Design of Compact Microstrip Hairpin Multi Bandpass Filter

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***Abstract* - Design, simulation and measurement of microstrip hairpin multi bandpass filter is presented. A one input port, one output port and multiple hairpin resonators are integrated to form the microstrip filter. These elements together function as single pole hairpin filter, three pole hairpin filter and five pole hairpin filter with frequencies of 6.1 GHz, 4.48 GHz to 7.24 GHz and 4.57 GHz to 7.54 GHz. This structures act as band pass filter. This filter exhibits better return loss, reduced interfacing losses, good selectivity at band edges, flat in-band gain response.**

Keywords: Single pole hairpin filter, three pole hairpin filter, five pole hairpin filter, resonator.

I. INTRODUCTION

In wireless communication systems, the antenna and the filter are the key components. While the antenna transmits and receives signals, the bandpass filter (BPF) selects signals in the operating band and rejects spurious (out-of-band) signals [2]. Band pass filters are essential part of any signal processing or communication systems, the integral part of super heterodyne receivers which are currently employed in many RF/Microwave communication systems [1].

In this paper, a Hairpin multi band pass filter is designed using the synthesis process of the band pass filter. The filter consists of input port, output port, hairpin resonators. The configuration in which the lumped elements are connected in this schematic is similar to that of a single pole, three pole and five pole band pass filter. If the inductance and capacitance are sufficiently high then it could create a resonant point in our frequency of interest which is typically 6.10 GHz. The theme of this paper is the design of compact multi pole hairpin band pass filters for communication. Bandpass filters for communication.

II. SYSTEM MODEL

The aim of this paper is to design a compact micro strip hairpin multi band pass filter which can pass the particular bands of frequency for various applications. In this we design single pole hairpin filter having single hairpin resonator, input pot and output port. Similarly, three pole hairpin filter having three hairpin resonator, input port and output port. Similarly, five pole hairpin filter having five hairpin resonator, input port and output port.

III. PREVIOUS WORK

In year 2013, Girraj Sharmal, Rajeshwar Lal dua, Yogesh Bhati published a paper named Microstrip Bandpass Hairpin Filter are essential part of any signal processing or communication systems, the integral part of superhetrodyne receivers which are currently employed in many RF/Microwave communication systems. In year 2014, N. Sekiya, S. Sugiyama, university of yamanashi, Japan published a research paper in IEEE named hts dual bandpass filter using stub-loaded hairpin resonators for mobile communication system to obtain sharp-cut off characteristics for mobile communication systems. In year 2014, Jian Li, Yongjun Huang, Guangjun Wen, Xiaolin Xue and Jiaming Song published a paper named compact and high selectivity microstrip bandpass filter using 2-stage twist modified asymmetric split ring resonator is composed of two pairs of twist-modified asymmetric splitring resonators (SRRs) to achieve three transmission poles within the passband and four transmission zeros at low and high rejection bands.In year 2015, Jin Li, Mark Hickle, Dimitra Psychogiou, and Dimitrious peroulis published a paper in IEEE named a compact l-band bandpass filter with rf mems-enabled reconfigurable notches for interference rejection in gps application include the design and realization of a compact, low-loss, static microwave bandpass filter (BPF) centered at the L1 GPS frequency fs=1,575 MHz with a ripple bandwidth BWs of at least 50 MHz.

IV. PROPOSED METHODOLOGY

Filter Design: The work is categorized into step by step increases the number of element in multipole hairpin band pass microstrip resonators. A magnetic field tunable band pass filters was designed based on partially magnetized yttrium iron garnet (YIG) operating at 6.10 GHz, which show low insertion loss and large frequency tunability. The ferrite substrate is chosen from the commercial product pure polycrystalline YIG from Trans-Tech Inc (G-113). The YIG Ceramic slab has a dielectric constant of €=14.59, an electric loss tangent tan δ =0.00004. Having low pass parameters, the band pass design parameters can be calculated by:

$$Q_{e1} = \frac{g_0 g_1}{FBW} \qquad Q_{en} = \frac{g_n g_{n+1}}{FBW}$$

$$M_{i,i+1} = \frac{FBW}{\sqrt{g_i g_{i+1}}}$$

Where: Qe1 and Qen are the external quality factors of the resonators at the input and the output. Mi, i+1 is the coupling coefficient between the adjacent resonators i and i + 1.

V. SIMULATION/EXPERIMENTAL RESULTS

Design of single pole hairpin filter: The length of hairpin is 4.1 mm, width of hairpin is 0.2 mm, length of feed line is 1.55 mm, width of feed line is 0.12 mm, gap width is 0.05 mm, internal gap of hairpin is 1 mm, height of copper 0.01 mm, length of substrate is 7 mm, width of substrate is 5 mm, height of substrate is 0.3 mm, substrate permittivity is 14.59 and loss tangent is 0.00004.

