SMALL SIZED DOUBLE-FOLD HAIRPIN LINE MICROSTRIP BANDPASS FILTER AT 2400 MHZ FOR RF/ WIRELESS COMMUNICATIONS

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ABSTRACT
A conventional hairpin-line resonator size is normally very large. The folded hairpin line resonator filters are compact, small sized and simple to design and fabricate. This paper presents a new class of folded hairpin line microstrip resonator filters with 40-50% reduction in size compared to the conventional hairpin line resonators. The proposed double-fold hairpin line microstrip filters are slow wave open loop type narrow band, high selectivity, small sized and low cost band pass filters for wireless/RF trans/receive communication systems for ground and space applications in S-band. In the proposed filter the cross couplings have been realized between adjacent and non-adjacent resonators. The ADS-Agilent make software have been used to design and simulate the filter having the double-folded hairpin line resonators. The measured results are close to the simulated results, with great reduction in size compared to the conventional planar hairpin line structure.

KEYWORDS---*Double-fold hairpin line resonator, slow-wave open–loop resonator, miniaturized hairpin line, coupling coefficients, ADS software, computed response.*

I. INTRODUCTION

Wireless and mobile communication systems have presented new challenges to the design of high quality miniature RF filters. Progress in size reduction is made by the compact miniaturized resonator filters, where the two arms of the U-shaped microstrip are further folded to form a pair of closely coupled lines to enhance the capacitive nature of open end arms [1]. The design of wireless and mobile communication systems, need high quality and small sized RF/microwave filters. Planar filters are the alternatives as they can be fabricated using printed circuit technology with low cost and size. The conventional hairpin line filters may be designed to reduced the size compare to the parallel-coupled line structure. Further progress in size reduction upto 50% is employed by further folding the two arms of the U-shaped microstrip resonator i.e. double-fold hairpin line structures [2]. The design of a single resonator has been accomplished in the given steps: the width of the microstrip is determined for 50 ohms, the peripheral of each resonator is made a square, length of the U-shaped coupled lines is extended to its maximum, the width of the coupled lines is made large and the space between coupled lines (gap) is made as small as possible. As a result, the lateral size of the resonator will be less compared to the open loop resonator at the same frequency [3]. The small size and compactness of the filter makes the design attractive for further development and applications in modern mobile radio systems. The RT-Duroid/Alumina substrate of dielectric constant 10.2 and thickness of 1.27 mm has been chosen for this design.
By using the imperical equations and graphs, we have obtained the total size of a fourth-order parallel coupled bandpass filter at 2400 MHz is 55 mm x 12 mm (660 mm^2).

The total size of the conventional fourth-order hairpin line(folded parallel coupled line) bandpass filter is 12 mm x 25 mm (300 mm^2=A).The total size of the required fourth-order double fold hairpin line bandpass filter is 144 mm^2(50% of A).

The resonators are composed of a transmission line and a lumped element capacitor and is represented by parallel -coupled lines instead of the lumped capacitor, shown in fig. 1.

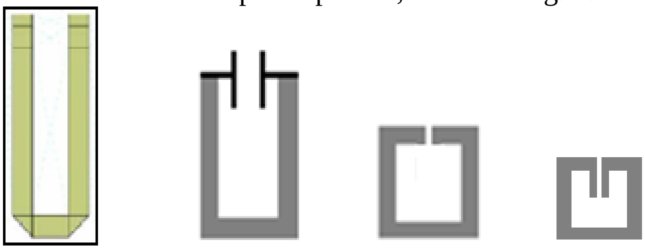

Fig 1. Actual, capacitor loaded, single-fold and doublefold hairpin line microstrip resonators

The filter can be realized by calculating the coupling coefficients between adjacent and cross-coupled (non-adjacent) resonators [1][2]

II. Design Procedure Of Double-Folded Hairpin Line Bandpass Filter

Hairpin-line resonator filters are relatively simple to design and build. To reduce the size of hairpin resonators, the arms of the resonator are reactively loaded with parallel coupled lines. Filters using these miniaturized resonators are 50% percent smaller in size than filters that use conventional hairpin line resonators [3].Design calculations of a 4 section double-folded filter can be done in the following steps:

