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# A Dual Band Crossed Slot Antenna for L5 and S Band

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**Abstract**—In the present work a dual band circularly polarized antenna for satellite applications resonating at S(2.492GHz) and L5(1.16GHz)band of frequency has been presented using probe feeding technique. The new aspect of the suggested work is the use of triangular-shaped corner trimming along the patch's diagonal and 45-degree slanted rectangular slots to accomplish circular polarization. The radiating structure resulted in an input reflection coefficient of -20.249dB and -30.524dB in the L5 and S band respectively along with a bandwidth of 0.0605GHz and 0.0916GHz. The axial ratio reported was close to 3 dB in the L5 band of the antenna.

**Keywords**- Dual-band, RHCP, NaVIC.

## I. INTRODUCTION

The official designation for the Indian Regional Navigation satellite system is NAVIC, which stands for Navigation with Indian Constellation. The Navigation Satellite System is utilized to give the user trustworthy and precise position and time information. Under typical circumstances, the goal is achieved and is easily attainable. Due to interference signals that can weaken the signals from Navigation Satellite Systems, signal availability will be reduced. However, signals from the Navigation Satellite System can be intentionally or unintentionally interfered with. The performance of the system is significantly impacted by the antenna because it is the first component in the navigation receiver chain. Additional efforts are performed to strengthen the low-power transmissions against high-power interference signals. Some of the applications of NAVIC include terrestrial, aerial, and maritime navigation, disaster management, vehicle tracking and fleet management, and connectivity with mobile phones.

## II. LITERATURE SURVEY

The authors Jasmeet Singh et al.[1] presented and validated by measurements a novel, straightforward-to-design, inexpensive, and simple-to-manufacture triple-patch penta-band antenna covering five mobile communication bands, which correspond to LTE-1800 UL and DL, LTE-2600, and UMTS-1900/2100. A broad bandwidth was accomplished by effectively combining the corner feeding and co-planar stacking concepts. The antenna can be used for many additional applications that call for wideband antennas due to its low profile and small design, which will make it broadly suitable in the connected automobile industry where demand for such antennas is rising. At all other frequencies, the realized gain was measured to be between 2 and 3 dBi. A dual band small circularly polarized patch antenna was designed by the authors Mishra et. al [2] for a dual band NaVIC (Navigation over Indian Constellation) receiver. In this paper, the layered patch antenna concept is used. This antenna is designed to pick up signals at 1176.45 MHz and 1575.42 MHz, which are known as L1 and L5, respectively. IRNSS and GPS signals are picked up using these bands. Peak gains of 6.47 dBi for the L1 frequency band are recorded with an angular beam width of 820, and 5.402 dBi for the L5 band are observed with an angular beam width of 88.30 degree. This study presents a dual-band, circularly polarized (CP), asymmetric dipole array antenna designed by Majid et al [3] for Global Positioning System (GPS) applications with a wide beam. By incorporating cross coupled slots integrated with a Balun, dual band operation were realized .The proposed structure can cover GPS, L1 and L2 bands respectively. Drawing inspiration from fractal geometry, Saraswat et al. (2014) suggested using a coplanar waveguide (CPW) fed wide slot antenna in their investigation. Achieving circular polarization across two distinct frequency bands was the main goal of this design. A monopole antenna's dual band response was obtained by carefully placing a circular parasitic patch on its back, which asymmetrically stimulated the grounded slot. The performance of the antenna was measured, and the simulation's outcomes were contrasted. The measurement showed that the two bands had input impedance bandwidths of 26% and 56%, respectively, and axial ratio bandwidths of 22.2% and 31.5%, respectively. Applications for 5G and satellite communication can both use the suggested antenna.

