

A Miniature Circular Polarized Fractal based Antenna for Satellite Applications

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Abstract

A compact circularly polarized fractal-based antenna for navigation application is proposed in this work. Due to its simple fabrication method and inexpensive price, microstrip antennas have emerged as the ideal option for antenna designs. By using fractal shapes, electrically larger dimensions can be accommodated into smaller physical areas, so that antenna miniaturization is achieved. The total size of the antenna is also, the antenna offers circular polarization at two resonating frequency bands 1.176GHz and 2.492GHz. The antenna is useful for the navigational applications. Compared to the most of the previously reported multi band circularly polarized antenna structure, the proposed antenna is compact in size, and can be fabricated easily on the single-layer PCB. Various parameters of the antenna like return loss, VSWR, radiation pattern, axial ratio, etc., are obtained using HFSS software.

Keywords: HFSS software, Satellite Applications, VSWR.

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INTRODUCTION

In order to allow desired behaviour and create a favourable trade-off between performance and increased design complexity, antenna setup has traditionally depended on physical parameters like patch length and substrate thickness. Micro strip patch antennas have sparked considerable interest during the last 20 years. A dielectric substrate is placed between a patch and a ground plane in a printed form of antenna known as a microstrip antenna. Microstrip antenna technology is chosen in this article to design the antenna since it is the most popular in the area of antenna technology due to its economic viability and uses in a broad range of microwave systems. Microstrip antennas have a number of key benefits, including low fabrication costs, lightweight, low volume, and low-profile configurations that can be made conformal. These antennas can also be mounted on satellites, rockets, and missiles without requiring extensive modification [1-3], and arrays of them can be produced with ease. Because of increase in electrical length, the frequency of the antenna decreases which helps us to design antenna in low frequency applications like microwave frequency, navigation and satellite applications and this advantage motivates us to design our proposed fractal antenna.

LITERATURE REVIEW

Nadir Hakem [4] designed a miniature dual frequency stacked patch antenna for the IRNSS applications with an operating frequency of 1.176GHz and 2.492GHz in the L and S bands. To obtain the required operating frequency, the patch has been chopped at its diagonal corners. A 50 Ω coaxial cable has been utilized to excite the antenna, and two layers of Rogers TMM 10 with a thickness of 3.81mm have been employed as the substrate material. To obtain dual frequency of operation, stacked patch technique has been employed. Proposed antenna includes two radiators, each of which controls a single operating frequency. The Proposed antenna is having dual frequency of operation at the frequencies of 1.176GHz and 2.492GHz with a gain of 2.19dB and 5.26dB respectively. The proposed antenna was created using the 3D simulator Ansys HFSS.

Bhargav Pansuria [5] developed a micro-strip patch antenna for Indian regional navigational satellite systems (IRNSS) receiver. Signals from the IRNSS positioning and accuracy services utilise the L5 (1.176GHz) and S (2.492GHz) bands. As a result, a single band micro-strip patch antenna with a simplified design is proposed and simulated in accordance with the requirements of IRNSS receiver modules. Additionally, the coaxial feed mechanism is used to feed the micro-strip patch antenna, and several aspects such as return loss, VSWR, axial ratio, gain, and radiation pattern are

explored.

G. Jeevagan Navukarasu Lenin [6] designed, simulated, fabricated E shaped navigation antenna successfully and the height of suspension and dimension of the patch is reduced significantly. The shape of proposed antenna will provide high gain which is required for the good operation of communication systems. The antenna is made using the FR4 substrate, which has a dielectric constant of 4.4. With a dielectric constant of 1, air is employed as a second substrate. Here, multiband frequency functioning is made simple with the aid of air. This antenna design and simulation is done by HFSS 13.0 software. For applications utilising the IRNSS and GPS frequency bands, the E-shaped navigation antenna is appropriate.

