International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

A Design of L-Band Chord Circular Horn Like Bow Tie Antenna for Satellite Navigation Application

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Abstract
This paper presents the design of a Chord circular horn like bow tie antenna intended for millimeter wave applications within the frequency range of 2.4 GHz to 7 GHz. A multi- objective function is formulated to optimize both the bandwidth and gain of the proposed antenna. The design of the antenna employs FR4 dielectric material, characterized by a dielectric constant (εr) of 4.4 and a loss tangent (δ) of 0.001. Following the successful optimization of the proposed antenna, its performance is assessed by evaluating the return loss and gain characteristics. Finally, after fulfilling the predefined objectives, an analysis of the radiation characteristics is conducted to gain insights into the antenna's radiation properties in E-plane and H-plan. This antenna is suitable for satellite navigation purpose.

Keywords: Bow-tie Antenna, satellite navigation application, return loss, VSWR, gain, semi-circled horn, directivity.

1. Introduction

Currently, the use of portable electronic mobile devices equipped with global positioning, navigation, and timing services has surged significantly. As of now, the Global Navigation Satellite System (GNSS) consists of four systems: GPS (United States), GLONASS (Russia), Galileo (Europe), and Compass (China). To enhance the precision and dependability of positioning and navigation, it is essential to utilize two or more of these systems. This necessitates an antenna that operates in multimode and covers all frequency bands for GPS/GLONASS/Galileo/Compass for portable electronic devices. Consequently, the antenna must function across a broadband range from 1163.72 to 1605.8865 MHz while providing circular polarization.

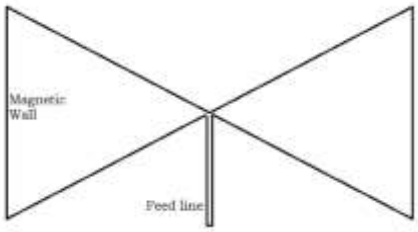
All navigation satellite signals are right-hand circularly polarized due to their superior mobility, better penetration through weather conditions, and reduced multipath reflections. Recently, circularly polarized antennas have been the subject of considerable research and interest. The common constraints associated

with circular polarization (CP) patch antennas include the limitations of the achievable impedance and axial-ratio (AR) bandwidths. Historically, the permissible 3-dB AR bandwidth for single-feed configurations tends to be less than 10% [1]. However, much broader impedance and AR bandwidths can be realized through multifeed CP patch antennas [2], [3]. Patch antennas featuring quadruple broadband feeds have been experimentally shown to achieve impedance bandwidths of approximately 70%-80% at -10 dB, along with 3-dB AR bandwidths of 80%. While the quadruple-feed CP patch antenna provides significantly wider impedance and AR bandwidth, it can lead to a very intricate feed network incorporating phase shifters and power dividers. To mitigate these drawbacks, [4]–[6] have proposed alternative designs of slot broadband circularly polarized antennas, yet the available literature indicates that their AR bandwidth is still insufficient when compared to the voltage standing wave ratio (VSWR) bandwidth.

2. Bow-tie antenna design

The basic structure of the bow-tie antenna is illustrated in Figure 1. The theory behind triangular patch antennas, referenced in [7], forms the basis for designing the antenna. Typically, the bow-tie configuration employs two triangular antennas, although circular shapes with magnetic walls can also be utilized, as noted in [8]. The antenna can be constructed on a Printed Circuit Board (PCB) on one side or both sides. A semi-circled bow-tie antenna was developed using the rectangular bow-tie antenna as a reference. The proposed antenna's dimensions were designed with a dielectric constant of 4.4 and a height of 1.6 mm, built on both sides of an FR4 substrate. A planar bow-tie array antenna was manufactured with copper as the conductive material on an FR4 substrate. This antenna is notably compact, measuring 55x325x1.6 mm^3 [W x L x H].

