DESIGN AND DEVELOPMENT OF A SINGLE FOLD HAIRPIN LINE MICROSTRIP BANDPASS FILTER AT 3250 MHZ FOR S-BAND COMMUNICATION SYSTEMS

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ABSTRACT

This paper presents a new class of folded hairpin slow-wave open-loop resonator bandpass filters of high performance, compact, low cost and reduced size of 35-45% compared to the conventional hairpin line microstip filters. The filters are not only compact sized due to the slow-wave effect, but also have a wider upper stopband resulting from the dispersion effect. These attractive features make the single fold resonator filters hold promise for RF/wireless, mobile communications and other ground and space applications. The experimental results are demonstrated and discussed. The design technique for a fourth-order single fold slow-wave open-loop resonator filter is presented by realizing the cross couplings between adjacent and non-adjacent resonators. The Agilent-make ADS, IE3D-Zealand and HFSS softwares have been used to design and simulate the filter at 3250 MHz Center frequency. The filter shows good microwave characteristics, moderate quality factor and more than -25 dBc stopband attenuation to suppress out of band harmonics. The results show very good agreement between the measured and simulated results with great reduction in size compared to the conventional hairpin resonator filters.

KEY WORDS—*Folded-hairpin line resonator, miniaturized filters, coupling coefficients, open-loop resonator, ADS and IE3D, softwares.*

I. INTRODUCTION

Wireless and mobile communication systems have created requirements of high performance, small sized and low cost RF/microwave filters. Planar structured microwave filters are as an alternative, as they can be fabricated by using printed circuit technology with mass production to reduce the cost. The small size, compactness and the low cost of the filters have attracted the researchers and designers for further development and applications in the modern mobile radio communication systems to meet requirements of narrow-bandwidth, low loss and high selectivity by cascading and cross coupling between adjacent and non-adjacent hairpin resonators. To make the design easy and simple, the peripheral of each resonator is made a square, the width of lines is made large and the space between coupled lines is kept minimum possible as shown in fig.3, 4 and 5[1-6][11-12]. We have chosen the Alumina substrate of dielectric constant 10.2 and thickness of 1.27 mm. By using the imperical equations, graphs and softwares, we have designed and developed the single fold resonator filter of reduced size of 35-45 % compared to the size of a conventional hairpin resonator filters at center frequency of 3250 MHz .The presentation is organized as follows. Section II describes the concept of hairpin resonator filters. Section III discusses the procedure for design and development of folded resonator filters. Section IV covers the discussion on achieved results. Section V provides information on future work and Section VI summarises the concluding remarks and importance of research work carried out on single fold resonator filter.

II. THE CONCEPT OF SINGLE-FOLDED HAIRPIN LINE RESONATOR

The total length of a parallel coupled filter with λ/2 straight microstrip line resonator is too much long and the size increases with the order of the filter. To solve this problem, a conventional hairpin resonator (U-shaped of half of λ/2 length) structures were developed, fig 1-a. Further size reduction is made possible by further folding the two arms of the conventional hairpin resonator to form a pair of closely coupled lines to enhance the capacitive nature of open end arms, fig.1-b.The area of such a resonator is approximately half of that a U-shaped hairpin resonator. This resonator equals a square loop resonator of lateral size of one-eighth of guided wavelength at the centre frequency. The resonator of this structure is known as single fold hairpin resonator as shown in fig.1-c[1][7-10]. This single-folding structure helps to reduce the size of filter up to 35-45% of the size of the conventional hairpin line bandpass filter (20 mm x 28 mm : 560 mm^2).

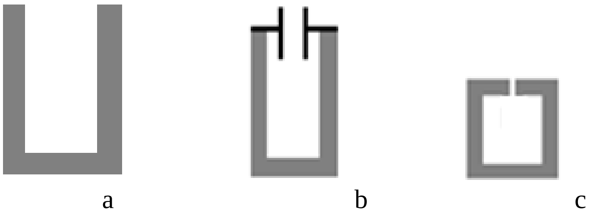


Fig 1. Actual, capacitor loaded, single-fold hairpin line microstrip resonators

III. DESIGN PROCEDURE

The design methodology and supporting software are available to design, simulate/optimize the single-folded hairpin line filters [2][4]. Design calculations alongwith the input/output tapped electrical length of folded hairpin line microstrip filters can be accomplished by finding the element values of LPF prototype with the help of the approximate synthesis method and the relations between the bandpass design parameters and the lowpass elements [3][6].

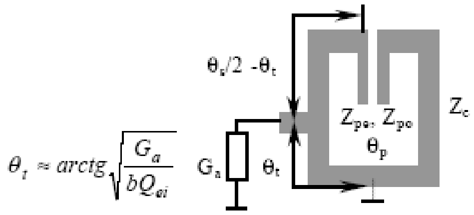


Fig.2 Input/output tapped electrical length.

