



# METAMATERIAL INSPIRED TRI-BAND ANTENNA WITH SRR AND SHORTING STUB

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## ABSTRACT

Two novel meta-material inspired antennas are proposed in this paper which can be applied for Mobile Satellite Services (MSS), Airport surveillance radars, WIMAX and S - Band applications. Antenna 1 has two triangular split ring resonators and fed by Co-planar Wave Guide (CPW). After Modelling and Simulating antenna1, three frequency bands 2.1~2.3GHz, 3.0~3.4GHz and 6.5~6.7GHz are obtained. To improve the characteristics, antenna 2 is proposed whose shape is modified by adding two Complementary rectangular shaped split ring resonators in the ground of antenna1. After Modelling and simulating antenna 2 it is observed that it enhances the properties of antenna 1 with improved characteristics. Antenna 2 has radiation efficiency of 0.998, front to back ratio of 1.0049 and peak directivity is 1.17.

**Keywords:** metamaterial, split ring resonator, coplanar wave guide (CPW), complementary split ring resonator.

## 1. INTRODUCTION

Now-a-days extensive researchers in wireless communication have concentrated their research work on meta-material based antennas. Metamaterials are the ones which exhibit some peculiar characteristics that don't exist in nature. Natural materials can only affect electric component of light but these meta-materials can affect the magnetic component by expanding the number of interactions possible. The word meta-material comes from the Greek word "meta", which means "to go beyond". The material which is constructed to possess some special features which does not exist in the traditional materials is called as meta-material. These materials are constructed by connecting different elements which are claimed from composite materials like metal or plastic. The materials are arranged in periodic pattern at ranges that are less than the wavelength of the phenomena that they influence [1-4]. Meta-materials are the materials whose specified properties are depending on the internal structure of the material it is composed instead of not depending on the matter of which they composed. It is possible to combine the small elements called unit cells to form a material which is suitable to meet the required features. Before the emergence of meta-materials, propagation of wave through the medium was explained as a static property of the materials similar to the colour of the material or hardness of the material [5-6]. The importance of these meta-materials is the arrangement of unit cells in different ways which result in the change of propagation of the wave. This can be done by changing either mechanical or electrical characteristics of each unit cell. The features of unit cell can be efficiently controlled to a high degree of precision [7-8].

Generally Split Ring Resonator (SRR) is used to produce characteristics that are similar to meta-materials. The structure of split ring resonator is such a nanostructure which helps it to become a basic unit of meta-materials [9-10]. Split ring resonators are used to produce desired magnetic susceptibility in metamaterials up to 200 THz. Each cell of SRR consists of pair of closed loops with separation at their opposite ends. The loops are

constructed with non-magnetic material like copper having a gap between them. Either concentric loops or square loops can be used with required gap between them. The produced magnetic flux in these rings will in turn produce the rotating currents in the rings. This rotating current produces its own flux to oppose the incident field in the rings [11-12].

The dipolar field pattern is produced in these split ring resonators. These split ring resonators allow resonant wavelengths which are longer than ring diameters because of these splits in the rings. But this doesn't happen in closed rings. Large capacitance values are produced because of gaps between the rings [13]. Because of this large capacitance values, it reduces the resonant frequency. The resonant wavelength becomes larger when compared to the structure dimensions which in turn results in low radiative losses and high quality factors. Because of dimensions of the structure is less than the resonant wavelength, it is difficult to observe the response at infrared regions and optical wavelength when required [14].

In this paper two novel meta-material based triband antennas are proposed with triangular split ring resonators and complementary rectangular split ring resonators. Antenna1 and Antenna2 both operate at similar frequency bands of 2.1~2.3GHz, 3.0~3.4GHz and 6.5~6.7GHz. But the  $S_{11}$  measurements of antenna2 are improved over antenna1.

