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Double Band RFID Reader Antenna Deploying Fractal Geometry

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ABSTRACT
A double band RFID reader antenna has been proposed and it can be used for 2.5GHz and 5.5GHz frequencies. In RFID reader, the respective frequencies are used for Automatic Vehicle Identification and Inventorymanagement applications. The concept of the fractal can be applied in design and analysis. A comparison of the return loss (S_{11})parameter is made between measured and simulated data from both transient domain solver and frequency domain solver.

***Index Terms*—Fractal antenna, Dual-band, RFID reader, CPW-Fed**

I. INTRODUCTION

In recent wireless communication, miniaturized antenna has become a necessity for many applications such as radar, microwave and space communication. As a crucial and integrated part of the RFID system, the designing of antennas with small physical size and multiband behavior continues to be a challenge, even with the tremendous impetus over the past decade [1,2]. The fractal structure contributes the improvement of performance by achievingsize reduction and multiband behavior in RFID antenna. The effect of fractal structure is related to a conventional antenna structure that optimizes the shape and size of the antenna, increasing its electrical length, thereby reduction in its entire antenna dimension. This effect is possible because of two important properties of fractal: the properties of space filling and self-similarity. The self-similarity property accounts for the multiband behavior of the antenna and the space-filling property for reducing the dimensions of the structure. [3]. The RFID products operated at different frequencies for different applications and performance requirement in specific geographical regions. When selecting a RFID reader, the general performance characteristics, physical dimensions, resonating frequency and the regulatory requirements associated for region of operationis initially considered.

In this paper, a simple model employed with fractal structure achieves volume reductionin the radiating patch and multi-frequency operation isobtained. An experimental investigation on broad banding the bandwidth impedance of a vertically stacked symmetrical triangular patch antenna with an edge feed. The CPW-Feed is chosen because it has the advantage of occupying less metalized area on the substrate than other existing patch triangular configurations [4].

The following section outlines the proposed design of fractal structured with CPW fed dual band monopole patch antenna. Session III discussed about the numerical and experimental results. The conclusions are concise in the IV session.

II. CPW FED MOOPOLE PATCH ANTENNA GEOMETRY

a. OPERATING PRINCIPLE

The entire dimension of the proposed antenna is 60 mm x 80 mm. Two equilateral triangular shape patches and rectangular ground plane geometries were simulated to optimize the antenna performance and coplanar grounds.The fractal antenna is fabricatedwith the thickness of 1.6 mm FR4 substrate (εr=4.5, $\tan\delta$=0.025).It is fed by a 50Ω SMA connector which is used to feed the antenna at the CPW line. Figure (1) shows the proposed antenna dimension.

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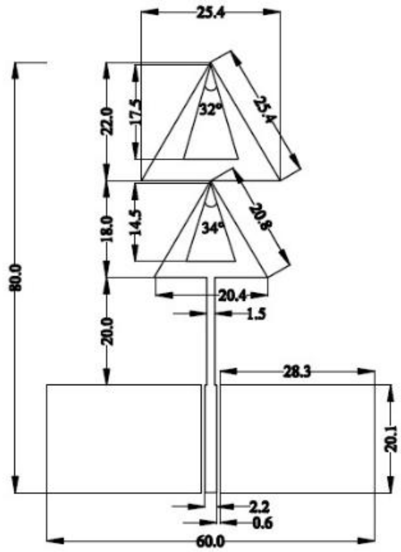
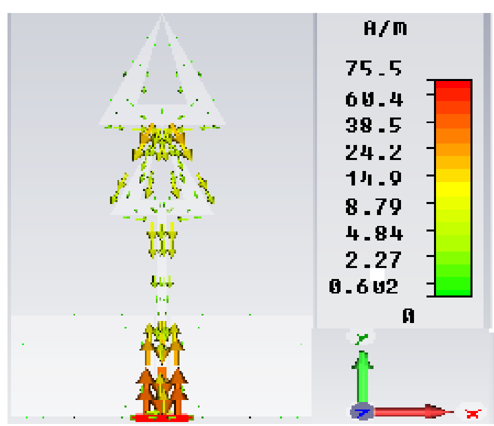


Figure 1: Proposed RFID Reader Antenna Dimension

A finite symmetrical ground planes are placed on both the sides of CPW feed line.A combination of triangular and rectangular ground achieves the dual-band characteristic. The upper resonance mode is determined by the CPW feed linelength, while the lower resonances are mainly due to the radiating patch. According to the length of the triangles, gap between the strip, width of the strip and length of ground planes, the bandwidth of the antenna can beoptimized. The wavelengths are 0.12m, and 0.055m respectively for the operating frequencies 2.5GHz, and 5.5GHz. From the survey, the maximum reading range is directly proportional to the wavelength [6].

