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QUAD BAND FILTENNA USING SPLIT RING RESONATORS TO NOTCH UNWANTED FREQUENCIES IN MEDICAL APPLICATION BANDS

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ABSTRACT

This paper demonstrates a novel multi band reject filter using complimentary split ring resonators .Here the proposed antenna was designed using Ansys HFSS software. This multiband reject filter attenuate frequencies at 2.67 GHz, 3.5 GHz, 6.6 GHz, 9.1 GHz and 11.3 GHz. This multiband reject filter is used to enhance the bandwidth and improve the return loss with the help of complimentary split ring resonators on the ground plane. The SRR is a common structure to implement meta-material properties. The SRR consists of concentric metallic plates etched on a dielectric surface which is used to increase the frequency attenuation characteristic and in turn placing these SRR at desired position led to increase of bandwidth from 0.1232 to 0.1561. The band reject filter is prone to frequency distortions which are removed by the complimentary split ring resonators. The split ring that was taken in the paper shown a good increase in the bandwidth but in order to increase the bandwidth more we opted to take an another complimentary split ring resonator over the original split, which increased the bandwidth more. The proposed band stop filter antenna characteristics are used for the medical application such as electrocardiogram.

Keywords: *Band Reject Filter, Complimentary Split Ring resonator (CSRR), Filtenna.*

1. INTRODUCTION:

Split ring resonators are used to exhibit metamaterial properties like negative permeability and permittivity. For construction miniature microwave circuits these structures are used. In some design criteria we use split ring resonators for design of filters especially on notch band or stop band filter. Generally Band Stop Filters are used to stop or eliminate certain band of frequencies as per the requirement. Here Band Reject Filter is designed using the Ring Resonators. Ring resonator is a set of waveguides in which a closed loop is coupled to both input and output. It is similar to meta-material type as it is an artificially produced structure. Using split ring resonators array which is periodic in nature, negative refractive index is obtained which is the basic feature of a metamaterial and so ring resonator is known to be a meta-material. Meta materials are the assembly of composite structured materials formed either from periodic or random arrays of scattering materials. It has been observed that certain meta-material configurations exhibit scattering properties consistent with the approximate frequency forms of permeability and permittivity curves. Both the permeability and Permittivities of the meta-materials are negative due to the negative refractive index of meta-materials. The common method to characterize the scattering properties of an electromagnetic material is to determine its refractive index (n) and impedance (z). As the permeability and permittivity can be expressed in terms of n and z, the scattering characteristics of meta-materials can be estimated by using the following formulae.

Electric permittivity, $\varepsilon=\frac{n}{z}$ --- (1)

Magnetic permeability, $\mu= nz$ --- (2)

As $n<1$ for metamaterials, it can be observed that $\varepsilon<1$ and $\mu<1$. In the present day scenario of the growing field of wireless communications, filters and antennas are becoming a crucial part of human life. Today there are various types of filters and this paper deals with the dual band reject filter which is used to eliminate frequencies at two points. So the frequency is chosen as per the requirement. The other applications of the dual band band stop filter are it can remove unwanted double spectrum and side band spectrum. It also

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removes the pass band insertion.Split rings are primarily used for the implementation of the metamaterials which are used for increasing the magnetic susceptibility as a result the resonant frequency is obtained accurately. Band stop filters are used in this paper to increase the eliminating bandwidth frequencies. Split ring resonators are now being widely used along with the filters in order to get exact stopping of frequencies at the given band. Every band stop filter has some characteristics like group delay, which is the amount of time that the signal has taken to completely pass through the filter. It determines the range of frequencies that can pass through the filter. It is represented by

$$T_g(\omega) = -\frac{d\phi(\omega)}{d\omega}$$

$$T_\phi(\omega) = -\frac{\phi(\omega)}{\omega} \qquad \text{------ (3)}$$

Where ϕ is the phase shift and T_g is the group delay of the filter.