## 2. ANTENNA DESIGN AND ANALYSIS

**Antenna 1:** It consists of two triangular split ring resonators and a co-planar wave guide (CPW). "Rogers RT/ duroid 5880" is used as a substrate for antennas whose relative permittivity is 2.2. The overall dimension of substrate is  $40 \times 40 \times 1 \text{ mm}^3$ . The designed antenna works for various applications like Mobile Satellite Services (MSS), WIMAX, Airport Surveillance Radar and S-Band applications. This antenna design is simulated using ANSOFT HFSS. The schematic diagram of antenna1 is shown in Figure-1. The detailed dimensions of antenna1 are mentioned in Table-1.

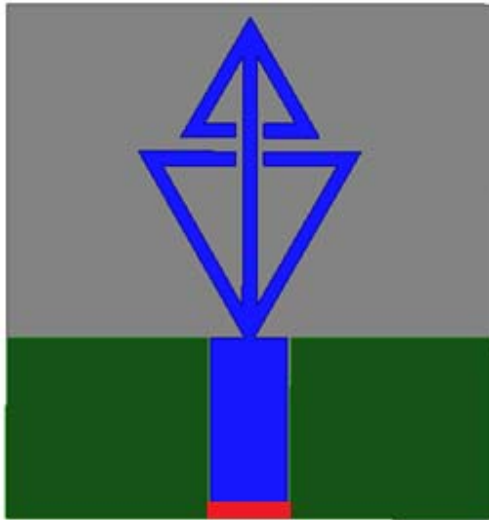


Figure-1. Schematic diagram of antenna1.

Table-1. Proposed dimensions of antenna1.

$l_g$	14.5	$a_1$	16	$D$	1
$w_g$	13	$a_2$	10		
$w_f$	5.5	$g$	2		
$g_f$	0.2	$w$	1		

**Antenna 2:** Antenna2 also operates in the same frequency bands as antenna1 but this is proposed in order to improve S11 results of antenna1. Here a complementary shape with two rectangular split ring resonators is designed and is directly inserted on the left part of ground in antenna1 which results in antenna2 design. Schematic

diagram of antenna2 is in Figure-2. The detailed dimensions of antenna2 are in Table-2.

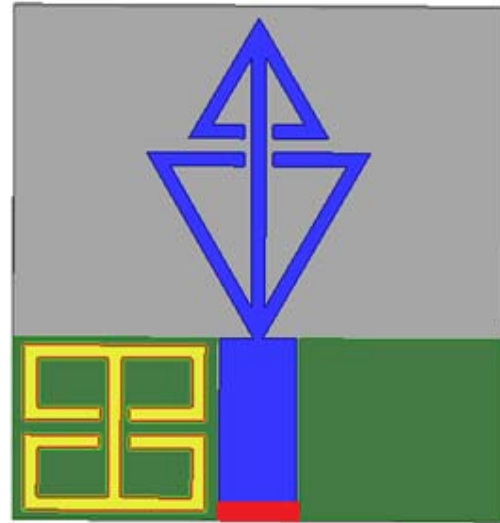


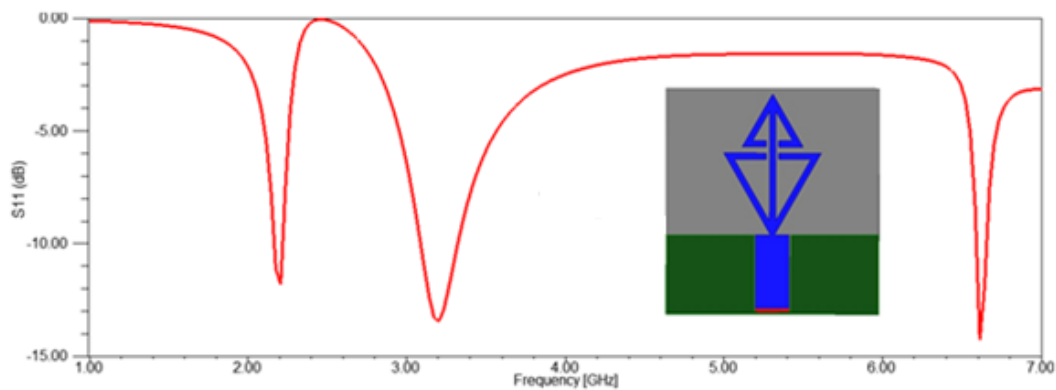
Figure-2. Schematic diagram of antenna2.

