Design and Simulation of two elements rectangular Microstrip Patch Antenna at 5.8 GHz for RFID Reader Applications with high Directivity and Gain

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***Abstract*— In this paper, detailed design of a 5.8 GHz two elements rectangular Microstrip Patch Antenna for use in the RFID Reader applications is presented.**

The patch antenna was designed using RT/duroid-5880 material, with a loss tangent tanδ = 9.10^{-4}, dielectric constant of 2.2 and thickness of 1.56mm, fed by a 50- microstrip line.

In the beginning, we defined our antenna as a single patch of a rectangular shape but after evaluating the antenna characteristics results such as gain, directivity and radiation patterns, we transformed it to a 2*1 linear array antennas.

The main aim is to improve directivity, gain and radiation patterns.

***Keywords*—Microstrip patch antenna; RFID reader; radiation pattern, return loss, Voltage Standing Wave Ratio, gain, directivity, HFSS, CST, array patch antenna.**

I. Introduction

The RFID technology is the abbreviation of radiofrequency identification technology. It is part of the electronic identification which is based on radiofrequency connections, in order to allow identification without any physical contact. This technology can identify, at more or less long distance, an object equipped with a tag capable of transmitting data using radio waves [1].

Four frequency bands are mainly used by RFID devices, ranging from low frequencies (125 kHz) to microwave frequencies (5.8 GHz). Each frequency band, whose characteristics give the RFID devices special properties in terms of reading distance, or propagation of waves in particular environments (water, metal, ...), corresponds to specific applications[2].

There are two basic components divided the RFID system, which are: the transponder and the reader.

The operation of the RFID system is as follows:

A radio signal is emitted by a reader via an antenna. Passive transponders passing through the electromagnetic energy emitted by this antenna to power and transmit the data they contain. At the end, these data will be transferred to the computer. The communication between the two components of the RFID system is generally done by a predefined communication protocol [3, 4].

The antenna can take several forms that can be rectangular, square, circular or simply a dipole. These forms are the most common because they are very easy to analyze and manufacture, but also offer a very interesting radiation pattern [5, 6].

As the antennas are part of the RFID system and as they play a substantial role, the RFID system assembly depends on the performance of the antenna like return loss, gain, directivity and bandwidth.

Fig.1 shows RFID system components.

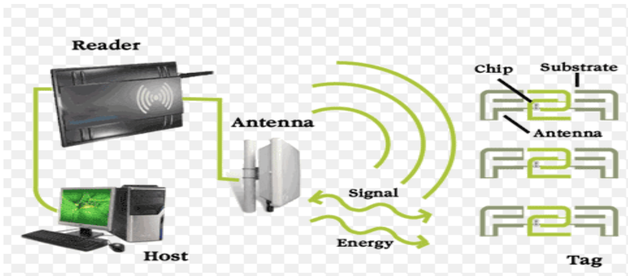

Fig. 1. Principle of an RFID system operation.

The main goal of this work is designing a 2*1 array patch antenna of rectangular shape, with high radiation performances, to identify objects or living things in motion that are at long distances from RFID readers.

II. ANTENNA DESIGN

A. *Antenna element design*

The use of Microstrip antennas has grown considerably in the field of RFID because of the low profile, the lightness, the small size of the structure and also a low cost of production.

Fig.2 presents the proposed simple patch antenna geometry.

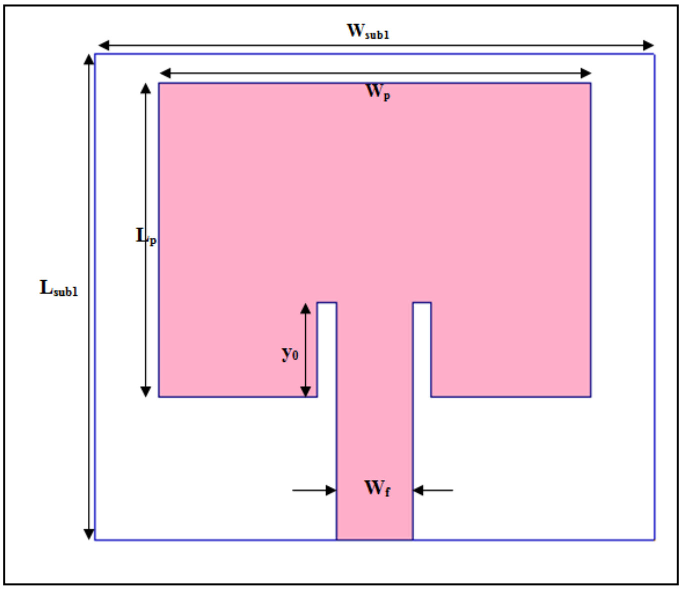

Fig. 2. Geometry of the proposed patch antenna.

