CIRCULARLY POLARIZED MICROSTRIP PATCH ANTENNA WITH ARTIFICIAL GROUND STRUCTURE FOR WIDEBAND APPLICATIONS

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Abstract- This paper represents the circularly polarized patch antenna by using an Artificial Ground structure with rectangular cells as a reflector for wideband applications. Designed antenna gives the transmitted wave and the AG structure gives the reflected wave. By properly combining these two waves wideband circular polarization can be obtained. Reflection phase changed by AG structure in accordance with the polarization state of a incident wave. HFSS software is used for simulation of the design. The obtained results from this design S11 characteristics < -10dB, 48.6% of impedance bandwidth, 20.4% bandwidth with 3dB axial ratio, 6dBi of gain obtained VSWR<2.These results are having good agreement with the simulated results. Antenna with a PEC reflector and without PEC reflector are almost having same radiation characteristics.

Key Words: Artificial Ground (AG) structure, Axial Ratio, Wideband, Circular Polarization, Patch antenna ***etc…***

1. INTRODUCTION

Now a days, Antenna requirements like, low profile, low cost, less weight, ease of fabrication are very important factors. For all these requirements we go for micro-strip patch antennas. These are popularly growing in the usage of satellite communications, radar applications and other wireless applications. In these micro-strip antennas we get two types of polarizations. In our requirement we go for Circular polarization because of better mobility when compared with linear polarization. However, these micro-strip antennas troubles with the narrow bandwidth and axial ratio band widths. The main problems with these patch antennas are less for impedance of < -10dB and axial ratio value of < -3dB. Many techniques are improved to increase these bandwidths, such as truncation of a opposite corners of the stacked patches [1]-[3], impedance matching networks of L-shaped probes [4], [5]. These types of matching networks and designs require longest antenna heights and extra impedance matching networks. These are very difficult to design and develop.

To reduce these difficulties effectively going for Artificial Magnetic Conducting (AMC) devices, such as Electromagnetic Band Gap (EBG) Structures. Artificial Ground (AG) structures, Unipolar Compact Photonic Band Gap(UC-PBG) structures have been studied.

Ordinary EBG's are having the small metal patches on the substrates, and having connection between the metal patches and the ground plane. These type of structures produce high impedance characteristics with in the frequency ranges and reflection wave are in phase. By comparing all the structures, AG structures are having no vias, and effectively band gap characteristics are not produced.. However, in phase reflection is same and the known frequency at this stage is called as AMC frequency. Metal patch dimensions in the EBG structures are changes the AMC frequency. In many antenna applications used these structures [6]-[17]. For example, impedance bandwidth of 21% has been obtained in linearly polarized antenna on EBG structures , by using rectangular unit cells on the AG structure had given 24% impedance bandwidth and 5.6% of axial ratio bandwidths, This is given by Yang[11] to circular polarized waves.

In this design, we used a rectangular unit cells on the top of the artificial ground structure, and calculated AR characteristics of the antenna. In the EBG structures vias is presenting and no vias is used in this AG structures, this will helps to avoid vehement dependence of S11 phase on frequency .this is results also from higher permittivity containing vias of EBG's. This EBG also gives the proximity in the band gap, it will effects on the variations in surface waves phase constants.

After simulating the structure , gives the wide impedance bandwidth 48.6% < -10dB S11, from 4.52 to

7.42 GHz. AR bandwidth of 20.4% at <3dB from 5.40 to 6.63GHz, both the simulated results are having good agreement.

2. ARTIFICIAL GROUND STRUCTURE

Artificial ground structure is also a electromagnetic band gap structure, but the difference is there is no connection between the patches and the ground plane. On the top of the AG structure we place rectangular unit cells with certain gap between the unit cells. These rectangular unit cells having the metal patches on the top side. This structure is attached with the patch antenna to generate circular polarization. AG structure with unit cells surrounded by periodic conditions given in Fig 1. The substrate material used is Rogers RT/Duroid 5880, thickness of the substrate is 3.2mm, permittivity of 2.2 and dielectric loss ($\tan\delta$) of 0.001.

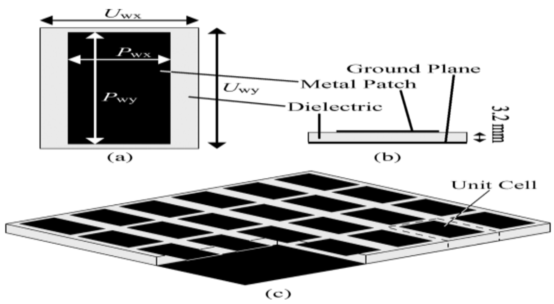


Fig 1: Rectangular-patch AG structure. (a) Top view of unit cell.(b) Cross sectional view of unit cell. (c)Geometry of the rectangular-patch AG structure.