The authors Yousef et al. [5] developed a dual-band, circularly polarized (CP), fabry-perot cavity antenna (FPCA) with a significant axial ratio bandwidth (ARBW), while maintaining a low-profile design. To attain a predominantly linear phase of transmittance across a wide frequency range for both low-pass (LP) components, while maintaining an approximate 90-degree phase difference between them, the researchers employed a partially reflective surface (PRS). This PRS consists of a dielectric layer with an arrangement of square loops on one side and asymmetric meander lines on the other side. Using a single-layer high impedance surface (HIS), the phase mismatch between the two low pass (LP) components of the reflected waves from the partially reflective surface (PRS) was fixed. The cavity is excited by an ideal low pass (LP) primary source, which has two embedded parasitic patches. Usman Illahi and associates (2016) created a rectangular dielectric resonator antenna (DRA) with circular polarization in their research. The sub-6 GHz 5G NR band, WiMAX, and satellite communications were the envisioned applications for the antenna. The rectangular dielectric resonator antenna (DRA) has been turned on using the newly created T-shaped monopole. Circular polarization (CP) with a greater gain has been produced by mimicking the higher-order degenerate modes using the proposed conformal metal strip. To increase bandwidth even more, a parasitic patch the right height and width was positioned on the DRA surface, precisely offset from a T-shaped strip. The intended frequency range was covered by this patch. The impedance-matching bandwidth has been able to be increased by 73%, and the axial.The authors Lara Fernandez et al. merged a dual L-band microwave radiometer and a Global Navigation Satellite System reflectometer into a single device. [7] and then integrated into a software-defined radio. The creation of the Nadir facing Antenna was one of this payload's design challenges. This antenna has to operate in dual bands at 1400-1427 MHz and 1575.42 MHz, be directional with a gain of more than 12 dB, have left-hand circular polarization, and adhere to stringent envelope constraints. Additionally, the antenna needed to have a small profile. Through a comprehensive trade-off analysis, it was determined that the optimal design for achieving maximum efficiency consists of an arrangement of six dual-band patch antennas. Each antenna is equipped with a diagonal feed mechanism to generate circular polarization. Additionally, the configuration incorporates six one-to-one stripline combiners. To build a single layer dual-band circularly polarized (CP) reflect array antenna, Zheng Liu et al. [8] modified the Pierrot cell to produce a dual-mode circular polarization selective surface (CPSS) cell. The use of the CPSS cell's enhanced three-dimensional geometry and high-order resonances is applied to attain dual-mode CP discriminating capability. The necessary phase modifications in both modes may be achieved by adjusting the cell rotation angle in an orthogonal dual-band reflect array comprising a single layer. Jaiverdhan et al. proposed the utilization of a compact dual wideband coplanar waveguide-fed circularly polarized square slot antenna (CPSSA). The antenna's radiating structure consisted of an inverted C-shaped patch, a grounded L strip, two grounded spiral slots, and a horizontal grounded slot. Circular polarization (CP) was achieved by incorporating a grounded L strip and two grounded spiral slots. The 3-dB axial ratio bandwidth (ARBW) of the lower band was enhanced by introducing a square hole in the left corner of the coplanar waveguide (CPW) ground plane, resulting in the creation of a notched band centered around 12 GHz. Experimental results reveal that the antenna's 3-dB axial ratio beamwidths (ARBWs) are 74.62% (5.01 GHz, 4.21-9.22 GHz) and 12% (1.37 GHz, 11.26-12.62 GHz), respectively. Furthermore, the antenna demonstrates impedance bandwidths of 92.70%. In a separate study, researchers Nawaz et al. (2010) introduced an innovative configuration for a dual circularly polarized (CP) patch antenna with the goal of enhancing inter-port isolation. Designed for satellite telemetry and telecommand applications in the S-band frequency range, this antenna features a bi-port configuration and a single-layered (planar) structure. The square radiator with rounded corners supports a dual-port planar antenna, exhibiting circular polarization properties (RHCP and LHCP) when excited from the respective ports. However, significant power leakage from the transmitter (Tx) to receiver (Rx) port results in relatively low RF isolation between the two ports. To address this issue, an adjustable self-interference cancellation (SIC) circuit was introduced to the system. This circuit effectively maintained a 3 dB axial ratio (AR) for both right-handed circular polarization and left-handed circular polarization, achieving inter-port isolation of 72 dB and higher.

## III. ANTENNA DESIGN

### *A. Methodology*

In the present work, a dual-band circularly polarized antenna has been designed on a FR4 substrate of permittivity 4.4 and thickness (h) 1.6mm. The structure is a stacked patch with coaxial feed. At first rectangular patch has been designed with corner trimming to get band 1 corresponding to 1.2GHz with RHCP as shown in Fig.1 and another elliptical patch has been placed on top of it with square bracket-shaped slots to get band 2 corresponding to 2.4GHz as shown in Fig.4. The width and length of the antenna were 53mm * 53mm and the length of the trimming section was 9.9mm. The geometrical details of the antennas have been specified in Table.1.The stacked patch layout has been given in Fig.3.The structure has been fed with a coaxial feeding arrangement of an inner radius of 0.7mm and an outer radius of 1.6mm.

