Original Article

Design and Simulation of Compact Dual Band Fractal Antenna for Navigation Applications

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Abstract

For navigation applications, a dual band fractal shaped microstrip patch antenna is developed and simulated. By employing fractal shape, dual-band features are produced. The proposed antenna operates at L5 (1.176GHz) and S(2.492GHz) bands. With the aid of the HFSS EM-tool, the proposed antenna is simulated. Low-cost FR4 epoxy serves as the substrate material for the suggested antenna. The circularly polarised, fractal-shaped micro-strip patch antenna is fed using a coaxial cable. Various other properties like return loss, VSWR, axial ratio, gain and radiation patterns are obtained and discussed.

Index Terms: Fractal Antenna, Sierpinski Shape, Navigation, Circularly Polarized Antenna, Return Loss.

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INTRODUCTION

Along with the Internet and mobile communications, Global Navigation Satellite Systems (GNSS) are emerging as major technological achievements in the contemporary world. The GNSS system offers a wide range of services, such as positioning, public safety, navigation, geographic surveys, time standards, surveillance, weather, mapping, and atmospheric data.

Indian Regional Navigation Satellite System (IRNSS) is the new entrant in the domain of space based positioning and navigational systems. Recently, IRNSS was renamed as NAVIC (NAVigation with Indian Constellation) [1]-[2]. Seven satellites make up the IRNSS constellation, with three in GEO orbit and four in Geo Synchronous orbit. Over India and a region that surrounds the country by about 1500 kilometres, the IRNSS System is anticipated to give accuracy better than 20 metres.

The IRNSS system uses the L5 (1.176 GHz) and S (2.492 GHz) frequency bands. On each of these frequencies, two services are provided: Standard Positioning Services (SPS) for civilian users and Restricted Services (RS) for certain users only. The IRNSS receiver's antenna is the first component to pick up signals coming from satellites in various orbital slots. A multiband antenna is recommended in order to receive two frequencies at the receiver end.

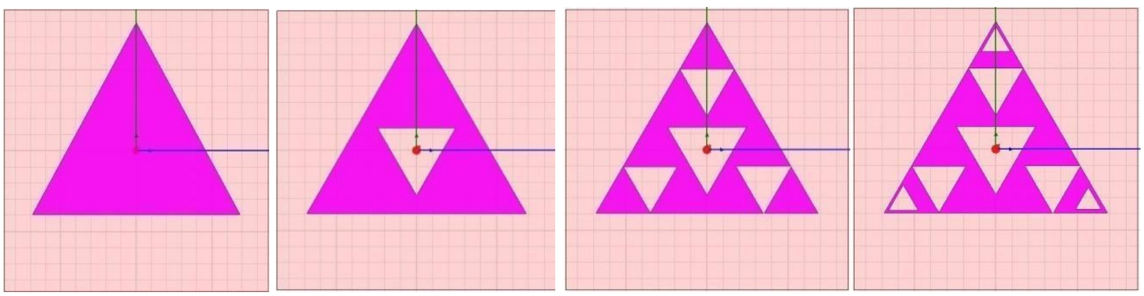
Various techniques are available in the literature to incorporate multiband behavior in antennas like use of parasitic elements, fractal shapes, applying various feeding techniques, using slots in the patch, metamaterials, stacked configuration of patches and defected ground structure concepts [3].

Out of all of these methods, fractal structure is the one used in this work to extract the multiband functionality from the antenna. Fractal shape is used in a wide range of fields, including biology, computer science, medicine, and the arts. Fractal geometries are helpful when developing compact, multi-frequency antennas. It has been found that numerous fractal geometries, including the Sierpinski gasket,Minkowski, Koch, Hilbert, and apollonian carpet, are useful in creating novel antenna designs [4]-[5]. The self-similarity property of the fractal shape is advantageous when designing multi-band antennas. In order to create the Sierpenski triangular fractal patch antenna, several iterations are doneon the basic triangular patch [6].