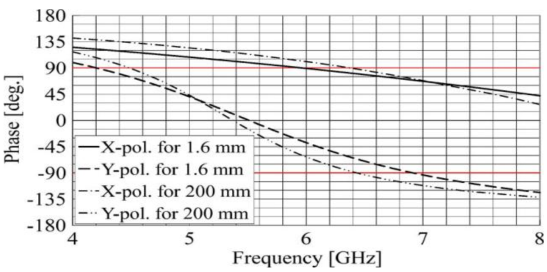


Fig.2: Reflection phase characteristics of AG structures with rectangular patches

This antenna design and simulation are done by using antenna design simulator HFSS V13.0 and results shown in Fig 2. From the adjacent wave port incident plane wave has been generated, it can be work as perfect conductor, at certain height 1.6mm above AG surface. When height of the wave port at 200mm, 0° reflection is shifted from 150MHz to higher frequency of 5.5 GHz. Based on these conditions distance between AG surface and wave port are changing from the reflection phases [19]. When comparing with each polarization the patch width and unit cell width are different so the polarization states will effects on reflection phase.

The designed structure is having the reflection phases are +90 and -90 for X and Y polarizations at a frequency of 6 GHz. The width of the unit cell is 6.5mm, length is 10mm, and width of the metal patch is 4.2mm, length is 9.25 mm. Circularly polarized waves are produced by using this with AG structure [11]. In this dipole antenna placed on the top of the AG structure [20] and rotated by an angle of 45 degrees, respectively with AG structure. Reflection phases are +90 and -90 respectively. Dipole antenna will generates a wave and another wave reflected from the AG structure and both will combined, two orthogonal is called as circularly polarized wave. In our design 45 degrees rotation angle of the antenna will not effect on the amplitudes of X and Y polarizations. However, angle increases from the 15 to 45 degrees with respect to x , the amplitude ratio changes by about 10dB, but no changes occurred in phase difference.

3. MICRO-STRIP PATCH ANTENNA ABOVE AG STRUCTURE

In this design the AG structure is place a major role to produce circular polarization. first we design a single patch antenna by using coaxial feeding technique and obtaining the results. The substrate using in this is Rogers RT/Duroid 5880, thickness of the substrate is 1.6mm, relative permittivity is 2.2, and dielectric loss ($\tan\delta$) is 0.001. In is a square patch antenna, length and width of the antenna is 16.8mm. In this design we are providing the rotation of the patch with an angle of 45 degrees. It is -10dB S11 bandwidth calculated as 5.2% and radiates linearly polarized waves.

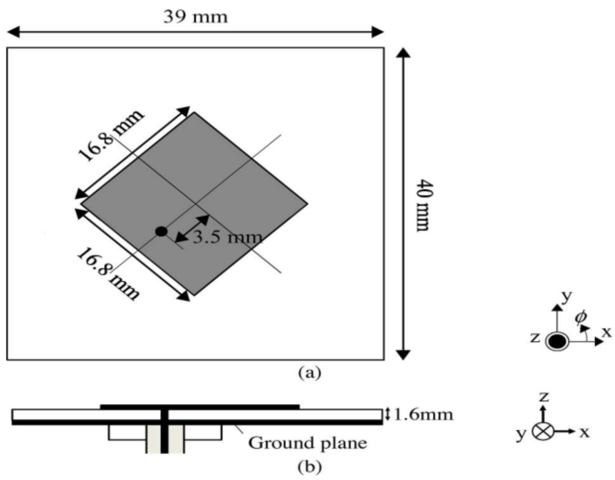


Fig.3: Geometry of micro-strip patch antenna above a conventional conducting ground plane with the antenna parameters shown; (a) top view and (b) cross sectional view.

