW control for reconfigurable BSF due to lack of the availability of methods to vary the inter resonator coupling. In fact, controlling the bandwidth independently from central frequency and vice versa is very difficult to achieve with the help of the available distributed topologies such as coupled line filters for narrow band applications, or the stub filters for medium and wide band applications as given in [12]. However there are some research contributions to control the bandwidth, which are with both tunable frequency and fixed center frequency as reported in [14-18].

The BSF consisting of anti-coupled line, short circuited by an open low impedance line has been reported in [14], the filter is showing narrow stopband at frequency 1.0 GHz and wide stop band of BW 2.9 GHz centered at 2.5 GHz. The switching between the connections has been done by the use of pin diode. A bandwidth reconfigurable BSF has been reported in [15], where the BW re configurability is achieved by modifying the connection between the unit cells. The filter shows the BW shift of 92.0 MHz to 63.0 MHz at different center frequencies. In [16], the varactor diode has been used to vary the stop band of the filter by varying the capacitive coupling. The filter shows the fractional bandwidth (FBW) variation of, 11.51 – 15.46% at center frequency, 1.46 GHz. The insertion loss is also varying with the bandwidth. The BSF consisting of evanescent mode presented in [17] shows bandwidth variation from 50.1 MHz at 40 dB equi-ripple response to 126.2 MHz at 20 dB equi- ripple response through electronic tuning of the resonant frequencies of the individual resonators. In [18] the BW tuning has been achieved by differentially two varactors attached at opposite ends of the resonator. A BW tuning of 70-140 MHz has been achieved by this filter. The BW variation in Band pass filter by varying the coupling capacitance has been discussed in [19]. where comb tooth structure has been used to vary the coupling capacitance, a fractional bandwidth variation of 0.85 to 6.48 % at center frequency of 3.5 GHz has been achieved by the method used in the paper.

The proposed band stop filter is exclusively designed for the application in International Mobile Telecommunications – Advanced. The proposed filter is novel in the sense of providing the independent control over center frequency and BW for IMT-A application. The dimension of the proposed filter is 21.5 x 21.5 mm^2. The effect of variation in the resonator dimension has been used for frequency variation while the comb-tooth structure [19] has been used for BW control. A BW variation of 23.0 to 146.0 MHz at center frequency of 3.5 GHz has been observed, which is suitable for IMT-A applications as was discussed in [20].

The paper is divided into six sections. Section II describes BSF design concept. Section III presents advancement in the BSF design to make it reconfigurable. Section IV discusses the filter implementation while Section V presents the experimental verification for the proposed work. Finally an overall conclusion of this work is reported in section VI.

2. BANDSTOP FILTER DESIGN

The prototype of proposed square ring reconfigurable BSF is based on the circuital model as shown in Fig. 1.

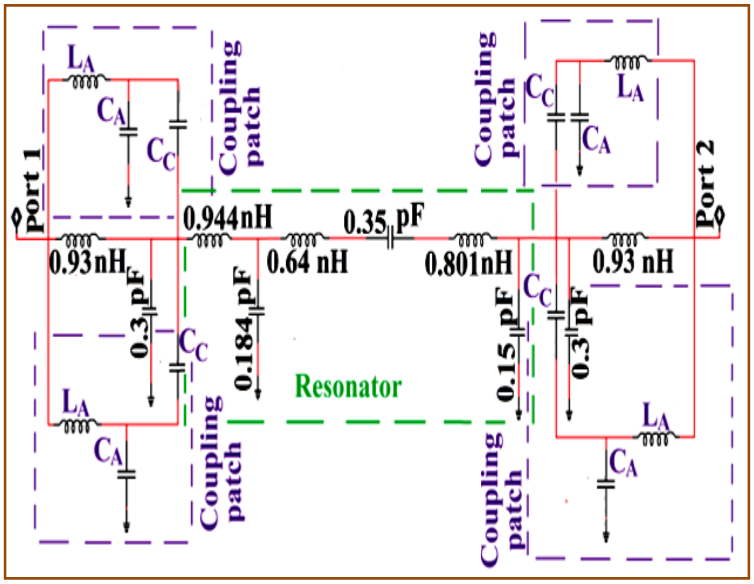

Fig.1. Circuital model of proposed BSF

In the broader sense the design can be divided into two major components, first the Square ring resonator and second the feed sections. Varying the design parameters of both the sections will provide frequency and bandwidth control respectively.

