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Compact Circular Polarized Stacked Patch Antenna for IRNSS and GLONASS Applications

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Abstract:
A single feed stacked circular polarized patch antenna for IRNSS and GLONASS applications is presented in this paper. The antenna is capable of generating right hand circular polarization with a single feed for the IRNSS operating frequencies of 1.176GHz and 2.492GHz along with the GLONASS operating frequency of 1.6GHz. Stacked patch concept has been considered to maintain the compactness of the antenna. Proposed design consists of three radiating patches and each patch radiate for a specific frequency. To achieve the capability of circular polarization all the three patches are truncated diagonally at the corners. Excitation to this stacked patch antenna is provided using a coax feed. Finite Element Method based Ansys HFSS software has been used to study the various antenna parameters. The proposed design is capable to receive the signals simultaneously from all the satellites of IRNSS and GLONASS.

Keywords:*Stacked Patch, Circular polarization, IRNSS, GLONASS.*

I. INTRODUCTION

Indian Regional Navigational Satellite System (IRNSS) is the navigational system developed by India for the requirements of the Global Navigation Satellite Systems (GNSS). GNSS is one of the achievement for the space technology around the world. It provides a number of services from civilian to military like positioning, navigation, mapping, public safety and weather information. The GNSS applications came into lime light along with the mobile phones and portable devices which are integrated with the navigational applications. GLONASS and GPS are leading the GNSS systems with their well established satellite systems which can provide a high accuracy of 95%. In general, for both IRNSS and GLONASS applications we will be using individual patch antennas on the roof and each antenna will be designed to be operated for a specific frequency. But this approach will have the effects of unwanted coupling in between the antennas if sufficient spacing is not provided between them [1]. IRNSS operates at two frequencies of L5 (1.176GHz) band and S (2.492GHz) band. Dual frequency of operation is essential to mitigate the adverse effects the ionosphere on the signals of IRNSS satellites. GLONASS will operate at the L1 frequency band of 1.6GHz. So to overcome the performance problems we need to integrate all the applications into a single antenna which is compact in size and the best solution for this will be using a stacked patch technique.

The stacked patch technique is a conventional technique to enhance the antenna parameters, depending upon the dielectric materials used and the dimensions of the radiating elements the parameter to be enhanced will be decided. To have multi band performance we need to have different radiating elements for different operating frequencies. A lot of antenna design engineers worked on the dual frequency antennas for different applications [2-4]. A dual frequency stacked patch antenna with circulation polarization is proposed in

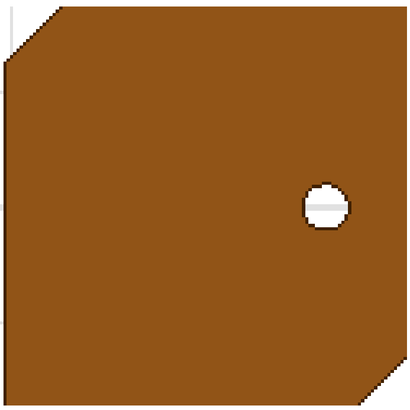
[5] the antenna consists of two feeds which excite two patches individually and a short is placed in between the first patch and the ground which makes the antenna more complex and cost effective.

A dual frequency proximity fed slot loaded patch antenna for the GPS frequencies of L1 band L2 bands is proposed in [6]. To achieve compactness meandered patches with high dielectric constant substrate are used. To tune the operating frequency additional stubs are placed to the patches independently and to get the circular polarization two probes are connected orthogonally in the antenna. A broadband antenna array with spiral radiating elements is proposed in [7], which covers the operating frequency range of 1.2GHz to 1.6GHz. This antenna is having a high gain of 9 dB and high directivity. But the proposed antenna can work for only GPS frequency of L5 band. A fractal antenna which can operate for the frequencies of IRNSS and GAGAN is proposed in [8], here a thick dielectric material of thickness of 3mm is been used. The antenna radiates at multiple frequencies of 1.175GHz, 1.575GHz and 2.492GHz with good radiation characteristics and impedance matching. But the antenna is a linear polarized antenna which is not acceptable for the navigational applications.