In designing a resonator the width of microstrip is determined by setting its characteristic impedance to 50 ohms. In the design topology the source power transfer to the load is obtained by coupling to the resonator-transmission line [3][8-10][13-15].The end resonators may be externally coupled by tapping instead of using a coupled section as shown in fig 2.The external quality factor, coupling coefficients and the coupling between adjacent microstrip resonators and other elements of the filter can then be worked-out by using standard equations, graphs, nomograms as shown in fig. 3,4 and 5[3-4][16-18]. We have used EM simulator to model the coupling coefficient and external hairpin transmission lines and bends are realized by using the MBEND90x and MLIN elements. [19-21].

(a). Desired specifications of the filter:

Centre Frequency (CF) : 3250 MHz
Insertion loss : < 5 dB
Pass band (3 dB) bandwidth : ± 20 MHz w. r. t. c. f.
Stopband (30 dB) bandwidth : ±80 MHz w. r. t. c. f.
Return loss : >15 dB
Input/output Impedance : 50 Ohms

(b) Design of a single-folded resonator at 3250

The layout structure of proposed single-fold hairpin line bandpass filter is shown In fig.5.

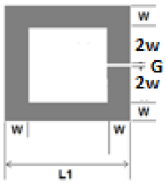


Fig.3. Structure of a bandpass filter

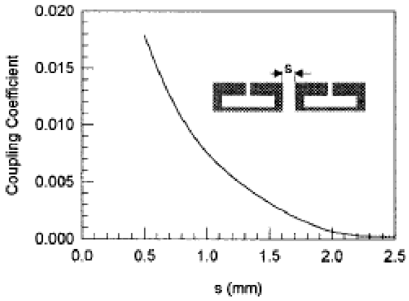


Fig.4 Coupling Coefficients for end-coupled single-fold resonator

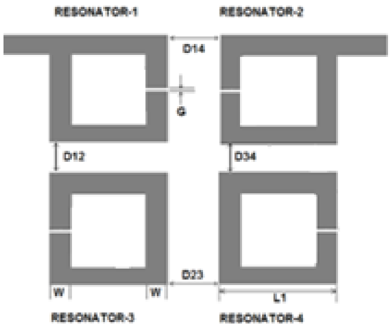


Fig.5 A fourth-order resonators [3]

Dimensions of resonators of the filter L_1 : 5.02 mm, W: 0.68 mm, G : 0.20 mm , $D_{12=}$ D_{34} :2.49 mm and D_{14}=D_{23} : 2.74 mm

* Size of the filter: 19 mm x 19 mm (361 mm^2 instead of 560 m m^2 of conventional hairpin line bandpass filter)

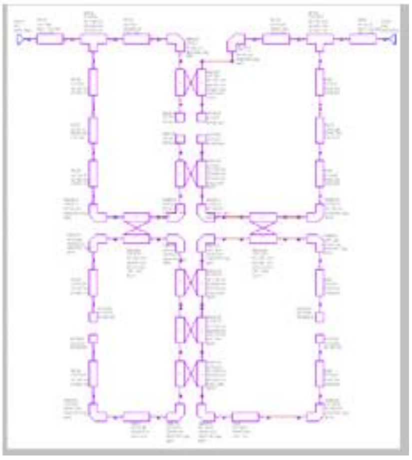
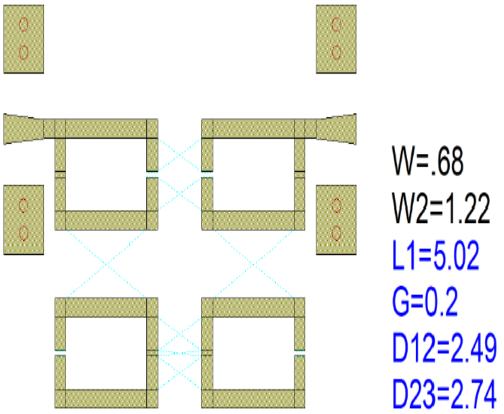


