Single Feed Stacked Circularly Polarized Patch Antenna For Dual Band NavIC Receiver of Launch Vehicles

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***Abstract*—A compact circular polarized antenna for multiband NavIC receivers is presented. Concept of stacked patches fed through single coaxial probe is employed. Two square patches are stacked one above the other to achieve dual band operation. Principle of corner chopping is used at L5 frequency band and a combination of corner chopping and stubs are used at L1 frequency band to obtain circular polarization and good return loss.**

The antenna is designed to receive L1 (1575.42 MHz) band GPS signal and L5(1176.45MHz) band IRNSS signal for the NavIC receiver on board ISRO launch vehicles with omni directional coverage.

The proposed antenna is designed, simulated and fabricated. This antenna has achieved a bandwidth of 2.1% and 3.5% at L5 and L1 frequency bands respectively. The measured gain at at L5 frequency is 5.9dBi and L1 frequency is 6.1dBi. Realization aspects, simulated and measured results are discussed

Keywords— Circular Polarization, Omni-directional, Stacked Patch, GPS, IRNSS, NavIC

I. NOMENCLATURE

- ε_r - Relative dielectric constant
- IRNSS- Indian Regional Navigation Satellite System
- NavIC- Navigation through Indian Constellation
- CP- Circular Polarization

II. INTRODUCTION

NavIC receiver which receives L1 frequency signal from GPS and L5 frequency signal from IRNSS is being proposed in launch vehicles of ISRO to aid the inertial navigation system to determine the vehicle's position and velocity accurately.

The electrical requirement for an antenna used for NavIC receiver in a launch vehicle is to have omnidirectional coverage with good circular polarization. Antenna element should be non-protruding and size should be compact and light in weight and it should withstand the high vibration, shock and other harsh outer space environmental conditions. Availability of limited space on launch vehicle's outer surface is a major challenge for the antenna design. Design of a single antenna that can cover both GPS and IRNSS frequency bands effectively and simultaneously can solve this problem. Circular polarized microstrip patch antennas are common design option for Satellite based navigation systems because they provide several advantages like low fabrication cost, conformal to vehicle ,light weight and ease of integration to circuit[1].There are two main methods to create circular polarization in rectangular or square microstrip patch antennas.[1]In the first method, the patch is fed at a single point and its boundary or interior is disturbed, so that two orthogonal modes with identical magnitude but with a phase difference of 90 degrees exist at a single frequency[2-3]. In the second method, two orthogonal modes are directly fed with a microwave device (like a branch line hybrid) which provide equal amplitude and 90degree phase difference. Single feed design has an advantage of being simple and compact. J. Anguera et. Al [4] details the concept of stacked patch design, in which there is at least one driven element at top which is connected directly to the feed network and a number of parasitic patches placed below the driven patch to obtain multiband operation.

A novel dual band single feed stacked microstrip patch antenna with circular polarization is proposed in this paper. It is compact, less complex and provides distinct separation of the two bands with good impedance bandwidth and axial ratio (AR). To make the antenna rugged, adhesive is applied between two stacked layers, a spacer and radome is provided over the top layer and it is enclosed in a frame.

Section III provides details of the antenna design and mounting configuration, Section IV comprises of the results and analysis and it also gives a glimpse of the simulation study of the antenna and section V concludes the paper.

