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Design of Circular Fractal Antenna with Tunable Radiation Pattern for Multiband Frequencies

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Abstract

A fractal circularly polarized antenna with tunable radiation pattern is proposed, Three layered antenna structure with back to back patch supports omni- directionality, These antenna structures were fed at two points with 90º phase shift splitter to support circular polarization. The fractal structures were designed so to operate at multiple frequency bands (S, C, Ku). The change in phase of excitation between two parallel structures provide tunable radiation pattern. The results and performance were analyzed through simulations on ADS tool**.**

Keywords: - Fractal antenna, tunable antenna, circularly polarized antenna, microstrip antenna.

I. INTRODUCTION

Fractal structures support multiple current modes with different electrical lengths, Hence multiple wavelengths. This provides a very wide bandwidth of operation and different frequency support. Fractal design can be complex structured one with support for various electrical wavelengths or a design with repeated symmetrical structures.

A complex structures provide support for different wavelengths in a much compact structure. This reduces the antenna size and makes it much applicable for mobile applications and integrating to surfaces of automobiles. The mathematical analysis of these structures is highly complex.

A symmetric fractal structure consists of a geometrical structure repeated multiple times within itself or interconnected. Different lengths of these structures provide support for different frequencies, Ratio of the lengths between the structure can approximate to the ratio of operating frequencies.

Circular polarization provides better performance for long distance transmissions such as satellite and tele-communications. This circular polarization can be achieved by different ways such as curved patch surfaces, linear polarized wave passed through a circular polarizer or by different feeding techniques. This design consists of feed provided at 90o phase shifts through a splitter to support circular polarization.

This structure consists of back to back patch surfaces fed through a probe supporting radiation in two planes to achieve omni-directionality, phase differences between the input feeds vary the radiation patterns of the beam, Hence by varying the input phase the beam direction can be controlled.

A circularly polarized omni-directional antenna structure with tunable radiation pattern is adopted from [1]. The antenna structure and design parameters from [1] were considered for further improvement in operating range. A fractal structure is proposed and the substrate is varied to observe antenna behavior. The fractal structure is designed such that antenna works in S, C, KU-bands.

II. ANTENNA DESIGN

A. Antenna Structure

This design consists of multiple symmetric structures with in main structure. The main structure consists of circular perimeter of diameter 35.4mm, the inner surfaces are etched in elliptical curves, which is muxed with similar structures with diameters of 12.8, 4.6 mm respectively.

The antenna consists of three conductive layers with two layers of substrate (FR4, permitivity 4.6, thickness 1.6mm each).Three layers of conductor include two fractal antenna patches, ground plane. Two SMA connectors are connected through opposite sides of the antenna by probe feeding.

The 6.8mm wide 50ohm microstrip square patch connect to quarter wavelength transformers (68 ohm impedance, 4mm wide, length 18.5mm) and then to 94mm microstrip sections (2mm wide). A microstrip power splitter connects to two 186ohm lines (0.2mm wide) connecting to the fractal structure at two different points with 90o phase difference.

The ground plane is smaller than the substrate. To provide omni-directional circular polarization. The 1.6mm thickness of substrate provides better bandwidth of operation and isolation from the other conducting surface.The distance between any two adjacent similar elliptical curves is 0.2mm, the ratio of distance from centre to elliptical curve edges (Re1/Re2, Re2/Re3) is ~2.8, where Re1, Re2, Re3 are 16.7, 6.1, 2.2mm respectively.

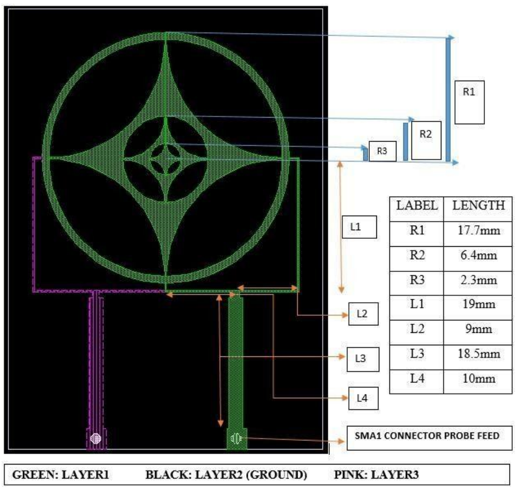

Fig1: Antenna structure

The antenna operation at a certain frequency with input feed phase difference between either ports show significant change in radiation pattern. With change in the phase between the feed applied at ports the beam is directed to different spatial directions.