1. Finding the element values of LPF prototype by using the approximate synthesis method[2].The relations between the bandpass design parameters and the lowpass elements [1]are:

$$Q_{ei} = Q_{eo} = C_1/\Delta\omega$$

$$k_{n,n-1} = k_{N-n,N-n+1} = \frac{\Delta\omega}{\sqrt{C_n C_{n+1}}}, \text{ for } n=1 \text{ to } N/2$$

$$k_{m,m+1} = \frac{\Delta\omega J_m}{C_m}, \text{ for } m=N/2,$$

$$k_{m-1,m+2} = \frac{\Delta\omega J_{m-1}}{C_{m-1}}, \text{ for } m=N/2,$$

where

$\Delta\omega$: fractional bandwidth of the bandpass filter,

C: Capacitance of the lumped capacitor

J : Characteristic admittance of the inverter,

N : degree of the filter

2. To calculate the resonator parameters: The length of the coupled lines can be calculated by:

$$\cot g\theta_p = \frac{-R + \sqrt{R^2 + 4Z_c^2 \sin^2\theta_s}}{2Z_c \sin\theta_s}$$

$$\text{and } R = \left(Z_{pe} + Z_{po}\right)\cos\theta_s - \left(Z_{pe} - Z_{po}\right).$$

where θ_s : Electric length of the resonator Z_c : Characteristic impedance

Z_{pe} :Even mode impedance Z_{po} : Odd mode impedance

3. Calculations for the coupling parameters: The values of coefficient of coupling between resonators can be calculated against the distances between the resonators. The design technique uses an approximation polynomial and a low filter prototype. The loaded Q factor and the mixed coupling coefficients between the different resonators can be calculated, as shown in figures 4 and 5[1][4]

4. Calculation of the input tapped electrical length :

$$\theta_t \approx arctg\sqrt{\frac{G_a}{bQ_{ei}}}$$

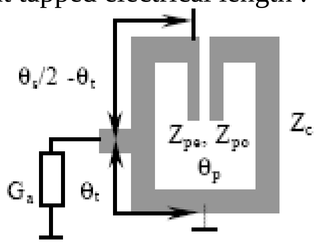

Fig.2 Input/output tapped electrical length

5. Calculation of the geometric parameters of the filter for an exact substrate[2][5]
6. Optimization of filter parameters by varying the geometric dimensions.[5]

III. FILTER SPECIFICATIONS AND CALCULATED DIMENSIONS

1. Center Frequency : 2400 MHz
2. Insertion loss : < 3 dB
3. 3dB Bandwidth : ± 36 MHz w. r .t. c. f
4. Stopband bandwidth : ± 55 MHz w. r. t. c. f.
5. Lower side attenuation : 30 dBc at 2345 MHz
6. Upper side attenuation : 30 dBc at 2455 MHz
7. Return loss : >15 dB in 3dB bandwidth
8. Input impedance : 50 Ohms
9. Output impedance : 50 Ohms

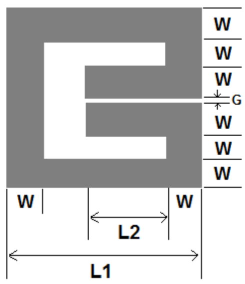

Fig.3. Structure of a double-folded resonator

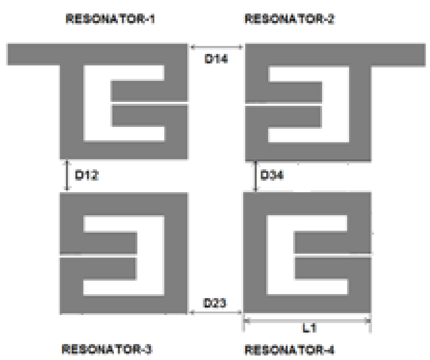

Fig.4. A fourth-order double-folded resonator filter

Dimensions of resonator of the filter
L_1 : 5.25 mm, L_2 : 1.95, W: 1.1 mm, G : 0.31 mm $D_{12}= D_{34}$:1.69 mm and $D_{14}=D_{23}$:1.87 mm
* Total size of the filter: 12 mm x 12 mm (144 mm^2)

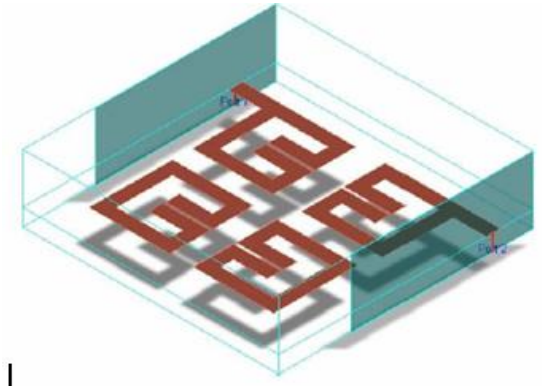

Fig.5: Three dimensional view of a fourth-order bandpass filter.