III. ANTENNA DESIGN ASPECTS

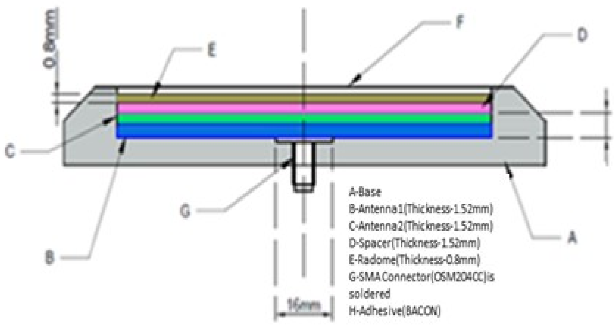

Figure 1. Antenna Assembly

The proposed antenna is a stacked patch design with single feed whose geometry is shown in fig.1. The antenna consists of two square patches stacked one over the other. The lower patch is designed to resonate at L5(1176.45MHz) frequency and the upper patch at L1(1575.42MHz) frequency. A coaxial probe of 50ohm impedance is connected to the top patch through a via hole in bottom patch. Electromagnetic coupling excites the bottom patch. Right Circular Polarization (RCP) is achieved by corner truncation of the square bottom patch. On the top patch, a combination of stub along one diagonal and corner truncation along another diagonal is used to achieve RCP. By this way a pair of orthogonal modes of same amplitude and 90 degree phase difference is generated in both patches to obtain circular polarization.

Rogers 6002 material with 60 mil (1.52mm) thickness and permittivity (εr) =2.94 is used as substrate for both layers. The ground plane size is 114mm x 114mm.The lower and upper patches have lengths of 72mm and 56mm respectively. A spacer of 1.52 mm thickness FR4 material and a radome of 0.8mm thickness Rogers 4003C material is provided above the top patch. The overall height of the antenna is 13mm.The bottom patch has a via hole of diameter 2.3mm. The geometry of bottom and top patches are given in fig.2 and fig.3 respectively.

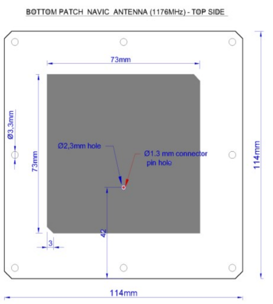

Figure 2: Bottom Patch

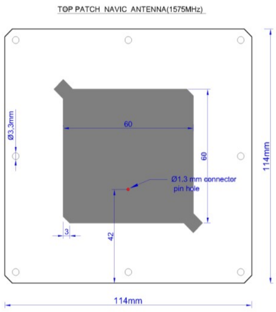

Figure 3. Top Patch

Dimensions of the stub and corner truncations have been optimized to obtain both good return loss and axial ratio at the desired frequencies by extensive simulations and experimentation. The centres of top and bottom patches are slightly offset to obtain good impedance matching at the feed point for both the desired frequencies.

In flight environment, 145 degree Celcius temperature is expected on antenna element. So, a radome (Rogers 4003 C material) was planned over the top patch to cover the antenna. A spacer of FR-4 material is provided over the top patch for clearance and radome is placed above it, to protect the patch. In order to make the antenna rugged, it is placed on an aluminium alloy frame. Further, mounting holes are provided on the frame for integration on the launch vehicle.

To obtain omni directional coverage two antenna elements are placed diametrically opposite on the launch vehicle and combined using a power combiner and connected to receiver via cables. This configuration is referred to as antenna system.Fig.4 illustrates the basic configuration of the antenna system. To increase reliability, two such antenna systems are proposed for the launch vehicles.

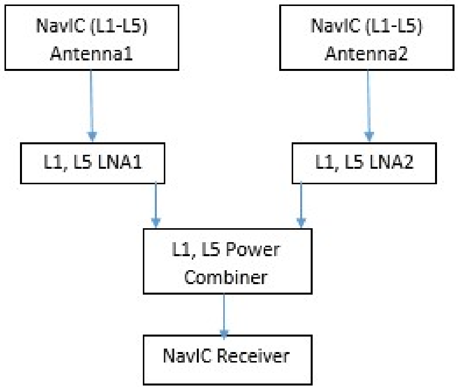

Figure 4: Antenna System Configuration

IV. RESULTS AND ANALYSIS

Simulation studies on the proposed antenna were carried out using the electromagnetic simulation tool, CST Microwave studio Suite .The single antenna element was simulated using its Time domain solver. The antenna system was simulated using the Integral equation solver. The corner truncations, stubs, diameter of via hole, offset between the centres of the two patches were optimised using the simulator. The use of stub along diagonal of top patch needs to be carefully designed to achieve good axial ratio and return loss at L1 frequency band. The dimension of stub and corner truncation in the top patch has a key role in achieving an axial ratio below 3 dB.