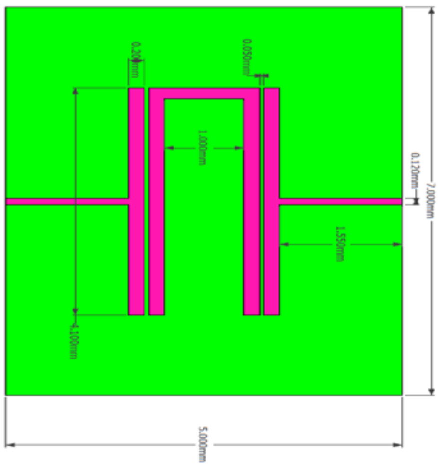

Fig. 4.1 single pole hairpin filter design.

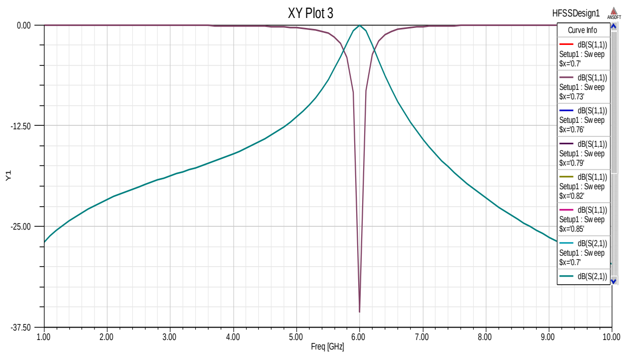

Fig. 4.2 Common graph for transmission band and return loss for single pole hair pin filter.

Return Loss and transmission band of Single pole Filter: Return loss is basically the loss of power in the signal returned or reflected by a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line.

Single pole hairpin filter: In single pole hairpin filter common graph for transmission band and return loss, we observed that single band frequency is 6.1 GHz, return loss (S11) is -35.62 db, bandwidth (S11) is 0.5045 GHz, insertion loss (S21) is 0.0644, bandwidth (S21 -3 db) is 0.4698.

Design of three pole hairpin filter: The length of hairpin is 4.1 mm, width of hairpin is 0.2 mm, length of feed line is 1.55 mm, width of feed line is 0.12 mm, gap width is 0.05 mm, internal gap of hairpin is 1 mm, height of copper 0.01 mm, length of substrate is 7 mm, width of substrate is 7.9 mm, height of substrate is 0.3 mm, substrate permittivity is 14.59 and loss tangent is 0.00004

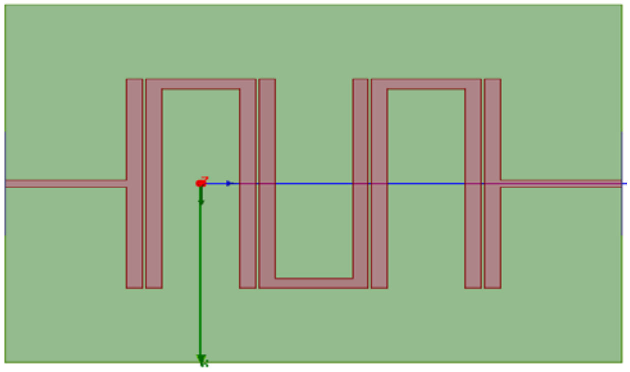

Fig. 4.3 single pole hairpin bandpass filter.

Return loss and transmission band for three pole hairpin filter: In three pole hairpin filter common graph for transmission band and return loss, we observed that left band frequency (LB)is 4.48 GHz, centre band frequency is 5.80 GHz, right band frequency (RB) is 7.24 GHz , return loss (S11) of left band is -18.55 db, for center band is 20.64 db, for right band is -21.07 db, bandwidth (S11) of LB is 0.232 GHz, for center band is 0.3533 GHz, for right band is 0.165 GHz , insertion loss (S21) of left band is 0.180, for center band is 0.105, for right band is 0.383, bandwidth (S21 -3 db) for left band is 0.223, for center band is 0.342 and for right band is 0.146.

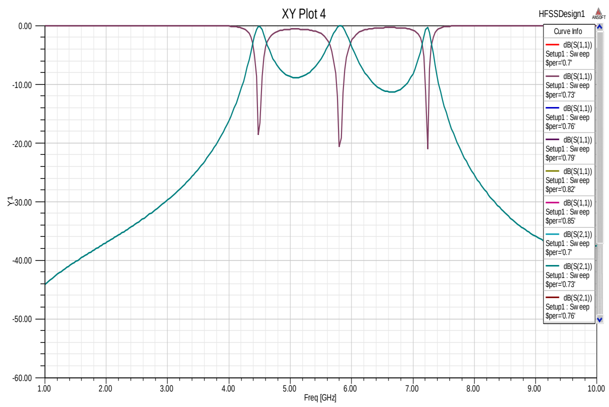

Fig. 4.4 common graph for transmission band and return loss for three pole hairpin filter

Design of five pole hairpin filter: The length of hairpin is 4.1 mm, width of hairpin is 0.2 mm, length of feed line is 1.55 mm, width of feed line is 0.12 mm, gap width is 0.05

mm, internal gap of hairpin is 1 mm, height of copper is 0.01 mm, length of substrate is 7 mm, width of substrate is 10.79 mm, height of substrate is 0.3 mm, substrate permittivity is 14.59 and loss tangent is 0.00004.

