New Antennas Based on Triangular Patch as a Solution for RFID Application

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Abstract — This paper covers the design of a new antenna for RFID applications at microwave frequencies. Five antennas are studied. The first three structures are inspired from a triangular patch, whereas the fourth and the fifth are inspired from a Sierpenski fractal antenna. The size reduction is more than 80%, which explains the utility of the proposed antennas.

Index Terms— Radio Frequency Identification (RFID), interrogator, bow tie, fractal antennas, Sierpenski.

I. INTRODUCTION

Radio Frequency Identification RFID is one of several technologies where the goal is to automatically identify goods with as little human intervention as possible. Auto-ID technologies tend to become more flexible, enabling data to be collected anywhere, anytime and without human involvement [1]. This technology, which is often presented as the next generation of barcodes, is now used in many fields such as transport (access control), libraries, animal tracking, and security.

An RFID system consists of three major components: a transponder, a reader and a computer with an RFID application. The RFID TAG contains an antenna and an integrated circuit chip, or IC. The reader (Interrogator) includes an antenna which communicates with the TAG [2]. When choosing the antenna we should take some points into consideration: the antenna type, its characteristics and performance in RF frequencies.

Firstly, in order to obtain a small TAG, we must reduce the size since it is the main component of the TAG. Reducing its size leads automatically to reducing the TAG size. Secondly, one of the important characteristics of the RFID system is the readable range Rr which is the maximum distance that the Interrogator can read from the TAG. This readable range depends on antenna gain [3].

Many works are interested in developing new small antennas for RFID systems with an acceptable parameter. Many works are based on replied dipole as in [4] where Galehdar, Thiel, and O'Keefe propose a new meander line dipole where they apply three methods to calculate the efficiency of electrically small wire antennas. Secondly, in [5], Morocco proposes a new meander line antenna and optimises the gain and the size by using a genetic algorithm. Thirdly, in [6], Tedjini, Vuong and Beroulle used the fractal technique to reduce antenna size. Lastly, in [7], Asniza et al. present a compact antenna based on the Hilbert curve fractal for RFID application.

In this paper, we will present a new compact antenna based on triangular and fractal antenna as a solution to RFID reader. The basic antennas are designed at 2.45 GHz, which is one of the frequencies used in RFID applications.

This paper is organized as follows: Section II deals with some characteristics of triangular patch and proposes its model; this patch represents the main component of the second and the third structure. In Section III, a Sierpenski antenna will be the main basis of our fractal structure. In the Section IV, the results will be discussed and analyzed, followed by a brief conclusion.

II. A TRIANGULAR ANTENNA FOR RFID SYSTEMS

1. Design of the patch antenna

Figure 1 shows the geometry of an equilateral triangular patch deposed on a dielectric substrate with a ground plan.

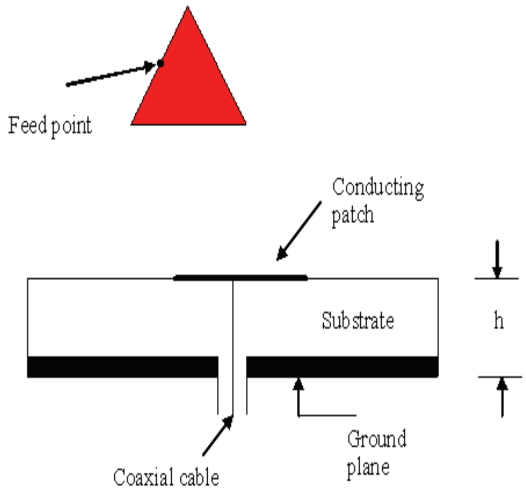


Fig. 1. Antenna structure (triangular patch).

The use of triangular patch provides the possibility of a multi resonator antenna which can be useful for an RFID reader to communicate with more than one TAG [8]. The resonance frequency is calculated using the equation (1) [9].

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}}\sqrt{m^2 + mn + n^2} \quad (1)$$

For the fundamental mode, m=1, n= 0, 'a' is the length of triangle, 'c' is the velocity of light and ε_r is the relative dielectric constant.

Concerning our work, the antenna is designed to resonate at 2.45 GHz and it is mounted on a substrate material with a thickness h = 3.6mm, a relative dielectric constant $\varepsilon_r = 2,6$, loss tangent (tangδ) = 0.002 and 'a' = 50mm. The patch is excited by a coaxial line at the middle of the right side Fig. 1.