The prototype antenna is fabricated and tested at ISRO facilities. Fabricated antenna is shown in fig.5c and bottom and top patches are shown separately in fig.5a and fig.5b respectively.

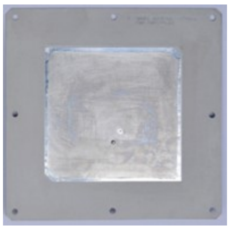

Figure 5a. Bottom patch

Figure 5b. Top Patch

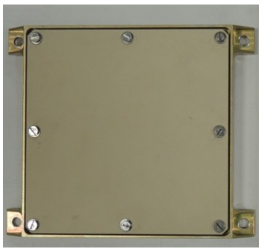

Figure 5c. Fabricated NavIC antenna

The simulated reflection coefficient (S11 in dB) of single antenna element is shown in fig.6.The measured reflection coefficient (S11 in dB) of the fabricated antenna (single element) is shown in fig.7.Good match can be observed between the measured and simulated results over both the frequency bands. The -14 dB impedance bandwidth for L1 and L5 frequency bands was obtained as 35 MHz and 20MHz, respectively on measurement.

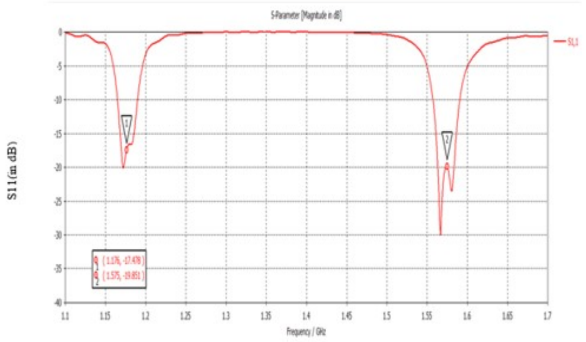

Figure 6. Simulated Reflection Coefficient (S11 in dB)

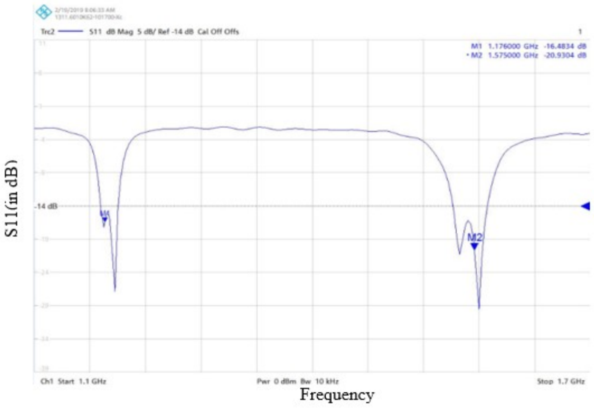

Figure 7. Measured Reflection Coefficient (S11 in dB)

The simulated axial ratio at broadside direction for L5 and L1 bands are shown in Fig.8a and Fig.8b respectively. The minimum axial ratio coincides with the resonant frequencies in the two bands. The simulated axial ratio at L5 frequency has minimum value of 2.9 dB and at L1 frequency has minimum value of 2.6dB.