Fig.6 Schemetic



Fif. 7 Layout and dimensions

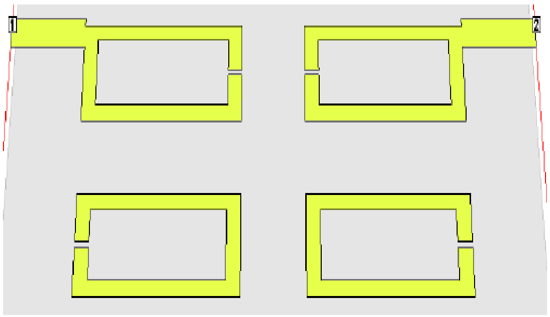


Fig. 8 Layout structure of the fourth-order filter

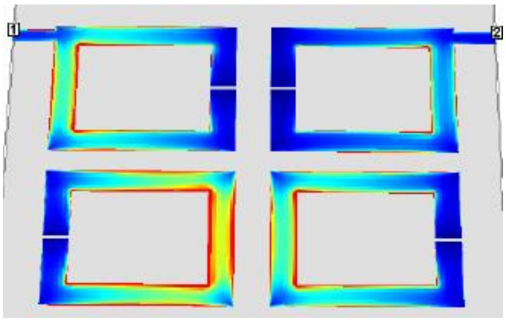


Fig. 9 Current distribution

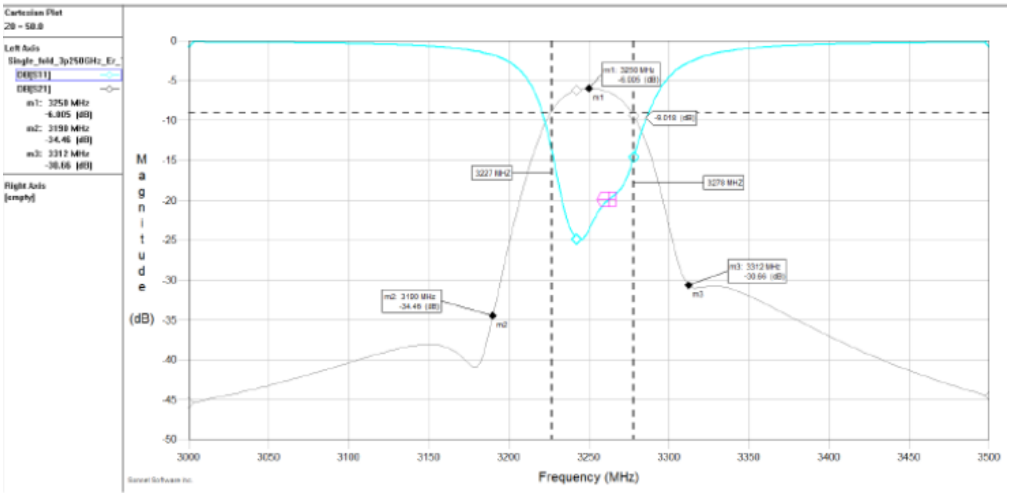