Table I. Feed Phase Difference to Beam Shift

Phase at ports 1 and 2		Phase difference	Beam shift
Port 1	Port2		
0º	0º	0º	-----
0º	180º	180º	+30º
180º	0º	180º	-30º
90º	270º	180º	+30º
180º	180º	0º	0º

Fig1. Represents the antenna design, the parameters of design are equal in measurements on both sides of antenna (layer 1 and layer 3). In Fig1. The green layer represents the layer1 conducting surface, pink layer represents the layer3 conducting surface. Black layer is the ground conductor. Feed is connected through probe/coaxial feeding technique.

III. ANTENNA OPERATION

The designed antenna works at multiple frequency ranges as it has multiple resonance points supporting multiple wavelengths. The fractal structure with outer circle is designed to operate at 2.4ghz the other fractal structures were designed with scaled dimensions of original structure. The elliptical slots with in the structure provide support for the radiation. This scaled variation in the slots is proportional to the operational frequencies.The Radius of outer circler patch can be obtained by

$$F = \frac{8.791 * 10^9}{fr\sqrt{\varepsilon r}} \tag{1}$$

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{\wedge}0.5} \tag{2}$$

$$ae = a\left\{1 + \frac{2h}{\pi \varepsilon r a}\left[\ln\left(\frac{\pi a}{2h}\right) + 1.7726\right]\right\}^{\wedge}0.5 \tag{3}$$

A. Mathematical Modelling

The mathematical structure for a fractal is very difficult task to derive, but an approximation with respect to the geometry of the structure can be done.The operating frequency for the outer circular antenna structure can be obtained by

$$fr = \frac{1.8412Vo}{2\pi ae\sqrt{\varepsilon r}} \tag{4}$$

The radius of the three circular structures within the antenna are 17.7(R1), 6.4(R2), 2.3mm(R3) respectively. Hence the wavelength supported by the structures will be in same ratio. The main frequencies of operation can thus be approximated by

$$\frac{f1}{f2} \sim \frac{lambda}{lambda} \sim \frac{R2}{R1} \tag{5}$$

The ratio approximates, The operating frequencies of fractal design to ~2.4, ~6.8, ~18.5 respectively. These frequencies can also be approximated using the ratio of lengths of the elliptical slots. The fractal structure supports many other wavelengths due to its complex structure and edges which supports the design to work at other frequencies.The elliptical curve lengths can be approximated with Re (Radius from centre to the outer edge of the elliptical curve). Re1, Re2, Re3 be the lengths from centre to three elliptical curve structures the curve lengths can be approximated as L~(πRe)/4. The ratio of the lengths L1, L2, L3 can be approximated to the ratio of their supporting frequencies.

$$L <\sim \frac{\pi Re}{4} \tag{6}$$

$$\frac{L1}{L2} <\sim \frac{f2}{f1} \tag{7}$$

$$f2 >\sim \left(\frac{L1}{L2}\right) f1 \tag{8}$$

The frequency approximations through this approach indicate operating points at >~5, >~12 GHz .

IV. SIMULATION AND MEASUREMENTS

The simulation and design of the antenna structure were performed in ADS tool, The simulation results of S11 and radiation pattern for different phase changes are plotted as below.

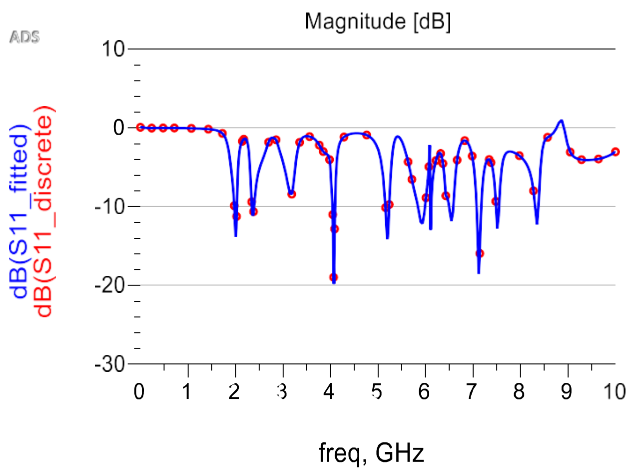

Fig 2. S11 vs Frequency(0-10 GHz)

The above plot shows the S11(reflection coefficient) of the design over the frequency range 0 to 10 GHz.