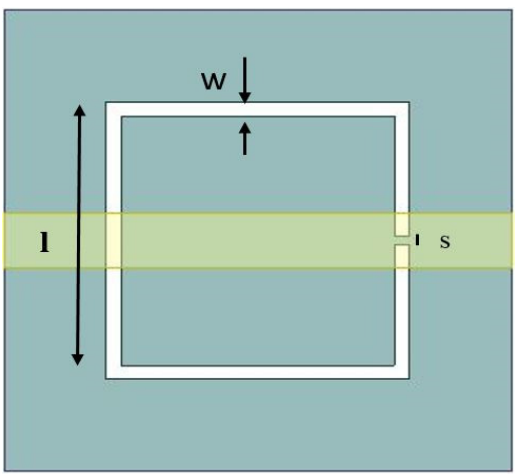

Fig 1.1 Single Split Ring Resonator

Resonating Frequency can be calculated as follows:

Resonating Frequency $f_r = c/2*L\sqrt{E_{eff}}$ --- (4)

Inductance L= $4*l - S - 4*W$ --- (5)

Where ‘c’ is the velocity of light = $3X10^8$ m/s, l = Length of the Split Ring Resonator (mm) S = Split Gap (mm), W = Width of the Split Ring Resonator (mm). Each Split Ring Resonator has a specific Resonating Frequency and as the number of rings increases resonating frequencies also increases. If the number of rings increases then the filter can be known as Multi Band Stop Filter where various band stops occur at the resonating frequencies. Due to the resonating frequency, notch occurs at the respective resonating frequency as a result bandwidth of certain frequencies is also eliminated. This is clearly explained in the design part.

2. EQUIVALENT CIRCUITS OF SPLIT RING RESONATORS:

The basic fundamental laws for getting metamaterial properties are defined with respect to inductance and capacitance based formulas. Split ring resonator: a well designed inductor resonating at ω << c/L → gives μ < 0 - - (4) and for Metal wires (continuous or cut): r << L → ε < 0 for ω << c/L resonance - - (5).