Fig. 10 Simulated response of the filter

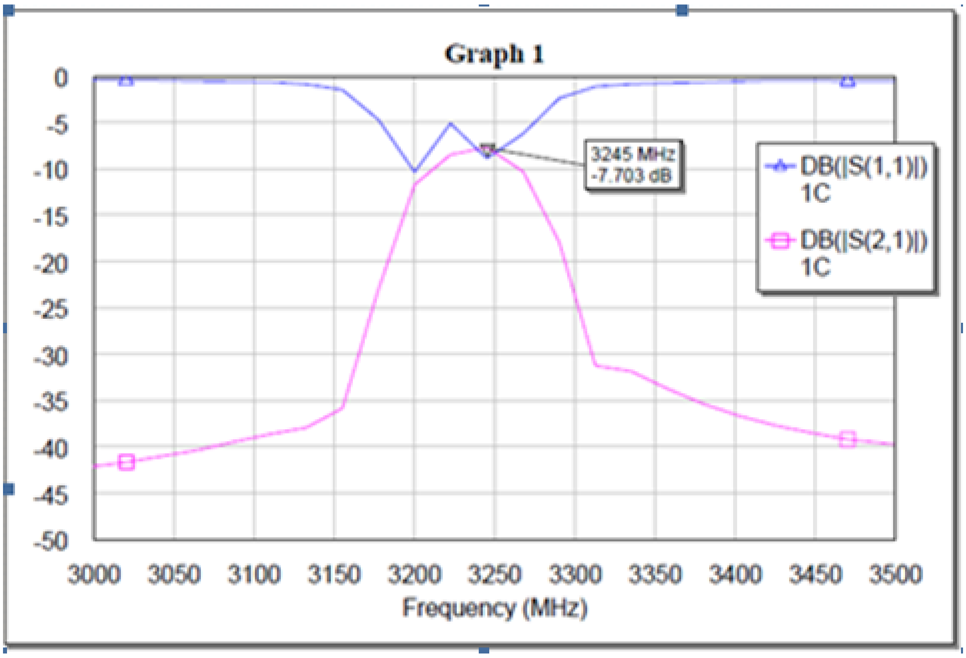


Fig. 11 Measured results of the single-fold filter at 3250 MHz

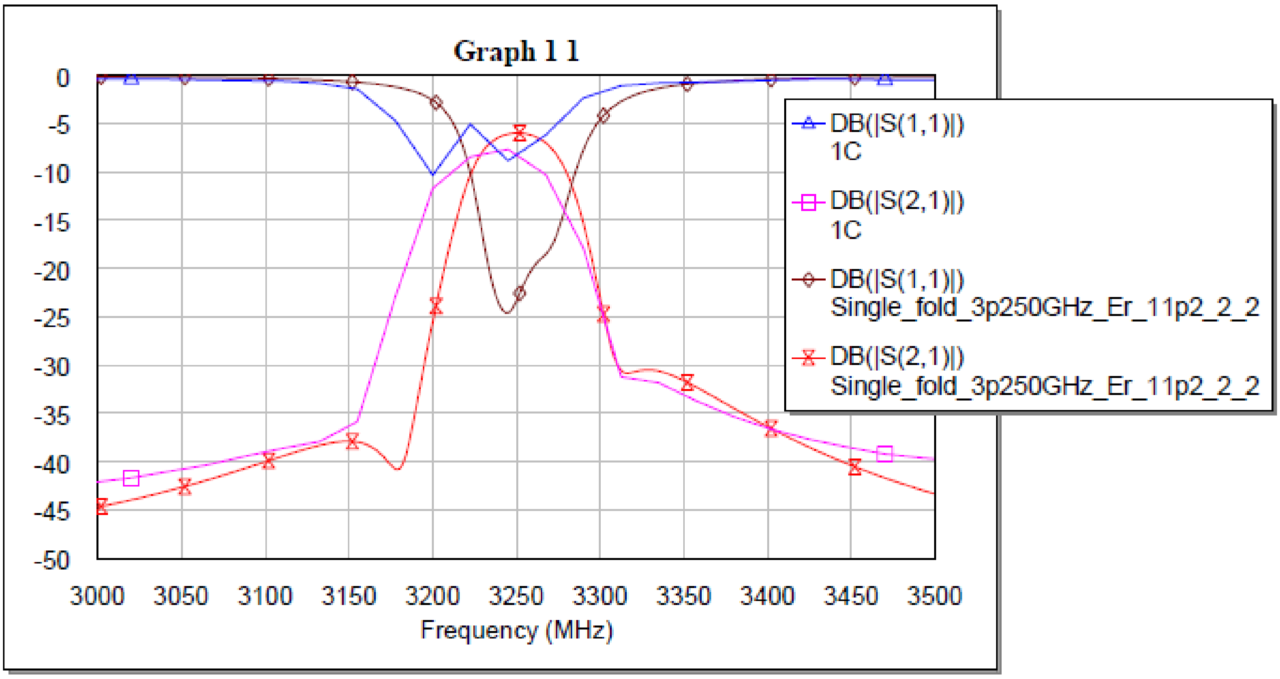
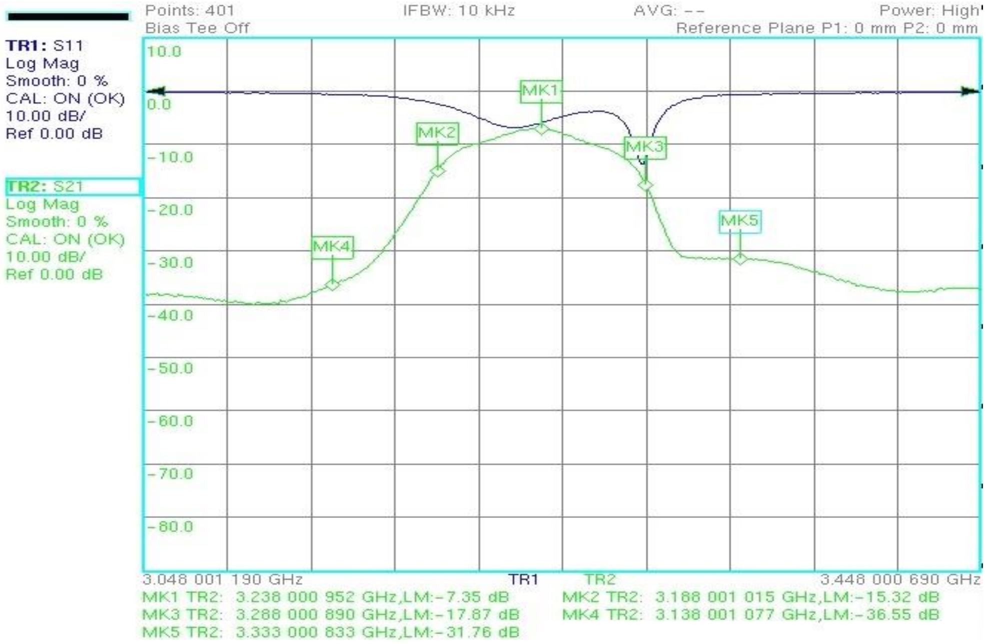


