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S-BAND MICROWAVE LOW PASS FILTER BASED ON METAMATERIAL

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***Abstract*- In this Paper, stepped impedance low pass filter is described. A high performance, low cost, small size, third order multilayered stepped impedance low pass filter is designed and it is fabricated in the middle layer. A periodic pattern of spiral hexagon split ring resonators are etched on the top layer of metamaterial structure. This paper describes the designing of stepped impedance low pass filter at cut off frequency 2.43GHz, with microstrip line implementation. Computer simulates technique (CST) software is used to simulate the filter, which is commonly used in microwave applications. The proposed filter has better results as compared to conventional stepped impedance low pass filter.**

***Index Terms*- Kuroda's identity, Richard transformation, Spiral ring resonator (SSR), Stepped impedance low pass filter.**

I. INTRODUCTION

Microwave filter is a two port, passive, linear device. Generally, the performance of filter is derived or described in terms of return loss, insertion loss and attenuation in stop band and so on. The practical filter have non zero attenuation in pass band and small signal output in the stop band, due to presence of resistive elements in the reactive elements of propagating medium. The minimization of insertion loss and large return loss are one of great concerning challenges of present and future for microwave communication devices. Low pass filter are often an important component of radio frequency circuits and microwave communication system. There are two methods of microwave filter design, first one is image parameter method and second one is insertion loss method [1]. Today most of the microwave filter designs are done with insertion loss method. In Insertion loss method, a filter response is defined by a transfer function. Transfer function is the ratio of the output voltage to input voltage. An ideal transfer function of low pass filter is characterized by a magnitude function that is constant in pass band and zero in stop band. Since such a low pass filter network can be described by quotient of finite degree rational polynomials. It is necessary to approximate these polynomials. There are four typical solutions to approximation problem are Butterworth (maximally flat), Chebyshev (equal ripple in pass band), inverse Chebyshev (equal ripple in stop band) and Elliptical (equal ripple in both pass band and stop band). The limitations of rejection characteristics in such low pass filters can be improved through increasing the pass band insertion loss by adding new sections [2]. However with insertion of new sections, increase the size of overall structure. In order to overcome these problems we can use metamaterial structures such as SRR, CSRR and so on. The Metamaterials were first introduced by Russian physicist Victor Veselago in late 1960s, Metamaterials are the artificial structures, which exhibit negative permeability and permittivity and negative refractive index [3]. Metamaterials are not found naturally in nature. There are various kinds of metamaterial structures are in use such as split ring resonator (SRR) and complementary split ring resonator (CSRR) etc. Split ring resonator (SRR) with negative permeability, as the name accomplishes that it is a complete circle of metal, which acts like inductive-capacitive resonator of an electrical circuit of filter. When the resonator sits in the magnetic field those changes with time, charge built up across the gap in the ring. At low frequencies, the current that oscillate within the resonator stay in phase with the deriving field but at higher frequencies, the current starts to lag, generating an out of phase response , which produces the effect of negative permeability at those higher frequencies. Hence metamaterial defined as "an artificial and manmade materials which gain its properties such as negative permeability and negative permittivity both from its structure rather than directly from its composition"

[4] [5]. In this paper, multilayered stepped impedance low pass filter, a hexagonal structure of metamaterial is designed at the top layer of designed structure in fig. The designing is done with computer simulated structure (CST) software.

II. DESIGN OF LOW PASS FILTER

The proposed microwave low pass filter is designed and simulated using Computer Simulated Technique (CST) software with dielectric constant 4.3 and cut off frequency 2.34GHz. The proposed low pass filter is designed with stepped impedance method. The general structure of stepped impedance microstrip filter uses a cascaded structure of alternating high impedance and low impedance transmission lines, in which high impedance lines act as series inductor and low impedance lines act as shunt capacitor. Filter implementation using Richard's transformation method and Kuroda's identities [5]. At high frequencies, the lumped elements of filter put off their working operation due to distributed nature of lumped elements. There are two major problems associated with microwave filter design. First one is within the limited frequency range only lumped elements work properly. At high frequencies, lumped elements stop their operation. This limitation is overcome with the help of Richard's transformation. In Richard's transformation, the lumped elements are converted into transmission line sections. On other hand, the distance between the components at the microwave frequency is not negligible. This limitation is overcome with the help of Kuroda's identities. The Kuroda's identities can be used to separate filter elements by using transmission line element [6] [7].

