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A Fractal Circular Polarized RFID Tag Antenna

Research Article

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Abstract: In this paper, we present a novel fractal antenna for radiofrequency identification (RFID) tags. The proposed antenna has a resonant frequency equal to 2.45GHz and circular polarization. The fractal technique was very useful to obtain a miniaturization of antenna size by more than 30%. The gain and directivity of the antenna are acceptable for the desired RFID application. All the results are obtained using CST Microwave simulation tool.

Keywords: Fractal antenna • Circular polarization • RFID tag

1. Introduction

In recent years, applications of radiofrequency identification (RFID) operating in the microwave frequency range have increased exponentially as it presents several advantages such as small label size, long-distance readability, and high data transfer rates. When commercial linear polarization (LP) is targeted to the person or object attached with an RFID tag with wrong orientation relative to the expected reader antenna polarization, a range of reading disturbances can occur because of polarization mismatch between the two antennas of the reader and the tag. So, in the case in which the RFID drive system uses an antenna with LP, the proposed solution to the polarization conflict problem is to use an antenna with circular polarization (CP). Much research has been conducted on the design of micro-strip antennas with CP radiation, and they are generally applied in 50 Ω wireless communication systems [?]. However, the RFID tag is usually designed with low resistance and high capacity. To achieve maximum power transmission, the input impedance (with inductive reactance) of the marker antenna must be adapted to the smart tag [2]. At present, very few RFID designs for UHF tags with characteristics of CP have been proposed [?]. In fact, recent research models of RFID tags that promise the possibility to be placed on the metal surfaces are generally linearly polarized [10, 11]. In this paper, a tag-shaped cross fractal slot antenna with CP radiation is presented. The benefits include low profile and compactness, and input impedance with the micro-strip feed line coupling, so that the problems of impedance matching can be avoided. The slot antennas are used in several applications, including monitoring, despite the narrow beam. Optimization of the slot length for a slot antenna in a single broad wall rectangular waveguide has been characterized in [?]. Improvement of the bandwidth and the impedance model is obtained by changing the conductivity and strength of the connection or by adding a coupling element [4], which is the case in this work. This paper is organized as follows: Section 2 describes a circular polarized antenna; Section 3 presents the application of a fractal technique for antenna miniaturization; Section 4

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presents the conclusions.

2. A circular polarized antenna

2.1. The proposed geometry

The structure and dimensions of the antenna are illustrated in Fig. 1 1. The proposed antenna has a transverse simple slot, and is supplied from the micro-strip line coupling of the slot line. It is a patch antenna mounted on a metallic surface. The radiation patch has dimensions of W x L (W=64 mm, L=64 mm) and is printed on a Roger 4003 substrate (ϵ r=3.55; tangδ=0.0027) with a thickness of h (h=1.6 mm).

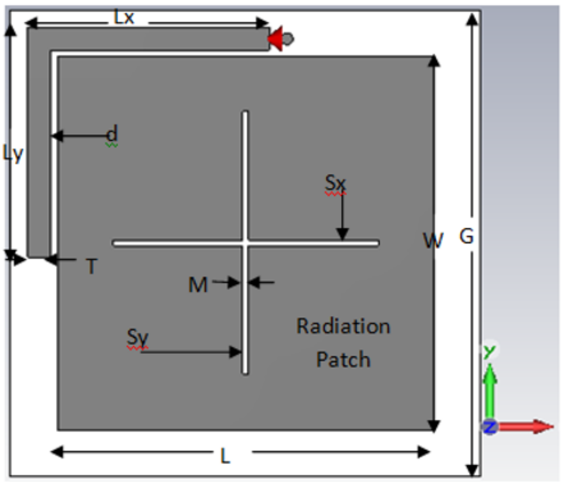

Figure 1. The proposed Circular polarization antenna.

In order to validate our work, we built an electrical model of the proposed antenna. The results can then be compared to result of electrical model. First, we have used the model used in our previous works. The circuit model is based on the cavity model with input impedance Z_{in}:

$$Z_{in} = \frac{R}{1+Q_T^2\left[\frac{f}{f_r}-\frac{f_r}{f}\right]^2} + X_L - \frac{RQ_T\left[\frac{f}{f_r}-\frac{f_r}{f}\right]}{1+Q_T^2\left[\frac{f}{f_r}-\frac{f_r}{f}\right]^2} \quad (1)$$

The Lumped model is developed according to following steps:

- The structure is divided into four cavities, and each cavity is replaced by an RLC model.
- The micro-strip line is replaced by an RLC model.
- The coupling between the line and the main antenna design is replaced by a coupling capacitance Cc.