b. ANTENNA PROTOTYPE

The primary aim is to design 2.5 GHz and 5.5 GHz as operating frequency for RFID reader applications. The fractal geometry reader antenna is simulated using the commercial software CST Microwave studio. In this design, FR- 4 is used as a substrate (thickness= 1.6mm, tanδ =0.025, ε_r= 4.3) with CPW feed.The following figure (1) shows the prototype geometry of dual band RFID reader antenna. Because of the triangular slots inside the equilateral triangles, a change in the current distribution was observed around triangular patch asthe effective length of the current pathway becomes large. Due to the implementation of fractal geometry, the area of the antenna is relatively minimized to 34% for 2.5GHz and 32% for 5.5GHz frequencies. The proposed antenna is simulated in transient domain solver and frequency domain solver, following which the results were compared.



(a)

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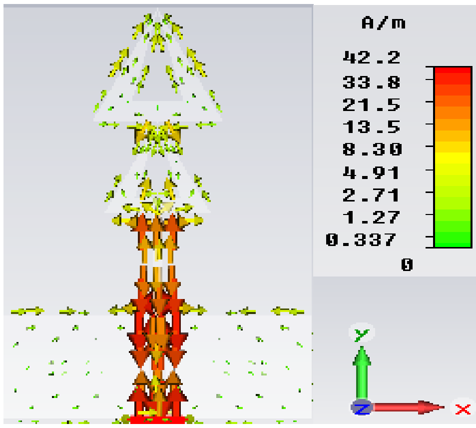
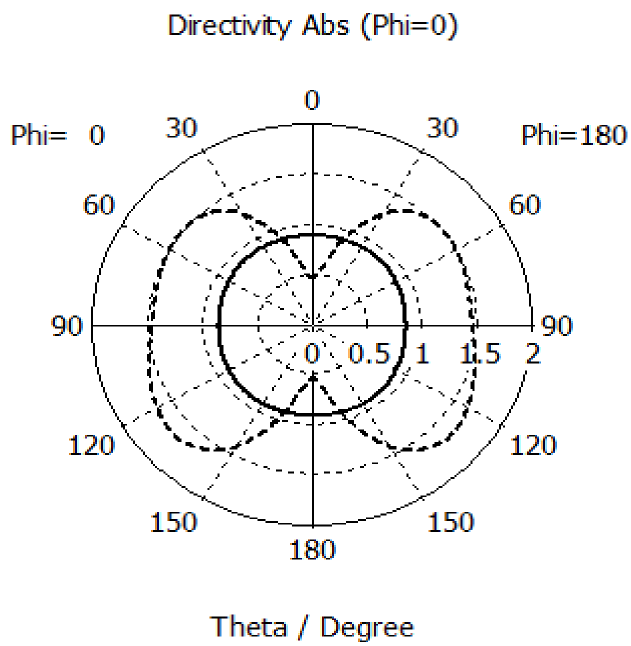


(b)

Figure 2 (a) & (b): Surface Current Distribution

The current distribution is illustrated in Figure 2 (a) & (b). the up and down arrows indicate the surface current distribution direction of the antenna. As estimated from the symmetrical nature of the patch structure, the current distribution is also symmetrically around the slots of the antenna. At *f*=5.5GHz the current around the corresponding bottom edges of the triangular slot is appreciably heavier than the other areas. From the figure 2 it can be observed that the surface current, strongly flows on the feed line and all around the slots. Due to triangular slot surface, currents are forced to travel around,thus resulting in longer current lines whileminiaturization in antenna size occurs due to the implementation of equilateral triangular patch fractal geometry. Therefore, it is evident that the resonances are controlled by the slots on the radiating element. The following figure 3 (a) and (b) shows the proposed antenna simulation results. The simulated results indicating the omni-directional far-field radiation pattern of the antenna, the doughnut shape proving to be extremely suitable for RFID Reader applications. It is observed that the radiating pattern of the antenna at 5.5 GHz is the most favorable result for inventory management in manufacturing industries.