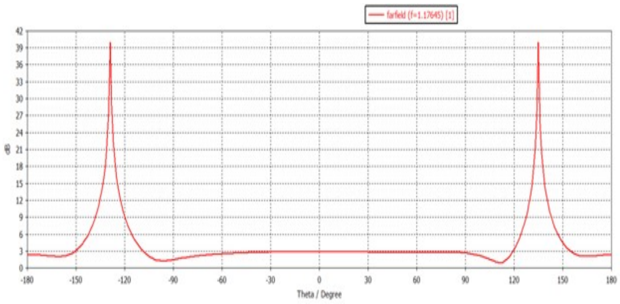

Figure 8a. Simulated Axial Ratio at L5

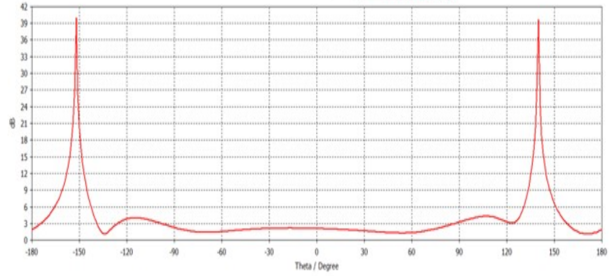

Figure 8b. Simulated Axial Ratio at L1

Simulated peak gain of antenna is 6.44dBi at L1 frequency and 6.31 dBi at L5 frequency. Measured peak gain of antenna is 6.1dB at L1 frequency and 5.9 dB at L5 frequency band. The polar gain pattern and 3-D far field gain plots are shown in figures 9a to 9g. The antenna radiation pattern measurement has been carried out for the centre frequencies of L1 and L5 bands in an anechoic chamber at URSC Bangalore.