Thanh Nghia Cao [7] designed a fractal antenna operating at two frequencies, 1.228 and 1.5745 GHz, suitable for GPS satellite system. Utilizing the Minkowski fractal island and the shorting pin on the radiating element, compact dimensions and dual frequency functioning were made possible. HFSS software was used for the design and numerical simulations. Antenna was fabricated using FR4-epoxy microwave laminate.

Maninder Singh [8] presented the comparison of two various fractal antennas. Both antennas were created utilizing FR4 glass epoxy substrates, which have relative permittivity values of 4.4. When compared to the developed antenna (a star-shaped fractal antenna), the various parameters of the existing antenna (a multi-fractal antenna), such as return loss, VSWR, gain, and bandwidth, reveal that the proposed antenna produces significantly better results. The developed antenna can be utilized for a variety of wireless applications, including WLAN, satellite communication, and long-distance radar telecommunication, and was simulated using the HFSS V13 tool.

i) Microstrip Patch Antenna

Most communication systems use microstrip antennas as an effective radiator. Microstrip antenna has inherently narrow bandwidth. However, these antennas have many design parameters that could be optimized by proper design methodology. Numerous configurations for diverse applications have been developed as a result of the many benefits of microstrip patch antenna [9-12], including its low weight, compact volume, and simplicity of manufacture utilizing printed circuit technology.

The necessity for smaller and low-profile antennas have pushed the microstrip antenna to the head of the pack due to rising demands for personal and mobile communications. A microstrip patch antenna, as depicted in figure 1, comprises of a radiating patch on one side of a dielectric substrate and a ground plane on the other. The patch can take any shape and is typically constructed of conductive materials like copper or gold. Typically, the feed lines and radiating patch are photo etched onto the dielectric substrate.

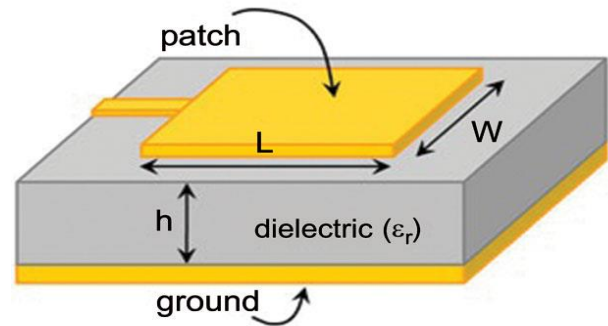


Figure 1: Basic patch antenna construction

ii) Fractal Antenna

Fractal antennas are multiband, high gain, and low-profile antennas that are utilized in many wireless applications due to their capabilities and competencies. Iterative geometry is the process of breaking down a shape into smaller versions. The self-similarity property of fractal antennas states that they have the same shape but are repeated with less length [13-14]. The fractal structure in figure 2 is used by many fractal element antennas as a fictitious combination of capacitors and inductors. As a result, the antenna exhibits a wide spectrum of resonances. This complexity results from the current's intricate arrangement within the structure, which is brought on by inductance and self-capacitance, and which may be selected and modified by picking the right fractal design. Fractal antennas typically have lower physical dimensions despite having longer effective electrical lengths, again because of this reactive loading. The structure has already provided the appropriate resonant input impedance, making fractal element antennas thinner than conventional designs and without the need for extra parts.

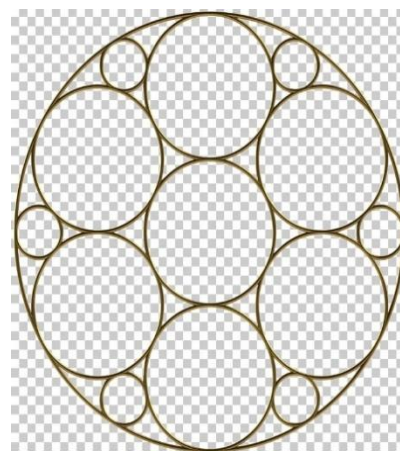


Figure 2: Fractal Antennas

Numerous fractal shapes have been utilized in antenna and array designs because of the self-similar feature. Basically, two types of Fractals are there, Deterministic and Non-Deterministic. Deterministic Fractals are further classified as Linear and Non-Linear. Deterministic Linear fractals

consists of Cantor curve, Koch curve, Hilbert curve, Minkowski curve, Apollonian and Sierpinski Gasket. The Mandelbrot set, Strange attractors, bifurcation diagrams, and Julia sets are examples of deterministic non-linear fractals. Fractal Brownian motion and diffusion-limited aggregation are two examples of non-deterministic fractals.