IV. SIMULATION/OPTIMIZATION BY USING ADS AGILENT TECH-MAKE SOFTWARE

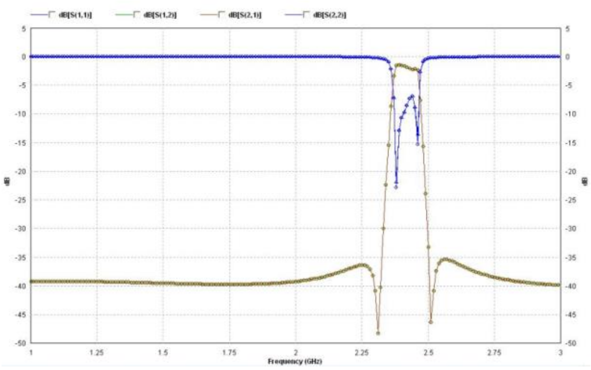

Fig.6: Simulated frequency response of a fourth-order double-fold hairpin line bandpass filter

1. Center Frequency : 2395 MHz
2. Insertion loss : < 3 dB
3. 3dB Bandwidth : ±40 MHz w. r. t. c. f
4. Stopband bandwidth : ±75 MHz w. r. t. c. f
5. Lower side attenuation : 30 dBc at 2315 MHz
6. Upper side attenuation : 30 dBc at 2465 MHz
7. Return Loss : 08 dB(min)in 3 dB BW

V. FABRICATION OF FILTERS

The filter circuit has been fabricated on a RT-Duroid, dielectric substrate having εr=10.2 and thickness 1.27 mm. Standard fabrication process have been adopted [7-9].The simulated results are close to the desired results[6][10][11][12].

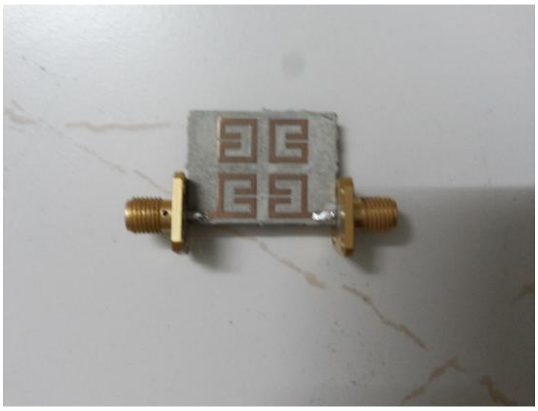

Fig.7. A fourth-order double-fold hairpin line microstrip bandpass filter of dimensions of 144 mm^2

VI. MEASURED RESULTS ON AGILENT-MAKE VECTOR NETWORK ANALYZER

The measured results are not very close to the designed and simulated/optimized results due to the limitations of the design in terms of inaccuracy of sharp folding and the coupling between the adjacent and cross-coupled folded hairpin line resonators.

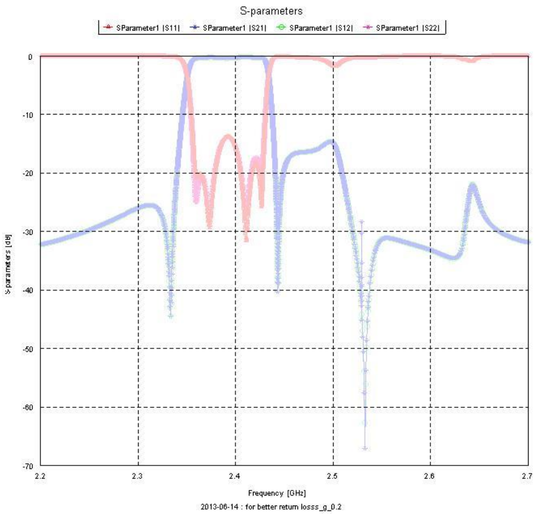

Fig.8: Measured frequency response and return loss of the filter.

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1. Center Frequency : 2395 MHz
2. Insertion Loss : < 3 dB
3. 3dB Bandwidth : ± 35 MHz w. r. t. c. f
4. Stopband bandwidth : ± 53 MHz w. r. t. c. f
5. Lower side attenuation : 30 dBc at 2342 MHz
6. Upper side attenuation : 30 dBc at 2448 MHz
7. Return Loss :14 dB(min) in 3 dB bandwidth

VII. FUTURE WORK

Though the obtained results are close to the desired specifications and simulated results but still we have to put more efforts to improve the performance in future by taking care in fabrication, mounting, connections and measurements[1-4][8]

VIII. CONCLUSION

This paper describes a fourth-order double-folded hairpin line microstrip bandpass filter design technique. The calculations of the filter can be done without using Full-wave EM simulator. The used formulas allow analytical calculations of the filter. The limitations of the design results in terms of inaccuracy of coupling between the adjacent and cross coupled multi-fold hairpin line resonators. The total size of fourth-order double-fold hairpin line filter is 50% of the conventional fourth-order hairpin line microstrip bandpass filter i.e. 144 mm^2 instead of 300 mm^2.