Fig. 12 Copmarision of simulated and measured results of the filter



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Points: 401            IFBW: 10 kHz            AVG: --                Power: High
Bias Tee Off                                   Reference Plane P1: 0 mm P2: 0 mm

TR1: S11
Log Mag
Smooth: 0 %
CAL: ON (OK)
10.00 dB/
Ref 0.00 dB

TR2: S21
Log Mag
Smooth: 0 %
CAL: ON (OK)
10.00 dB/
Ref 0.00 dB

3.048 001 190 GHz                    TR1      TR2                 3.448 000 690 GHz
MK1 TR2:  3.238 000 952 GHz,LM:-7.35 dB      MK2 TR2:  3.188 001 015 GHz,LM:-15.32 dB
MK3 TR2:  3.288 000 890 GHz,LM:-17.87 dB     MK4 TR2:  3.138 001 077 GHz,LM:-36.55 dB
MK5 TR2:  3.333 000 833 GHz,LM:-31.76 dB
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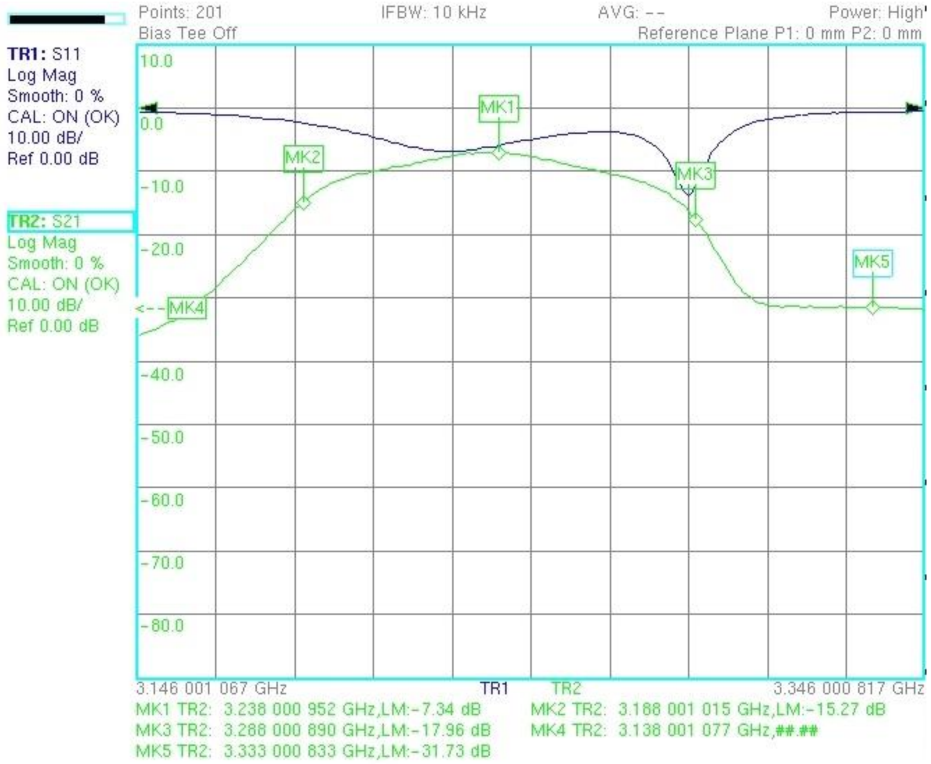
Fig. 13 Measured results of the fabricated filter