Table-2. Proposed dimensions of antenna2.

$l_g$	14.5	$a_1$	10	$D$	1
$w_g$	13	$a_2$	16	$l_s$	13
$w_f$	5.5	$g$	2	$b_s$	5.5
$g_f$	0.2	$w$	1	$w_s$	1

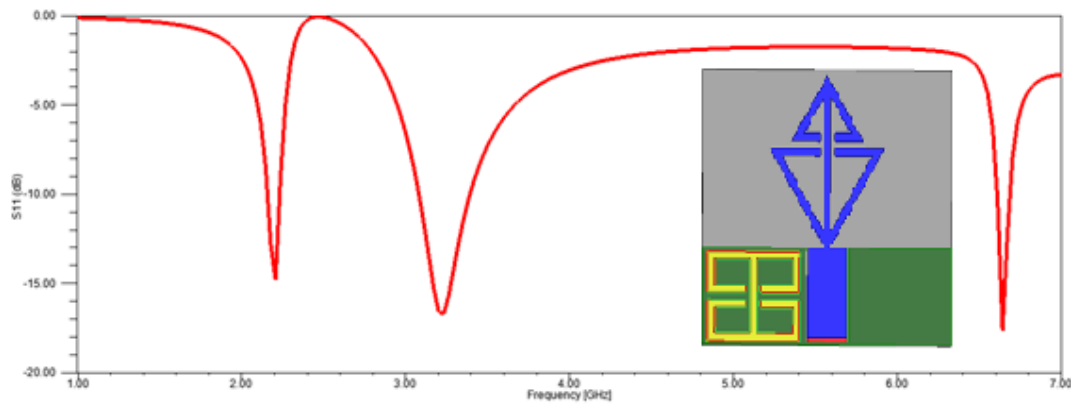
### 3. RESULTS AND DISCUSSIONS

The following are the results obtained after simulating antenna1 and antenna 2 in Ansys HFSS.

Figure-3. Simulated  $S_{11}$  for antenna1.

In this plot it is observed that the 1<sup>st</sup> band frequency at 2.2 GHz with a return loss of -11.8 dB and 2<sup>nd</sup> band frequency at 3.2GHz with a return loss of -

13.43dB and 3<sup>rd</sup> band frequency at 6.2 GHz with a return loss of -14.25 dB.



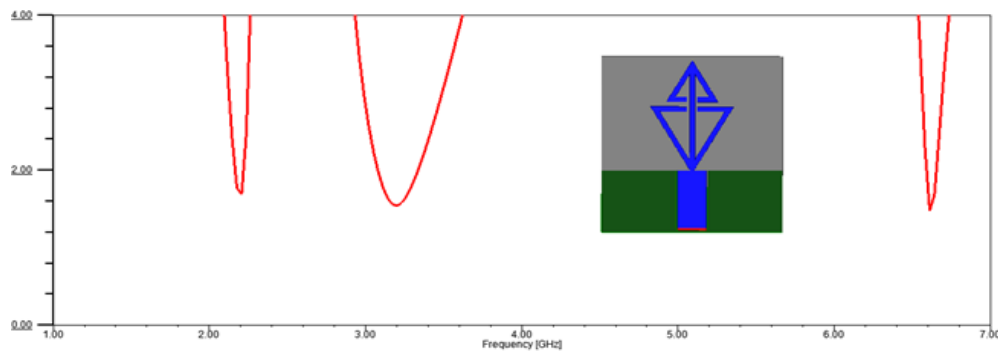
**Figure-4.** Simulated  $S_{11}$  for antenna2

In this plot it is observed that the 1<sup>st</sup> band frequency at 2.2 GHz with a return loss of -14.78 dB and 2<sup>nd</sup> band frequency at 3.2GHz with a return loss of -16.68 dB and 3<sup>rd</sup> band frequency at 6.2 GHz with a return loss of -17.6 dB.

