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USE OF JERUSALEM FRACTAL SHAPESLOTS FOR DESIGNING OFDUAL BAND PROBE FED PATCH ANTENNA

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Abstract: *Fractal shapes are widely used in computing, analysis and design. Recent trends suggest positive outcomes of using fractal shapes in electromagnetics. In this paper, Jerusalem Cube fractal shape is introduced in conventional patch antenna for L1 band. A Dual Band antenna resonating at 1.41 GHz and 3.37 GHz, L and S Band respectively, is constructed using said fractal shape. Comparison of Return Loss and Gain is shown with conventional antenna.*

Keywords*: Fractal Antenna, Jerusalem Cube Fractal, Patch Antenna, Probe Fed Patch Antenna.*

I. INTRODUCTION

Increasing users and expansion of reach has made field of mobile communication extremely attractive to researchers these days. One of the ways to provide suitable answer to the increasing demands of this field is to create antennas with wider bandwidths, higher gains and smaller sizes. Due to incorporation of such properties in present antenna designs, antennas have gone far from their basic definition of “a metallic device for radiating or receiving radio waves”.

One promising type of antennas to answer most needs of present wireless industry is printed antennas or patch antennas [1]-[2]. These antennas are widely used in mobile handsets, base stations and satellite communications. They are easy to design, easy to fabricate, low profile and less space consuming. In its simple most structure, patch antennas are merely a combination of a ground plane, a radiating patch and a separating substrate. The whole design is fed either by a co-ax probe or my Microstrip line. However, lots of various designs have been proposed in the literature to provide multiband or wide band solutions. Use of slots [5]-[6], dual feeding [3] and multiple substrates [4] are commonly seen around researches of past few years.

A novel technique to create patch antennas with better properties is to use fractal shapes in design [9]-[12]. Fractals are shapes which repeat themselves at different scales defined by iterations. These are space filling structure and mathematically infinite in nature. Every part of the fractal geometry is a reduced or enlarged version of the whole. Hence, they are called self-similar structures. The term Fractal was first coined by Benoit Mandelbrot in 1975 based on the Latin word “fractus” which means uneven or broken. Fractal geometries are complex and cannot be defined easily using Euclidian geometrics. Creation of fractal shape out of a given design may take modifying, adding or removing a part of it and then repeat the same exercise at every scale [7]-[8].

Due to their self-similarity and space-feeling properties, fractal shapes can be utilized in preparing wideband and multiband antennas with better properties and smaller sizes. Variety of researches using fractal shapes in monopole, dipole and patch antennas are noted using Sierpinski gasket [10], Koch curve [12], tree-fractal [11], swastika shape [9] and many others. This particular paper throws light on use of design pattern of Jerusalem Cube fractal as slots in a probe fed patch antenna.

II. DESIGN OF ANTENNA

2.1. The Jerusalem Cube Fractal

The Jerusalem Cube is a simpler design compared to many other fractals. In its basic concept, it is made on a square or a rectangle by making 9 equal parts of it. From the nine such parts, a regular cross (the ‘+’ sign) is cut out of the center square. Thus made design is repeated with a one third scale at the rest of the eight parts. The exercise can be repeated to numbers of levels. Fig. 1 shows the Jerusalem Fractal up to three levels.

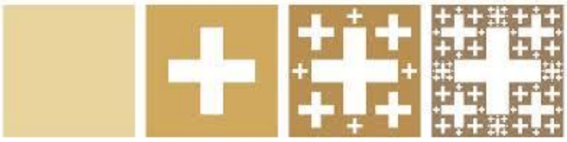


Fig.1. Jerusalem Fractal up to three levels

The fractals are easier to understand visually compared to mathematical expressions. However, modelling of such shapes get more complex by each level. In this study, we have shown effect of using the core shape of this fractal, the '+' sign as slots in patch antenna as shown below.