Frequency control

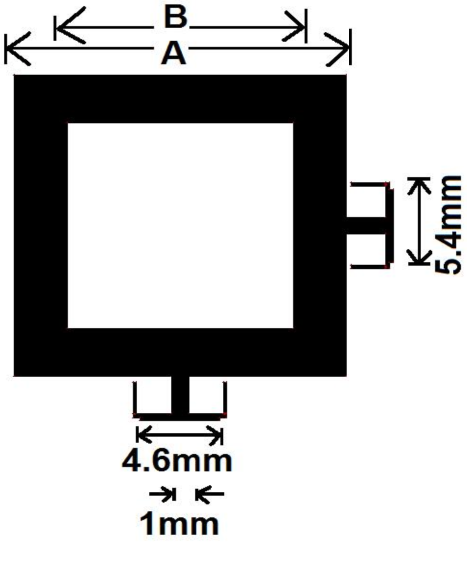

Fig. 2 : The basic layout model for frequency control

The basic layout model for frequency control is shown in Fig. 2. In the diagram the outer dimension and inner dimension is represented by A and B respectively. The ring structure appears by removing a portion of metal from the center of patch turning it into an annular ring.

It has been observed by comparing the ring structure with equal sized solid rectangular patch that the ring structure forces the current to take longer path and decreases the frequency of operation . This verifies the concept discussed in [21] . This concept has been used in this work for frequency control. Effect of ring width variation has been shown in fig 3 and 4 and has been tabulated in Table-1

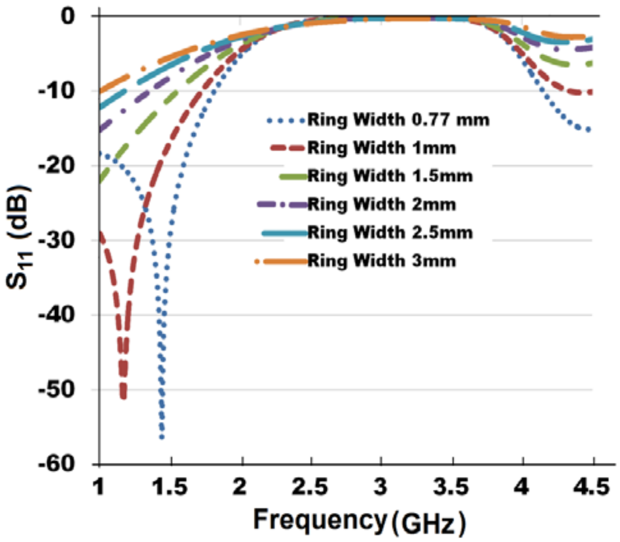

Fig.3 : Reflection Loss in dB vs Frequency in GHz plot for BSF shown in fig. 2

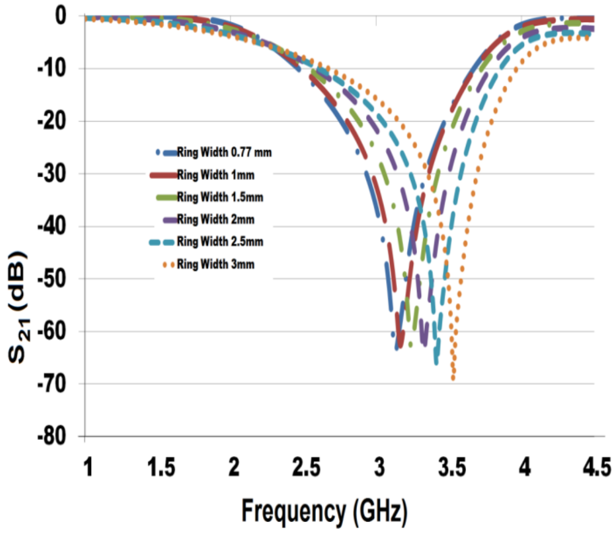

Fig 4 :Insertion loss in dB vs Frequency in GHz plot for BSF shown in fig. 2

Table 1: Summarized outcome for the filter shown in fig. 2

RingWidth (MM)	f_0 (GHz)	S_{21} (dB)	S_{11} (dB))	BW(MHz) (at -50dB)
0.77	3.1	63.9	0	119
1	3.1	-62.4	0	112
1.5	3.24	63.0	0	105
2	3.31	-64.0	0	100
2.5	3.42	-67.7	0	98
3	3.52	-70.0	0	83