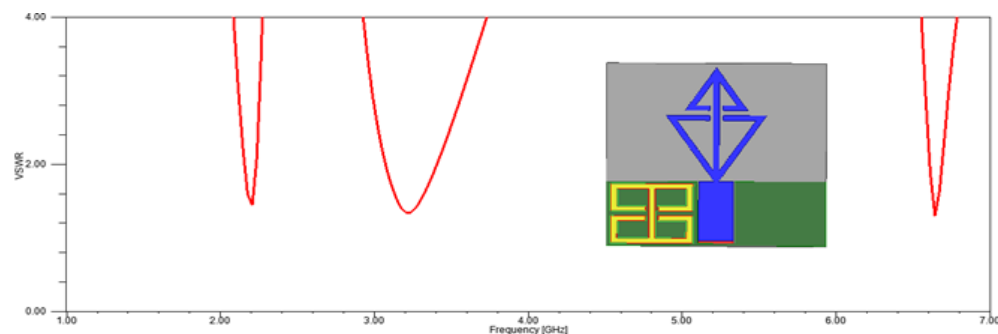
**Table-3.** Comparison of  $S_{11}$  for Antenna1 and Antenna2.

Frequency (GHz)	Antenna1 $S_{11}$ (dB)	Antenna2 $S_{11}$ (dB)
2.2	-11.8	-14.78
3.2	-13.43	-16.68
6.2	-14.25	-17.6

From the above table it is clear that  $S_{11}$  for antenna2 is improved over antenna1 by inserting a complementary rectangular split ring resonator in its ground.



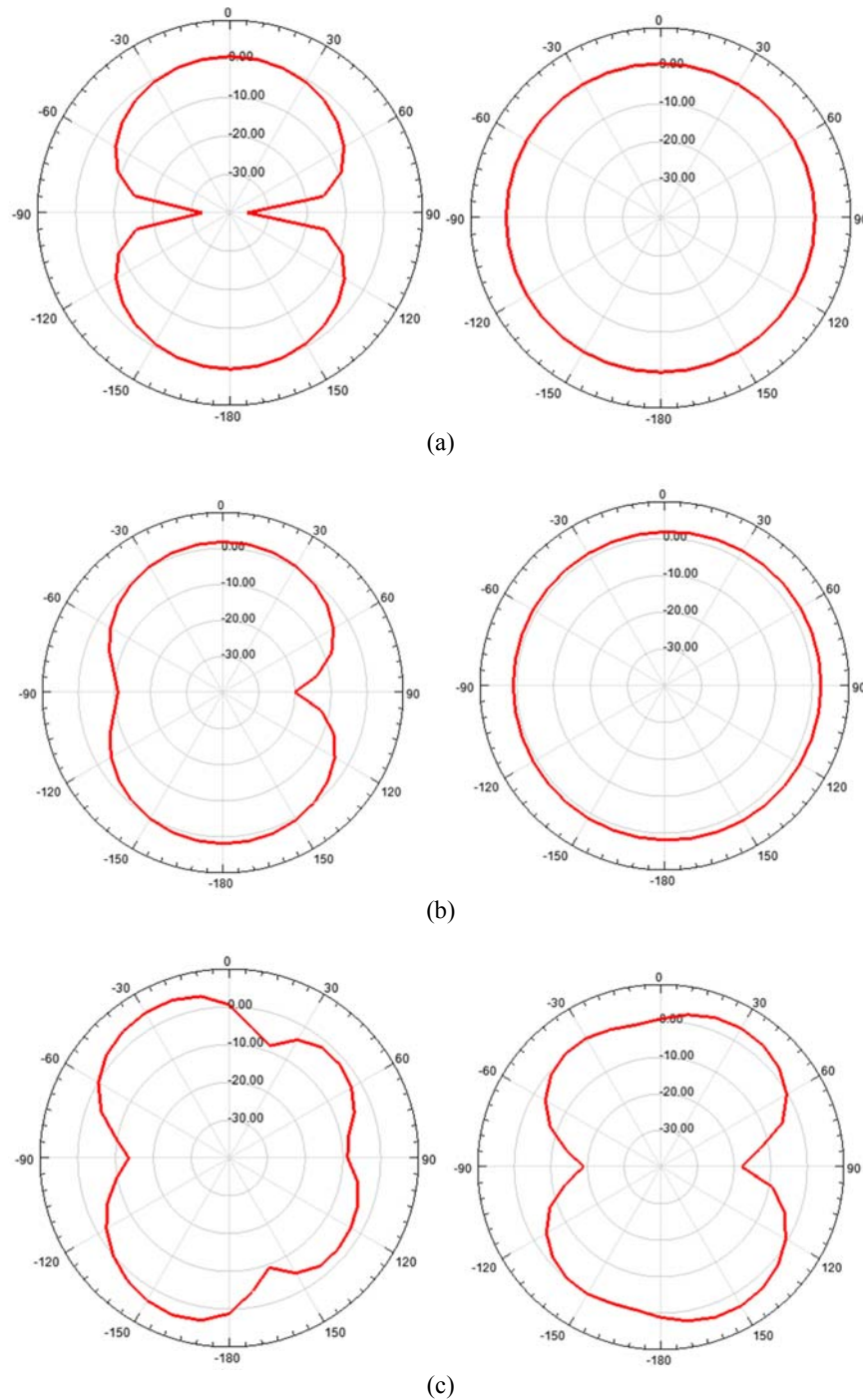
**Figure-5.** VSWR for antenna1.