RELATED WORKS

A GPS application-specific single feed circularly polarised microstrip slot antenna has been created and it resonates in the L1 GPS band at 1.575 GHz[7]. A spiral antenna array with a frequency of 1.175GHz employing RT Duroid substrate is presented [8]. Above mentioned two antennas operates at single frequency. However if the IRNSS receiver employs an antenna that operates at both L5 and S bands then the errors due to the ionosphere can be eliminated using the frequency diversity of the two signals.

Two layer stacked, dual band, Right-handed circularly polarised, micro-strip antenna for IRNSS receiver is developed. The antenna operates at L5 band (1.176 GHz) and S band (2.492 GHz) frequencies [9]. A coaxially fed E-shaped patch antenna with high gain is presented. The antenna's substrate FR4 which has a dielectric constant of 4.4 is used. The second substrate is air and its dielectric constant is 1. 100 mm x 100 mm x 6 mm is the size of the substrate[10]. ADS software is used to create a triangular fractal patch antenna with a slot for IRNSS application. Due to the self similarity property of fractal shape, this antenna resonates at the L5 (1175 MHz), L1 (1575.42 MHz), and S (2492.08 MHz) bands[11]. Although these antennas operate at a variety of frequencies, the thickness of these antennas is larger.



(a) 0th iteration (b) 1st iteration (c) 2nd iteration (d) 3rd iteration

Fig 1: Iteration Process

So in this paper a compact multi band fractal shaped antenna is proposed for IRNSS receiver. The antenna thickness is small comparatively, and it is capable of receiving the signals from IRNSS satellites at both L5 (1.176 GHz) band and S (2.492 GHz) bands. This proposed antenna is designed and simulated using Ansys HFSS Software.

ANTENNA DESIGN

In order to minimize the impact of the ionosphere on the IRNSS signals, dual-band antennas are preferred. The dispersive properties of the ionosphere cause a frequency-dependent phase shift (group delay) that is the main impact of the ionosphere on IRNSS signals. By using a dual band antenna, this negative effect is reduced. Fractal geometry offers the solution by most effectively designing multiband antennas.

Numerous fractal geometrical patterns have been discovered to be beneficial in the development of multiband antennas. Serpinski gasket is one of the fractal geometrical structures.

By Utilizing the formula, the side length of the equilateral triangle is determined [12].

$$f_r = \frac{2c}{3b\sqrt{s_r}}$$

Where c represents velocity of light f_r is the resonant frequency.

s_r is the substrate's dielectric constant.

A basic equilateral triangular patch with a side of 81.07mm is initially created. The design equation is used to compute the side of the triangle antenna. By removing the central triangle whose vertices are situated at the midpoints of the sides of the equilateral triangle patch, fractal geometry is incorporated into the equilateral triangular patch. Repeat the process for the remaining triangles. Totally three iterations has been done to achieve the required multiband frequencies as shown in figure 1.

The substrate material is made of FR4 epoxy, which has a loss tangent of 0.02 and a dielectric constant of 4.4. The overall size of the substrate is 87.22mm x 87.22mm x 0.8mm. The ground plane is trimmed at the corners as shown in the figure 2, to achieve circular polarization. The patch is fed with 50ohm coaxial cable. In order to match the antenna's impedance, the feed point's location is crucial.

Later in order to achieve the desired operating frequencies and proper circular polarization optimization has been done by varying key geometric parameters like.

a) The dimensions of the ground with truncated corners.
b) Feed position.
c) The dimensions of the patch at different levels of iterations.

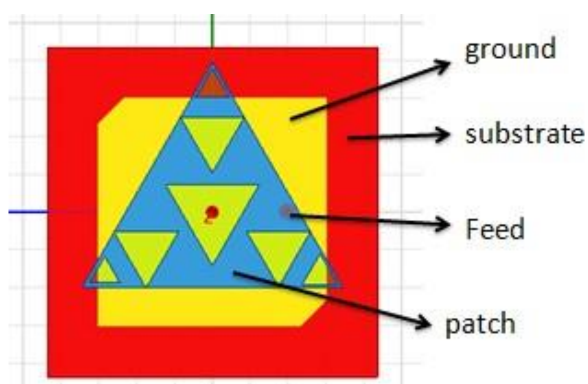


Fig 2: Proposed Antenna with Truncated Ground

The final size of the antenna after optimization is obtained by using HFSS software and the optimized dimensions are consolidated in table I.