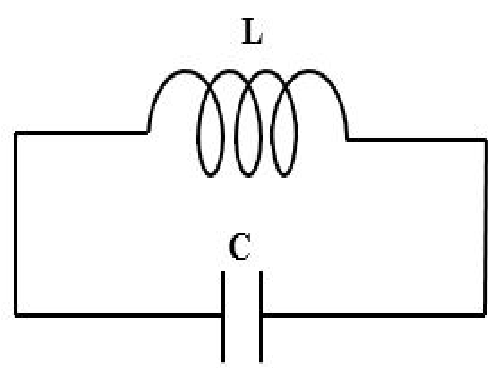

Fig 2.1 Basic Circuit Of Single Split Ring Resonator

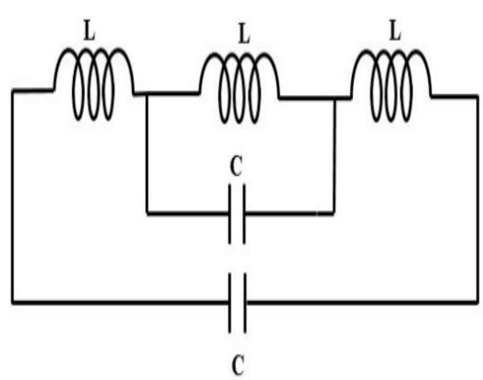

Fig 2.2 Basic Circuit Of Double Split Ring Resonator

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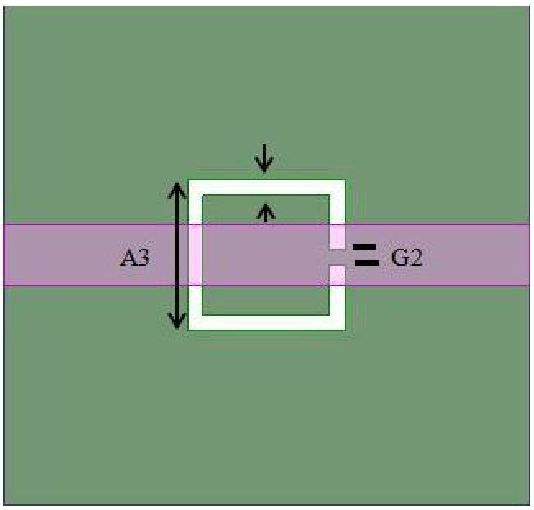
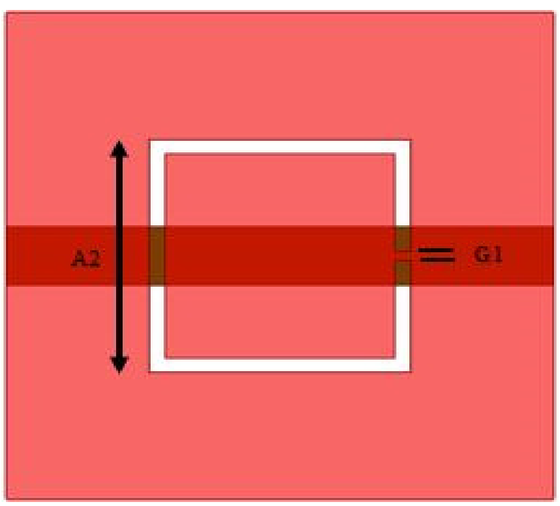
The advantages of using metamaterial structures in the antenna modeling is
Increases directivity (n=0),
Increases radiation power,
Reduces surface waves,
No need of source matching,
The antennas use metamaterials in the structure to improve the performance of the antenna systems. They could possibly allow high directivity, small size and tunable frequency.

3. ANTENNA DESIGN AND SPECIFICATION:





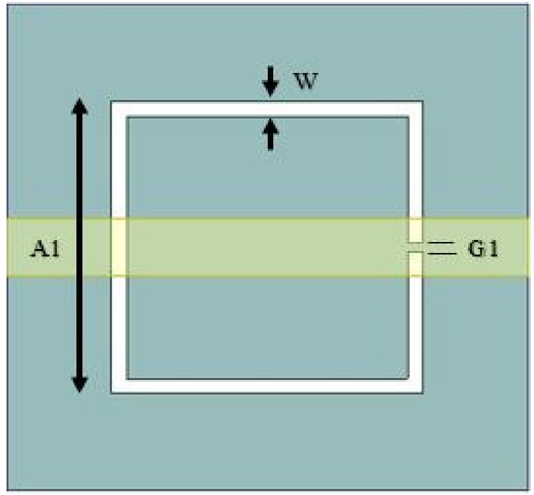


Fig 3.1 Split Ring Resonator Unit Cell With Different Dimensions

Duality Concept is used to derive a Multi Complementary Split Ring Resonator from a Multi Ring Split Ring Resonator which is having a simple structure. Multi Ring SRR can have apertures or metal plates to derive the complimentary structure using the Bobbinet principle. In the multi ring complementary split ring resonator, therefore negative permittivity is achieved by the transformation of negative permeability. The number of resonances is achieved by counting the number of rings present in the multi-ring CSRR. Therefore number of resonances is known by counting number of rings. Here we use High Frequency Structural Simulator (HFSS) to design filter and parameters like Return Loss and Bandwidth are observed. Here 10mm*10mm size substrate is used and the single split ring resonator is designed with multiple dimensions as shown above. Figure 3.1(a) represents split ring of dimension A1*A1. Figure 3.1(b) represents split ring of dimension A2 X A2. Figure 3.1(c) represents split ring of dimension A3 X A3.