(a)

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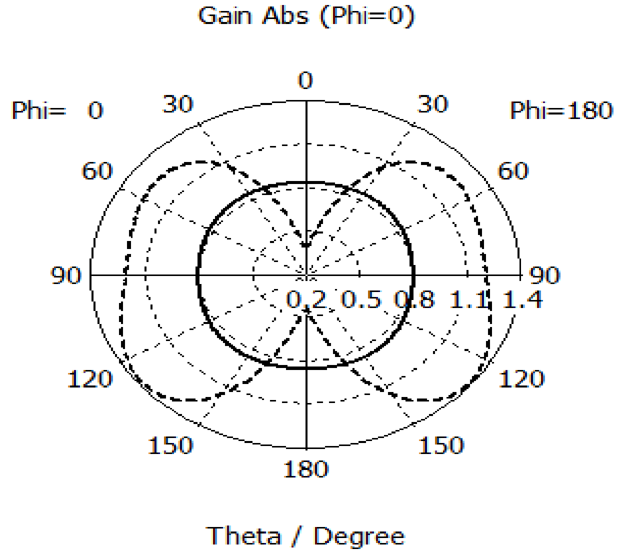

(b)

Figure 3 (a) and (b) Radiation Pattern for the Antenna at 2.5GHz and 5.5GHz.

III. RESULT AND DISCUSSION

a. SIMULATION RESULT

The simulation is carried out by the CST Microwave Studio transient solver and the frequency domain solver. The first reference frequency is 2.5GHz, the return loss curve shows S_{11} value obtained at -28.66dB,with respect to -10dB, as reference indicates 170MHz as bandwidth (2.46-2.6 GHz).For the second operating frequency at 5.5GHz, the corresponding S_{11}parameter occurs at -19.52dB with respect to -10dBas reference, is 830MHz as bandwidth (5.25-6.08 GHz). From the simulation it is also observed that the VSWR bandwidth is 160MHz at 2.5GHz and 900MHz at 5.5GHz of the reader antenna.Figure 4. Shows the results of measured and simulated return loss of the proposed antenna.

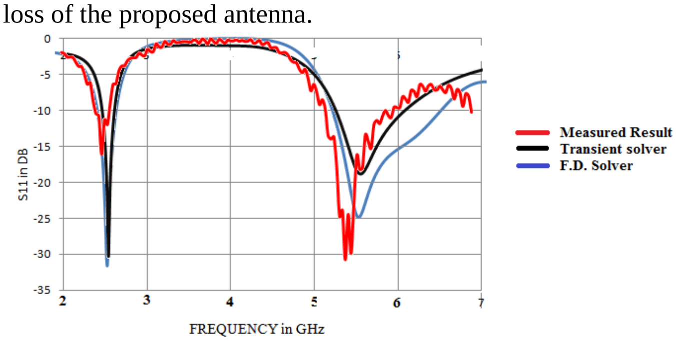

Figure 4 Simulated and Measured Results of Prototype

b. EXPERIMENTAL RESULTS

After completing of the simulation, it was determined that the results were satisfactory. Following which, the reader antenna was fabricated on a 60 mm x80 mmFR4 substrate.The practical antenna made by using SMA connectors, was soldered to the edge of the antenna. Using an Agilent N9917A VNAnetwork analyzer, the reflection coefficient of the composite antenna is measured as displayed in Figure 5. The discrepancy between the simulated and measured results may be due to the capricious association during measurements. In addition, matching is also observed around 2.5 GHz and 5.5 GHz to the resonances over the desired frequency bands, the typical measurement setup with prototype of an antenna is shown inFigure 6.

Figure 6: Measurement setup

c. CALCULATION OF READ RANGE

The RFID reader antenna require a uniform and strong field distribution over a specified range without any degradation in the performances. The field distribution is observed by the read range of an antenna. The range can be calculated from the antenna parameters like reader antenna gain, received and transmitted power and operating frequency. The Friis transmission equation helps to evaluate the read range with the received and transmitter powerP_r, P_T, andthe gain of receiver and transmitter antennaG_r, G_T,the read rangeR, the velocity of lightc, the wavelengthλ, and the frequency of operation f [7&8]. This antenna gives a maximum good read distance of 9.5 m for an input power of 13 dBm

Power Densitycalculated from

$$p = \frac{P_T}{4\pi R^2} \qquad (1)$$

Considering the transmit antenna gain G_t, then the power density is

$$p = \frac{P_T}{4\pi R^2} G_t \qquad (2)$$

then the received power becomes

$$P_R = \frac{P_T\, G_t\, G_r \lambda^2}{(4\pi R)^2} \qquad (3)$$

IV. CONCLUSION

The main property of the fractal antenna is to maintain small in size and obtain multi-band. This paper introduced RFID reader antenna with equilateral triangular patch. The antenna exhibits a 10 dB bandwidth of 170MHz at 2.5GHz and 830MHz at 5.5GHz. The proposed antenna can be achieved a wide operating bandwidth with good impedance matching. The maximum read range obtained by the reader antenna is 9.5 m. The size of the antenna is relatively minimized to 34% for 2.5GHz and 32% for 5.5GHz frequencies.

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