Table I: Optimized antenna dimensions

Parameter	Value (mm)
Substrate (L x W)	87 x 87
Substrate thickness (t)	0.8
Side Length of triangle(0^{th} iteration)	68.6
Side Length of triangle(1^{st} iteration)	24.8
Side Length of triangle(2^{nd} iteration)	17.4
Side Length of triangle(3^{rd} iteration)	9.3
Ground Plane	61 x 61
Truncated corners in Ground	12.06

Simulation Results

A. Return Loss

S11 is the return loss, which is a measure of the difference between forward and reflected power in an RF system. The S11 parameter indicates how much power is reflected from the antenna. Figure 3shows the findings for the return loss of proposed sierpinski triangular fractal antenna. It demonstrates that the antenna resonates at frequencies of 1.176 GHz and 2.492 GHz, with corresponding return losses of -10.64dB and -12.71dB respectively.

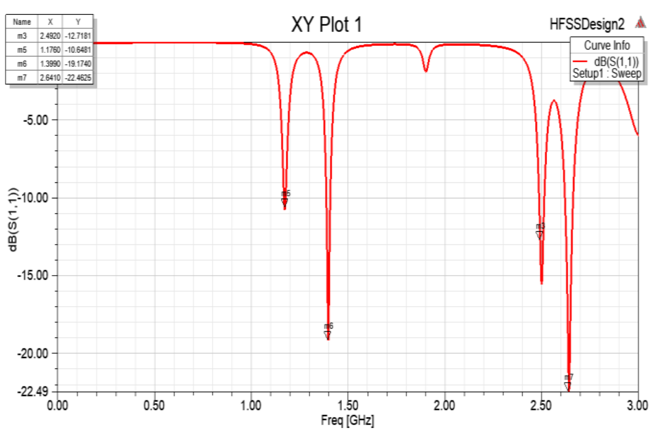


Fig 3: Frequency Vs Return Loss

B. VSWR

The voltage standing wave ratio (VSWR) is the ratio of maximum to minimum radiofrequency voltage. The proposed antenna has a VSWR of 1.96 at 1.176GHz and 1.64 at 2.492GHz. Tthe plot is shown in figure 4. So this parameter ensures maximum power transfer from a source, through a transmission line and then to antenna, because it is in the acceptable range from 1 to 2.

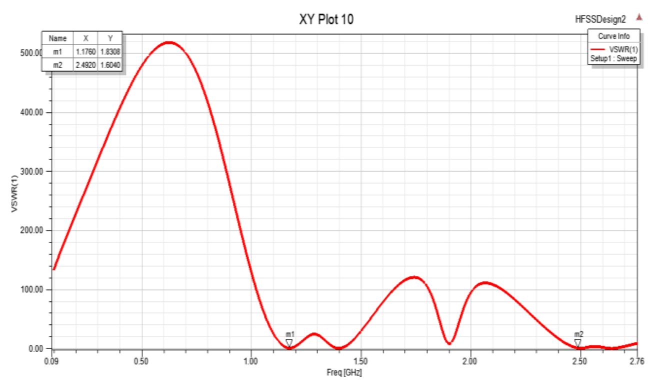


Fig 4: Frequency Vs VSWR

C. Axial Ratio

The axial ratio variation with frequency is depicted in Figure

5. The performance of a circularly polarised antenna is characterized by its Axial Ratio (AR). The ratio of orthogonal components of an E-field is referred to as AR. The proposed antenna has attained AR values below 3 dB in the L5 and S bands by precisely selecting the appropriate truncated corner dimensions in the ground plane. At 1.176GHz, the axial ratio is 2.13dB, and at 2.492GHz, it is 2.5dB. This guarantees the antenna's ability to provide circular polarisation, which is crucial for navigational purposes. It is also clear that even though the return loss is

-19.1dB and -22.4dB at other resonating frequencies i.e.1.39GHz and 2.64GHz the axial ratio is greater than 3dB so the antenna will not receive those frequencies because of polarization mismatch.