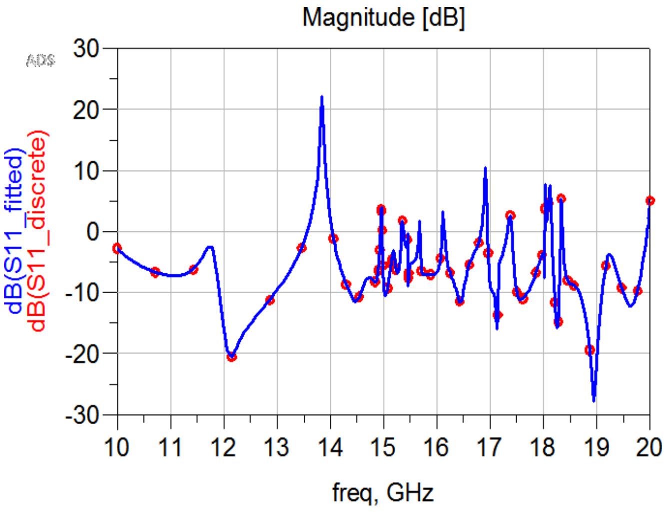

Fig 3. S11 vs Frequency(10-20 GHz)

The above plot shows the S11(reflection coefficient) of the design over the frequency range 10 to 20 GHz.The operating ranges from simulation results could be observed that the operating frequencies of antenna are at 2, 2.4, 4, 7, and 18, as estimated through mathematical calculations.

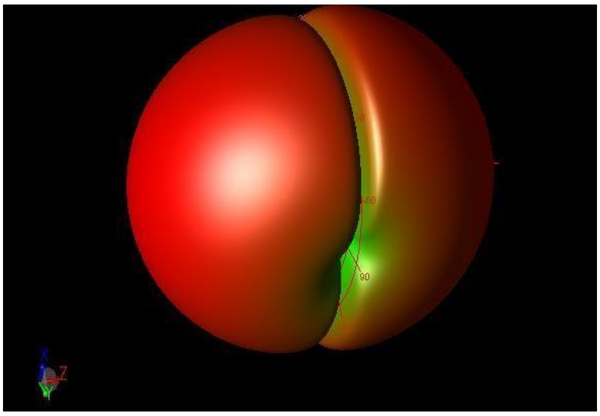

Fig 4. Radiation pattern with 0^0 phase difference between feed: no shift in beam pattern

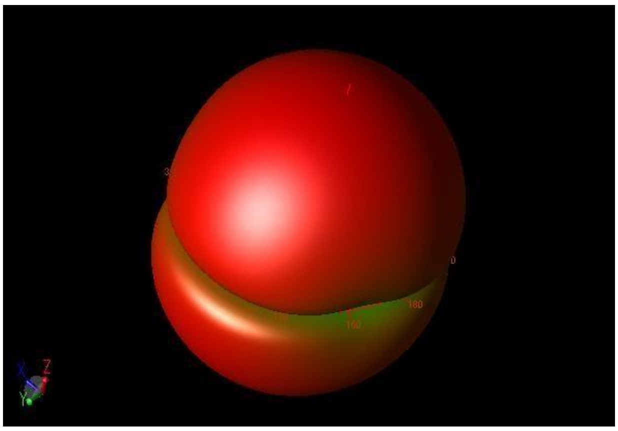

Fig 5. Radiation pattern with 180^0 phase difference: 60^0 shift

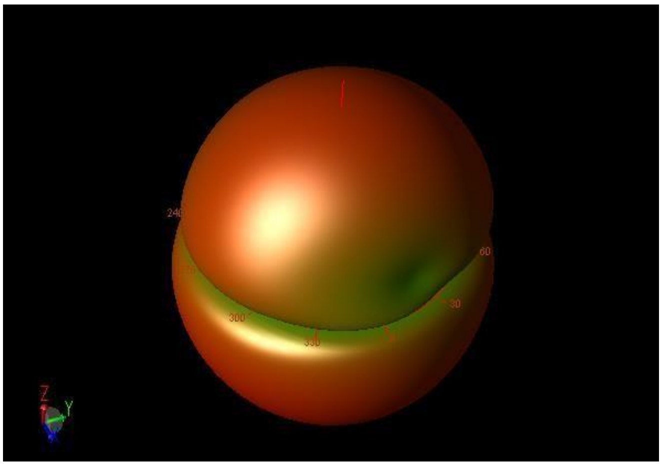

Fig 6. Radiation pattern with -180^0 phase difference: -60^0 shift

The above three radiation pattern show the shift in beam pattern with respect to the input phase variation, above. observations show the beam shift is between one half to one third of applied phase difference (Ph/2 < beam shift < Ph/3, Phase is applied phase difference).

V. CONCLUSION

The simulation and measurement were performed over ADS tool. the antenna characteristics were observed. Designed antenna works at multiple frequency ranges over S, C, Ku-Bands. This provides flexibility to operate in multiple application environment, (ISM, RADAR, LOWER SATELLITE COMMUNICATIONS).Further development of antenna requires wider bandwidth in ISM and other L, S-bands for cognitive and SDR applications.

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