Bandwidth control

The layout model for bandwidth control is shown in fig. 5. From the above discussion we have selected proper ring arrangement such that we may have outcome at frequency 3.5 GHz . in the design The feed sections are associated with additional patches of variable width 'W'. For the proposed design these additional patches are called as coupling patches. Both the feed sections have two coupling patches, one on the upper side and other on the lower side of the feed.

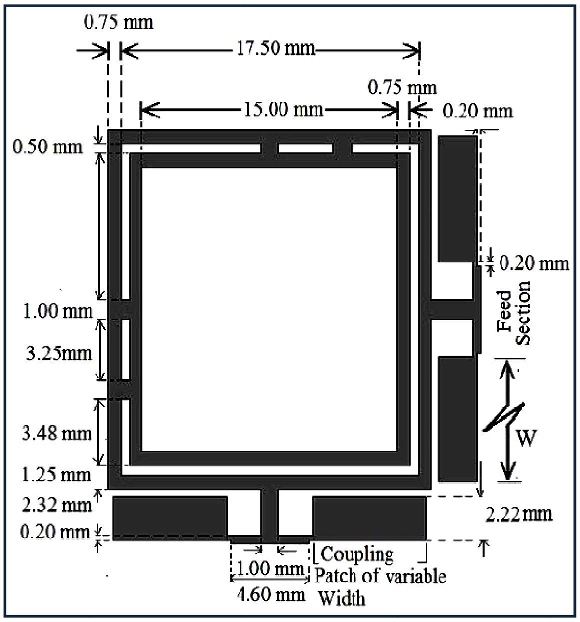

Fig.5. Layout of the BSF with coupling patch of variable width.

The proposed filter is symmetrical in shape. The direct couple technique has been used for exciting the resonator. The variation in width ‘W’ of coupling patches provide variation in coupling capacitance between the resonator and the coupling patches.

In Fig. 1, L_A and C_A represent the equivalent inductance and capacitance which are variable in nature and provide equivalent effect as coupling patch of variable width ‘W’. The variable coupling effect between the resonator and the coupling patch is denoted by equivalent coupling capacitance C_C. Due to variation in coupling capacitance between the input/output feed and the resonator, variation in BW is achieved. The outcome obtained from Ansoft Designer of equivalent circuital model is shown in Fig. 6. For L_A= 1 nH, C_A= 0.8 pF and C_C = 0.4 pF.

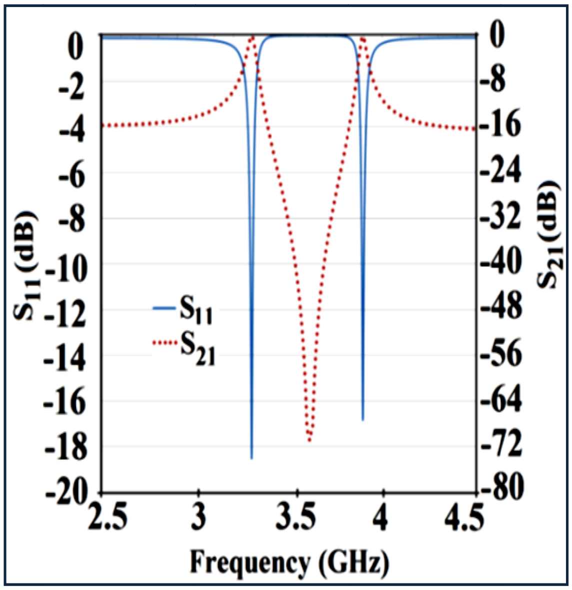

Fig.6. S-Parameters vs. frequency response of circuital model of BSF shown in fig. 1

Zeland, IE3D and Ansoft Designer simulation tool has been used for simulation. The analysis of the effects of variation in width ‘W,’ of the coupling patches has been shown in Figs. 7 and 8, and summarized in Table 1. The objective of the work is to design a BSF especially for IMT-A which requires a BW variation of 20-100 MHz The minimum BW of 21 MHz has been obtained for patch width ‘W’ equal to 0.20 mm for S_{21} at 26.2dB. Therefore to observe the bandwidth variation, the comparison of BW has been done at S_{21}, -26.2dB.