ANTENNA DESIGN

A fractal antenna exhibits multi-band behavior and it is a self-similar design of an antenna shape [15-17]. Consecutive iterations of circles are used to create the Apollonian gasket fractal antenna. The proposed antenna's ground is created by trimming the ground plane's edges, and it is designed on a FR4 epoxy substrate with a relative permittivity of 4.4, a loss tangent of 0.02, and a thickness of 1.6mm. The transmission line typically has 50Ω impedance. The proposed geometry contains number of iterations which consists of self-similar geometry of primary shape. A circle with a radius of 12 mm is placed in the zeroth iteration. Three circles with a combined radius of 6.1 mm are positioned outside the primary circle in the first iteration, at an angle of 120° from the Centre of main circle. Finally in 2nd iteration, three more circles are placed outside the 1st iteration circles with the radius of 3.19mm at an angle of 120° from the centre of 1st iteration circles and the final structure of the designed antenna would be as shown in figure 3 (d).

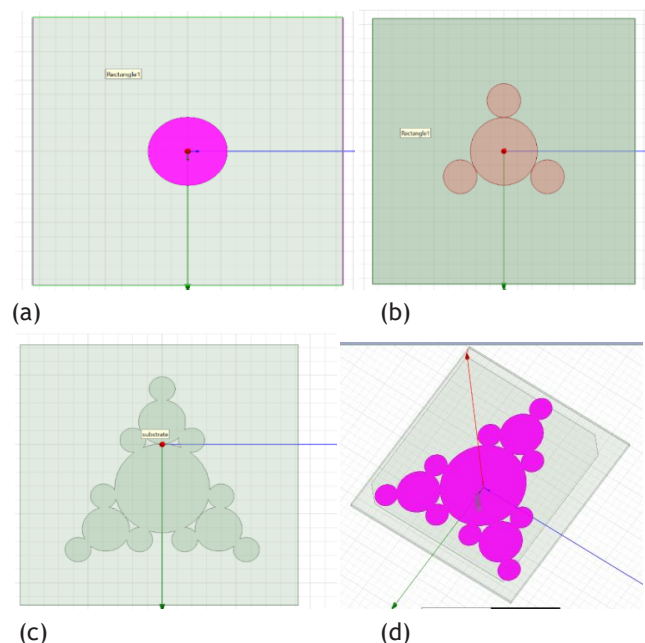


Figure 3: a) 0th iteration (b) 1st iteration (c) 2nd iteration (d) Proposed Antenna

By using the process and settings mentioned above with Apollonian gasket fractal antenna shape, the desired frequencies are obtained. The proposed antenna is excited by 50-ohm coaxial feeding, with the outer conductor

reaching the ground plane and the inner conductor extended to a patch. The fundamental benefit of the feeding method is that impedance matching may be accomplished by placing the feed at any desired point inside the fractal patch.

Parametric Analysis

It is not possible to reach all of the targeted antenna parameters with the original designed values. Also before performing optimization parametric analysis is done to know the effect of various antenna parameters on its performance.

a) Substrate

The substrate's initial dimensions of 85mm x 85mm x 1.6mm is unsuitable for the intended frequencies, thus parametric analysis is used in optimetrics. When applying parametric analysis to a substrate, only one precise value, 132mm x 132mm x 1.6mm exhibits the appropriate frequencies of 1.176GHz and 2.492GHz. Figure 4 depicts the return loss versus frequencies for different substrate dimensions.