All the model parameters are calculated from the geometry parameters of the structure and the characteristics of the substrate. The model is shown on Fig. 2.

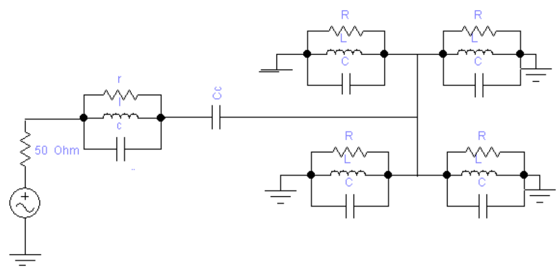

Figure 2. Electrical model of the proposed antenna.

2.2. Simulation Results

For parameter optimization and impedance matching, commercial EM software, CST Microwave 11, which is based on finite element method (FEM), was used for antenna simulation. The antenna structure was modeled as shown in Fig. 1. The parameters Lx and Ly were set as variables for impedance tuning. In order to simulate the tag performance on metallic surface, the tag antenna was modeled on a 64x64 mm metal plate.

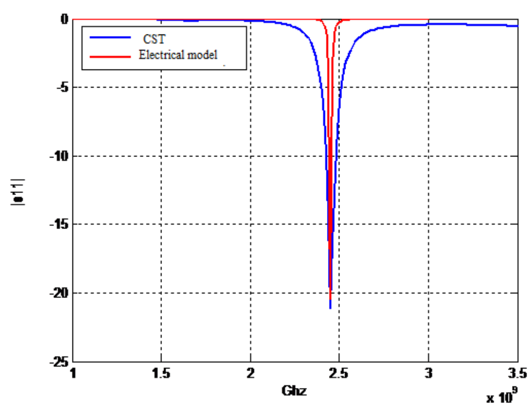

Figure 3. The reflection coefficient S11 of the antenna with optimized parameters.

Fig. 3 presents the measured return losses when concurrently tuning the horizontal and vertical-section lengths (Lx and Ly) of the open-ended micro-strip line. The results are compared to the electrical model and, as can be seen, the same resonant frequency with small differences

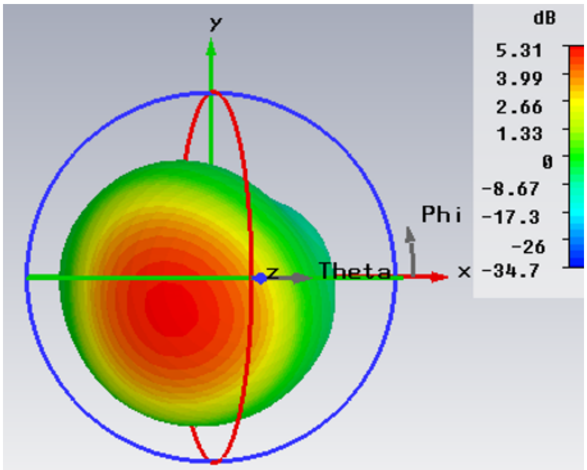

Figure 4. The simulated 3D radiation pattern of the patch antenna proposed.

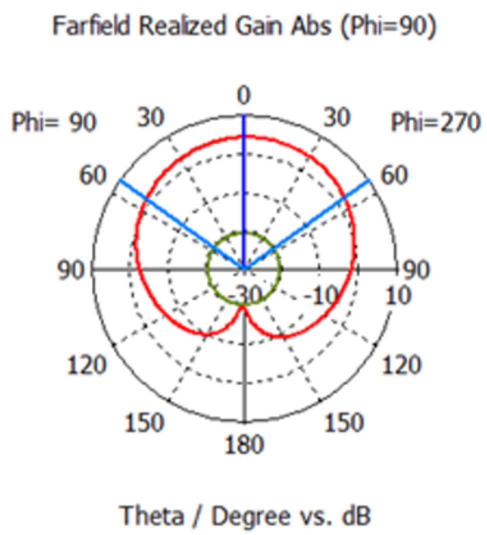

Figure 5. Simulated far-field radiation patterns at 2.45 GHz for proposed antenna.

in bandwidth is obtained. Various combinations of Lx and Ly, with a fixed total length of 47 mm, were used in this study. It was found that as long as Lx+Ly is equivalent to 47 mm (Lx of 15 mm and Ly of 32mm were most often used) good impedance matching can be achieved in this range of interest. At the same time, the tuning of both parameters will affect the CP performances of the proposed tag antenna. However, since both radiation fields are orthogonal to each other, their optimized Sx and Sy lengths are similar. Hence, the effects on the amplitude and phase variation of the two orthogonal radiation fields by tuning Sx only (with Sy as a fixed value) were studied.