It has been observed that by varying the width of the special patch, the BW of the filter varies. Therefore it can be observed that variations in the width of all the four special patches are responsible for the BW control.

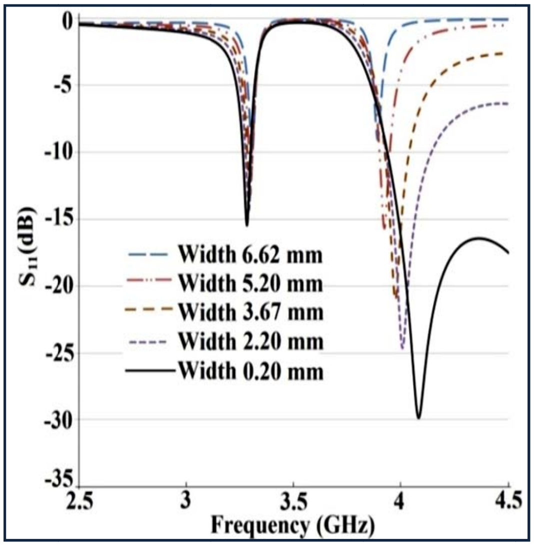

Fig.7 Simulated reflection loss v/s frequency plot for the filter shown in fig. 5.

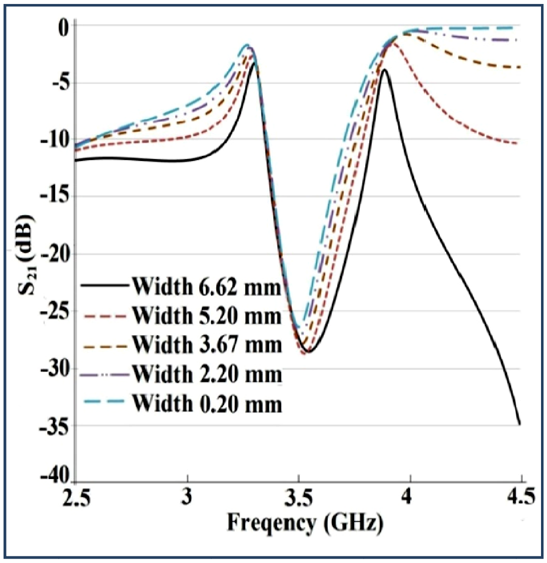

Fig.8. Simulated insertion loss v/s frequency plot for the filter shown in fig. 5.

Table 2: Summarized outcome for the filter shown in fig. 5

Width **’W‘** (MM)	f_0 (GHz)	S_{11} (MHz)	S_{21} (MHz)	BW(MHz) (at -26.2dB)
0.20	3.500	-0.31	-26.38	21
2.20	3.510	-0.226	-27.027	53.
3.67	3.514	-0.169	-27.797	80.

5.20	3.525	-0.0997	-28.678	113.
6.62	3.531	-0.0499	-28.514	143.

From Table 2, following inference has been observed, which are used to develop the proposed reconfigurable ring patch BSF.

1. Increasing W increases FBW.
2. Increasing W improves stopband reflection loss.
3. Increasing W improves stopband insertion loss.
4. Center frequency and attenuation was not effected much, by varying W.

3. RECONFIGURABLE BANDSTOP FILTER

The coupling patches of variable width 'W' are divided into small sections which results in a comb-tooth structure as shown in Fig 11. The proposed structure has seven teeth, denoted as A, B, C, D, E, F, and G.