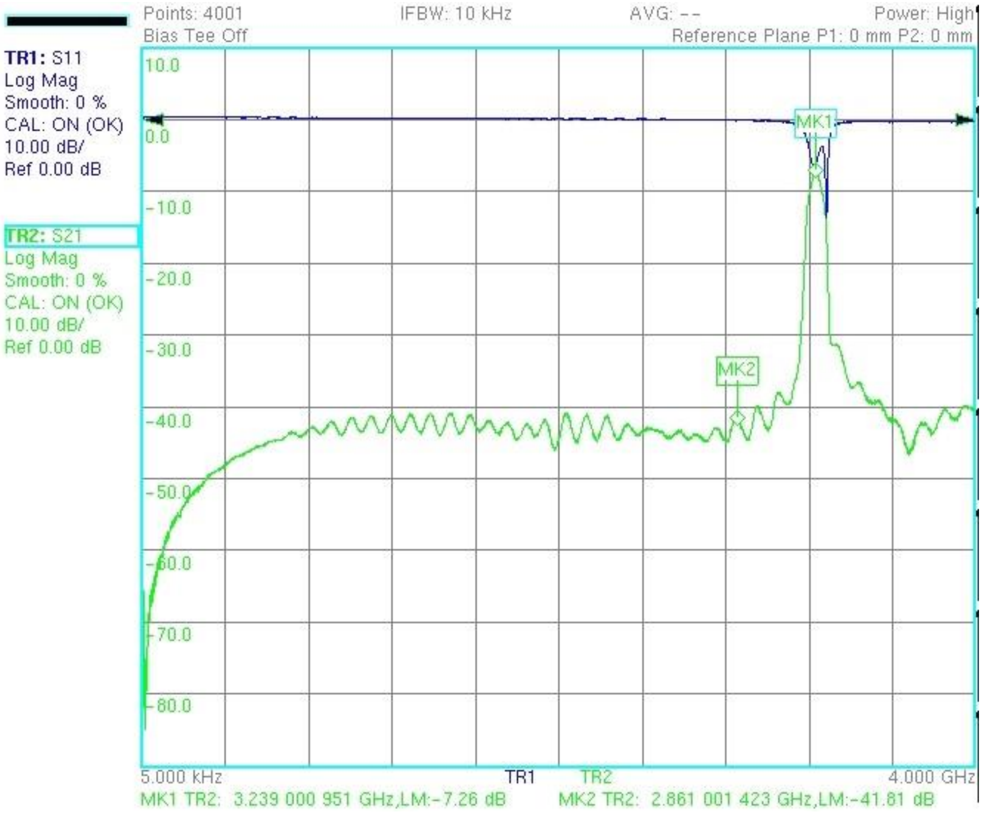
Points: 201
IFBW: 10 kHz
AVG: --
Power: High
Bias Tee Off
Reference Plane P1: 0 mm P2: 0 mm

TR1: S11
Log Mag
Smooth: 0 %
CAL: ON (OK)
10.00 dB/
Ref 0.00 dB

TR2: S21
Log Mag
Smooth: 0 %
CAL: ON (OK)
10.00 dB/
Ref 0.00 dB

MK1 TR2: 3.238 000 952 GHz,LM:-7.34 dB
MK2 TR2: 3.188 001 015 GHz,LM:-15.27 dB
MK3 TR2: 3.288 000 890 GHz,LM:-17.96 dB
MK4 TR2: 3.138 001 077 GHz,##.##
MK5 TR2: 3.333 000 833 GHz,LM:-31.73 dB

Fig. 14 Measured results of the fabricated filter



Points: 4001
IFBW: 10 kHz
AVG: --
Power: High
Bias Tee Off
Reference Plane P1: 0 mm P2: 0 mm