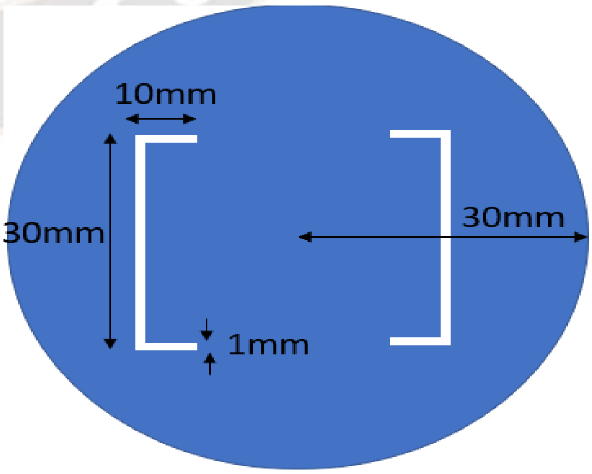


Figure 1. Top view of the proposed antenna for the L5 band.

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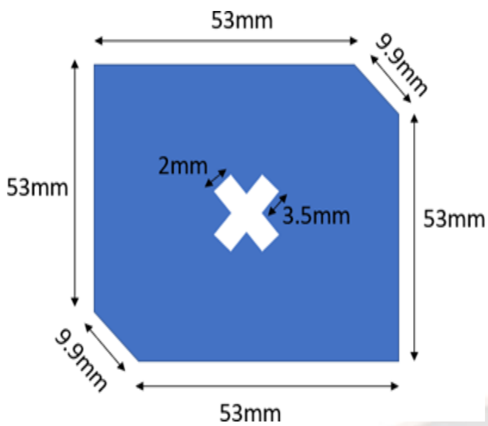


Figure 2. The dimension details of the proposed antenna

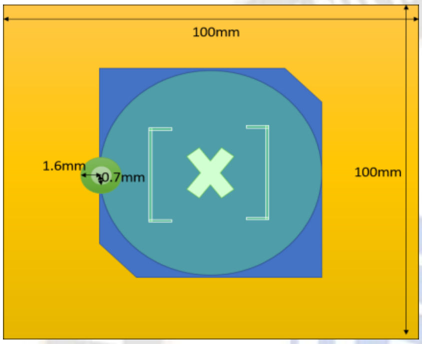


Figure 3. Antennas stacked on top of each other on the ground plane

### *B. Design Parameters*

Table. I show the dimensions and other design parameters of the proposed antenna.

TABLE I. PARAMETERS OF THE ANTENNA.

| ANTENNA VARIABLES | VALUE |
|---|---|
| Frequency Band | L5 Band |
| Antenna dimensions (in $mm^2$) | 60x 60 |
| Substrate Length and width (in mm) | 100 x 100 |
| Slot length and width (in mm) | 9 x 2 |
| Height (in mm) | 0.158 |
| Triangular slot trimming | 9.9 x 7 x 7 |

### *C. Proposed Algorithm*

(i) Get the input parameters namely the operating frequency, substrate type, and permittivity.
(ii) Estimate the length & width of the patch using a transmission line for the L5 band corresponding to half wavelength resonance conditions.
(iii) In order to achieve impedance matching using a probe feed, it is necessary to establish a connection between the inner conductor and the patch, while connecting the outer conductor to the ground plane. The point of contact of the probe can be approximately between L/4 and L/6 away from the patch center.
(iv) Assign perfect E boundary condition for the patch and the ground plane and Radiation boundary to the air box surrounding the patch.
(v) Perform a validation check on the antenna and run the design for simulation.
(vi) Estimate the input reflection coefficient of the antenna and check if it's below -10dB.
(vii) If yes then proceed to place the slot and perform corner trimming to achieve circular polarization and optimize the antenna and check if the axial ratio is well below 3 dB in the mentioned frequency range else optimize the slot length and the width to achieve RHCP. Place another elliptical patch on top of patch 1 to get the second band.

### *D. Design Equations*

The width '*W*' of the patch antenna is given by,

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

Where $c$ is the free space velocity of light, $f_r$ is the resonant frequency, and $\varepsilon_r$ is the dielectric constant of the substrate.