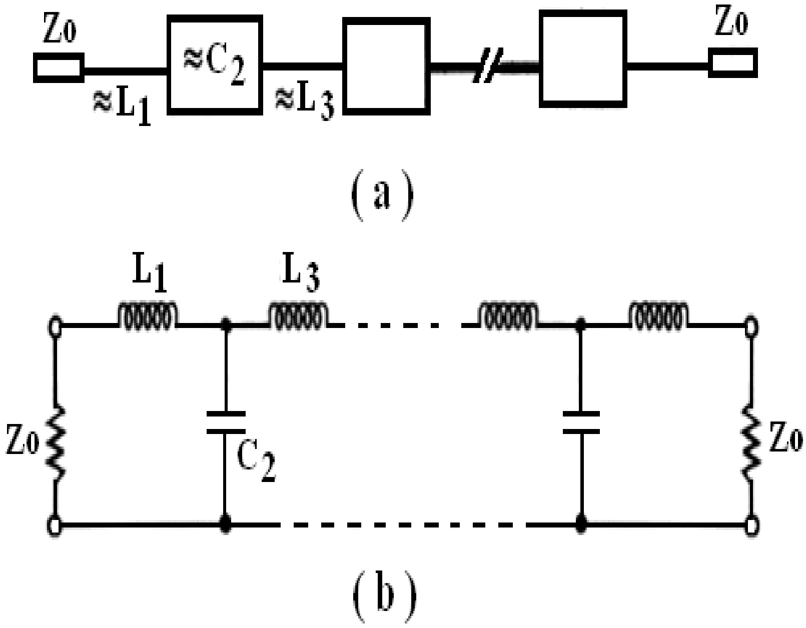

Fig. 1 Layout of stepped impedance low pass filter structure.

III. DESIGN EQUATION

A third order (N= 3) low pass prototype with maximally flat low pass filter.

n	g 1	g 2	g 3	g 4
3	1.000	2.000	1.000	1.000

For the normalized cut off frequency Ωc = 1, using the element transformations to get the values of inductors and capacitors.

$\text{Li} = \frac{Zo.\Omega c}{2\pi.fc.go}.gi$ i =1, 2, 3

$\text{Ci} = \frac{go.\Omega c}{2\pi.fc.Zo}.g2$

The electrical length of inductor section can be calculated as

$\beta\ell = \frac{\text{LR0}}{\text{Zh}}$

Electrical length of capacitor section is given by

$\beta\ell = \frac{CZ\ell}{R0}$

Where R_0 is the filter impedance and L and C are the normalized element values of the low pass prototype.

IV. FILTER DESIGN AND RESULTS

Layout of conventional stepped impedance low pass filter is shown in fig. 2. The simulated result of reflection (s11), transmission (s21) parameter of frequency response for conventional low pass filter is shown in fig. 3.

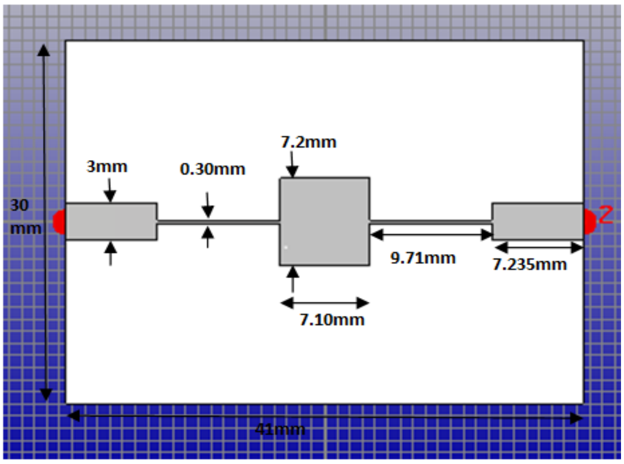

Fig. 2 Layout of conventional stepped impedance low pass filter.