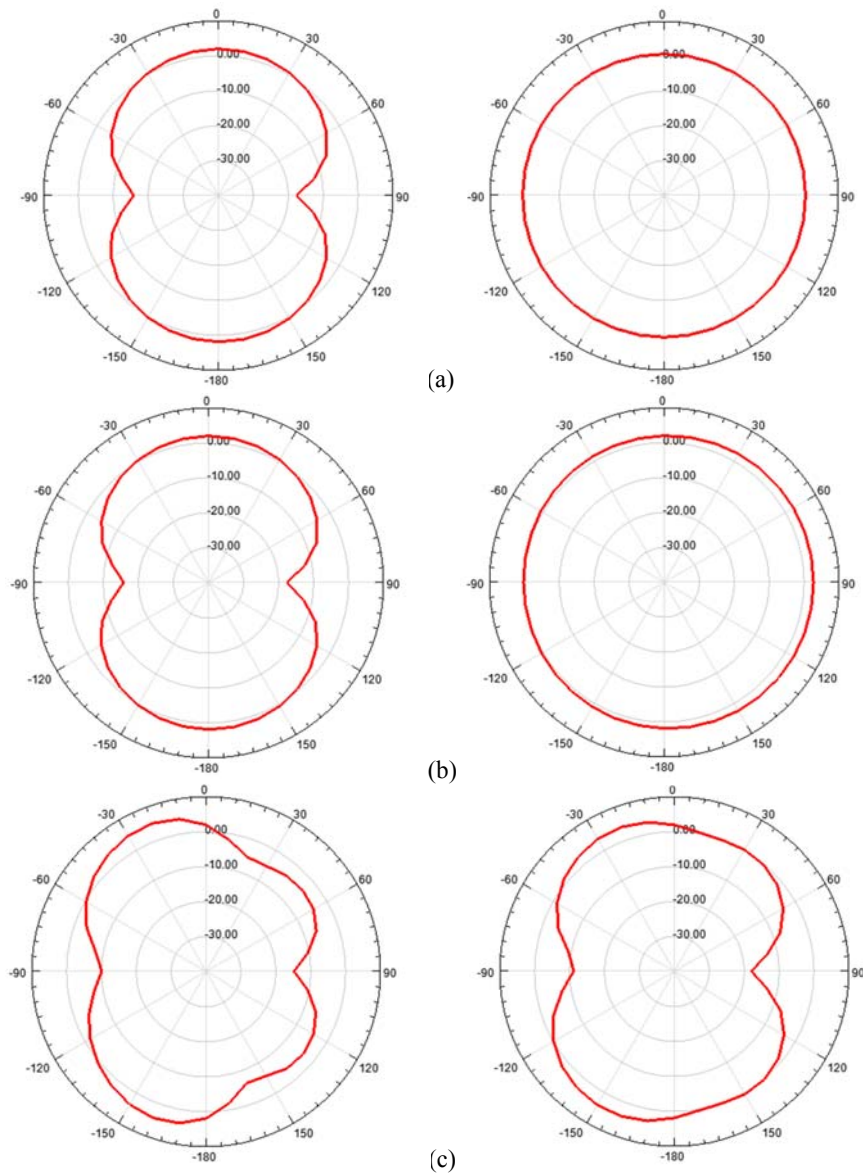
**Figure-6.** VSWR for antenna2.