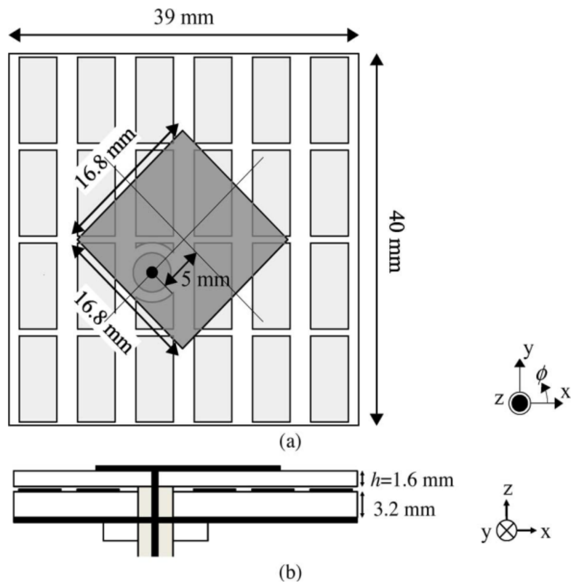


Fig.4: Geometry of micro-strip patch antenna above the AG structure with rectangular unit cells. The parameters of the AG structure are described in Section II and those of the antenna are the same as for the reference patch antenna. (a)Top view and, (b)cross-sectional view.

Reference antenna showed in Fig 3. Completion of above process and obtaining all the results and replace the conducting ground plane with the Artificial Ground structure with unit cells, mentioned in the previous section. The total geometrical view of the design showed Fig4.The artificial ground structure having 6x4 unit cells and the total dimensions of 39x40 mm, and using a substrate thickness of 3.2mm.To maintain needed input impedance, we use coaxial SMA connector. For this extension we go for coaxial feeding technique. To avoid coupling between the cable and AG patches, removing the some part of the AG patch where the cable is connecting, for this with radius of 3.25mm we place a hole, the coaxial cable radius is 2.45mm the difference between the both radius are 0.8mm .By examining, we confirm that, there is no effects occurred by increasing the hole up to 4.25mm. no change occurred in the input impedance characteristics and AR characteristics. The S11 parameter characteristics are showed in Fig5, along with the single patch antenna showed before. After combining the reference design with AG structure, it is providing the large bandwidth of 47.9 %(4.60-7.50GHz) at less than -10dB, when compare with the reference antenna bandwidth is 5.2% for the 1.6mm thickness. So many authors have given the relationship between the reflection phase and EBG structure and the return loss of dipole antenna [19][21][22].comparing the Fig5 and Fig2, input impedances are to be matches for any reflection phase in the AG band, in this one reflection phase curves for X,Y polarization is at least with in +90 or -90 and other approximately +(90+30) or -(90+30) for the present structure. When compared these results with the previously reported in [21] both are same. AG patch area and appropriate substrate thickness will give broadband design of AG.

Two parallel resonances will occur around both the ends of the AG band with the design as mentioned above. An appropriate patch height should be chosen based on the impedance characteristics shown in Fig6. Larger reactivity and smaller value of the real part of the impedance is possible with the thickness of the substrate increases. It is also causes to lower frequency and reducing the frequency dependence [19]. Shifting of the higher frequency resonance to higher frequency is possible with imaginary part. This is possible with the extension in the central conductor of the coaxial cable, at the ends of the AG band we have to maintain small variation between two parallel resonances , the height of the patch on the reflection phase is also considerable [19]. These are comes under AR characteristics. Based on all these information we conduct that wideband performance is based on the function of the antenna design like, substrate thickness, feed position, etc and the AG design.

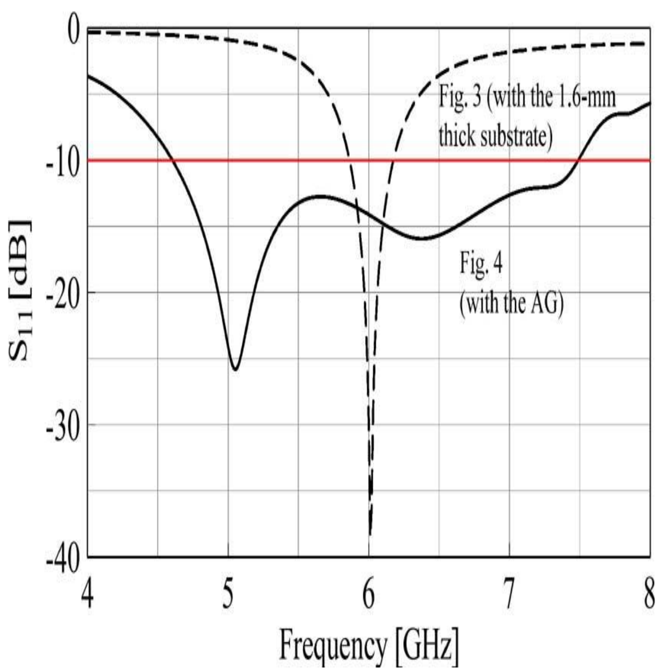


Fig.5: S11 characteristics of the structure shown in Fig4 along with those of a1.6-mm-thick reference antenna.