The structure is simulated by ADS which uses the Momentum method. The method of moments is a frequency domain technique. It is used in the electromagnetic analysis of structures by solving the integral equations. The method consists of dividing the antenna structure into wires or metal plates. Then each piece is subdivided to a number of segments that are small enough compared to the frequency's wavelength so that we can assume they have constant current. With the current then the electric and magnetic fields can be derived and important parameters such as impedance, return loss, gain, and directivity will be calculated.

One of the strengths of this method is that it is very intuitive, due to of its conceptual simplicity. Another advantage is that if only analyzing one frequency, it provides the results very quickly. However, its weakness is that if a large range of frequencies is to be analyzed then the computations will take a long time.

To study this structure, an electrical model is developed. The electrical model is useful for parametric analysis not to design of the antenna. It is useful to know what has occurred to the input impedance when modifying antenna characteristics: geometry, parameters, feeding point. This model is derived from the cavity model of rectangular patch where the parameters are calculated from the input impedance [10]. The triangular patch is replaced by its equivalent rectangular patch [11]. This one is modelled by a resonant parallel RLC circuit, and the coaxial line is considered as an inductive reactance X_L, Fig. 2.

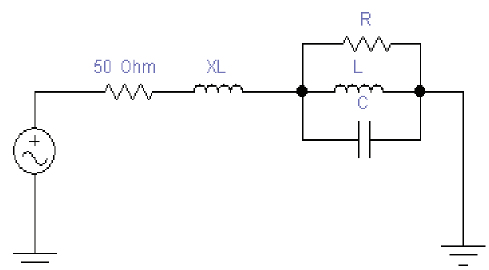


Fig. 2. Electrical model with C=0.168 nF, L= 25.11 pH, R= 66.66 Ohm, $X_L = 1nH$ (triangular patch).

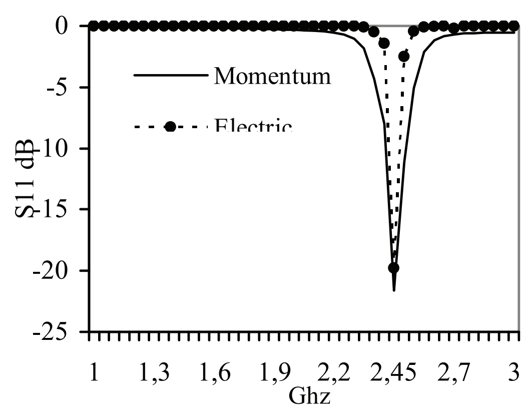


Fig. 3. Return loss for both physical and model patch.

As demonstrated by Fig. 3, a good agreement has been achieved between the electrical model and Momentum. The band width differs by about 50Hz.

2. A multiple triangular patch

a. First Example:

In the second structure, we use four triangle patches which are excited in the middle as shown in Fig. 4. Every triangle patch is an equilateral with an edge a = 7mm, then the antenna dimensions are 14mm x 13.9mm which is mounted on a dielectric with a thickness h = 0.65mm and $\varepsilon_r = 2.3$.

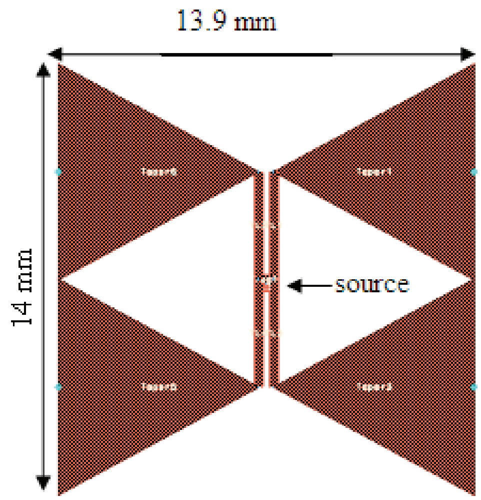


Fig. 4. Antenna structure (first structure).