TR1: S11
Log Mag
Smooth: 0 %
CAL: ON (OK)
10.00 dB/
Ref 0.00 dB

TR2: S21
Log Mag
Smooth: 0 %
CAL: ON (OK)
10.00 dB/
Ref 0.00 dB

MK1 TR2: 3.239 000 951 GHz,LM:-7.26 dB
MK2 TR2: 2.861 001 423 GHz,LM:-41.81 dB

Fig. 15. Measured results in 4 Ghz span

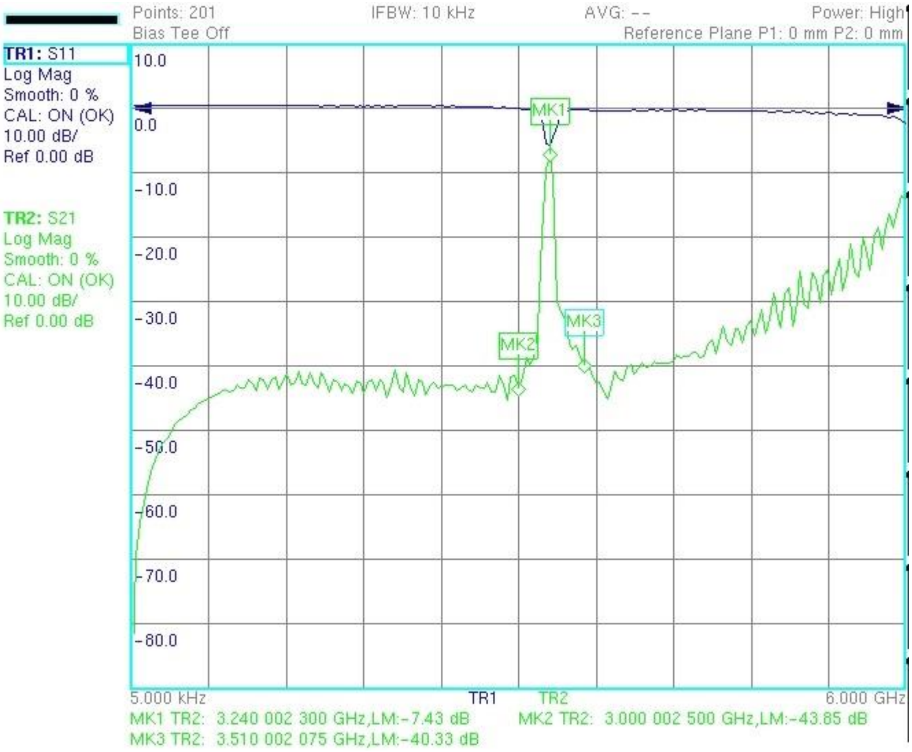


Fig. 16 Filter response in 6 GHz span

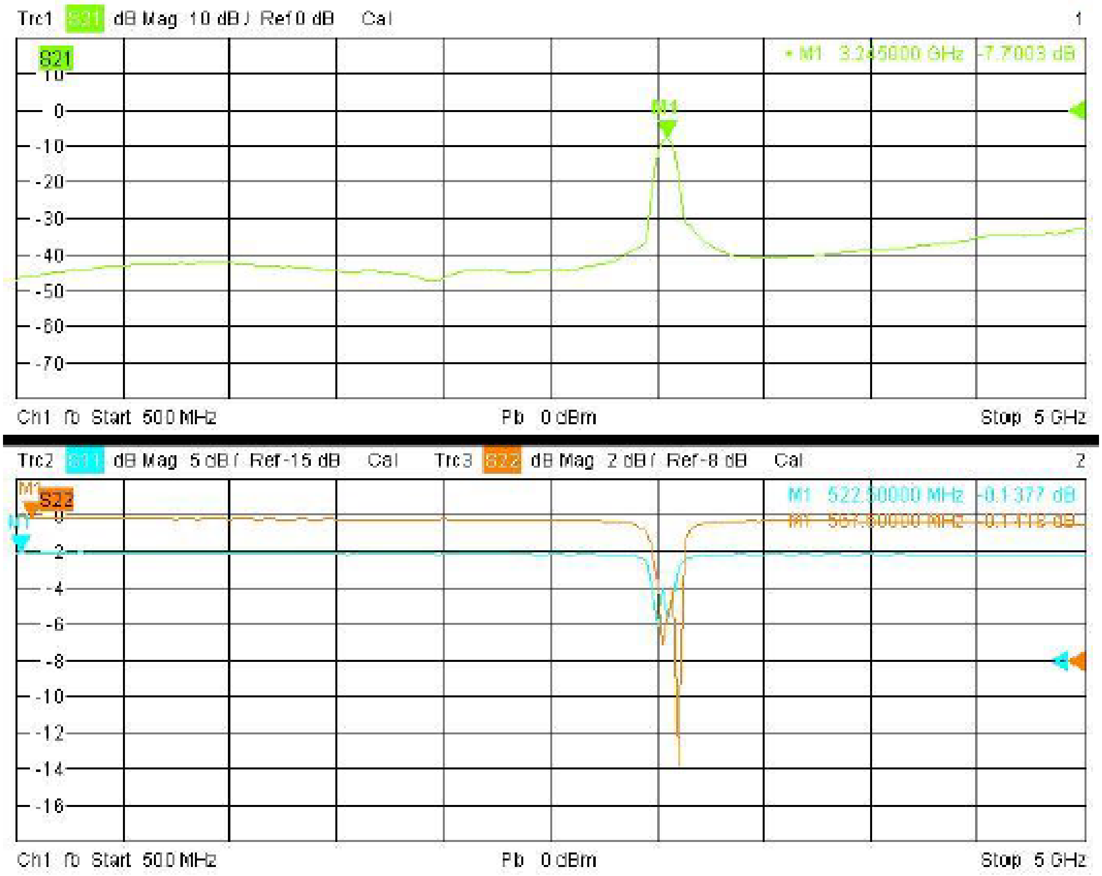


Fig. 17 Measured results in 0.5 GHz-5 GHz frequency span

Table 1: Comparison of Simulated and Measured Results Of Folded Hairpin Line Filters

S. No.	**Parameters**	**Unit**	**Design Specs.**	**Single-fold Simulated**	**Single-fold Measured**	**Deviation**	**Remarks**
1	Center frequency	MHz	3250	3250	3245	05	Acceptable
2	Insertion loss in band	dB	< 6	6.06	7.703	1.6	Acceptable
3	Passband 3dB-band width	MHz w.r.t.c.f.	±20	±20	±22	±2	Acceptable
4	Stopband 30 dB bandwidth	MHz w.r.t.c.f.	±80	±80	±78	±2	Acceptable
5	Return loss in passband	dB	>15	>10	>5	10	Poor but acceptable
6	Size of filter /(Reduction in size)	mm^2 /%	Minimum	19 mm x 19 mm=361 mm^2	**64% of A/ Reduction (36 % of A)**	------------	Acceptable