The 'L' is the length of the patch antenna given by,

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \quad (2)$$

The incremental length of the patch is given by,

$$\Delta L = 0\cdot412\frac{\left(\frac{w}{h}+0\cdot264\right)\left(\varepsilon_{reff}+0.3\right)}{\left(\varepsilon_{reff}-0\cdot258\right)\left(\frac{w}{h}+0\cdot8\right)} \quad (3)$$

Where '$h$' is the thickness of the substrate and $\varepsilon_{reff}$ is the effective dielectric constant of the patch, which is given by,

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right] \quad (4)$$

## IV. SIMULATION RESULTS

The details stimulated results of the CRPA antenna are discussed below. The structure has been designed, simulated, and validated using HFSS version 22 and the results have been neatly tabulated as shown in Fig. 4.

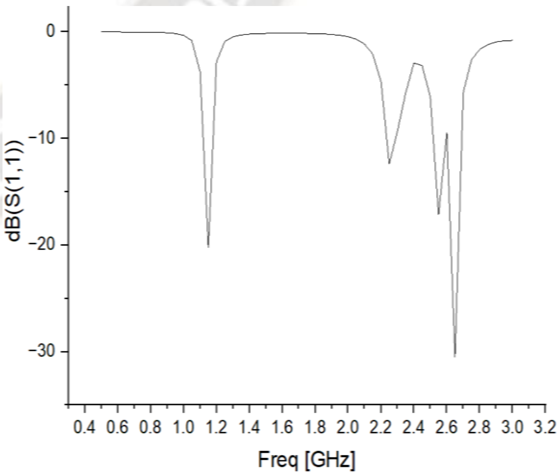


Figure 4. Input reflection coefficient plot of the antenna resonating at L5 and S-band respectively. The simulated values were -20dB and -30dB corresponding to lower and upper frequency bands respectively.

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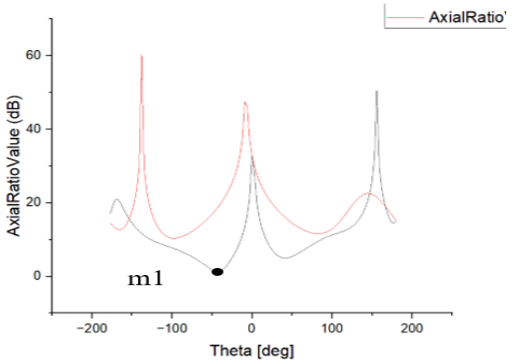


Figure 5. Axial ratio plot of the antenna resonating at L5 band.

The reported value was 3.4dB as indicated by marker m1.

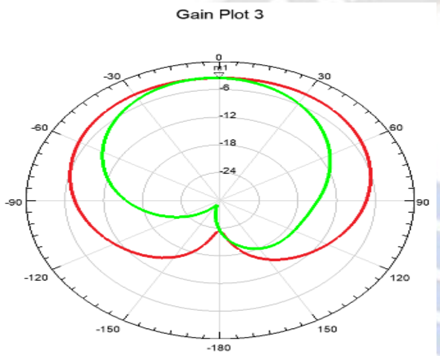


Figure 6. Fig.6 Two-dimensional gain plot of the antenna resonating at L5 band.

The peak boresight gain reported was -1.27dBi as indicated by m1.

## V. RESULTS AND DISCUSSIONS

The antenna's input reflection coefficient plot is depicted in Fig. 4. The s11 readings is less than -10 dB in both interest frequency bands, indicating that the antenna was operating on two bands simultaneously. According to Table. II, the corresponding bandwidths reported were 0.0605GHz and 0.0916GHz. The axial ratio of the antenna is 3.4. dB, as shown in Fig. 5. From Fig. 6, the antenna's peak boresight gain was -1.27dBi for the L5 frequency range of interest in both the E and the H planes.

TABLE II. SIMULATED RESULTS OF THE DUAL-BAND ANTENNA

| Antenna Results | Frequency Band 1 | Frequency Band 2 |
|---|---|---|
| Resonant Frequency | 1.17 GHz | 2.5 GHz |
| Input reflection coefficient(S11) | - 20 dB | -30.0 dB |
| Bandwidth | 0.0605 GHz | 0.0916 GHz |
| Axial ratio | 3.416 dB | - |

## VI. CONCLUSION

The current study involves the construction of a dual-band circularly polarized antenna that is intended to resonate at frequencies corresponding to the L5 and S-bands. By incorporating a slant 45degree slot and corner trimming along the diagonal of the patch, circular polarization was achieved. The structure reported a very good input reflection coefficient and bandwidth which meets the requirement of the present-day satellite application.

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