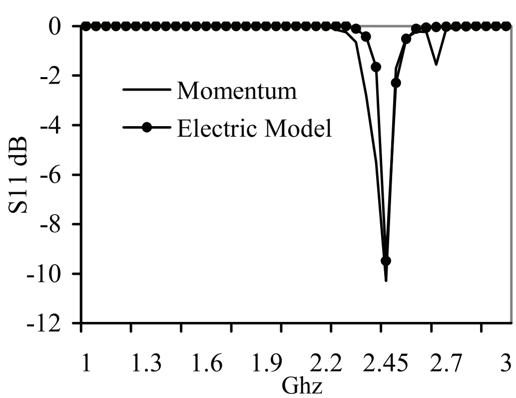


Fig. 5. Return loss of both physical and model patch (first structure).

Compared to the initial triangular antenna, the reduction size of the new structure is more than 70%. Besides the simulation of the S parameters gives the resonant frequency a gain of 1.6 dB and directivity is 4.5 dB and the band width is equal 80Hz which are good parameters for RFID system, Fig. 5.

b. Second Example

The proposed patch is composed by four triangles, shown in Fig. 6. This structure is inspired by a bow tie patch antenna. Only one transmission line links the four triangles. We keep the same dielectric thickness and permittivity of last example.

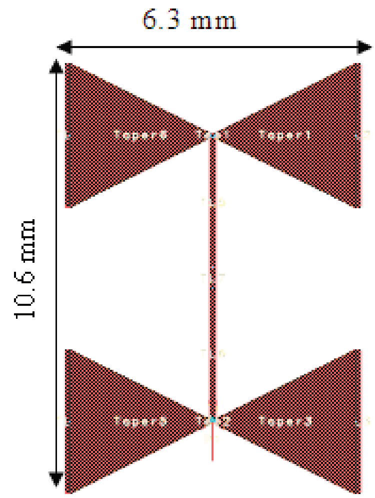


Fig. 6. Antenna structure (second structure).

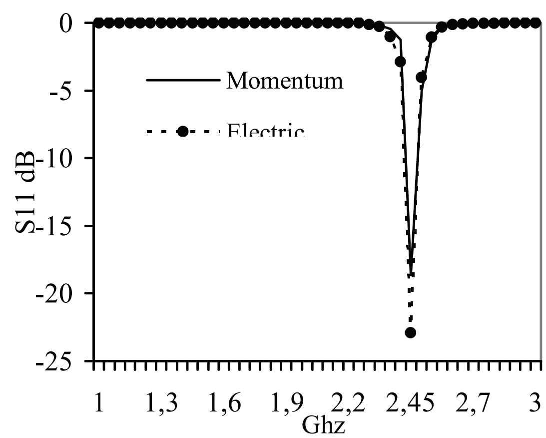


Fig. 7. Return loss of both physical and model patch (second structure).

The dimensions of the present antenna are about 10.6mm×6.3mm which means that the dimensions of antennas are reduced more than 80%. We used the same technique to calculate the parameters of the model. The return loss is shown in Fig. 7. The resonant frequency is 2.45 GHz and the band width is 80 Hz for both approaches. The gain and the directivity are 1.62dB and 4.87dB, respectively.

III. FRACTAL ANTENNA FOR RFID SYSTEM

1. A monopole Sierpenski

The fractal technique is used to obtain a special antenna as in RFID systems. The main geometric characteristics of fractal antenna are an infinite perimeter, a finite surface and a fractal dimension D.

The general concept of fractals can be applied to develop various antenna elements. The fractal technique allows as obtaining smaller and multiband frequencies antennas. Furthermore, the dimension and geometries can be defined through Euclidean dimension and self-similarity dimension [12]. For this reason, fractal antennas have been a recent topic of interest.

In this section, we will present a different fractal antenna based on the Sierpenski microstrip antenna and a novel fractal antenna which is simulated with our model. The obtained results are compared to Momentum data.

The Sierpenski gasket has the geometry described by Sierpenski in [13]. It is constructed by subtracting a central inverted triangle from the main triangle. This procedure is repeated every iteration. The triangles number is noted Nn, the triangles length is noted Ln and the fractional area is An; they are calculated after every iteration [14]:

$$N_n = 3^n \qquad (2)$$

$$L_n = \frac{1}{2^n} \qquad (3)$$

$$A_n = L_n^{\,2} N_n = \left(\frac{3}{4}\right)^n \qquad (4)$$

Figure 8 shows the first three iterations of Sierpenski antenna which are mounted on substrate material with a dielectric constant $\varepsilon_r = 2,52$ and loss tangent (tang δ) = 0.002 and a thickness h=3.2mm. The patch is exited by a coaxial feed line at the middle of the right side.