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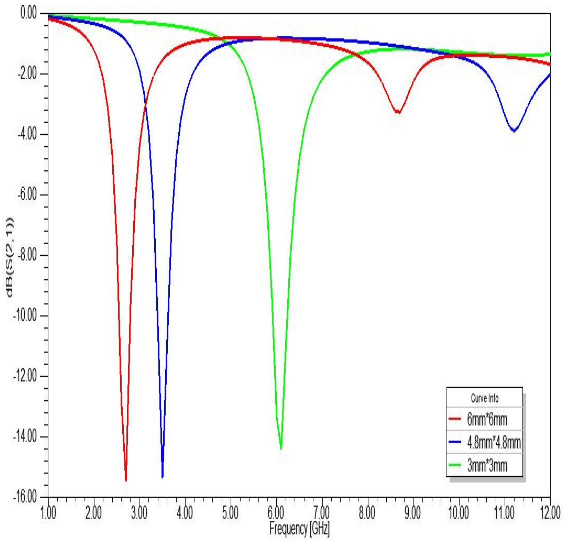
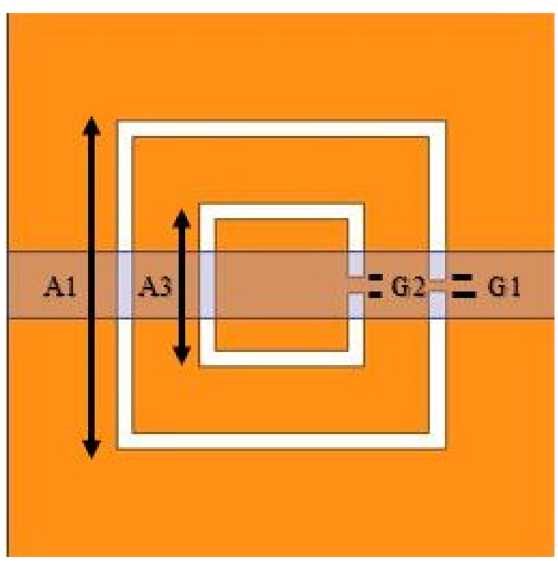


Fig 3.2 Transmission Loss Characteristics Of Split Ring Resonators

The figure 3.2 shows the number of bands, their bandwidth and return loss of varied split ring resonators split ring resonator antenna. From the plot it is observed that the minimum return loss of -15 dB is obtained at 2.9 GHz frequency followed by -15.4 dB at 3.5 GHz, -14.1 dB at 6 GHz. Total of three bands of frequencies are obtained with a maximum band width of 2 GHz having the frequency range between 1.9 – 6.1 GHz. All these bands of frequencies support many applications.



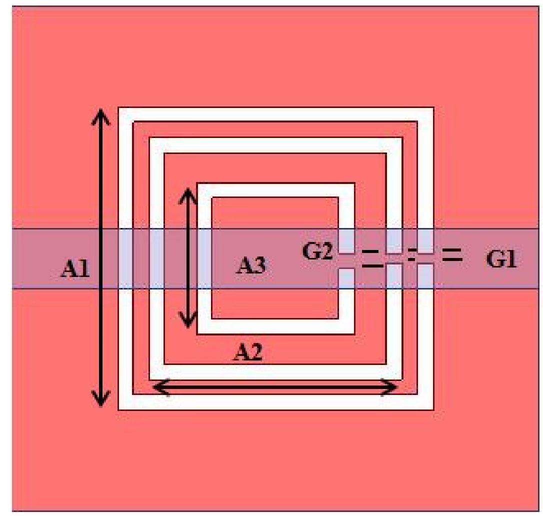


Fig 3.3 Band Stop Filter With Different Band Stops

Figure 3.3(a) represents Dual Band Stop Filter with Two Split Rings. It is also known as Single Unit Cell I. Figure 3.3(b) represents Multi Band Stop Filter with Three Split Rings.

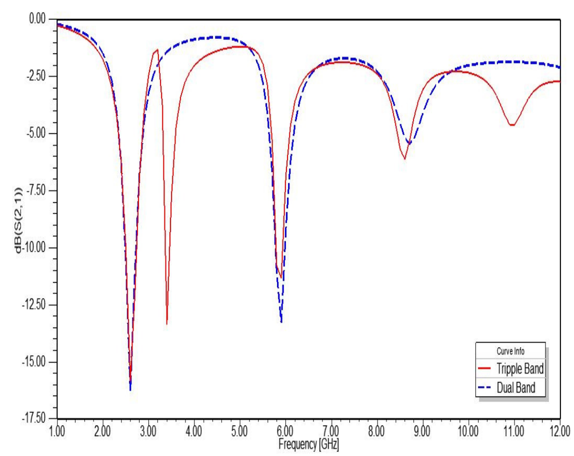


Fig 3.4 Transmission Loss Characteristics Of Single Unit Cell

The figure 3.4 shows the number of bands, their bandwidth and return loss of varied split ring resonators antenna. From the plot it is observed that the minimum return loss of -16 dB is obtained at 2.6 GHz frequency followed by -13 dB at 5.9 GHz for Single Unit Cell I and -14 dB at 2.6 GHz, -12 dB at 3.4 GHz and -11dB at 5.8 GHz for Single Unit Cell II. All these bands of frequencies support many applications