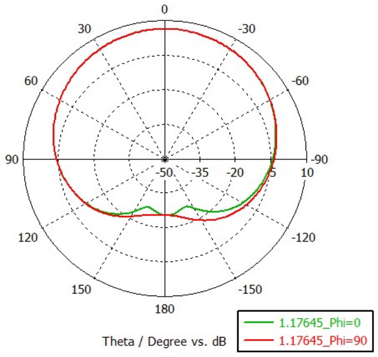

Figure 9a. Simulated Polar Radiation Pattern at L5

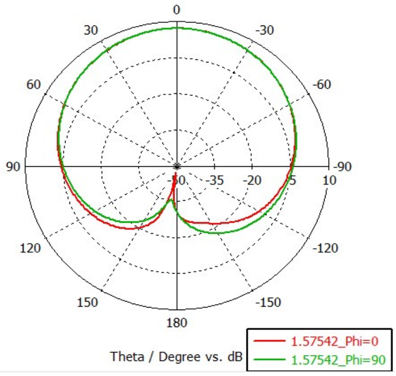

Figure 9b. Simulated Polar Radiation Pattern at L1

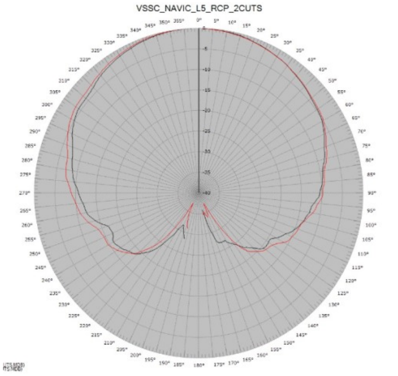

Figure 9c. Normalized measured Radiation Pattern at L5

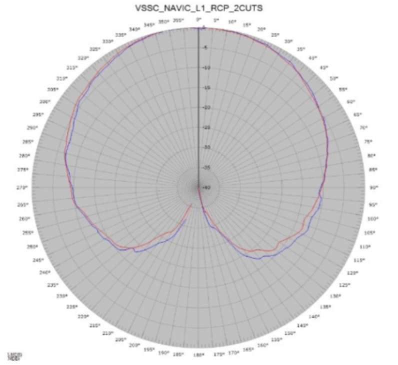

Figure 9d. Normalized measured Radiation Pattern at L1

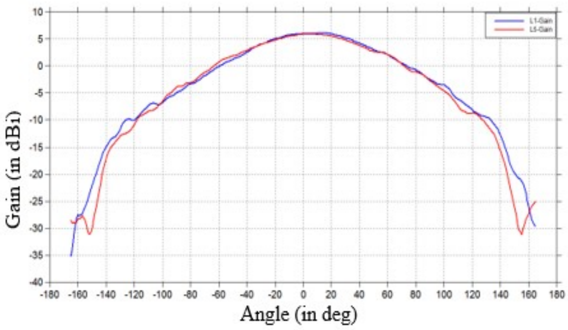

Figure 9e. Measured 2D Radiation Pattern at L1 and L5

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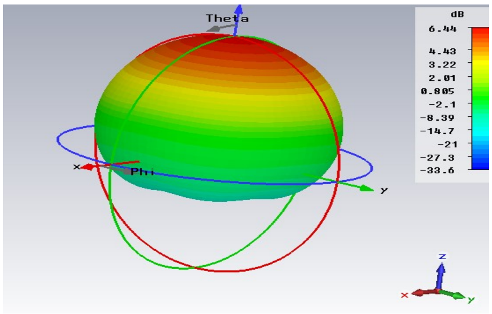

Figure 9f. Simulated 3-D Radiation Pattern at L1

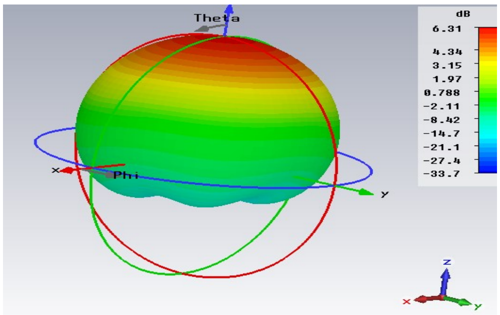

Figure 9g. Simulated 3-D Radiation Pattern at L5

Simulated 3-dB beam width at L1 is 82.5 deg and at L5 is 89.9 deg. The antenna has a measured 3 dB beam width of 85.9 deg. at L5 and 81.9 deg. at L1.

The antenna has symmetric radiation pattern along boresight direction. Measured RCP gain is larger than LCP gain by 15 dB in bore sight direction (Fig.10). Thus, Cross polar discrimination (XPD) of more than 15 dB is available in both L1 and L5 frequency bands. This is sufficient for the present application.

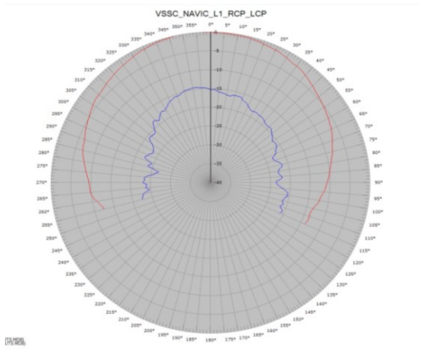

Figure 10.Measured boresight RCP and LCP gain

Antenna system was simulated with launch vehicle segment modelled as a cylinder of 2.8m diameter(Fig.11).Simulated 2-D radiation pattern of the antenna system for both frequencies at theta 90deg. cut are given in fig.12a and fig.12b. Measured reflection coefficient graph of the antenna system is given in Fig.13.

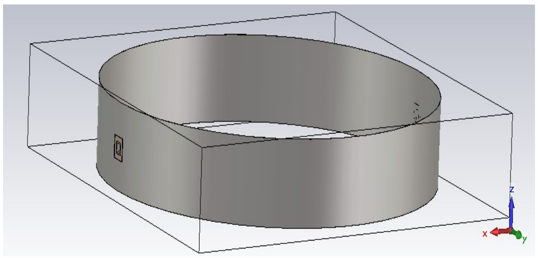

Figure 11. Simulation model of antenna system mounted on launch vehicle segment

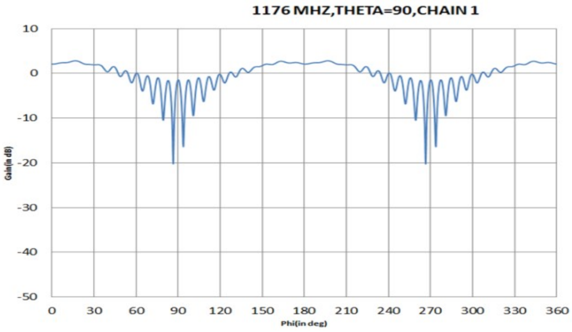

Figure 12a.Simulated 2D Radiation Pattern of Antenna system at Theta 90 deg(L5)