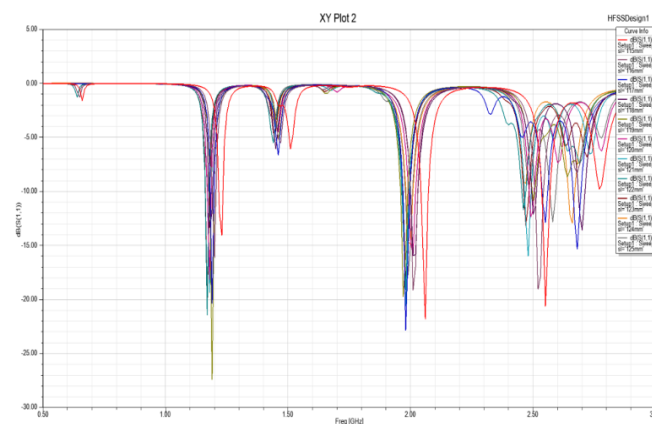


Figure 4: Parametric analysis for substrate

b) Ground

There are many ways to obtain circular polarization, and one of them is ground truncation. This reduction of ground dimensions contributes to the circular polarization. In order to get circular polarization the ground diagonal corners are trimmed. When a trimmed portion of the ground is subjected to parametric analysis, one precise ground trimming value at the desired frequencies is obtained, and that value is 14.95mm x 15.11mm. This parametric analysis is shown in figure 5.

c) Feed Position

The position of feed place a major role interms of impedancing matching at the desired frequencies. Proper feed position can be obtained with the aid of parametric analysis on the position in both x and y directions. From the figure 6 it is observed that at (7.3, 0.5)mm the impedance matching is good and the other parameters like polarization is also better.

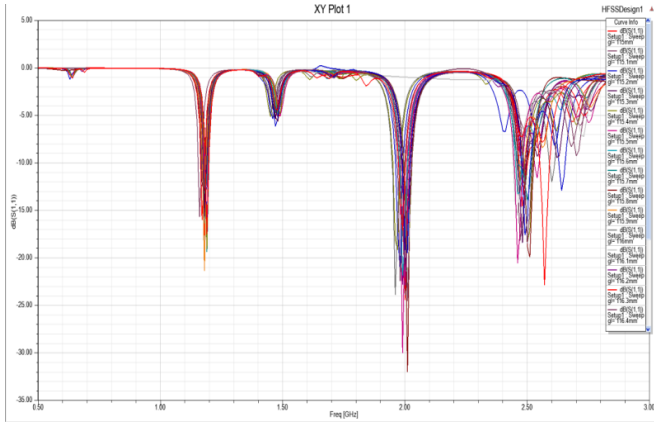


Figure 5: Parametric analysis for trimmed ground

d) Patch

Initially the scaling factor for the patch is 1. For this scaling factor the results are not in the acceptable range. So parametric analysis is done on the size of the antenna with scaling factor. On applying parametric analysis to the scaling factor for the patch, for 1.98 value the results are reasonably good as shown in the figure 7.