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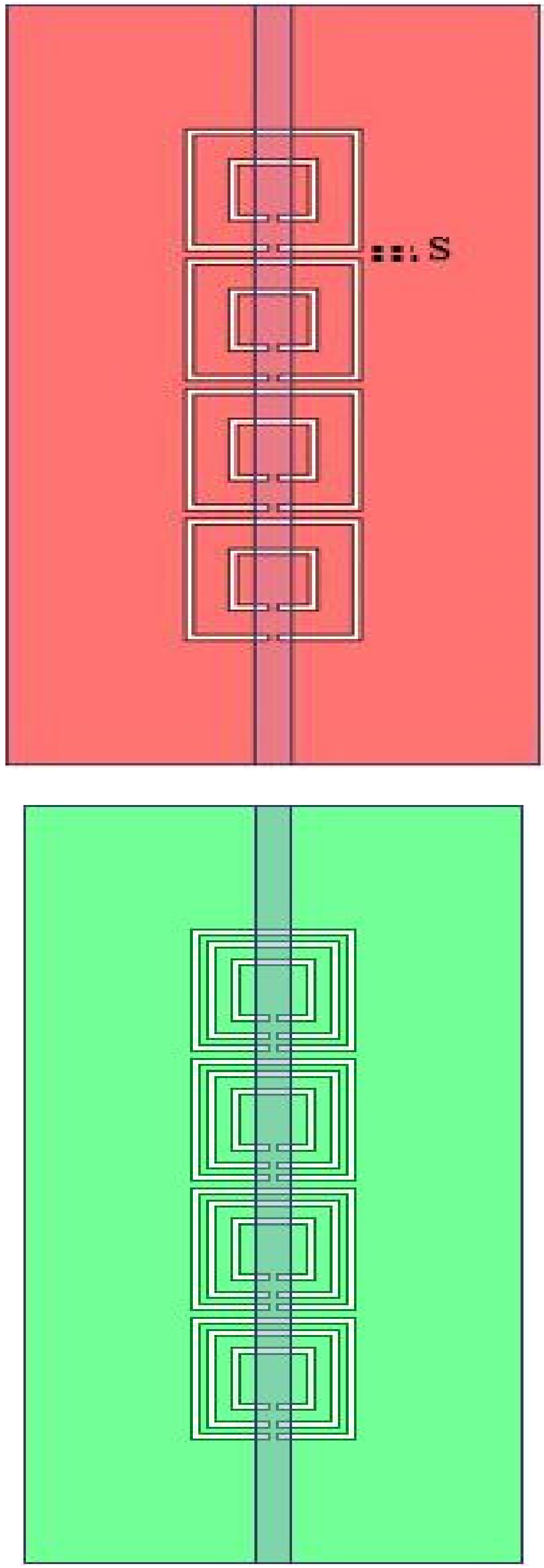