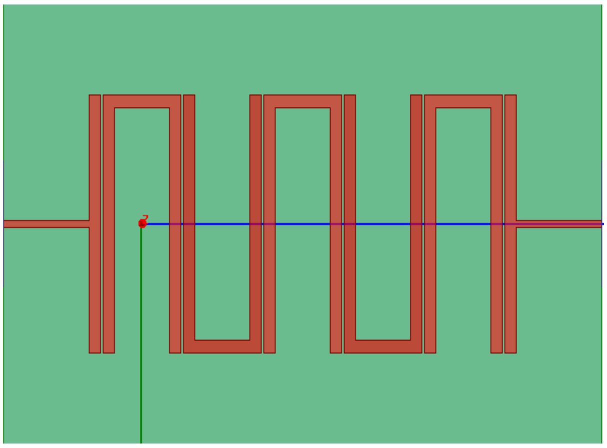

Fig. 4.5 five pole hairpin bandpass filter

Transmission band and return loss for five pole hairpin filter: In five pole hairpin filter common graph for transmission band and return loss, we observed that left band frequency second left band is 4.57 GHz, for first left is -17.00 db, for first right band is -23.75 db, for second right band is -13.53 db, bandwidth (S11) for second left band is 0.069 GHz, for first left band is 0.159 GHz, for center band is 0.186 GHz, for first right band is 0.133 GHz, for second right band is 0.056 GHz, insertion loss (S21) for second left band is 0.479, for first left band is 0.103, for center band is 0.161, for first right band is 0.218, for second right band is 1.249, bandwidth (S21 -3 db) for second left band is 0.053, for first left band is 0.151, for center band is 0.175, for first right band is 0.122 and for second right band is 0.028.

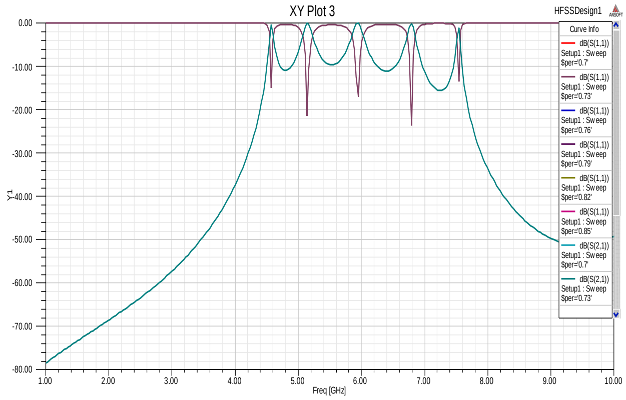

Fig. 4.6 common graph for transmission band and return loss for five pole hairpin bandpass filter.

Simulations were performed using the commercially available HFSS software. The higher insertion loss is mainly due to conductor and dielectric losses. The aim of this paper is to design a compact micro strip hairpin multi band pass filter. As demonstrated by the design and the results obtained in chapter 4, a compact micro strip hairpin multi band pass filter has been successfully designed having a frequency range: Single pole hairpin filter - 6.1 GHz. Three pole hairpin filter - 4.48 GHZ TO 7.24 GHZ. Five pole hairpin filter – 4.57 TO 7.54 GHz The substrate dimensions are 7 mm AND 5 mm. The area of square patch for is 35 mm2. Hence the designed filter is compact enough to be placed in typical devices.

TABLE 1. PERFORMANCE COMPARISON OF SINGLE POLE, THREE POLE AND FIVE POLE HAIRPIN FILTER

Parameters/No of Pole	**Single pole**	**Three pole**			**Five pole**				
	SB	LB	CB	RB	2nd LB	1st LB	CB	1st RB	2nd RB
freq	6.1 GHz	4.48	5.80	7.24	4.57	5.14	5.95	6.79	7.54
S11(-10db)	-35.62	-18.55	-20.64	-21.07	-15.11	-21.59	-17.00	-23.75	-13.53
3dB S11BW	0.5045	0.232	0.3533	0.165	0.069	0.159	0.186	0.133	0.056
IL (S21)	0.0644	0.180	0.105	0.383	0.479	0.103	0.161	0.218	1.249
3dbn S21BW	0.4698	0.223	0.342	0.146	0.053	0.151	0.175	0.122	0.028

VI. CONCLUSION

A hairpin multi band pass filter is proposed. The design process is based on filter synthesis approach. The proposed structure exhibits good out-of-band gain suppression, compact size, good frequency response and good skirt selectivity at the band edges. The proposed structure can help to reduce the size and cost of the communication system by combining two components into one.

VII. FUTURE SCOPES

We can increase the frequency band for filter so that our designed filter will be used for WIMAX applications of higher frequency band.

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