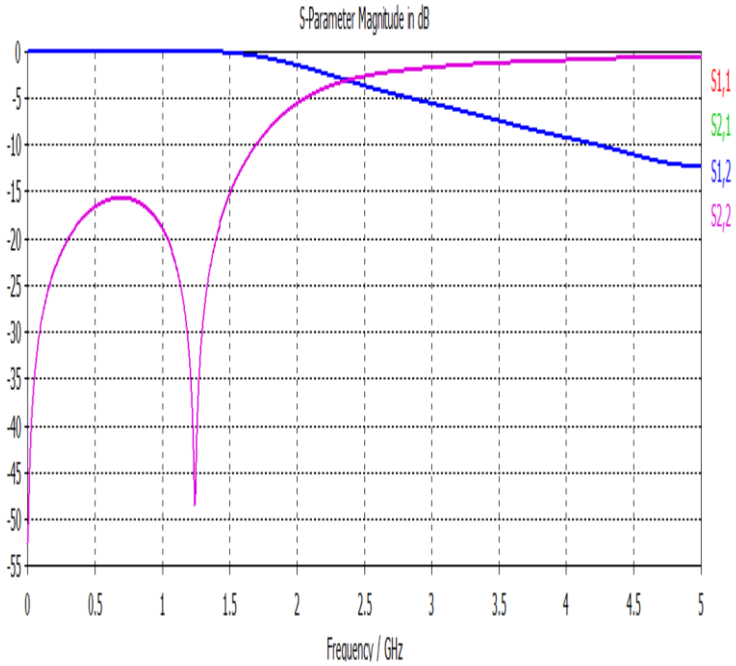

Fig. 3 Simulated result of s11, s21 parameter for convention stepped impedance low pass filter.

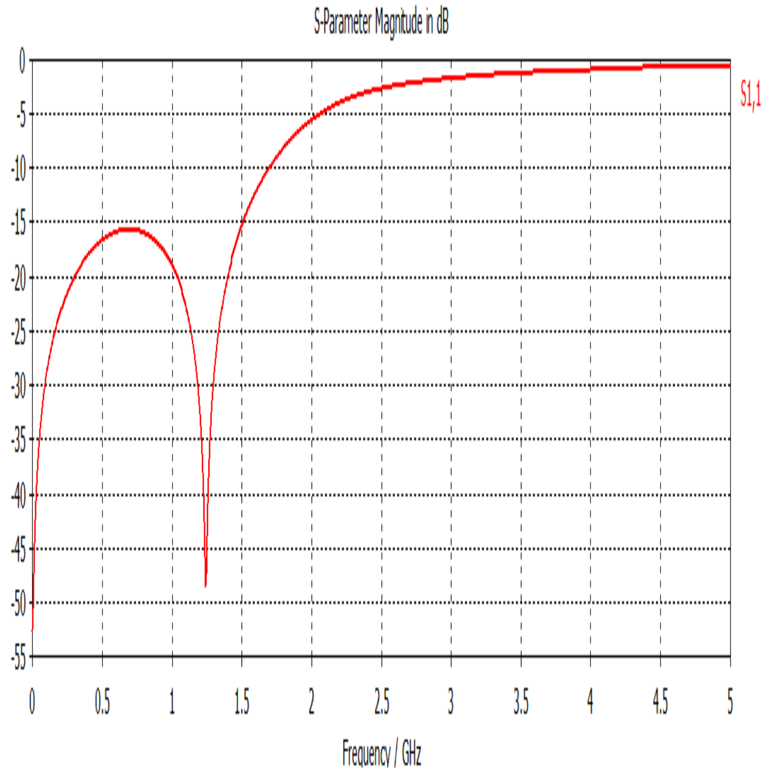

Fig. 4 simulated result of s11 parameter for conventional low pass filter.