Fig 3.5. Band Reject Filter With Four Cells

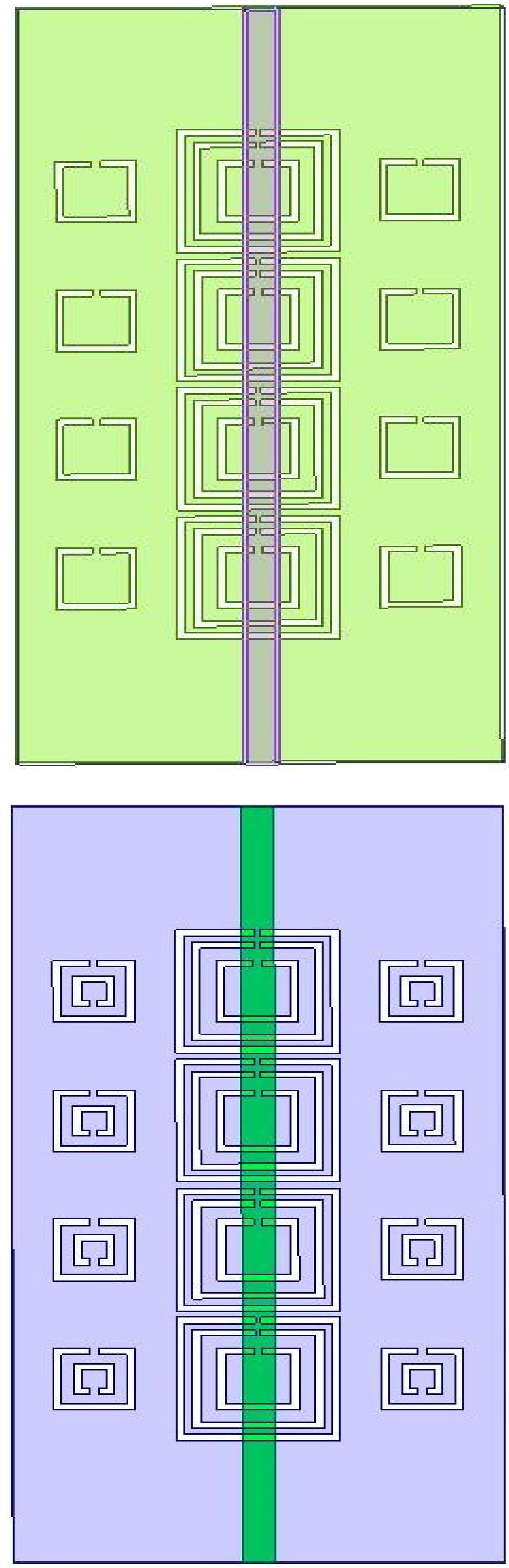

Fig 3.6. Proposed Filters I And II

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Figure 3.5(a) represents the band reject filter with Four Cells I. Figure 3.5(b) represents the band reject filter with Four Cells II. Four cells II is also known as Original Filter with substrate 36.9mm*18mm. Here a gap of S=0.3mm is maintained between each Single Unit Cell. Figure 3.6(a) represents the original filter and additional splits of dimensions 3mm*3mm. Figure. 3.6(b) represents the original filter and complimentary split ring resonators with dimensions 3mm*3mm and 1.5mm*1.5mm. Dimensions of Complimentary Split Ring Resonator are given in table 1.

Table 1: Antenna Parameters

Single Ring CSRR(mm)			Double Ring CSRR(mm)	Triple Ring CSRR(mm)
A1=6	A2=4.8	A3=3	A1=6, A2=3	A1=6,A2=4.8 ,A3=3
G1=0.2	G1=0.2	G3=0.3	G1=0.2, G2=0.3	G1=0.2,G2=0 .2
W=0.3	W=0.3	W=0.3	W=0.3	W=0.3

4. RESULTS AND DISCUSSION:

Figure 4.1 represents return loss of four unit cell I and Four unit cell II. This return loss characteristics are used in bandwidth calculation of band reject filter which is discussed later. Figure 4.3 represents return loss of Proposed Filter I, Proposed Filter II and Original Filter. This return loss characteristics are used in bandwidth calculation of band reject filter and the impedance bandwidth is measured. The reflection coefficient and transmission coefficient are simulated and analyzed in this work. The transmission coefficient less than -15 dB at operating bands is giving confidence for applicability of the antenna at desired medical band applications.