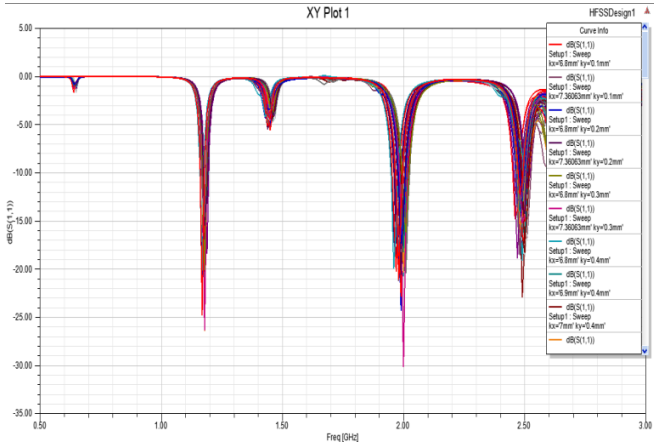


Figure 6: Parametric Analysis for Feed Position

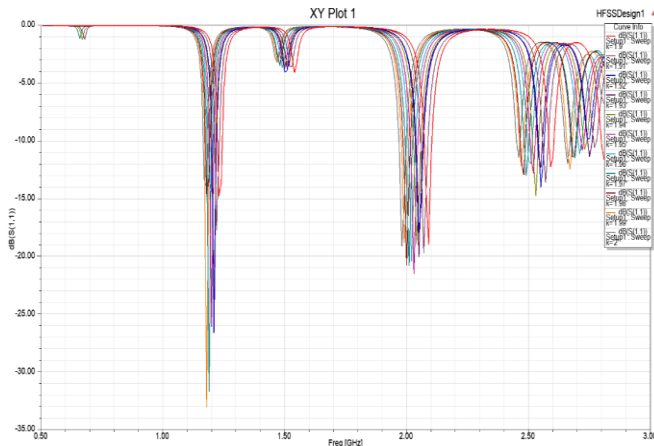


Figure 7: Parametric analysis for patch

After performing optimization on all the above mentioned parameters, the final dimensions of the proposed antenna Apollonian Gasket Fractal Antenna is given in Table 1.

Table 1: Dimensions of Apollonian Gasket Fractal Antenna

| Parameter | Dimensions (mm) |
|--|-----------------|
| Substrate | 132 x 132 |
| Ground Plane | 69 x 65 |
| Circle radius(0 th iteration) | 12 |
| Circle radius(1 st iteration) | 6.1 |
| Circle radius(2 nd iteration) | 3.19 |
| Trimmed portion in the Ground | 10.5 |

SIMULATION RESULTS

The return loss plot and all the other antenna parameters are presented below after the cost of optimization almost reaches zero.

i) Return Loss

Return loss is a measurement of the relative strength of the signal reflected by a transmission line because of impedance mismatch. Standing wave ratio (SWR) and reflection coefficient (Γ) both influence return loss. According to figure 8, a high return loss is preferred because it indicates how well the impedance matching is there between the source and load via transmission line. The antenna resonates at 1.176GHz and 2.492GHz with return loss of -13.62 dB and -15.53dB. Though the antenna resonates good at frequencies closer to 2 GHz and 2.5 GHz the polarization is not in the acceptable range and hence because of polarization mismatch those frequencies are not selected by the antenna.

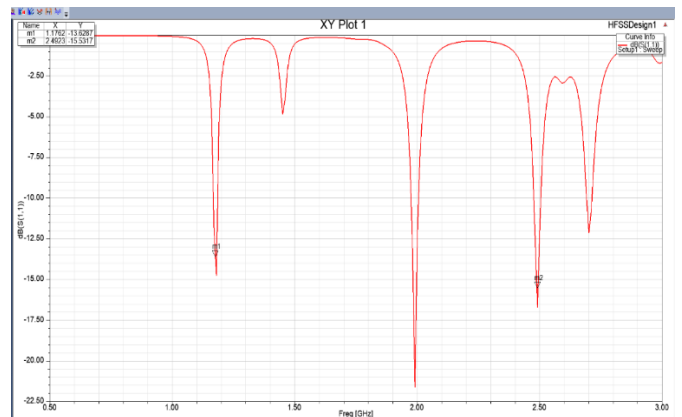


Figure 8: Return Loss Plot

ii) Axial Ratio

The ratio between the major and minor axes of a circularly polarized antenna pattern is known as the axial ratio (AR) of an antenna. This ratio would be 1 if an antenna had perfect circular polarization (0dB), but the ratio less than 3dB also

considered for circular polarization. The proposed antenna have the axial ratios for frequency 1.176GHz as 2.3dB and for frequency 2.492GHz as 3.9dB as shown in figure 9.