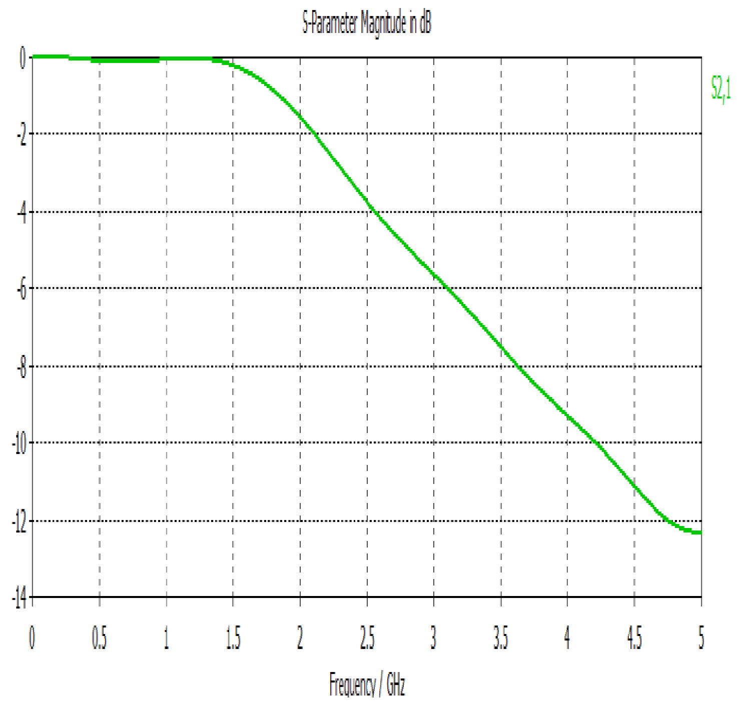

Fig. 5 simulated result of s21 parameter for conventional low pass filter.

For better performance of low pass filter we have applied metamaterial structure on the top layer of low pass filter. In this proposed paper, Hexagon split ring resonator structure have been designed on the top layer of conventional low pass filter, at the height of 3.276mm.

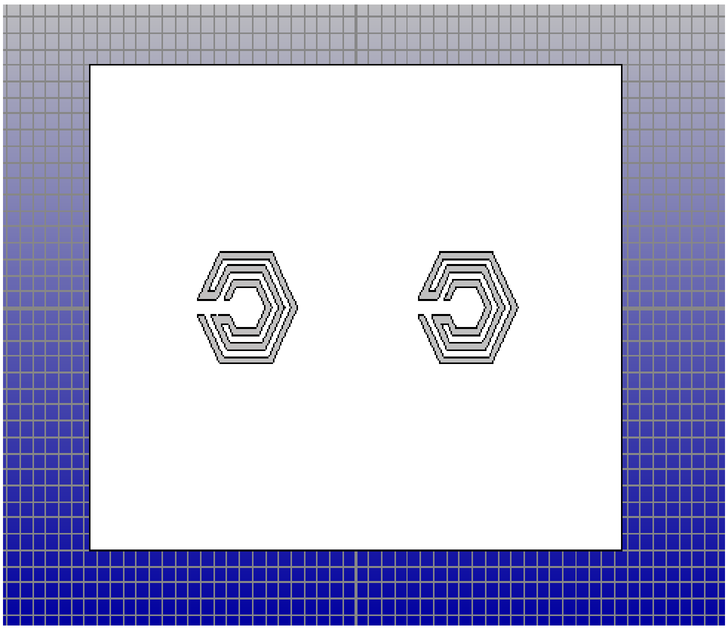

Fig. 6 Layout of hexagonal structure of top layer multilayered stepped impedance low pass filter.

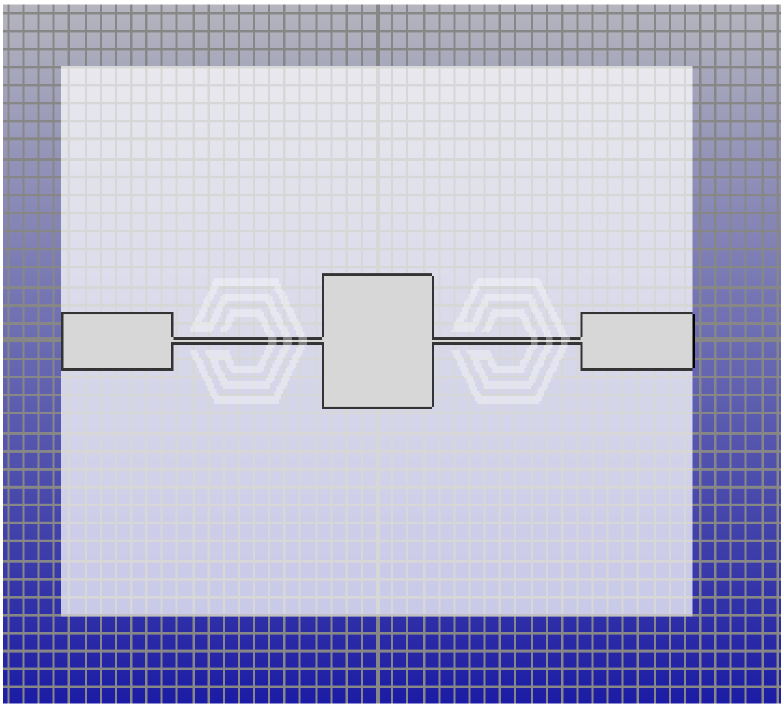

Fig. 7 layout of proposed low pass filter with spiral hexagon resonator at the top layer.