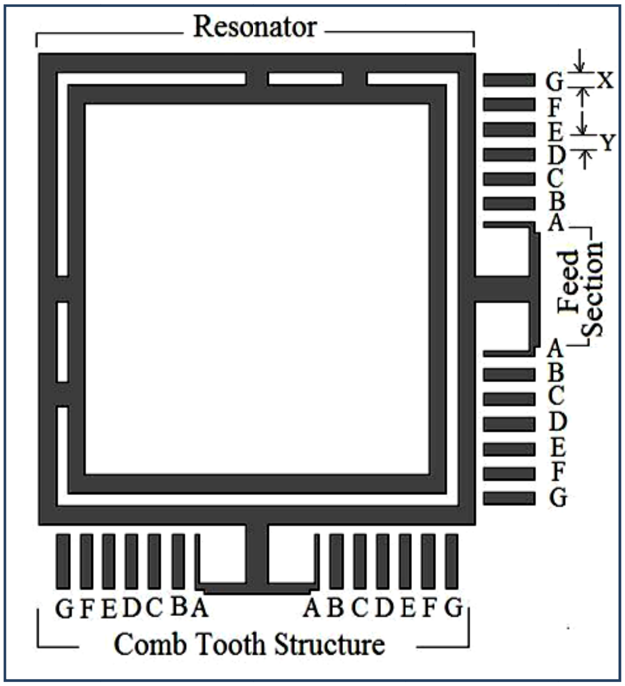

Fig. 9: Proposed reconfigurable BSF

Each tooth has width 'X' except tooth A, whose width is 0.2 mm. The spacing between the two consecutive teeth is 'Y'. The amount of BW variation as well as the minimum and maximum BW depends on the values of 'X' and 'Y'. Thus the values of 'X' and 'Y' must be chosen on the basis of application requirement. In the reported design, the values of 'X' and 'Y' are taken to be 0.5 mm each.

4. DESIGN IMPLEMETAION

This section describes the filter layout including the method to connect teeth. The filter is built on Rogers RT/duroid 5870 material, having a dielectric constant,(ε_r), 2.33, loss tangent, tan(δ), 0.02 and thickness, (t), 1.57 mm.

The reconfigurability of filter can be achieved by using pin diodes or the RF MEMS switch. However to simplify the fabrication, shorting point method has been used. For connecting teeth, thin copper wires of diameter, 0.20 mm were used. On the basis of the design, seven combinations of teeth connections are possible, as summarized below in Table 3

Table 3: Tooth Combination

Case	Connection Combination
1.	No Teeth are connected together
2.	Tooth A and B are connected together
3.	Tooth A, B and C are connected together.
4.	Tooth A, B, C and D are connected together
5.	Tooth A, B, C, D and E are connected together
6.	Tooth A, B, C, D, E and F are connected together
7.	Tooth A, B, C, D, E, F and G are connected together

The symmetry of the design is always maintained. The layout detail of the filter is shown in Fig. 9. Seven different cases of the combinations are listed in Table 3. In order to connect any of the two teeth both the teeth need to be shorted. The BW variations were observed only when any of the teeth were connected to tooth A which is directly connected to the feed.

The simulated result, for seven cases listed in Table 2 is shown in Figs. 10. and 11.

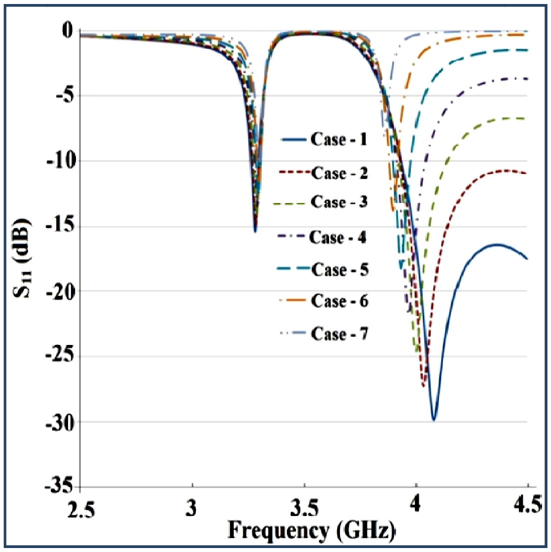

Fig.10. Simulated reflection loss v/s frequency plot for the filter shown in fig. 8.