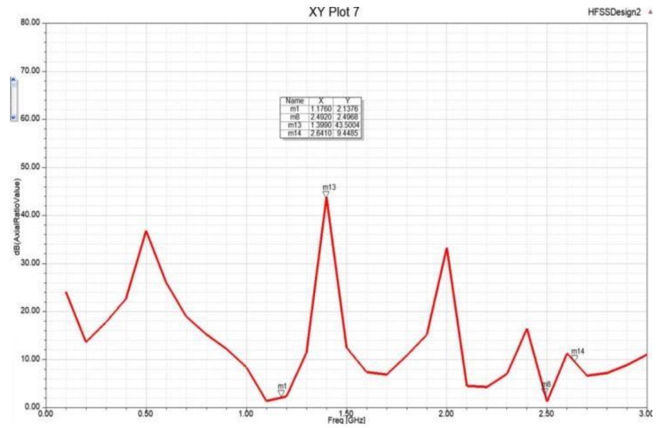


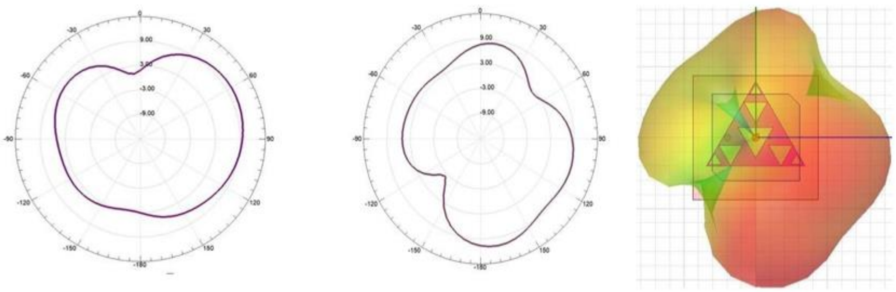
Fig 5: Frequency Vs Axial Ratio

D. Radiation Patterns

The E plane and H plane radiation patterns in 2D are shown in figure 6. Also the overall 3D radiation pattern from the antenna is given below in figure 6. The E plane pattern is simulated at φ=0^0 and H-Plane pattern at ϴ=90^0

From the simulation, gain of the proposed antenna is observed very less and it is not in the acceptable range. So this parameter can be improved by using gain enhancement techniques like metamaterial structures, superstrates, shorting pins and reflectors etc.

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.



(a) E-Plane (b) H-Plane (c) 3D Pattern

Fig 6: Radiation Patterns

Table II: Comparison of antenna parameters

Antenna Structure	Antenna Size(mm^3)	Resonating Frequencies(GHz)	Return Loss(dB)	Axial Ratio(dB)
[9]	100 x 100 x 9.5	1.176, 2.492	-13.1, -14.2	< 2
[13]	73 × 73 × 6.4	1.575,1.227	< -10	< 3
[14]	80 x 80 x 7.6	1.176, 2.492	-16.6, -20.1	-
[15]	150 x 150 x 2.3	1.176, 2.492	[1]-27,-20	< 2
[Proposed]	87.2 x 87.2 x 0.8	1.176, 2.492	-10.6, -12.7	< 3

Conclusion

In this work, a dual-band circularly polarised fractal antenna that resonates at 1.176GHz (L-Band) and 2.492GHz (S-Band) is presented. Key geometric parameters for the antenna were first calculated as initial values using a straightforward closed-form equation, and then further optimised using simulation tool. Important antenna properties such as return loss, VSWR, axial ratio, and radiation patterns are measured and confirmed to be within acceptable limits. The gain must be improved, though. The suggested design is a good option for IRNSS navigational applications.

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