In this plot it is observed that VSWR is between 2:1 at desired frequencies, which is suitable for designing an effective antenna.



**Figure-7.** Simulated radiation pattern of antenna 1 (a) 2.2 GHz (b) 3.2 GHz (c) 6.6 GHz.



**Figure-8.** Simulated radiation pattern of antenna 2 (a) 2.2GHz (b) 3.2GHz (c) 6.6GHz.

Figure-7 and Figure-8 shows the radiation pattern in E plane and H plane of antenna1 and antenna2 respectively at three different operational frequencies. It is

observed that radiation pattern in H plane is Omni directional for both antenna1 and antenna2 at 2.2GHz and 3.2GHz whereas radiation pattern in E plane is 8 shaped.



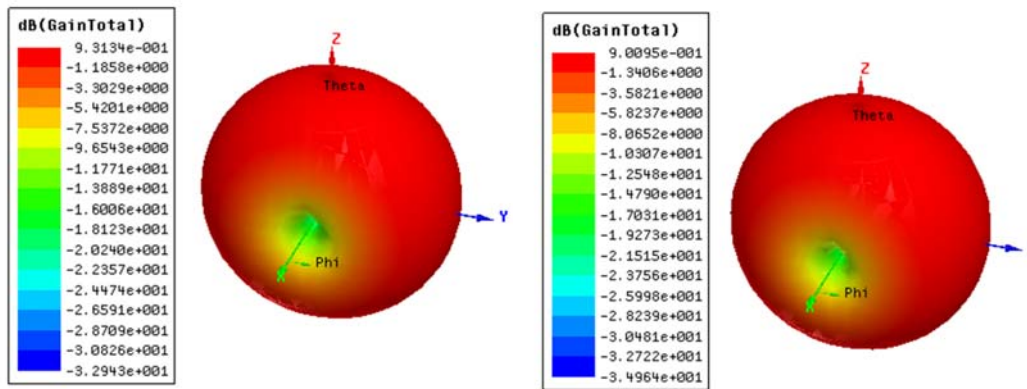


Figure-9. 3D polar plot for antenna1 and antenna 2 at 2.2 GHz.

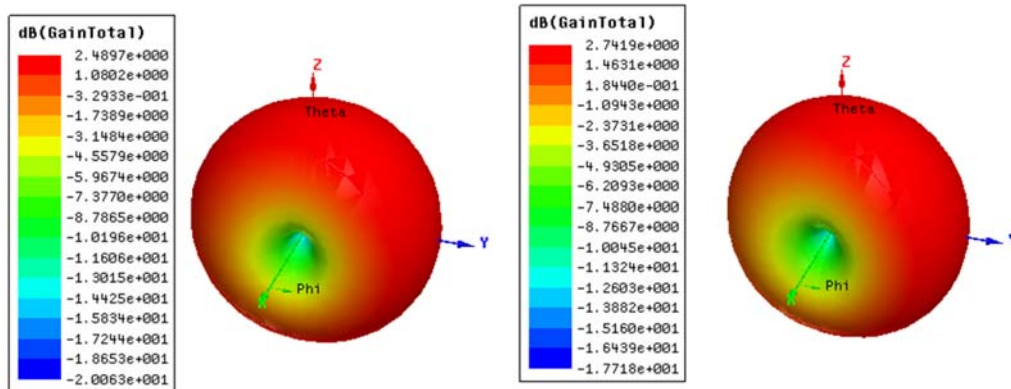


Figure-10. 3D polar plot for antenna 1 and antenna 2 at 3.2 GHz.