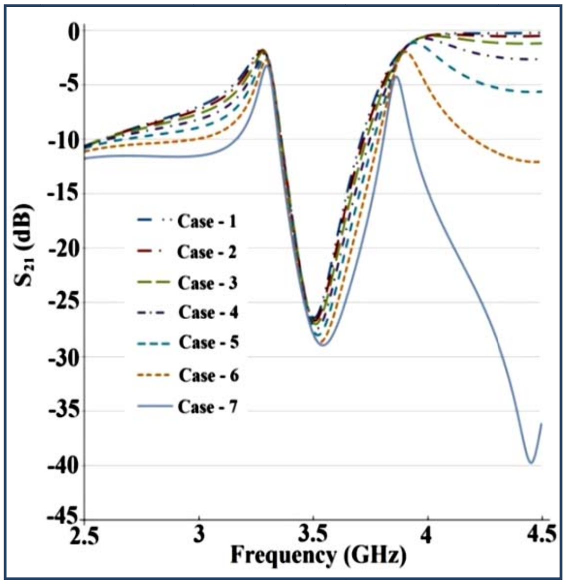

Fig.11. Simulated reflection loss v/s frequency plot for the filter shown in fig. 8.

Figs10 and 11 respectively shows the reflection loss and insertion loss characteristics of the BSF for different tooth connections. The minimum BW of 23 MHz has been obtained for case 1 with stopband insertion loss, -26.37 dB, stopband reflection loss, -0.30dB at center frequency of 3.508 GHz. The maximum BW has been obtained for case 7 with BW of 146 MHz, stopband insertion loss of -28.93 dB, stopand reflection loss, -0.05 dB at center frequency 3.541 GHz.

The prototype of the proposed filter is shown in Fig. 12. However in this figure shorting of tooth has not been shown for clarity in the figure.

5. EXPERIMENTAL VERIFICATION

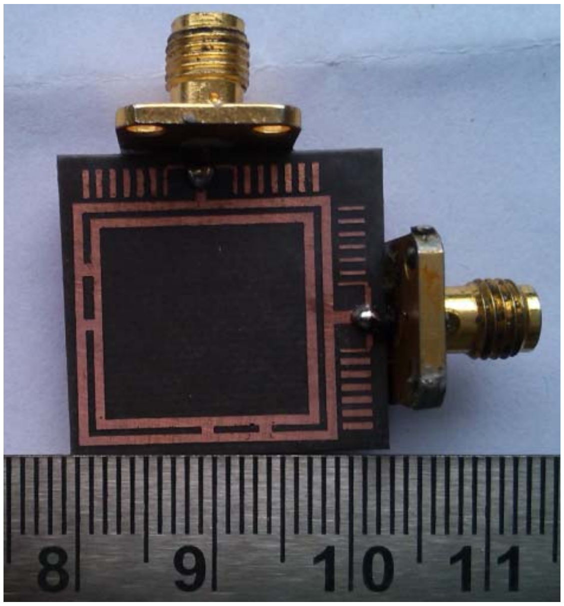

Fig.12. Prototype of proposed bandstop filter

This section reports various measurement results for the proposed filter. A Vector Network Analyzer (VNA) has been used for the measurement of the parameters for the fabricated prototype. The simulated and the experimental results are summarized in Table 4.

Table 4: Comparative simulated and measured results for proposed filter

Analysis	*Case*	*f_0* (GHz)	S_{11} (dB)	S_{21} (dB)	BW (MHz)at -26.2dB
Simulated	1.	3.508	-0.30	-26.37	23
Measured		-3.514	-0.26	-26.22	14
Simulated	2.	-3.509	-0.27	-26.65	39
Measured		-3.516	-0.23	-26.39	28

Simulated	3.	-3.509	-0.23	-26.98	51
Measured		-3.519	-0.22	-26.74	44
Simulated	4.	-3.516	-0.18	-27.41	67
Measured		-3.520	-0.13	-26.85	59
Simulated	5.	-3.519	-0.14	-27.98	98
Measured		-3.523	-0.16	-27.43	67
Simulated	6.	-3.529	-0.09	-28.66	116
Measured		-3.532	-0.12	-27.84	76

The simulated results show a wide variation in BW (23-146 MHz) with a very small permissible variation in resonance frequency measured in KHz range and so can be neglected. The experimental results show same trend as the simulated result however because of the expected fabrication error the respective comparative values are not exactly the same which can be observed from Table 3. The graphical comparison of the simulated and the experimental results for case 1 and case 7 are shown in Fig 13 and 14 respectively. Fig. 15 shows the comparison of simulated, fabricated and circuit model simulated outcome for case 7.