II. Design of Stacked Patch Antenna

Proposed antenna is a compact dual band triple frequency right hand circular polarized stacked patch antenna which is having a compact size of 80mm×80mm×11.43mm, the basic radiating elements are square patches which are been truncated diagonally at the corners to achieve circular polarization. The antenna is feed with a coaxial feed at the position of (0,7mm) from the antenna center. The radiating elements are stacked into three layers. The lower patch is having a dimension of 35mm×35mm which is been truncated by 5mm diagonally in the corners as shown in figure 1(a). Rogers TMM10i substrate has been used which is having a high dielectric constant of 9.8 for all the three layers of the antenna. The thickness of the each substrate layer is 3.81mm. A substrate with high dielectric constant and high thickness is considered to obtain the compact antenna. The lower patch is been designed to radiate at 1.176GHz with right hand circular polarization. The middle patch is having a dimension of 24.5mm×24.5mm and is been truncated by 2mm diagonally in the corners as shown in the figure 1(b). The middle patch is been designed to radiate at 1.6GHz with right hand circular polarization. A circular slot with a radius of 2mm is etched in the both the lower patch and middle patch at the feed position to facilitate necessary coupling between the patches. The upper patch is having a dimension of 19mm×19mm which is been truncated by 3.5mm diagonally in the corners as shown in figure 1(c). The upper patch is been designed to radiate at 2.492GHz with right hand circular polarization. Figure 2. shows the proposed stacked patch antenna both in top view and cross sectional view.

(a) 1.176GHz



(b) 1.6GHz

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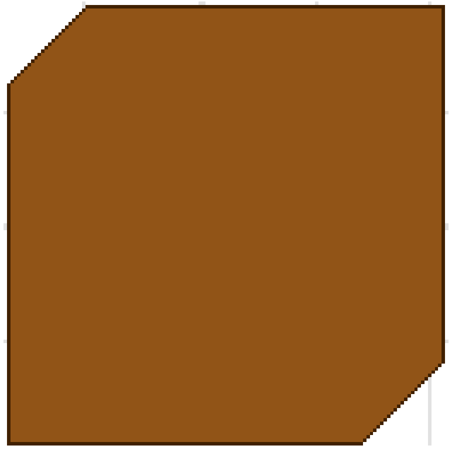
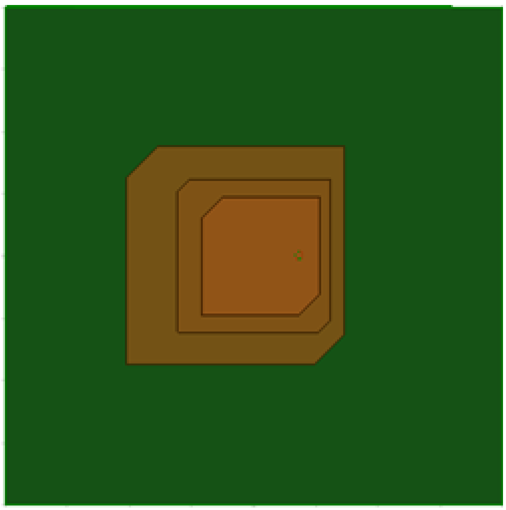
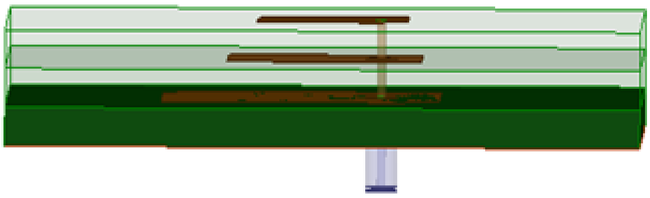


(c) 2.492GHz

Figure 1. Basic Radiating Element.