Figure 1. Basic Bow-tie antenna



2.1 Chord Circular Horn Like Bow Tie Antenna

The dimensions of the circular patch antenna are calculated for the dominant $TM^{Z}{}_{110}$ mode, where z is the vector perpendicular to the circular patch. The substrate the height h is much smaller than the resonant wavelength λ. The ground plane is assumed to be infinite and all the metallic surfaces are lossless [9], [10]. Due to the fringing of fields the electrical size of the circular patch is larger than its physical radius a and it is calculated a_e is derived from Eq. (1) and (2).

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}+1.7726\right)\right]\right\}^{\frac{1}{2}}} \quad (1)$$

$$a_e = a\left\{1+\frac{2h}{\pi a\varepsilon_r}\left[\ln\left(\frac{\pi a}{2h}+1.7726\right)\right]\right\}^{\frac{1}{2}} \quad (2)$$

The geometry of partially grounded florescent shaped circular loop patch antenna. The dimensions of the substrate are 14mm x 14mm, the thickness of the substrate is 1.6mm [11] – [15]. Ground is partially structured and the dimensions are shown in table 1. The antenna uses the micro strip line feeding technique.

Figure 2. Chord Circular Horn like bow tie antenna with microstrip feeding

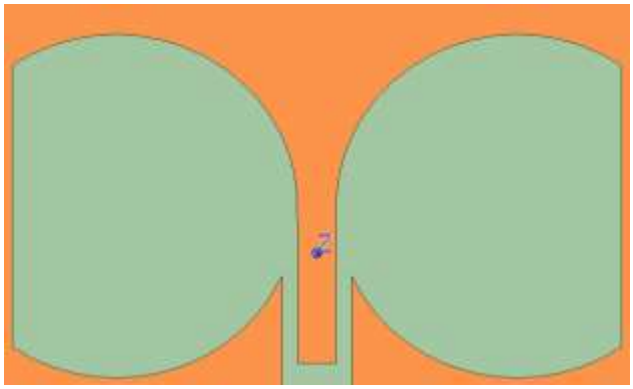


Table 1. Parameters of Chord Circular horn like bow-tie antenna

Parameter	Chord Circular Horn Like bow-tie antenna
L_S	90mm
W_S	56mm
L_G	90mm
W_G	56mm
W_R	41.65mm
L_F	21.44mm
W_F	10mm

3. Results and Discussions

The Novel Chord Circular horn like bow-tie antenna was designed using HFSS. The simulated result of the return loss is shown in figure. 3 and it obtain -10.7 dB at 3.28 GHz. Similarly the simulated result of VSWR measurement is shown in the figure. 4 and obtain 5dB at 27.17 GHz.

Figure 3. Simulated result of return loss of proposed antenna

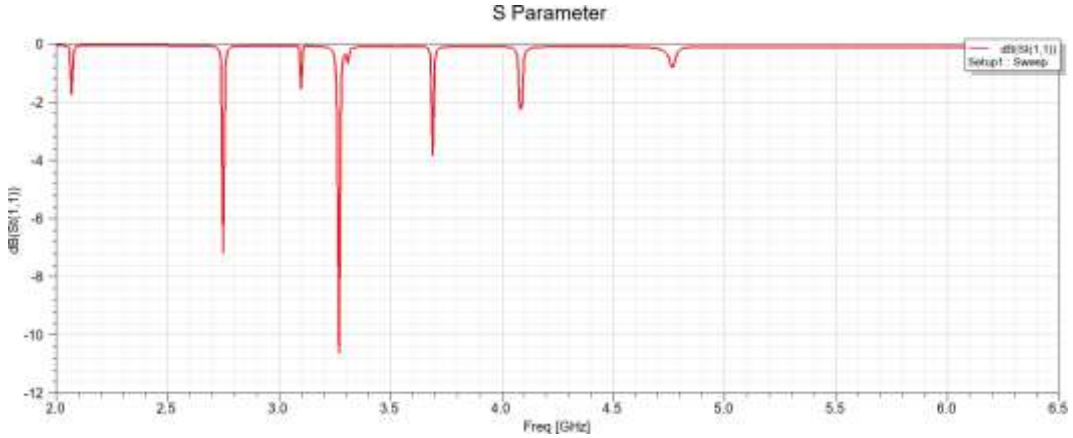
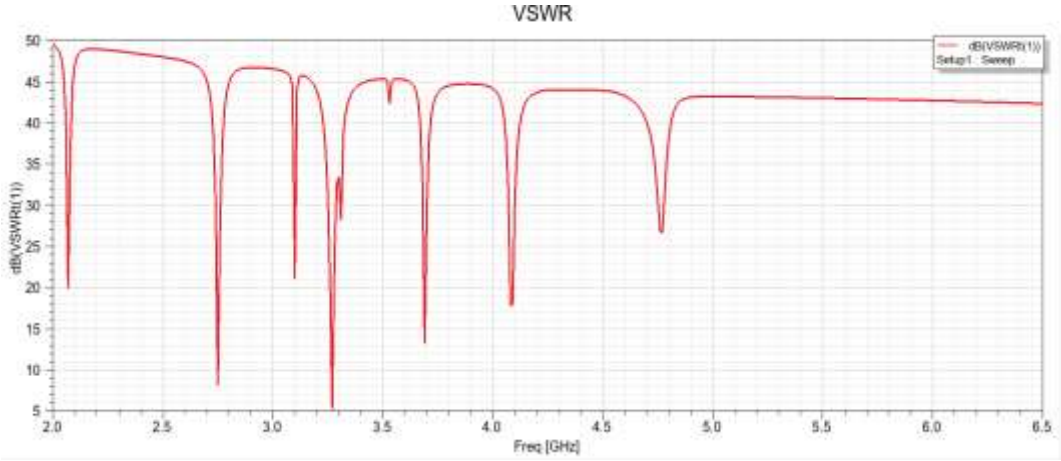