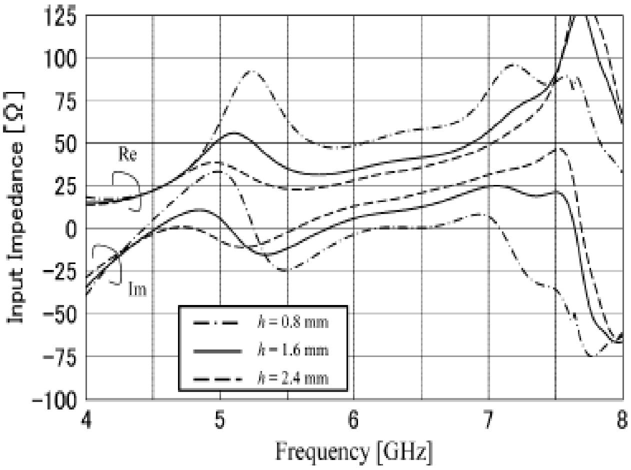
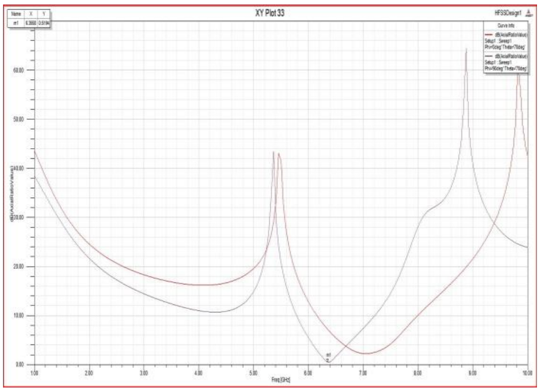
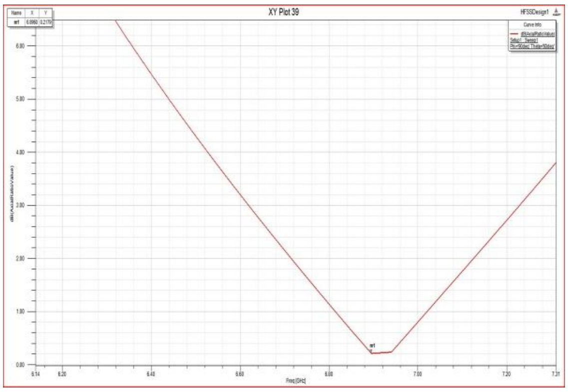


Fig.6: Variation in impedance with substrate thickness above the AG

The designed structure can radiates circularly polarized waves at around the 6.8GHz. this is shown in the Fig7(a). The difference between the X, Y components in the far field, as shown in Fig7(b). Is approximately 90 degrees at 6.8GHz.



(a). Single patch



(b). Main design

Fig. 7: AR characteristics of the structure shown in Fig.2 and Fig3.

Electric field in the antenna structure is observed by using labeled position represented in Fig8(a) and Fig8(b). Comparison between the X-component point $P3/P3'$, Y-component point $P1/P1'$, and X-component point $P4/P4'$, Y-component point $P2/P2'$ gives the phase difference, rectangular patch AG structure phase difference produce large variations with the frequency. On the other side phase differences are almost constant and close to zero for the square patch AG structure. These phase differences are calculated from the, adjacent patches in the AG structure produced phase differences on the electric field. At 6.8GHz both the Figs shown in Fig 9 and fig 7(b) similar with rectangular AG curves. This denotes that phase differences in the far field are caused by phase differences between electric fields from adjacent patches. However, 3dB AR bandwidth is not very wide of this square patch antenna.

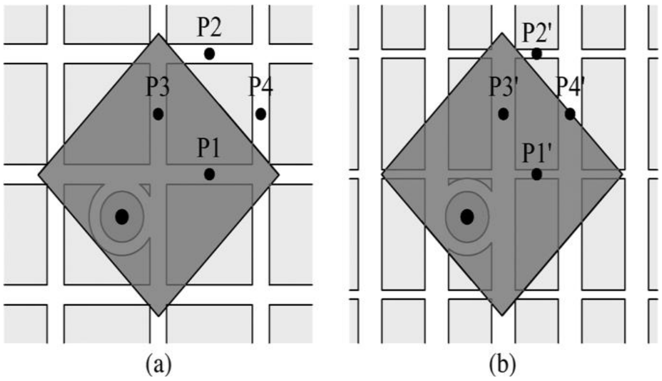


Fig. 8: Magnified schematic of the two structures. (a) Square-patch AG structure .The size of the square patch for 0 reflection phase at 6 GHz is 8.35 mm x 8.35 mm and the spacing between adjacent patches is 1.65 mm. The substrate size is the same as (b). (b) Rectangular-patch AG structure.