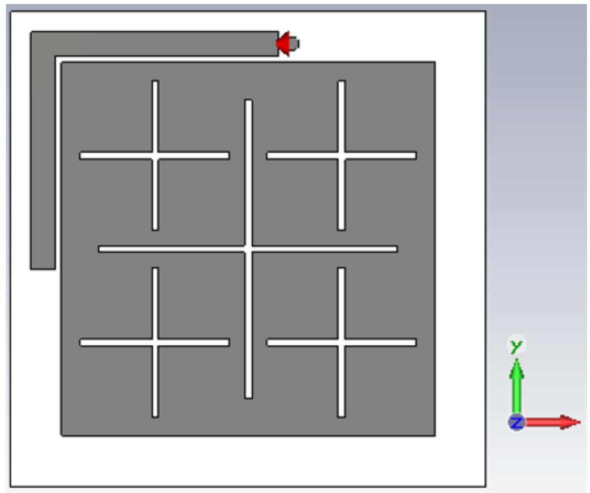

Figure 6. Geometry of the proposed circularly-polarized RFID tag antenna.

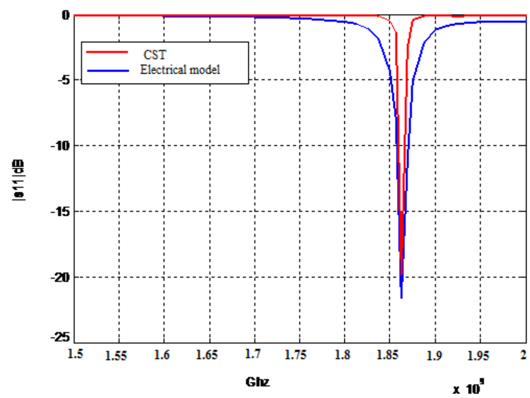

Figure 7. Return loss of the proposed antenna.

Under all these considerations, the parameters were optimized. The Lx is set as 15 mm and the Ly is set as 32mm. With these dimensions, the antenna reflection coefficient is calculated as shown in Fig. 3. The smallest reflection coefficient value is located at the frequency of 2.45GHz and below.

3. Miniaturization of the proposed antenna

All fractals have self-similar forms, that is to say that some of their parts have the same shape as the whole object, but at different dimensions. The construction of fractal shapes is performed by the application of an infinite number of iterations. Fractal antennas can take various forms,

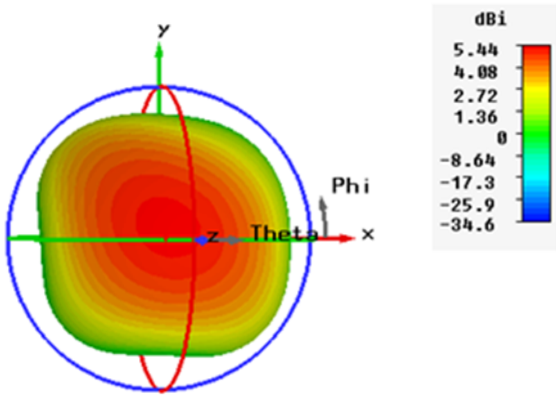

Figure 8. The simulated 3D radiation pattern of the fractal patch antenna proposed.

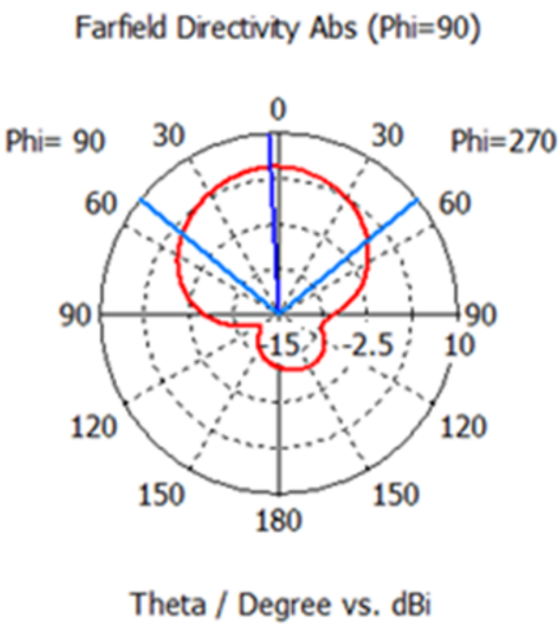

Figure 9. Simulated far-field radiation patterns at 1.89 GHz for proposed antenna.

and shapes include the Koch fractal [3], which shortens a monopoly quarter wave antenna, modeling a loop antenna with Minkowski Fractal Island [2]. Also, the Sierpinski gasket can be used as a monopole fractal [4]. In this paper, a new fractal antenna is proposed as shown in Fig. 6, which shows that the proposed structure of the fractal block consists of four identical radiation patches.