2.2. Antenna Design

The frequency under consideration is (L1 Band) 1.57 GHz, around the standard GPS band. The substrate used in modeling the antenna is Rogers RT / Duroid 5880 from HFSS library. It carries dielectric constant (εr) is 2.2. The height of the antenna substrate (h) is 1.56 mm. The length of the edge of the square patch L = 59.1 mm as per conventional calculations based on the GPS frequency under consideration. The length of the edge of square ground plane L_G = 78 mm.

For designing the patch step by step with Jerusalem fractal, antenna modeling software Ansoft HFSS version 13.0 is used. Co-axial cable feeding is used to excite the patch for radiating. A conventional patch for L1 band with above mentioned dimensions was made. The location of co-ax feed was optimized for impedance matching and was found to be fx= 15 mm. Fig. 2 shows the antenna schematic.

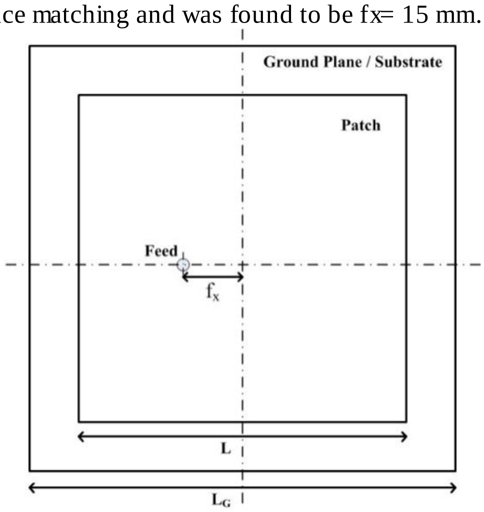


Fig.2. Conventional Patch Antenna

The slots of the shape of cross in Jerusalem fractal were removed from each center of edges on conventional patch. Fig.3 shows the schematic.

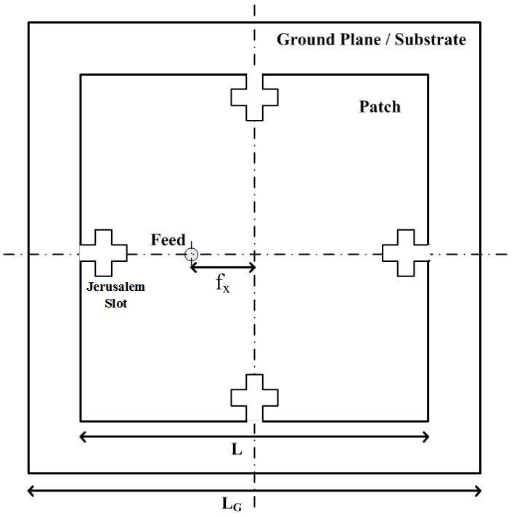
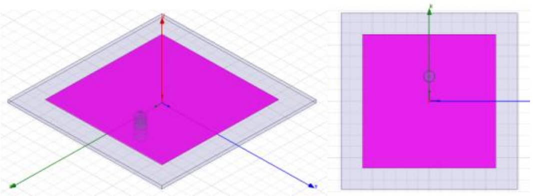
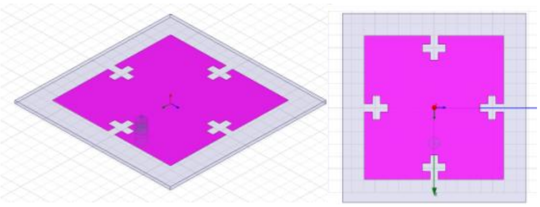


Fig.3. Jerusalem Slots on Patch Antenna

The size of the slot cut from the patch are in square of 10 mm x 10 mm. Width of the a single side of the cross is 3.33 mm. The feed location was retuned to 14.6 mm in order to achieve maximum power transfer. The antennas thus made in the design software HFSS 13.0 are shown in Fig.4 below.