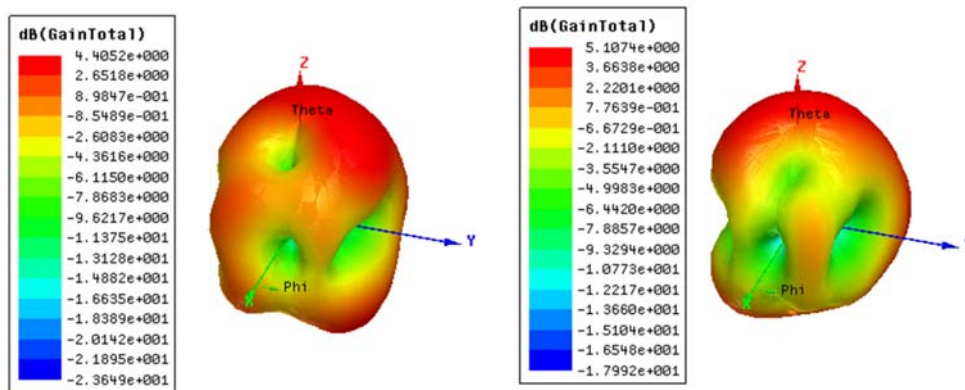


Figure-11. 3D polar plot for antenna 1 and antenna 2 at 6.6 GHz.

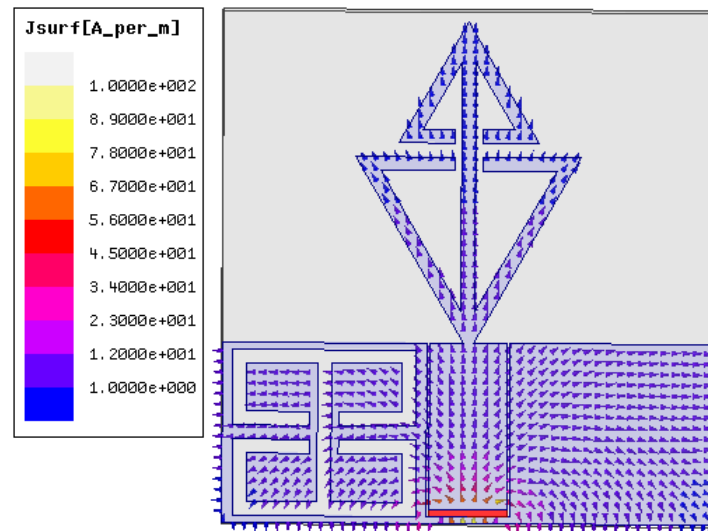


Figure-12. Current distribution of proposed antenna.

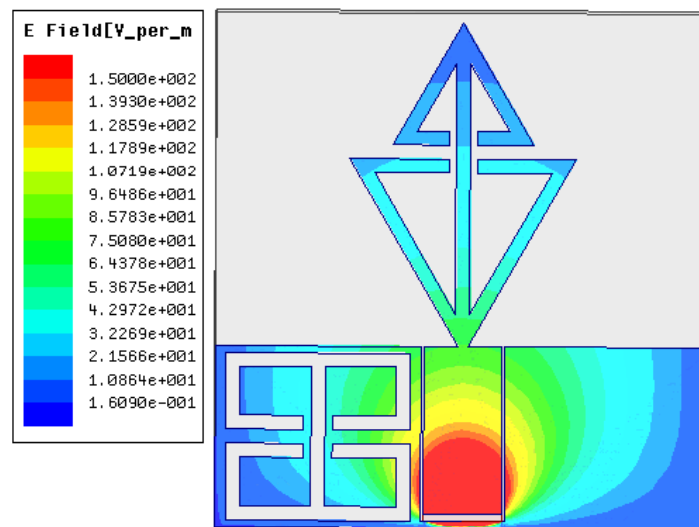


Figure-13. E-Field distribution for proposed antenna.