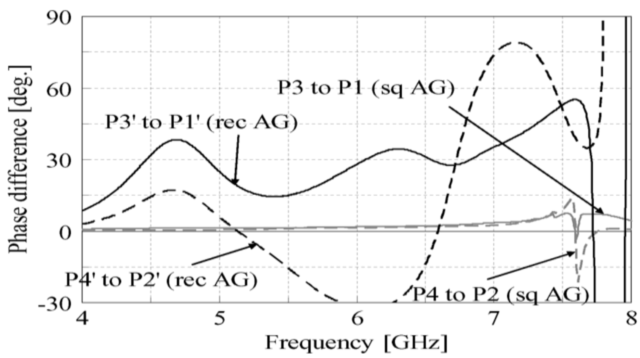


Fig. 9: Phase differences in the electric field between adjacent patches for the square (sq) and rectangular (rec) AG structures.

4. CIRCULARLY POLARIZED MICRO-STRIP PATCH ANTENNA USING AG STRUCTURE

To obtain circularly polarized waves with micro-strip antenna using AG structure feed position of the antenna is important. By using the trial and error method we change the feed point. Continuously by changing the feed point we can get some good results at one point. By comparing the results at all points we choose one point where the results are good. That point we consider as feed point.

Other one is to get good results is the size of the ground plane. we verify the results by changing the sizes from 39x40mm(optimized) to 60x60mm. The differences between the results with the different ground plane are showed in Fig10. From this fig we get the AR and S11 characteristics. Although there is no significant change in S11 characteristics is observed in increasing the ground plane size. AR is seen to increase around 6.5GHz, at this frequency phase differences are reduced from 90 degrees to 20 degrees and 5dB electric field increment in Y-component. Size of the ground plane should be considered for generating circular polarization curves.

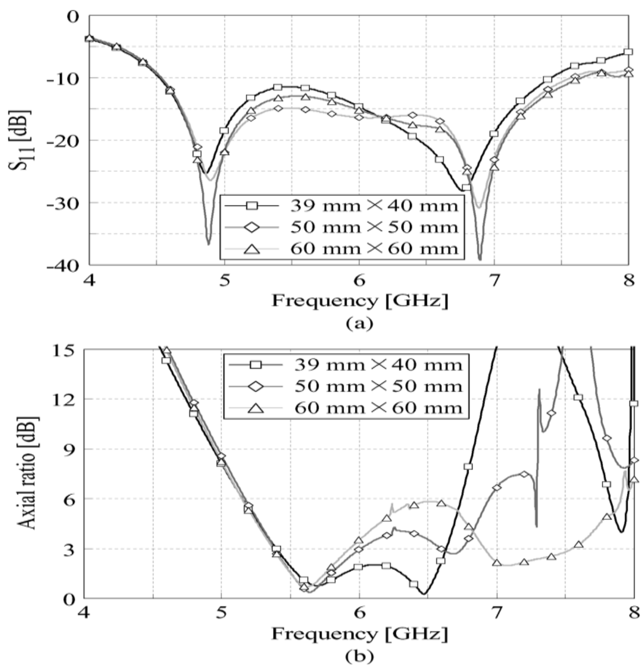
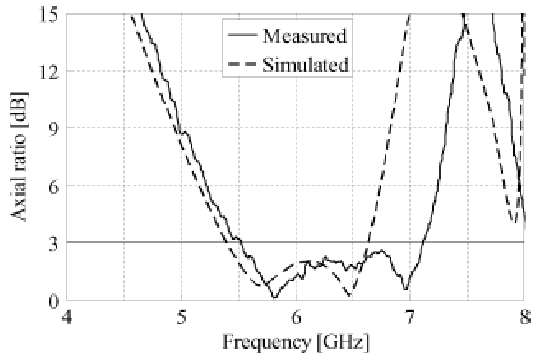
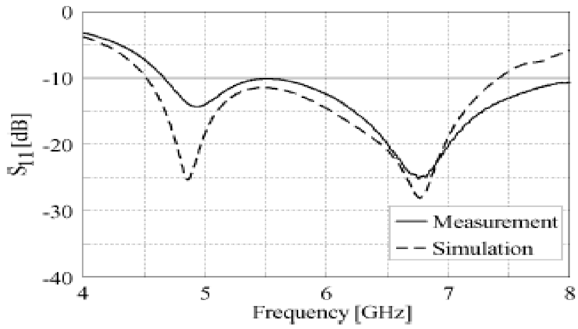


Fig.10: Dependence of (a) S11 and (b) axial ratio characteristics on ground plane size.