REFERENCES

[1] Ilia G. Iliev and Marin V Nedelchev "CAD of Cross CoupLed Miniaturized Hairpin Bandpass Filters" Microwave Review, pp-49-52, December 2002.
[2] Hong,J. S. and M. J. Lancaster, "Couplings Microstrip Square Open-Loop Resonators for Cross-Coupled Planar Microstrip Filters" IEEE Trans.Microw.Theory Tech. Vol. 44 ,No.12, 2099-2109, Dec 1996
[3] Deng P H,Y S Lin,C H Wang and C H Chen,"Compact Microstrip bandpass filters with good selectivity and stopband rejection" IEEE Trasanction on Microwave Theory and Techniques(MTT) Vol.54, No.2, pp533-39, 2006
[4]. Prayoot Akkaraethalin and jaruek Jantree "Microstrip Slow Wave Open-Loop Resonator Filters with Reduced Size and improved Stopband Characteristics" ETRI Journal, Vol.28 No. 5, October 2006.
[5] Jen-Tsai Kuo, Ming-Jyh Maa and Ping-Han Lu "A Microstrip Elliptic Function Filter with Compact Miniaturized Hairpin Resonators" IEEE Microwave and Guided Wave Letters, Vol 10, No.3, pp-94-95, March 2000.
[6] Levy R., direct Synthesis of Cascaded Quadruplet (CQ) Filters, IEEE, and Trans. on MTT, Vol.43, and pp 2940-2944, 1995
[7] Wang Y X, B-Z Wang and J Wang "A compact square loop dual mode bandpass filter with wide stopband" Progress in Electromagnetics Research, Vol.77, pp 67-73, 2007
[8] Rodrigo Neves Martins and Humberto Abdalla Jr. "Techniques Yield Tiny Hairpin-Line Resonator Filters" MWRF, pp 1-11, November 1999.
[9] **Fei**, L., H. Gan, Z. Wang and W. Lu, "Novel Compact triple-bandpass filter using $\lambda/4$ resonator pairs with Common via ground" Proceeding of the Progress in Electro- magnetic Research Symposium, pp: 1220-1224, 2012
[10] Tscai, W.L. and R.B. Wu. "Tri-band Filter design using substrate integrated waveguide resonators in LTCC. Proceeding of the IEEE International Symposium on MTT-S Microwave Digest. 2011.
[11] Lai, X., N. Wang, B. Wu a "Design of tri-band filter based on stub loaded resonator and DGS resonator" IEEE Microw. Wirel. Compon. Lett., 20: 265-267, 2010
[12] ADS Agilent-make Software's for Design and Simulation

Authors Biography

Jagadish Shivhare, joined ITM, Gurgaon on 05 September 2003 after taking Voluntary Retirement (20 years services) from Indian Space Research Organization (ISRO/DOS, Govt. of India), Ahmedabad Centre (Gujarat). During his 20 years services in ISRO (August 1983–August 2003), he was actively involved in many National and International R & D projects for ground and space applications. He had designed and developed various types of RF/Microwave filters(including High Temperature Superconductive Filters), Sub-systems and Systems for different types of Receiving terminals, Earth stations and Communication Satellites such ISTRAC, DRS, TVRO, IMESS, INMARSAT, GPS, Radio Astron etc. At present he is in ITM University, Gurgaon, India and still working on planar structured hairpin line microstrip bandpass filters in RF/Microwave ranges for ground and space applications. So far he has published/presented 43 technical papers in national/international journals/conferences in India and abroad.

Shail Bala did her Ph.D. (Electronics & Communication) from Delhi University**,** M. Tech (Electronics & Communication Engineering) from IIT Delhi and B.Sc. (Electrical Engineering) from Delhi College of Engineering. She joined IGDTUW in 2002. She has 32 years of experience at DCE (now Delhi Technological University). She is the life member of S.M.I.E.E.E. (USA), Fellow I.E.T.E. (India). She has published 20 research papers in International/ National Journals.