The simulated return loss is shown in Fig. 9. As can be seen, after three iterations, the resonant frequency is reduced by more than 51%. This implies that the resonant length of the antenna can be reduced by more than 51%.

This change is very important in reducing RFID system size. But as can be seen in Table 1, the main performances of the antenna are conserved until the second iteration with a high gain and directivity and a comparative return loss but after the third iteration the antenna performances decrease.

When looking at the radiation pattern of the first iteration of the Sierpenski gasket antenna, we can say that the radiations are virtually unchanged with the original structure, and as for the second iteration, it's clear that the antenna is less omnidirectional due to fractal effect, Fig. 10.

2. A multiple Sierpenski microstrip antenna

The fourth antenna is composed of Sierpenski gasket patches. The four triangles are connected by two microstrip lines and exited by a coaxial line at the middle, Fig. 11. The antenna is deposed on a dielectric substrate with thickness h = 0.65mm and $\varepsilon_r = 2.3$. The dimensions are 13.4mm x 13.9mm whereas the original dimensions are 50mm x 43mm, thus the size is reduced by more than 72%.

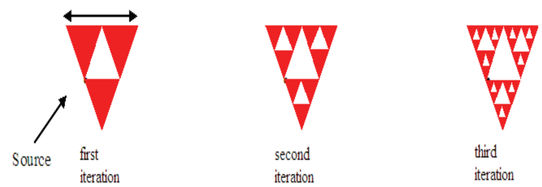


Fig. 8. First three iterations of Sierpenski antenna.

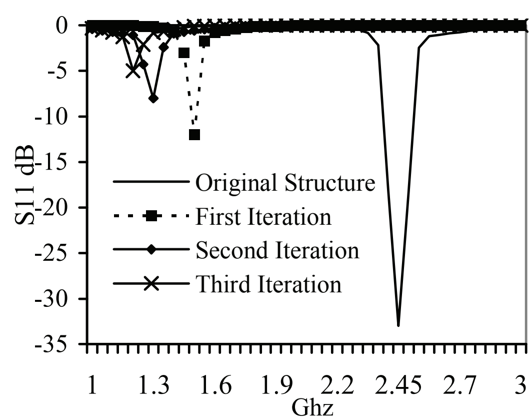
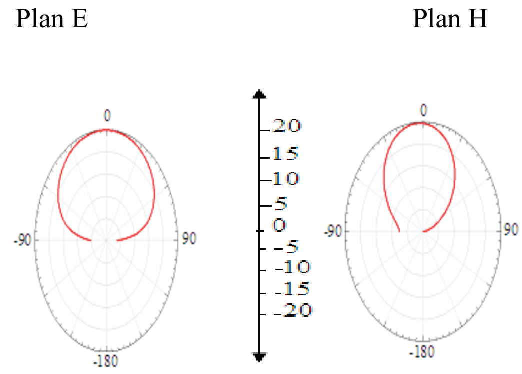


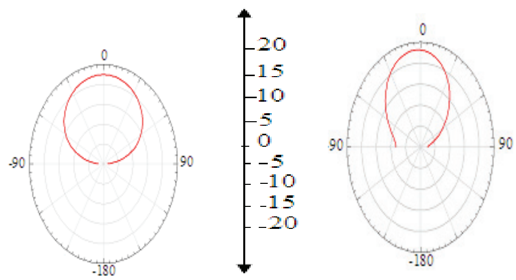
Fig. 9. Return loss of Sierpenski antenna.

Table 1: Performance of the three first iterations of Sierpenski antenna.

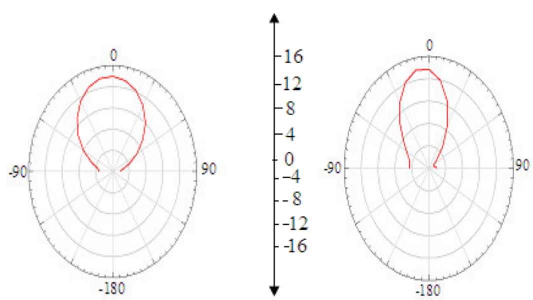
	f_r (GHz)	S_{11}(dB)	G(dB)	D(dB)	reduction %
original structure	2.45	-33	6.41	7.87	0
first iteration	1.5	-12	3.95	4.62	38
second iteration	1.25	-8	2.92	4.80	49
third iteration	1.2	-5	1.85	4.81	51



(a) Original structure



(b) First iteration



(c) Second iteration

Fig. 10. Radiation pattern (Etotal) of triangular and Sierpenski patch.