Conventional Antenna



Antenna with Jerusalem Slots

Fig.4. Simulation Models of Conventional Antenna and Antenna with Jerusalem Slots

III. RESULTS AND DISCUSSION

Return loss and Gain results are extracted for comparing conventional as well as Jerusalem fractal implemented in patch antenna. Fig. 5 shows the comparison in the Return Loss plot. Plots ofboth the antennas are shown with different shade for better representation of comparison.

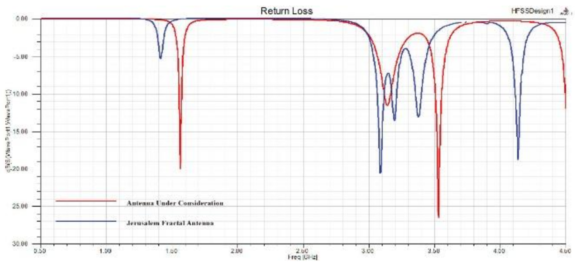
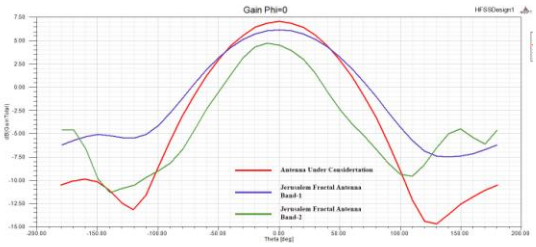


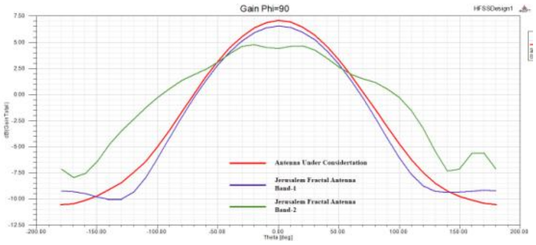
Fig.5. Comparison of Return Loss plots of both conventional antenna and Antenna with Jerusalem Slots

The Return Loss plot clearly shows shift in resonant frequency. This enables further reduction in size of patch in order to keep the resonant frequency constant. Also, creation of three various bands in s band regime is noted. The study of Gain plot clarified that only one band out of three emerging at S band gives positive gain value. Hence, the antenna tested here resonates at 1.41 GHz (L Band) and 3.37 GHz (S Band) compared to single band of 1.57 GHz (L1 Band) of the conventional antenna.

The gain plot is shown below in Fig. 6 for Phi = 0 and Phi = 90 for both the resonating bands. The antenna proposed here shows promising gain for both the resonant frequencies. For 1.41 GHz, the gain is 6.42 dB while for 3.37 GHz it is 4.31 dB. Compared to Gain of the conventional antenna of 7 dB, a slight decrease in Gain is noted due to insertion of slots.



Gain in dB at Phi = 0



Gain in dB at Phi = 90

Fig.6. Comparative Analysis of Gain of Conventional Antenna with both bands of Antenna with Jerusalem slots

The Findings of Return Loss and Gain compared to conventional antenna of L1 band (1.575 GHz) is shown in Table 1.

Table 1: Comparison of Results of Antenna with Jerusalem Slots

Antenna Type	Results	
	Return Loss (dB)	**Total Gain (dB)**
Conventional antenna	-20.00	7.35
Jerusalem Slot Antenna Band 1	-5.41	6.42
Jerusalem Slot Antenna Band 2	-13.15	4.31

IV. CONCLUSIONS

The research shows positive effects of using fractal shapes in Microstrip Patch antennas. The research can conclude the following observations:

I. Antenna for L1 band was converted into a Dual band antenna resonating at L and S bands using Jerusalem fractal as slots in patch.

II. Return Loss value at the first resonating band was suffering was poor. However, the second resonating frequency was delivering a better Return Loss value.

III. The Gain values were satisfactorily well and endorsees the fact of the antenna being dual band with better characteristics.

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