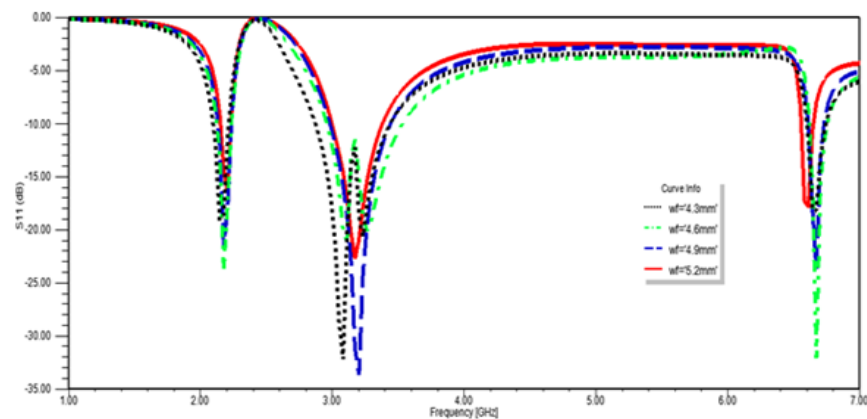
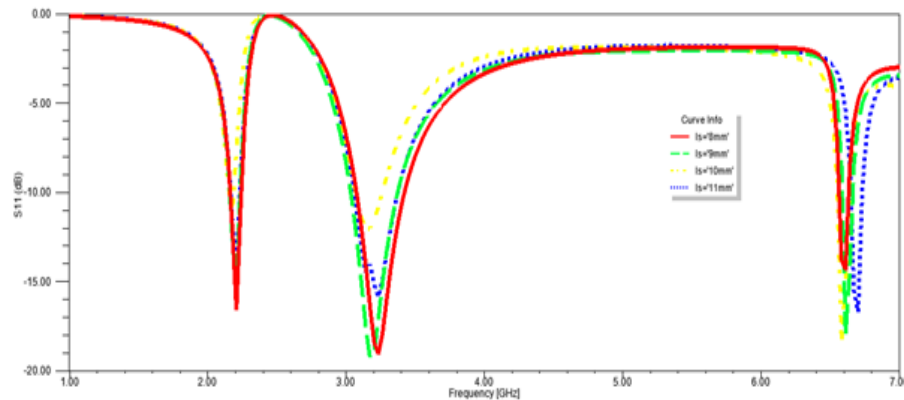


Figure-14. Parametric analysis report for antenna 2 by varying wf.



Parametric analysis was done for antenna1 by varying width of the feed port ( $w_f$ ). Report of S11 for four different samples of  $w_f$  is given by varying the length from 4.3mm to 5.2mm. The 4.3mm plot is represented by

“black colour dotted line” and 4.6mm plot is represented by “green colour dot dashed line” and 4.9mm plot is represented by “blue colour long dashed line” and 5.2mm is represented by “red colour solid line”.



**Figure-15.** Parametric analysis report for antenna2 by varying ‘ls’.

Parametric analysis was done for antenna2 by varying length of rectangular split ring resonator (ls). Report of S11 for four different samples of ls is given by varying the length from 8mm to 11 mm. The 8mm plot is represented by “red colour solid line” and 9 mm plot is represented by “green colour long dashed line” and 10mm plot is represented by “yellow colour dot dashed line” and 11mm plot is represented by “blue colour dotted line”.

#### 4. CONCLUSIONS

Two compact, planar and CPW-fed tri band antennas inspired by triangular split ring resonators and complementary rectangular split ring resonators are designed and simulated using Ansys HFSS. Both antenna1 and antenna2 operates at three frequency bands covering applications like Mobile Satellite Services (MSS), airport surveillance radars, WIMAX and S-Band applications. By adding complementary rectangular split ring resonator in antenna2 it showed better return loss plot compared to antenna1. The proposed antennas have the advantage of simple structure making them easy for fabrication.

#### ACKNOWLEDGEMENTS

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