The return loss for this antenna is shown in Fig. 12. We can see that the resonant frequency is about 2.45 GHz, the gain and directivity are 1.7dB and 4.81dB respectively which are a good performances for the RFID system.

The principal advantage of the proposed fractal antenna is the size reduction percentage (more than 72%). As for the radiation pattern, this antenna is less omnidirectional due to its small size but it is still acceptable in RFID applications where the readable range in which the reader can identify the TAG is very short (about 1m), Fig. 13.

Finally, as it is clearly demonstrated in the results, the examples of multi triangular patch, and the multi Sierpenski micro strip antenna are very useful for RFID systems because they are very small and they present a suitable gain, directivity and band width. In addition to the simplicity of realization, we think also that the first example of

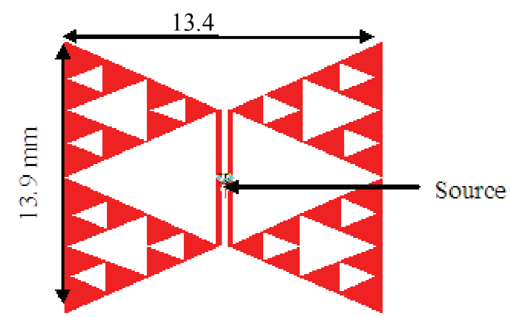


Fig. 11. Antenna structure (multiple Sierpenski antennas).

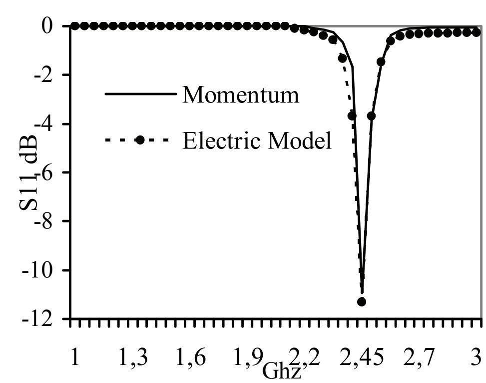


Fig. 12. Return loss of physical, first and second model antenna (multiple Sierpenski antenna).

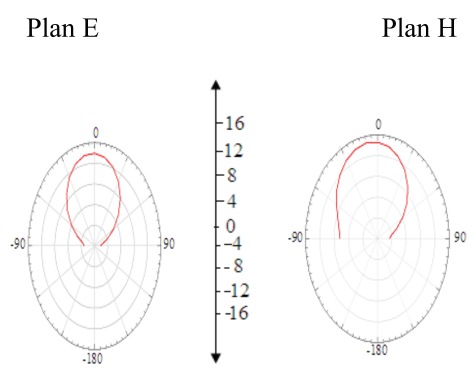


Fig. 13. Radiation pattern (Etotal) of multiple Sierpenski patch.

multi triangular patch presents a dimension much reduced compared to the other antenna with similar parameters (Table 2). Moreover, the monopole triangular patch and the monopole Sierpenski present a good gain and directivity but they are not small enough.

Table 2: Performances of new antennas.

	Dimension W/L (mm)	BW_{-3dB}	G(dB)	D(dB)
1	50*43	100	6.41	7.81
2	24*20.6	100	2.83	4.81
3	13.9*14.1	80	1.6	4.5
4	10.6*6.3	80	1.62	4.87
5	13.9*13.4	100	1.7	4.81

Where:
1: Monopole Triangular patch
2: The third iteration of Sierpenski antenna
3: The first model of multi triangular patch
4: The second model of multi triangular patch
5: The multi Sierpenski micro strip antenna

IV. CONCLUSION

In this paper, two approaches are used to reduce the size of a RFID antenna. The first one is based on a multiple triangular patch whereas the second one is based on using fractal technique. The height reduction, the simplicity of realization, and its acceptable characteristic give our antennas a great interest in RFID system.

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