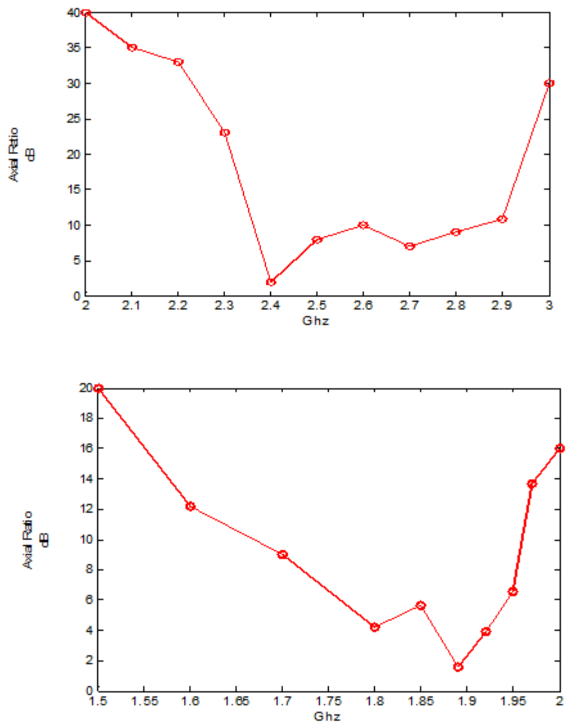

Figure 10. Axial ratio of the proposed antenna in the wide direction ($\theta = 0°$).

3.1. Geometry

The Circular polarization antenna of the RFID tag, as shown in Fig. 6, is formed on the substrate Rogers 4003, with thickness 1.6 mm and relative permittivity 3.55 (loss tangent 0.0027). Printed on the opposite side of the 80 (G) x 80 mm square ground plane is a 64 (L) x 64 mm cross-slot loaded square patch coupled to an L-shaped open-ended micro-strip line, where the coupling distance is d=1 mm. Both horizontal and vertical sections of the micro-strip line (with width T) are located along the X and Y directions, respectively, with dissimilar lengths Lx=32 mm and Ly=15 mm. Located at the open-end of the horizontal section is an RFID tag chip terminated by a shorting pin. As for the cross slot embedded into the square patch, it is formed by two narrow slots (with 1 mm width) located centrally along the X and Y axes with lengths Sx=45 mm and Sy=45 mm, respectively. Small slots are parameterized with Sx, Sy and L.

3.2. Simulations Results

The behavior of the fractal antenna proposed was simulated by CST microwave, where it was modeled as a rectangular patch printed copper (35 μm thick) on a substrate of 1.6 mm Rogers 4003 with a partial ground plane on the other side of the substrate.

Figure 7 shows the return loss of the designed antenna. The result is compared to the electrical model. The resonance frequency is 1.87 GHz. The resonance mode is less than -25 dB. As shown in Fig. 7, the antenna is excited at 1.87 GHz and -10 dB with an impedance bandwidth of 50MHz (1.8-1.85GHz).

The radiation patterns in the far field for the E-plane and H-plane of the antenna with two typical frequencies in the operating bands have been shown with Figs. 4 and 8. The gain of fractal antenna is 5.31 dB before miniaturization, and afterwards is 6.57 dB, for both resonant frequencies. For the first model of the proposed antenna, the axial ratio in the wide (θ=0°) direction is a function of frequency as shown in Fig. 10a. The -3dB axial ratio CP bandwidth is about 2.5 MHz around the center frequency of 2.4 GHz. Note that the minimum axial-ratio value is about 2.2 dB at the center frequency, which indicates that the circular polarization is pure, and is the same for the second mode as shown in Fig. 10b. The second mode axial ratio in the angle θ=0° has a bandwidth of about 10MHz and frequency around 1.87GHz. Note that the minimum axial-ratio value is about 1.58 dB at the center frequency, which indicates that the circular polarization is pure.

3.3. Conclusion

In this article, a new fractal antenna was proposed, which is based on linear cross fractal geometry that has been optimized for microwave RFID applications. Simulated performance results are presented for the two iterations of the fractal antenna, operating at 2.45 GHz for the first and 1.87 GHz for the second, which means a reduction of antenna size. The results and discussion presented in this work are meant to provide an intuitive point of view on the fundamental requirements regarding the RFID antenna and circular polarization.

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