(a)AR characteristics



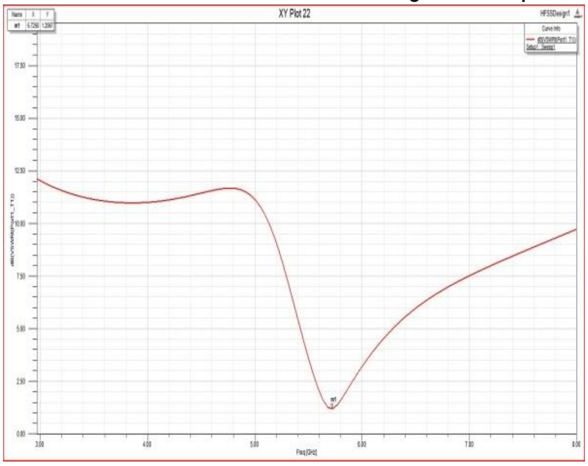
(b).S11characteristics

Fig11. Measured S11 and AR results compared with the simulated results.

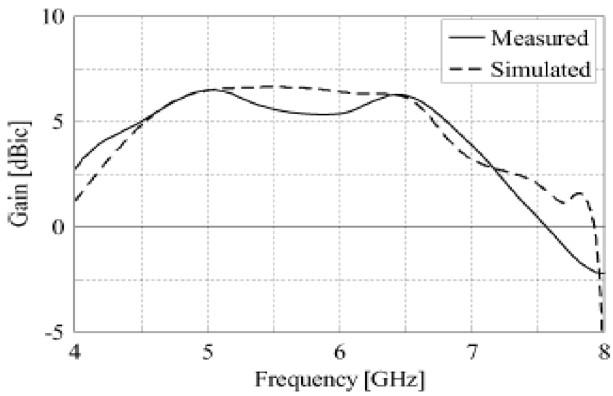
5. EXPERIMENTAL RESULTS

To view the experimental results, finally the designed antenna tested by using the antenna simulation software (HFSS). For the antenna design we use the substrate Rogers RT/Duroid 5880. The thickness of the substrate is 1.6mm, For the AG structure design also we used the same material with the thickness of 3.2.as mentioned earlier, large hole is drilled for connect the coaxial cable SMA connector. This SMA connector fed by 50Ω characteristic impedance. Comparison of the simulated and measured results for the S11 and AR characteristics given in the Fig 11(a) & 11(b), respectively. Both sets of results show a large bandwidth at less than 10 dB. The simulated bandwidth of 48.6% (4.52–7.42 GHz) is actually smaller than the ensured value of 54.6% (4.67–8.18 GHz). This is smaller value than measured value of 54.6 %(4.67-8.18GHz).

AR was shown in Fig11 (b). Where $\theta = 0^{\circ}$ and $\Phi = 0^{\circ}$. AR bandwidth is 20.4% (5.40-6.63GHz) at less than 3dB. These results are better when compared with the reference antenna. We get different types of circular polarizations at different frequencies. Gain value nearly 6dB.VSWR value nearly 1.22. Although the measured and simulated results show generally good agreement, the small differences between them may be due to the experimental environment and alignment problems during measurements.



(a).VSWR results-VSWR=1.20



(b).gain value of main design=6.59

Fig. 12: Measured VSWR and Gain characteristics of the proposed structure compared with simulated results.

6. CONCLUSION

A wideband circularly polarized antenna designed by using the Artificial Ground structure with the rectangular unit cells. X, Y polarizations respectively having the reflection phase as $+90^{\circ}$ and -90°. By using this structure we provide wideband width. A S11 bandwidth of 48.6% at 10 dB in simulation and 54.6% in practice, along with an AR bandwidth of 20.4% at3 dB in simulation and 25.2% in practice is achieved. We extend this also by using rectangular patches or circular patches.

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