(a) Antenna Top view

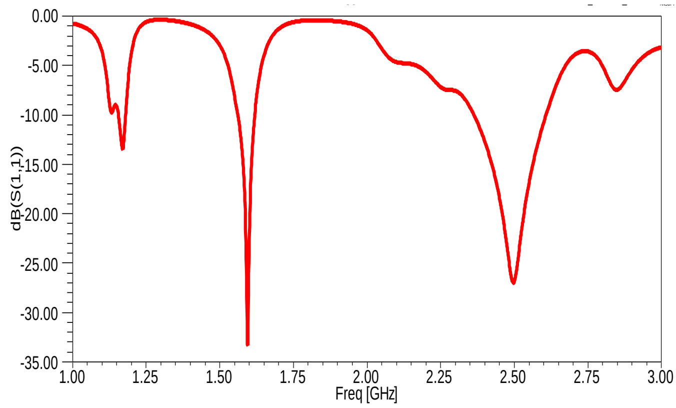


(b) Antenna Cross section view

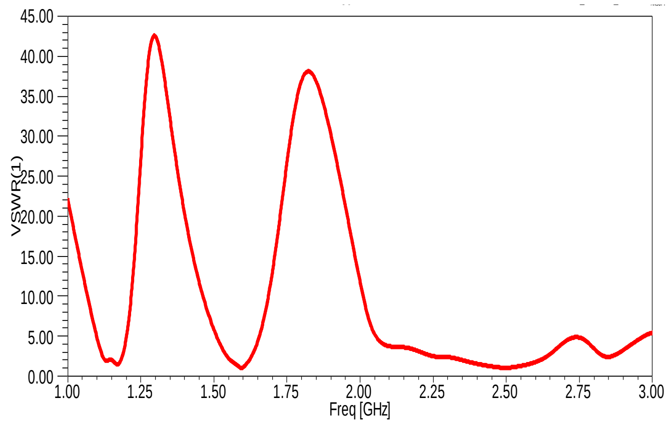
Figure 2. Stacked Patch Antenna.

III. RESULTS AND ANALYSIS

The proposed stacked patch antenna is designed, simulated and the results are been verified by using the Ansys HFSS software, Figure 3 depicts the simulated S_{11} and VSWR plots of the stacked patch antenna. The obtained center frequencies exactly matches with the IRNSS and GLONASS frequencies the three resonating frequencies obtained are 1.176GHz, 1.6GHz and 2.492GHz which exactly matches with the allocated frequencies for the above applications.



(a) Reflection Coefficient

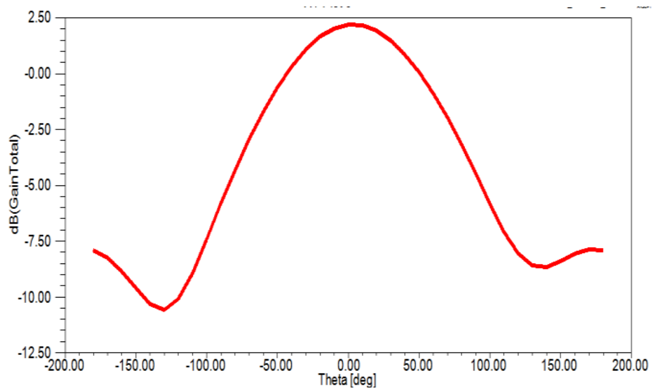


(b) VSWR

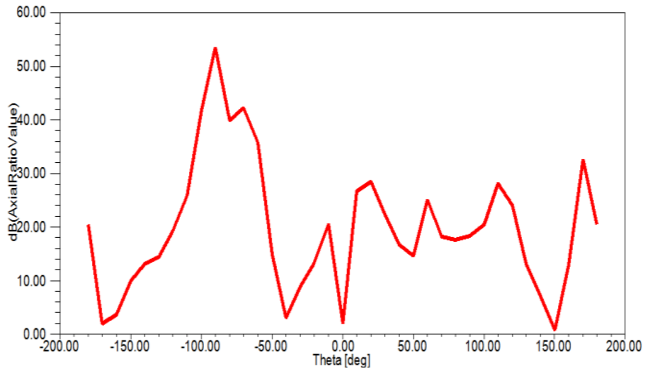
Figure 3. (a) Reflection Coefficient (b) VSWR

The IRNSS L5 band is having a -10dB impedance bandwidth of 40MHz which is greater than the MHz bandwidth allocated for the IRNSS L5 band services. Similarly IRNSS S band is having a -10dB impedance bandwidth of 100MHz which is very much greater than the MHz bandwidth allocated for the IRNSS S band services and GLONASS L1 band is having a -10dB impedance bandwidth of 60MHz which is greater than the MHz bandwidth allocated for the GLONASS L1 services.