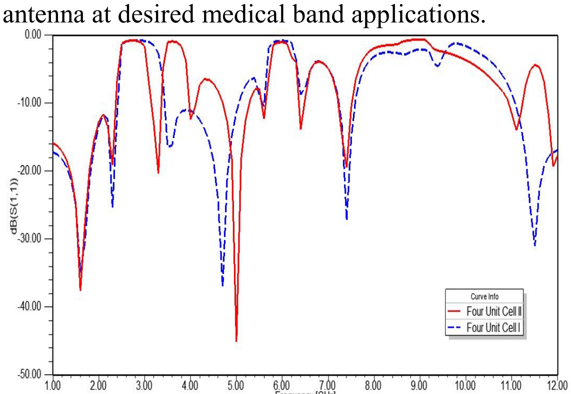

Fig 4.1. Reflection Loss Characteristics Of Four Unit Cells

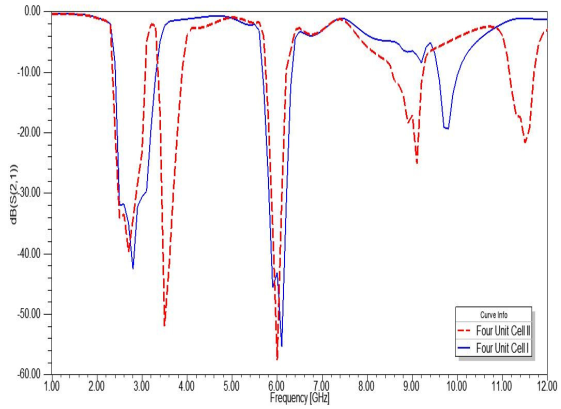

Fig 4.2. Transmission Loss Characteristics Of Four Cells

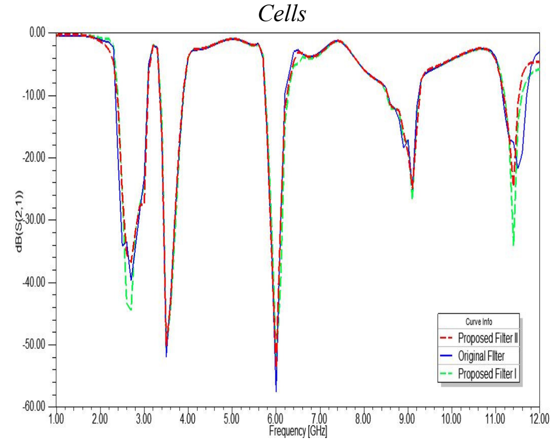

Fig 4.3. Transmission Loss Characteristics Of Proposed Filter I And Proposed Filter II

The Below Table represents the Bandwidth Improvement in the proposed filter I and II over the Original Filter Design and it seen clearly in Reflection Loss Parameters.

Table 2: Dimensional Characteristics

ORIGINAL FILTER	PROPOSED FILTER I	PROPOSED FILTER II
0.2231	0.2316	0.2260
0.1480	0.1568	0.1684
0.5838	0.5914	0.5964
0.1232	-	0.1561
0.2889	0.2954	0.2990

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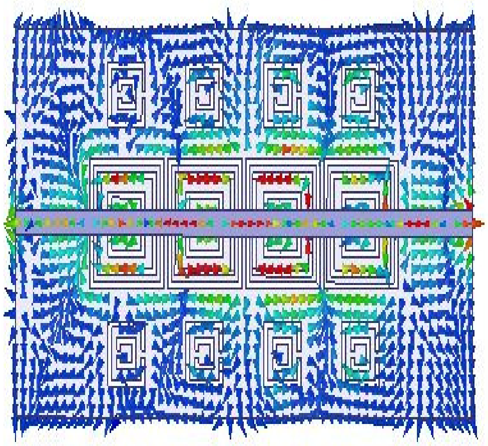

Fig 4.4. Current Distribution Of The Proposed Filter II

The proposed model with triple split ring beneath the feed line on ground plane and adjacent complementary split ring resonators are providing better isolation and associated current distribution as shown in Fig 4.4. The current distribution on the resonators is oriented in opposite direction on each unit.

5. CONCLUSION:

The design and analysis of the filtenna with band reject characteristics by ring resonators are improved in the proposed filter I over the original filter. From the results of proposed filter II, it is observed that the bandwidth is more improved over the original filter and it has an improved bandwidth over the proposed filter I. The split ring that was taken in the paper shown a good increase in the bandwidth but in order to increase the bandwidth more we opted to take an another complimentary split ring resonator over the original split, which increased the bandwidth more. The proposed band stop filter antenna characteristics can be used for the medical application such as electrocardiogram.

6. ACKNOWLEDGEMENTS:

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