Figure 4. Simulated result of VSWR of proposed antenna



The proposed Chord Circular horn like bow-tie antenna is fabricated with FR4 substrate material and it is tested with help of Agilent N9926A device. The fabricated result of the return loss is shown in figure. 5 and obtain -12.53 dB at 3.457GHz and - 23.15 dB at 1.931GHz. Similarly VSWR measurement is shown in figure. 4 and obtain 1.619 dB at 3.457 GHz and 1.165dB at 1.931 GHz.

Figure 5. Fabricated result of return loss of proposed antenna

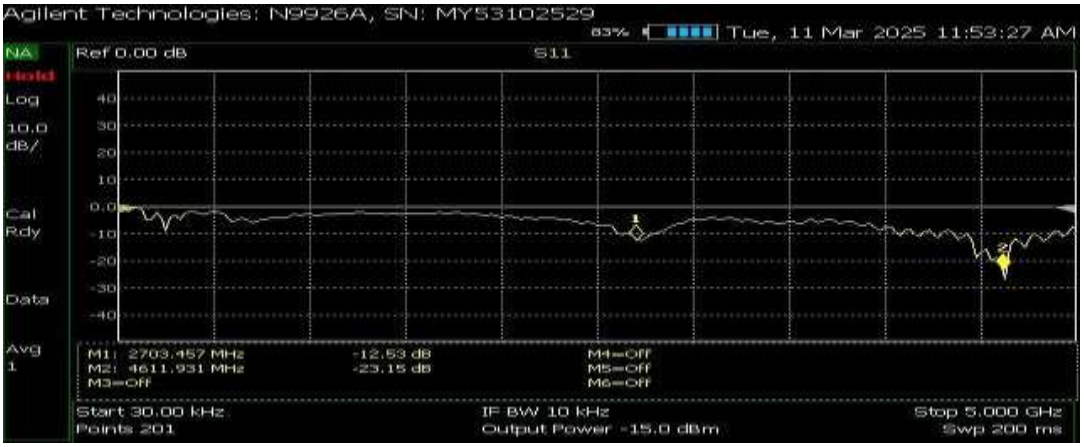
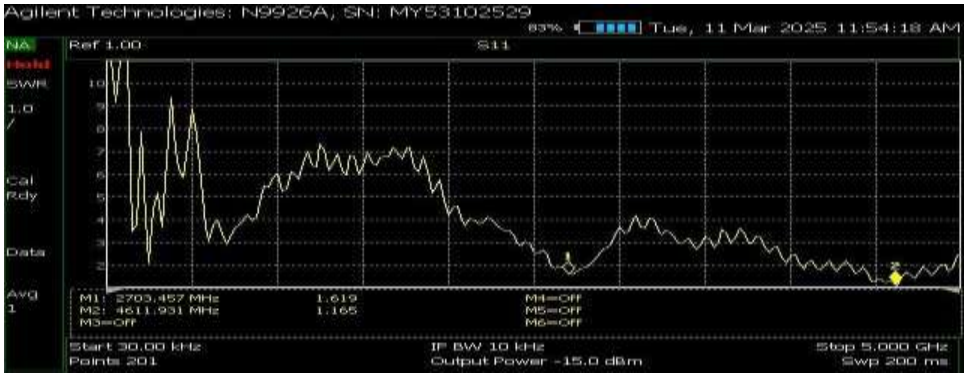
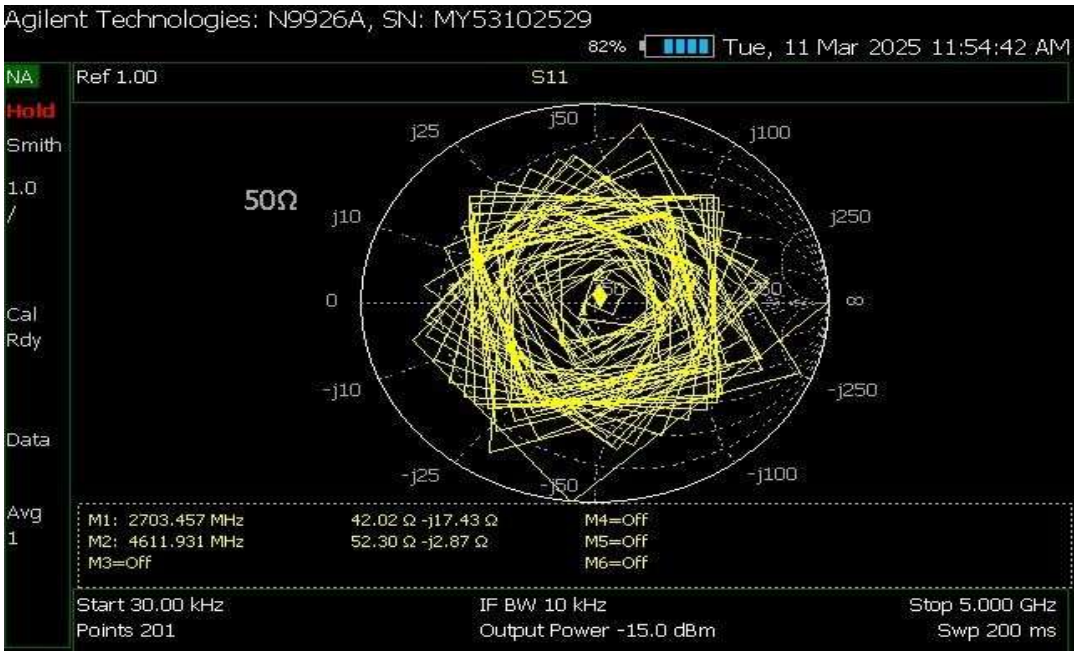


Figure 6. Fabricated result of VSWR measurement of proposed antenna



Similar to that Impedance measurement is shown in figure. 7 and obtain 42.02dB at 3.457 GHz and 52.30dB at 1.937GHz.

Figure 7. Fabricated result of Impedance Measurements of proposed antenna



4. Conclusion

A Chord circular horn like bow tie antenna was designed from 2.4 GHz to 7 GHz with bandwidth ratio 14.2%. The proposed antenna is very simple to model and physically compact. A fitness function was designed to optimize two performance parameters at a time. After Successful optimization, the -23.15 dB return loss at 4.61 GHz with a maximum gain of 5.8 dB. In the future, more than 2 performance parameters can be designed based on this work as a reference. Also, the radiation characteristics of the proposed antenna satisfy the criteria in both E-plane and H- plane. This proposed antenna is widely suitable for series of Satellite Communications and Broadcasting applications.

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