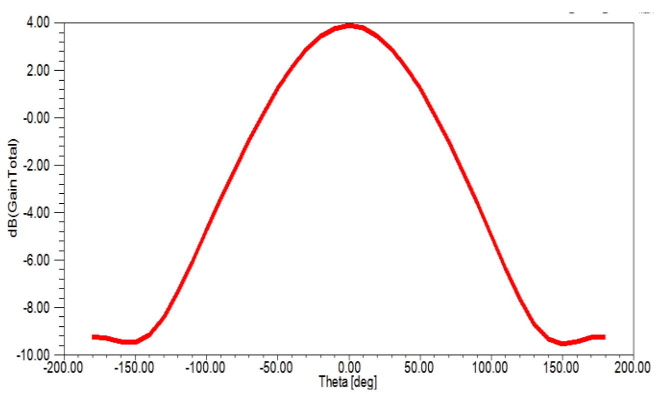
In the Figure 4 below, the simulated gain and axial ratio plots of the proposed antenna are shown, For the proposed antenna observed a gain of 2.19dB, 3.90dB and 3.71dB and a axial ratio of 2.93dB, 2.88dB and 3.04dB at the operating frequencies of 1.1762GHz, 1.60GHz and 2.492GHz respectively. A symmetrical gain distribution is observed and the majority power is concentrated in the broad side of the antenna.