 # Optimized dimension of a conventional hairpin line bandpass filter:20 mm x 28 mm : 560 mm^2 i.e. (A) for reference.

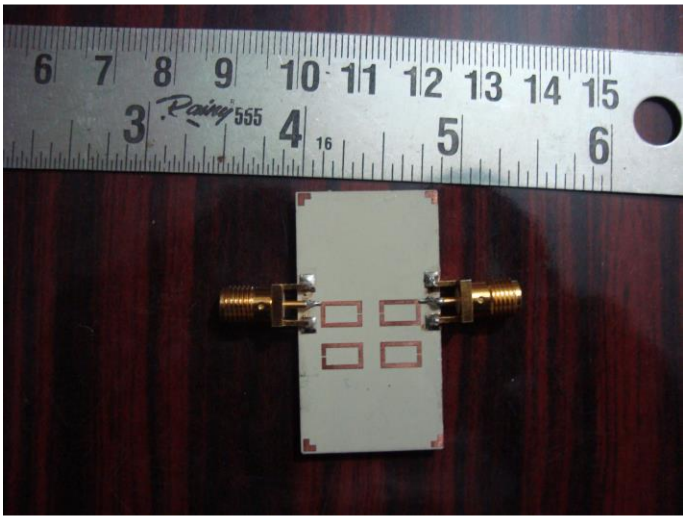


Fig. 18 Photographs of the developed filter

IV. RESULTS AND DISCUSSIONS

We have simulated a fourth-order single fold hairpin line microstrip bandpass filter by using ADS and IE 3D-Zealand softwares. The simulated schematic diagram, optimized dimensions, layout structure and current distribution are shown in figs.6, 7, 8,and 9.The simulated at center frequency 3250 MHz and insertion loss of 6.06 dB, lower/ upper 3dB bandwidths are 3230/ 3270 MHz and more than 30dBc attenuation at 3170 MHz and 3330 MHz as shown in fig.10. The measured results are shown in figs. 11, 12, 13, 14, 15, 16, and 17. Due to the inaccuracies in fabrication, undesired cross coupling between non-adjacent resonators, improper input-output connections, grounding etc. the measured results show that the lower side 3dB bandwidth occurs at 3228 MHz and upper side 3 dB bandwidth shifts to 3272 MHz as shown in figs 13 and 14. The bandwidth in stopband (30dBc) is slightly reduced from ±80 MHz to ±78 MHz i.e reduced by ±2 MHz. The rate of slope is 0.5 dB/MHz, which meets the requirement of attenuation in stopband as shown in figs 15,16 and 17. The return loss is poor but acceptable as shown in table-1. The measured and simulated results are in good agreement as shown in frequency response of comparision between measured and simulated results, fig.12.The photograph of filter is shown in fig.18. The optimized dimensions of the filter is 19 mm x 19 mm (361 mm^2) compared to 20 mm x 28 mm (560 mm^2 =A) of the conventional hairpin line bandpass filter i.e 64 % of A or reduction in size by 36% of A.

V. FUTURE WORK

This paper presents the research work on single fold resonator filters with reduction in size upto 35-45% compared to the size of a conventional hairpin resonator filter. Further folding of the single-fold resonator is possible in the form of double fold and four fold hairpin resonator filters to reduce the size by 45-55% and 55-65 % respectively for future requirements of miniaturization for modern mobile/ RF/ wireless communication systems for ground and space applications.

VI. CONCLUSION

This paper presents the design techniques of a single-fold hairpin line bandpass filter. The reduction in size of the fourth-order single fold hairpin resonator filter is approximately 36% of the optimized size (A) of a conventional hairpin line bandpass filter at 3250 MHz centre frequency. The measured results are very close to the simulated results. There are limitations of the design in terms of inaccuracy of sharp folding and coupling between the adjacent and cross-coupled folded hairpin line resonators. The developed filters can be used for trans/receive RF/wireless/mobile communication systems.

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Jagdish Shivhare was actively involved in many National and International R & D projects, such ISTRAC, DRS, TVRO, IMESS, INSAT, INMARSAT, GPS, Radio Astron . He was invited as a Session Chairman for an International Conference on Superconductivity (ICS-2000), USA, Conf "IEEE-Microwave-2008" at University of Rajsthan. He has published/presented 48 technical papers in National and International Journals and Conferences held in India and abroad. He is reviewer of IEEE-MTT-USA, Electronics Letters-IET-UK Journals and regular reviewer of IEEE-Conferences. He has received Dr. B. R. Ambedakar Medals (two) in December 1986, for best technical presentations in Hindi and English.

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