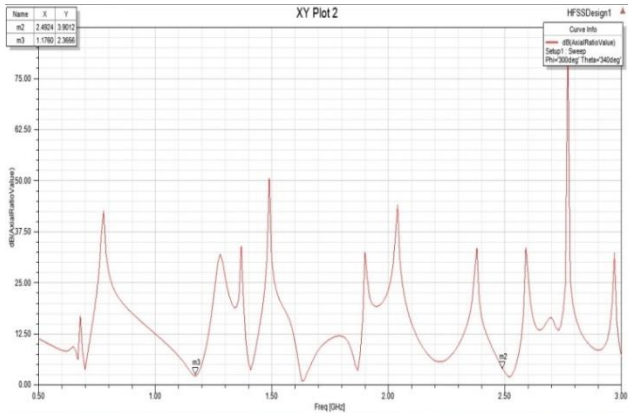


Figure 9: Axial Ratio Plot

iii) 3D Radition Pattern

The term "radiation pattern" in the field of antenna design refers to the strength of the radio waves coming from an antenna. Figure 10 depicts the 3D Radiation Pattern of the proposed antenna and it is observed from the plot that antenna radiation pattern is Omni directional.

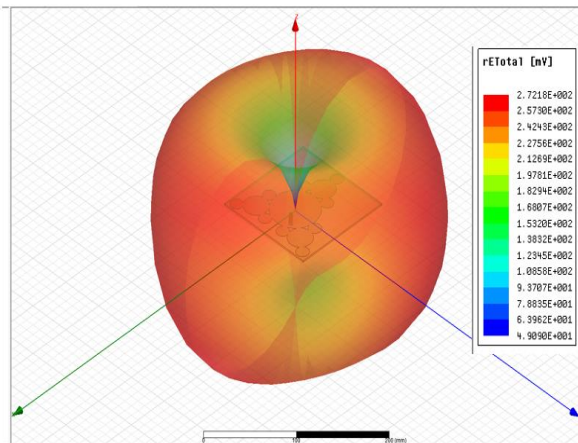


Figure 10: 3D Radition Pattern

iv) 2D Radition Pattern

Figure 11 and figure 12 depicts the proposed antenna's radiation patterns in the E and H planes at the resonance frequency respectively.

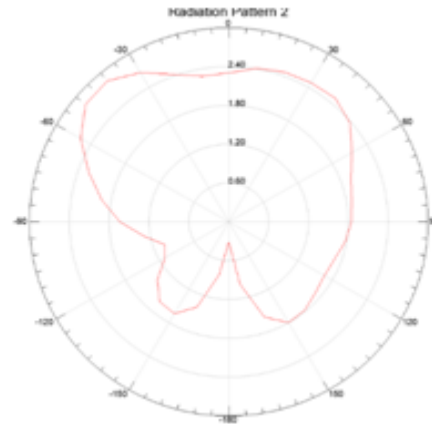


Figure 11: E-Plane Radiation Pattern

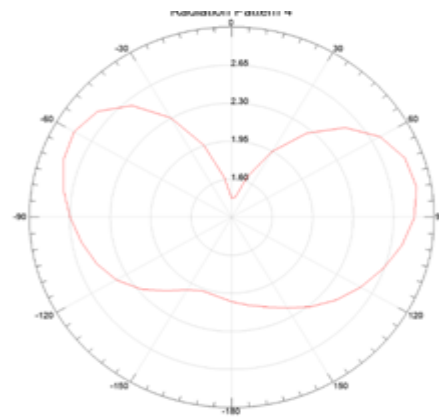


Figure 12: H-Plane Radiation Pattern

v) Voltage Standing Wave Ratio (VSWR)

VSWR is the ratio of maximum to minimum radio frequency voltage. The proposed antenna has a VSWR of 1.6 at 1.176GHz and 1.4 at 2.492GHz as shown in figure 13.