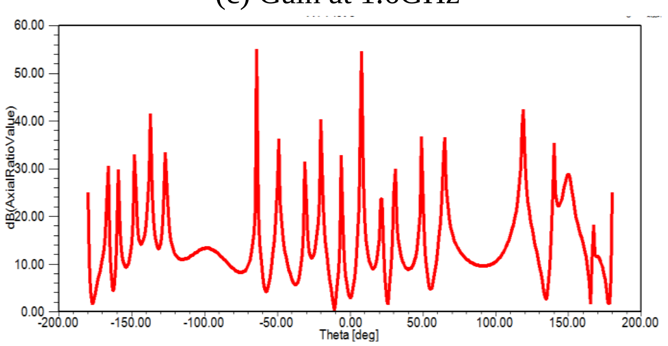
(a) Gain at 1.176GHz



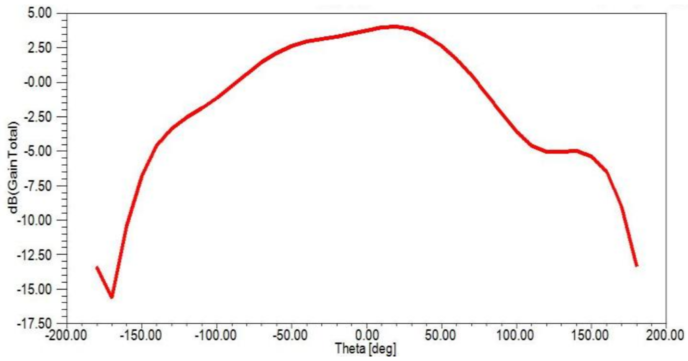
(b) Axial Ratio at 1.176GHz



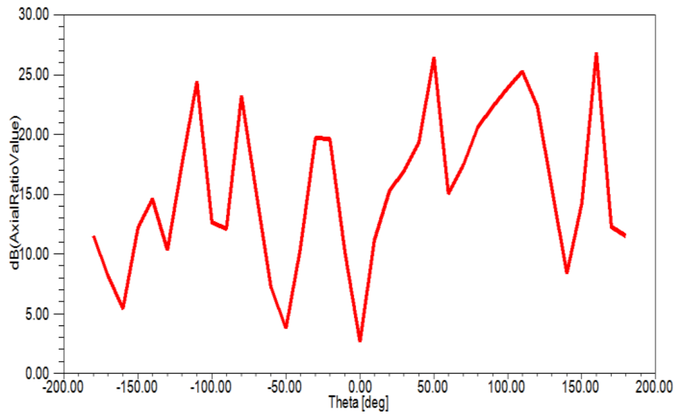
(c) Gain at 1.6GHz



(d) Axial Ratio at 1.6GHz



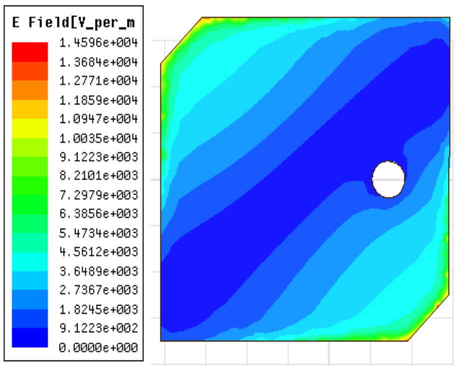
(e) Gain at 2.492GHz



(f) Axial Ratio at 2.492GHz

Figure 4. Gain and Axial ratio plots.

Figure 5 below shows the current distribution patterns in different radiating patches. From the plot it can be clearly observed that the coupling between the antenna elements is efficiently done by the radial couplers placed in the lower and middle patches and the excitation provided to the upper patch has been transferred to the middle and lower patches efficiently.



(a) 1.176GHz

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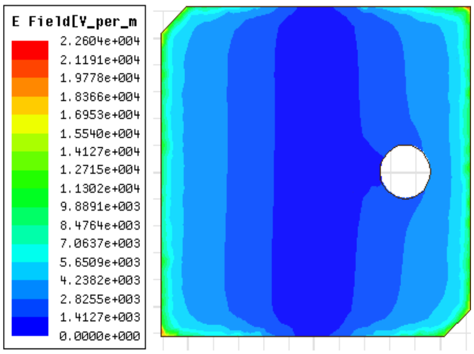
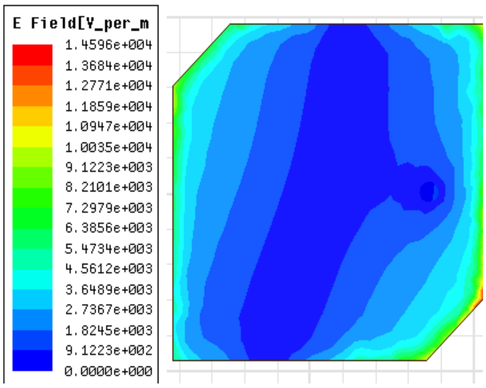


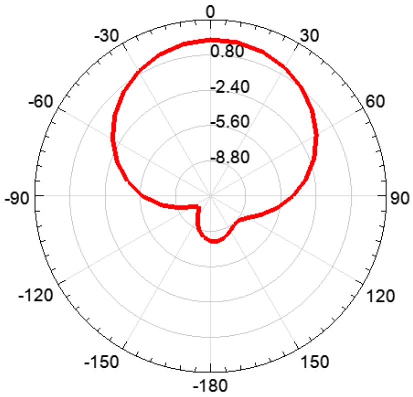
(b) 1.6GHz



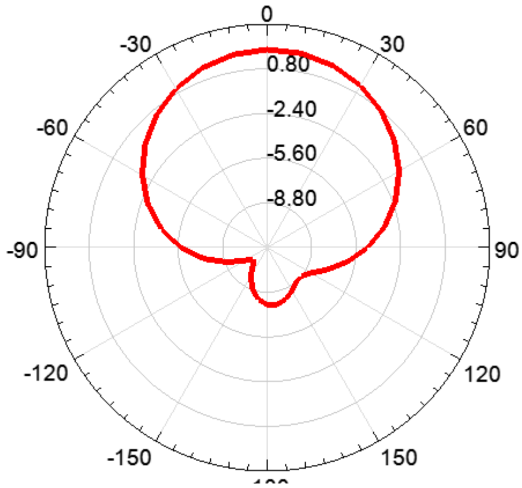
(c) 2.492GHz

Figure 5. Current Distribution.

Figure 6 below shows the simulated Elevation and Azimuthal plane radiation patterns of the proposed antenna, a broad side radiation pattern is observed with a symmetrical shape which is very essential for the Navigational Applications.

