Design of Circular Polarized Patch Antenna for NaviC Receiver Applications

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Abstract. In this paper, a circular polarized patch antenna at NaviC and S-band is presented for Indian Regional Navigational Satellite System (IRNSS) receiver applications. For this application proposed antenna is satisfying the criteria of circular polarisation with a bandwidth of 2477 MHz to 2508 MHz. The shape of proposed antenna exhibits good gain which is required for the good operation of communication systems for IRNSS. Antenna is operating at frequency of 2492.08 MHz (S-band) with a return loss better than -15 dB and has the stable radiation pattern. For designing of this antenna a conducting patch of 27.5 mm x 27.5 mm and a FR-4 material with thickness of 1.6 mm and dielectric constant of 4.3 is used as a substrate material. In addition to this, the antenna is fed with a coaxial feed technique and matched with 50 Ω input impedance of antenna. The parameters like radiation pattern, VSWR, E field, gain and axial ratio are analysed and achieved by CST studio Suite.

Keywords: IRNSS, circular polarized antenna, FR-4 material, NaviC application, axial ratio

1. Introduction.

Due to certain limitations of GPS, in case of complex and hostile situations, GPS alone in India and Asia-Pacific regions cannot meet the requirements of accuracy and results to poor tracking and navigation. [1]. To overcome these limitations of GPS, using a constellation of geosynchronous equatorial orbit (GEO) and geosynchronous orbit (GSO), Indian space research organization (ISRO) built an Indian regional navigation satellite system (IRNSS) known as NaviC. The IRNSS is an independent, indigenously developed satellite navigation system and under the total control of Indian government [2]. The Indian GPS system named "IRNSS" provides two types of services, first is standard positioning service (SPS) which is available for all the users and second one is restricted service (RS), which is an encrypted service available only to the authorised users such as army, navy and Indian security systems [3].

The operating frequencies of IRNSS are supposed to be operated on L5 band (1176.45 MHz) and S band (2492.08 MHz). The distribution of 7 satellites of IRNSS is as 3 satellites are installed in geo
stationary orbit and 4 in geosynchronous orbit [4]. Using this satellite system information of accurate position of Indian user’s can be provided in India and extended range of 1500 km of India’s boundary [5-6]. IRNSS provides the high accuracy of user’s velocity, time and position in real time applications. Another satellite system used for tracing is global navigation satellite systems includes (GNSS) constellation of satellites that transmit positioning and timing data to determine the user’s location. GNSS include Europe’s Galileo, the USA NAVSTAR global positioning system (GPS), Russia’s GLONASS and China’s BeiDou navigation satellite system. Among all, GPS is a space-based satellite system developed by U.S government which provides the position, velocity and time information of users anywhere in the world. Each GPS transmits three frequency bands L1, L2 and L5 with frequencies of (1575.42 MHz), (1227.60 MHz) and (1176.45 MHz) respectively [7-8]. Being a confined space it is a big challenge to integrate an antenna on board of IRNSS receiver. A compact microstrip antenna being small in size, light in weight, ease of construction and low cost meets the requirements of easily integration of antenna on limited space of INRSS receiver board. The limited space and light weight are big challenges for INRSS designer. Till now no more work has been carried out on IRNSS systems, and other services associated with these systems will be available in upcoming years [9-10]

2. Proposed antennas Design.

The design of simple rectangular microstrip antennas with specified information includes the dielectric constant of the substrate (\(\varepsilon_r\)), the resonant frequency (\(f_r\)), and the height of the dielectric material (h) is shown in “Fig.1”. The design frequency and width of antenna is calculated using the transmission line model. The resonant frequency of rectangular patch antenna for TM010 (dominant mode) is a function of length of patch. Usually it is given by equation 1.

\[
(f_r)_{010} = \frac{1}{2L\sqrt{\varepsilon_r/\mu_0\varepsilon_0}} = \frac{\theta_o}{2L\sqrt{\varepsilon_r}} \tag{1}
\]

where \(\theta_o\) is the speed of light in free space.

For a practical patch antenna to provide good radiation efficiency, width of patch is given by equation 2 [11].

\[
W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r+1}} = \frac{\theta_o}{2f_r\sqrt{\varepsilon_r+1}} \tag{2}
\]

The compact, simple and schematic design of proposed antenna with coaxial feeding is shown in “Fig. 2”. The circular polarization characteristic of rectangular patch antenna is achieved by diagonally
modifying the corner of conducting patch. FR-4 material having tangent loss of 0.025, dielectric constant 4.3 and being a low cost is used as a substrate material of designed antenna. The dimension of the proposed antenna is 100x100x1.6 mm$^3$. The characteristics impedance of coaxial feed is 50Ω. The dimensions of designed antenna are given in table no.1.