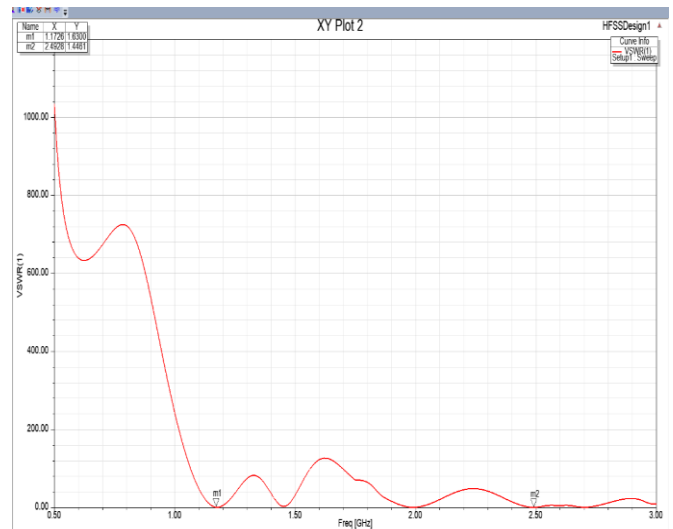


Figure 13: VSWR

Gain

As shown in figure14. the gain values at the frequency 1.176GHz is -12.6dB and at frequency 2.492GHz is -4.9dB. This is the disadvantage with the proposed antenna but it can be improved using gain enhancement techniques like metamaterial structures, superstrates, shorting pins and reflectors etc.

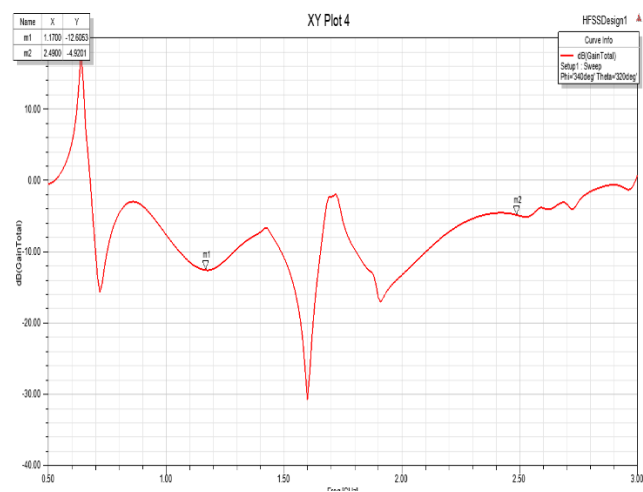


Figure 14: Gain Vs Frequency

Table II: Comparison of antenna parameters

| Antenna Structure | Antenna Size(mm ³) | Resonating Frequencies(GHz) | Return Loss(dB) | Axial Ratio(dB) |
|-------------------|--------------------------------|-----------------------------|-----------------|-----------------|
| [18] | 100 x 100 x 9.5 | 1.176, 2.492 | -13.1, -14.2 | < 2 |
| [19] | 150 x 150 x 2.3 | 1.176, 2.492 | -27,-20 | < 2 |
| [Proposed] | 132 x 132 x 1.6 | 1.176, 2.492 | -13.62,-15.53 | 2.3, 3.9 |

Table II shows the comparison of key antenna parameters among this work and previously reported ones. From the table it is observed that the proposed antenna size is small especially in terms of thickness of the antenna and the other parameters are in acceptable range.

CONCLUSION

A compact circularly polarized fractal-based antenna for satellite applications is designed and simulated using HFSS software. The constructed antenna is small and have achieved good impedance matching, radiation pattern, return loss and axial ratio. The simulated results show that the antenna radiates in the L-Band and S-Band. All parameters are almost within the required satisfactory range. However, the gain needs to be enhanced. Therefore, the designed

circularly polarized fractal-based antenna is effective and efficient to work in satellite based navigation applications.

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