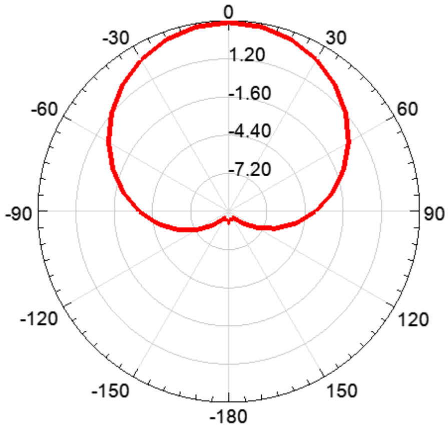


E-Plane

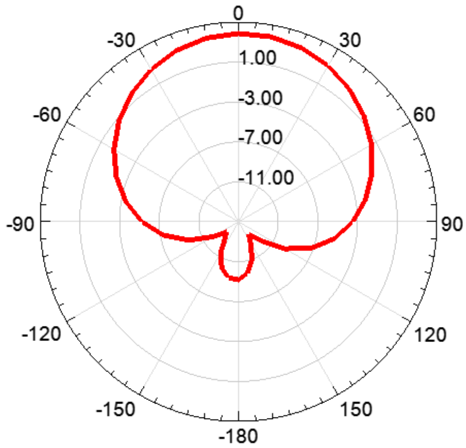


H-Plane

(a) 1.176GHz



E-Plane



H-Plane

(b) 1.6GHz

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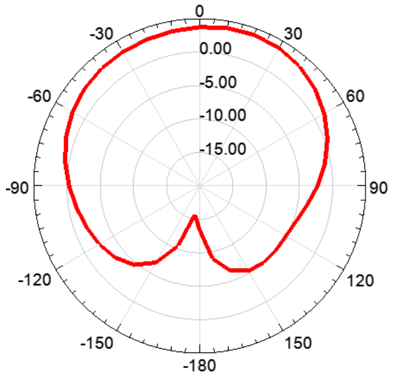
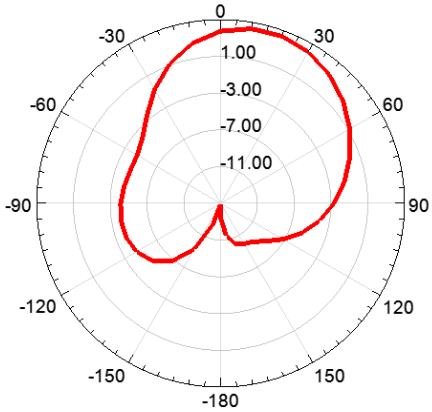


E-Plane



H-Plane

(c) 2.492GHz

Figure 6. Radiation Patterns (E-Palne and H-Plane).

Figure 7 shows the measurement results of the fabricated antenna model. The measured results are having a very near match with the simulated results.

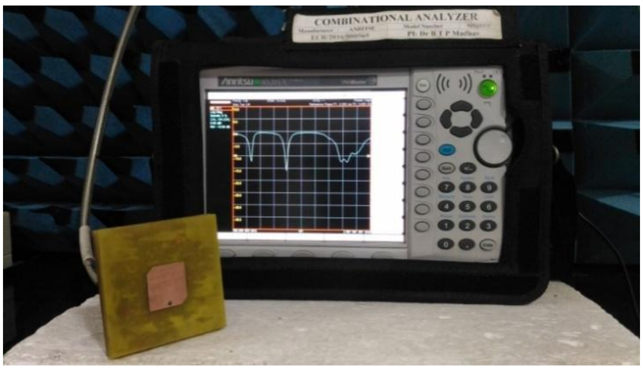


Figure 7. Fabricated antenna under measurement

IV. CONCLUSION

A compact broadband Stacked Patch antenna model has been designed which is operating at the three resonating frequencies of 1.176GHz, 1.6GHz and 2.492GHz which exactly matches with the allocated frequencies for the navigational applications of IRNSS and GLONASS. Rogers TMM10i substrate has been used to design the antenna. The antenna has been modeled such that it have Right hand circular polarization. Observed good Return Loss, gain and axial ratio for the proposed antenna with a broadside radiation pattern. For the proposed antenna observed a gain of 2.19dB, 3.90dB and 3.71dB and a axial ratio of 2.93dB, 2.88dB and 3.04dB at the frequencies of 1.1762GHz, 1.60GHz and 2.492GHz respectively.

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