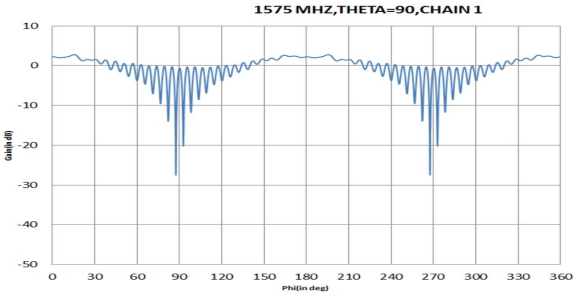

Figure 12b.Simualted 2D Radiation Pattern of Antenna System at Theta 90 deg(L1)

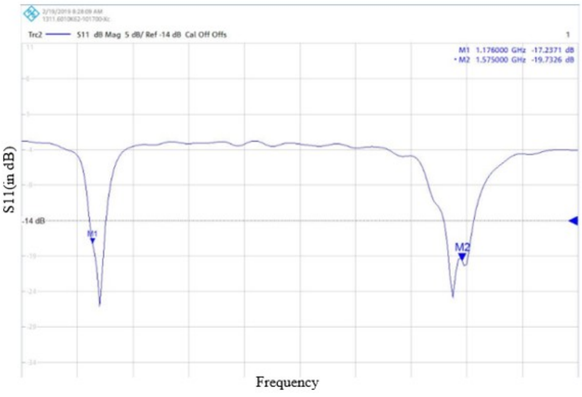

Figure 13.Measured Reflection Coefficient(S11 in dB) of antenna system

Table:1. shows that the measured results have a very close match with simulated results. The small difference in results could be due to cable losses, fabrication imperfection and SMA connector

Table 1. Comparison of Simulated and Measured results of Proposed Antenna

	Gain (in dB)		Beam width (in deg.)		Axial Ratio		Return Loss (in dB)	
	L1	L5	L1	L5	L1	L5	L1	L5
Simulated	6.4	6.3	82.5	89.9	2.9	2.6	17.4	19.8
Measured	6.1	5.9	81.9	85.9	3.0	2.9	16.4	20.9

Since, this antenna is proposed for use in launch vehicle, it should withstand vibration and shock during the launch phase, extreme thermal and thermo-vacuum environment. During the development stage of this antenna, it was observed that during thermo-vacuum test, tuning frequency of L1 frequency band shifted 50 MHz to higher side due to increased gap between top and bottom patches. For avoiding this shift, two patches were bonded with non-conductive adhesive(BACON).Subsequently, antenna was subjected to thermo-vacuum test and antenna performance was normal.

Influence of via hole diameter of bottom patch on the reflection coefficient (S_{11}) was also studied. Diameter of centre pin of connector is 1.3mm. So, diameter of via hole was changed from 1.5mm to 3mm. As the diameter increases from 1.5mm to 2.3mm, return loss of antenna at L1 frequency increases with little effect on L5 frequency. As the diameter further increases from 2.5mm to 3.0mm, return loss of antenna at L1 frequency decreases with little effect on L5 frequency. So, based on this study, optimum via hole diameter of 2.3mm was selected for this design.

V.CONCLUSION

A compact single feed stacked dual band circularly polarized patch antennafor the NavIC receiver has been realized.The antenna provides good performance in both L1and L5 frequency bands. The dual band operation has been obtained by using two patches stacked one over the other.

Corner truncation and stub techniques have been implemented to achieve improved return loss and minimum axial ratio. The broad beamwidth, good cross polar discrimination, high gain and rugged design of this antenna makes it ideal for the NavIC applications of Indian Launch Vehicles.

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