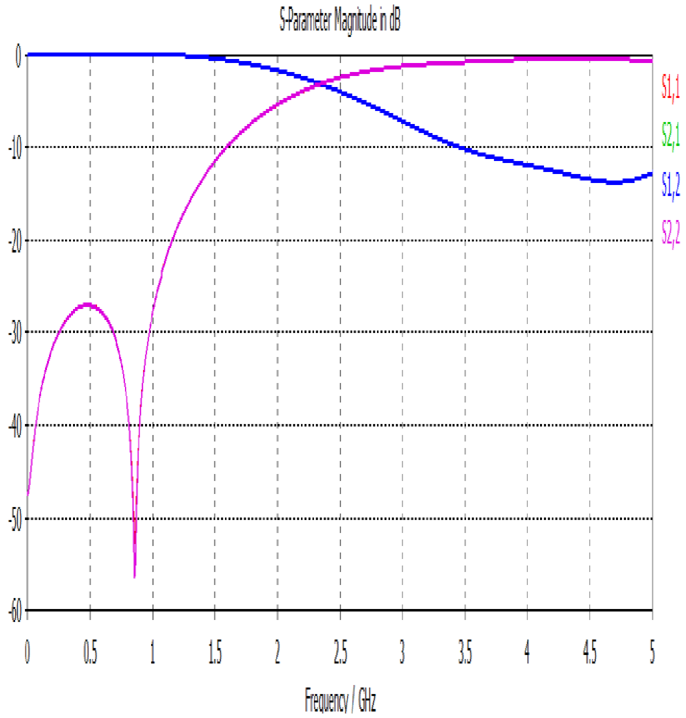

Fig. 7 simulated result of s11 and s21 results of proposed low pass filter, with cut off frequency 2.34GHz.

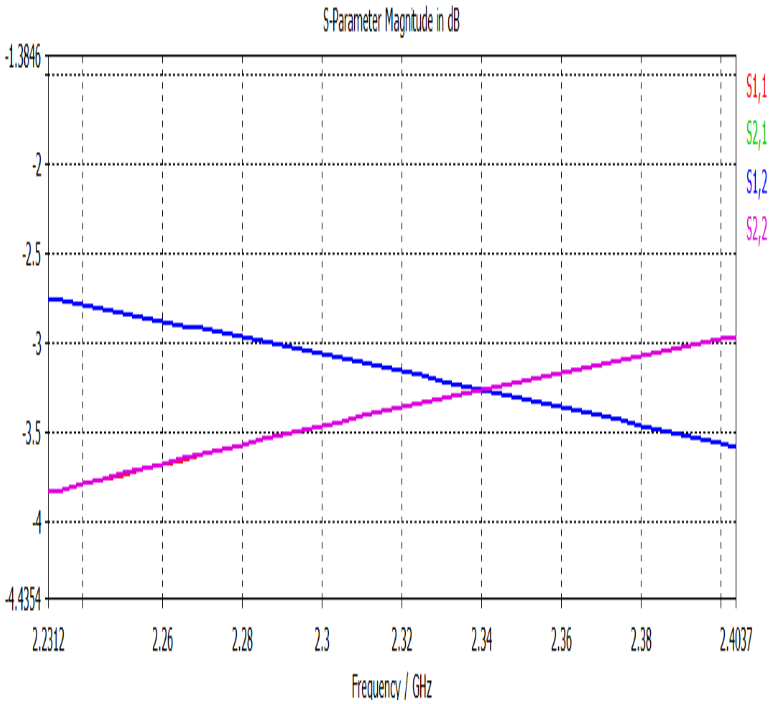

Fig. 8 shows the sharp view of cut off frequency.

V. CONCLUTION

This paper proposed stepped impedance low pass filter with cut off frequency 2.34GHz. The new design of stepped impedance low pass filter has better results as compared to conventional microstrip low pass filter.

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