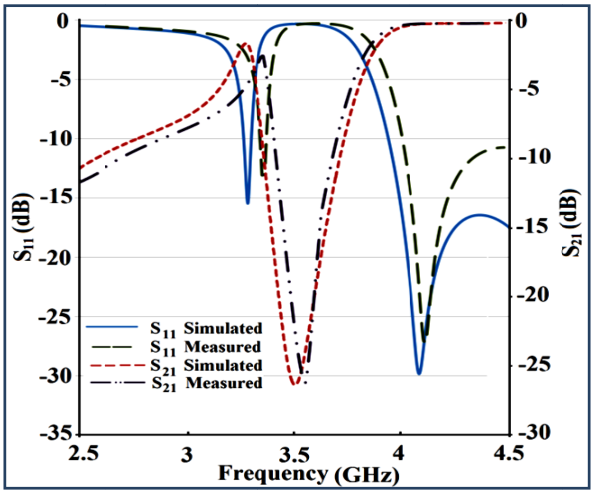

Fig.13. Comparison of simulated and measured result for case1

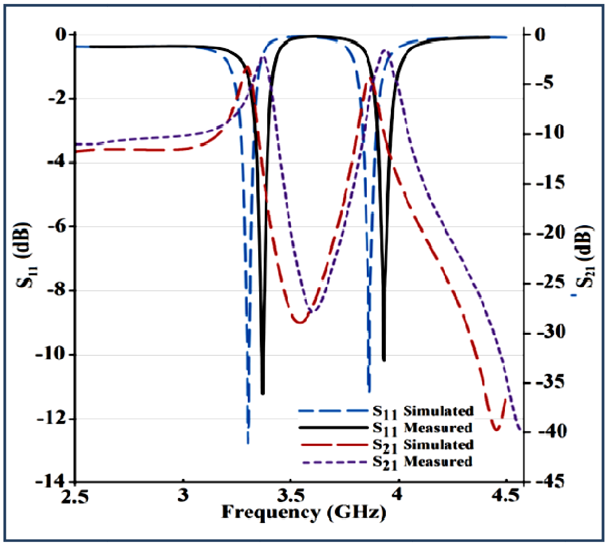

Fig.14. Comparison of simulated and measured result for case 7.

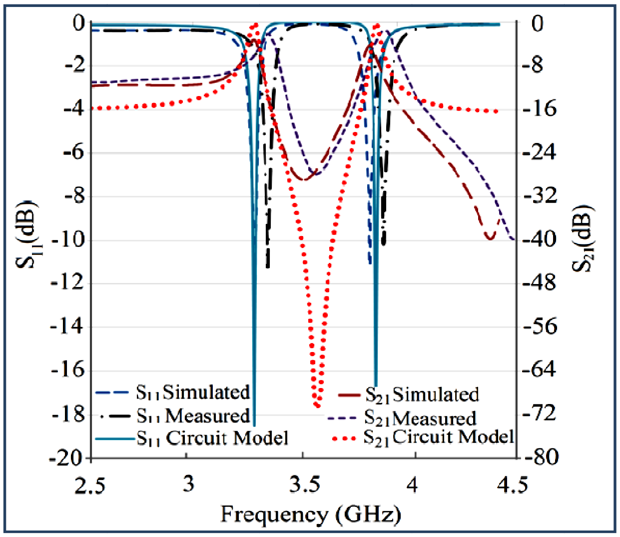

Fig.15. Comparison of Simulated, circuit model, and measured results for case 7.

6. CONCLUSION

This paper provides a new approach of BW control for the reconfigurable Bandstop filter. With this approach a new reconfigurable square ring BSF has been designed and developed using RT/duroid 5870, which is operating at resonance frequency of 3.541 GHz with BW variation of 23.0-146.0 MHz This technique is very much useful in achieving required BW control with a constant resonant frequency. It is the width 'X' and spacing 'Y' between the two consecutive teeth which are responsible for resultant BW.

Although in this paper shorting point method has been used to realize the reconfigurability, the pin diode or other switching elements such as MOSFET or RF MEMS can also be used to connect the two consecutive teeth to improve the flexibility of the design. Due to simple structure and small size of the filter it may find an application in IMT-A.

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