3. Results and Analysis

The designed antenna has been simulated using the CST studio suite and the results are analyzed on the basis of return loss, gain, impedance matching and axial ratio.

### Table 1: Antenna Dimension Table

| Parameters | Dimensions (mm) |
|------------|-----------------|
| Lg         | 100             |
| Wg         | 100             |
| Lp         | 27.50           |
| Wp         | 27.50           |
| R          | 4.50            |
| k          | 0.67            |
| d1         | 3.00            |
| d2         | 2.28            |
| Xf         | 0.00            |
| Yf         | -6.98           |

Fig.2. Design of the proposed antenna

Fig.3. Design of Circular polarization, Antenna-1, Antenna-2, And Antenna-3

Initially simple rectangular patch antennas designed at 2500MHz is shown in "Fig.3". The designed antenna is divided in three parts. In antenna-1 a simple square is considered without any modification and it behaves linear polarized antenna. In antenna-2 two opposite corners are modified, and in antenna-3 all the four corner of antenna are altered to generate the circular polarization. "Fig.4" Shows surface current distribution of antenna of all the three antennas separately. In antenna-1, there we can see that it represents linear polarized characteristic because direction of field arrows linearly opposite at phase angle 0° and 180° and patch dimension Lp=Wp, which mean it generates one of orthogonal mode at 2.5 GHz frequency. The axial ratio for all antennas are shown in "Fig.5" In case of Antenna-1 axial ratio is 40 db that’s why this is linear polarized antenna.
For generation of Circular polarization characteristics we have to excite simultaneously orthogonal modes at same frequency at 2500 MHz by coaxial feed. So in case of antenna-2, Surface current is slightly rotated at 0° and 180°, and Wp>Lp and diagonal corner modified to generate 90° phase shift between orthogonal modes means two orthogonal modes trying to excite simultaneously but not exact, so axial ratio down to 11.72 dB as shows in "Fig. 5".

And finally in Antenna-3 surface current is rotated to 90° from initial stage antenna-1, and round shape of the diagonal corners are modified. So combination of diagonal corners and small difference of size of Lp and Wp are responsible to generate circular polarization characteristics. In this case basically, two orthogonal modes are excited simultaneously with same amplitude and 90° phase difference between orthogonal modes, its axial ration is 0.82 dB.

The S11 parameters of all three antennas are shown in “Fig.6”. The entire three antennas are well resonating at the designed frequency and return loss is below 10 dB in all the three cases. The Electric field distribution is shows in "Fig.7" and used for identification of nature of circular polarization characteristics, according to phase variations, the field continuously moving in right hand side
direction, so that we can say the proposed antenna has right handed circular polarization (RHCP) characteristics.

Fig.6: S11 parameter of Antenna-1, Antenna-2 and Antenna-3

Fig.7: Electric field distribution of proposed antenna with different phase angle

"Fig.8" shows S11 parameter and “Fig.9” shows axial ratio of proposed antenna to measure the impedance bandwidth of antenna. From S11 plot impedance bandwidth is 124 MHz from 2449.9 to 2573.6 MHz, and axial ratio bandwidth at 3 dB is 31 MHz from 2477.5 to 2508.2 MHz and shown in "Fig. 9" which is operating frequency for IRNSS (NavIC) from 2483.50 to 2500.00 MHz.

Fig.8: S11 parameter for impedance bandwidth
Fig. 9 Axial ratio for bandwidth

"Fig. 10" Shows the gain of antenna. The gain of antenna is 2.83 dB and 3 dB beam-width is 79.7°.

Fig.10 Gain of proposed Antenna

A good impedance matching can be observed from Smith chart shown in “Fig. 11”. A 50 Ω characteristics impedance at 2500 MHz frequency and input impedance of antenna (46.13+j16.41) Ω, for antenna matching with characteristics impedance, real part of input impedance of antenna is equal to characteristics impedance and imaginary part of input impedance is equal to zero.

4. Conclusion

The design of circular polarized patch antenna for NaviC receiver applications is presented in this paper. The proposed antenna has been designed and analyzed using their performance characteristics like gain, bandwidth and impedance matching. The Single band right hand circular polarized antenna design at 2500 GHz frequency with impedance bandwidth of antenna from S11 at -10db standard is
124 MHz from 2449.9 to 2573.6 MHz and axial ratio bandwidth at 3dB is 31 MHz from 2477.5 to 2508.2 MHz, which is operating frequency for IRNSS (NavIC) from 2483.50-2500.00 MHz.

5. References

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