It is formed by two conductors (radiating element and ground plane) mounted in parallel and separated by a substrate whose should have a permittivity value in the range of 2.2<εr <12, which has a ground plane on the other side [6].

The proposed antenna has a rectangular shape and fabricated on a RT/duroid-5880 substrate with a relative permittivity 2.2, loss tangent tanδ = 9.10^{-4} and thickness of 1.56mm, fed by a 50-microstrip line.

The single patch Dimensions are obtained by (1) and (2) respectively, where ε_{reff} is the effective permittivity, given by (3) and ΔL is the extension of the length calculated from (4) [7].

The width of microstrip line is calculated from (5), where Z_0 is characteristic impedance of the inserted microstrip line and h (1.56mm) is the substrate's thickness. The length of slot (Y_0) can be calculated from (6) [6, 7, 8].

$$w_p = \frac{C}{2*f_r} * \sqrt{\frac{2}{\varepsilon_r+1}} \tag{1}$$

$$L_p = \frac{C}{2*f_r\sqrt{\varepsilon_{reff}}} - 2*\Delta L \tag{2}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} * \left[1 + 12 * \frac{h}{w_p}\right]^{\frac{-1}{2}} \tag{3}$$

$$\Delta L = 0.412 * h * \frac{(\varepsilon_{reff}+0.3)(\frac{wp}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{wp}{h}+0.813)} \tag{4}$$

$$Z_0 = \frac{60}{\varepsilon_{reff}^{\frac{1}{2}}} * \ln\left[\frac{8h}{w_f} + \frac{w_f}{4h}\right] \tag{5}$$

$$Y_0 = \frac{Lp}{2*(\varepsilon_{reff})^{1/2}} \tag{6}$$

f_r is the resonant frequency and C is the speed of light.

Table 1 presents the patch antenna dimensions.

TABLE I. DIMENSION OF SINGLE ELEMENT AND ARRAY STRUCTURE

Variables	*Values (mm)*
L_{sub1} (simple element)	25.54
W_{sub1} (simple element)	29.44
L_p	16.54
W_p	22.44
W_f	4
Y_0	5

B. *2*1 array antenna design*

It is necessary designing an antenna with highly radiation performances (gain, directivity) to get the long distance communication requirements and the easy way to do it is increasing the radiating elements number.

In this part, we kept the same specifications (Permittivity, type and thickness of substrate) and the same single patch antenna dimensions at the design frequency.

This structure is composed by two identical elements and for exciting the proposed array antenna, we used a simple power divider. The feed line network parameters are maintained at Z_1= 50Ω for the initial feed line which splits into two ones with impedance Z_2= 100Ω as shown in figure below.

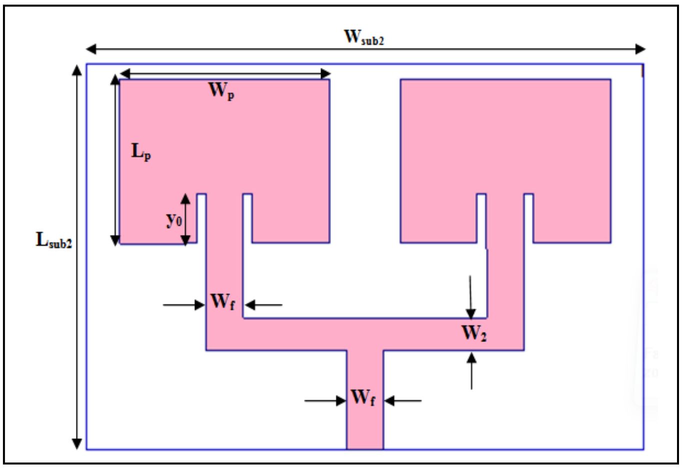

Fig. 3. Geometry of the proposed linear array antenna 2x1.

The parameters changed between simple antenna and 2*1 array antenna are listed in the following table.

TABLE II. DIMENSION OF 2*1 ARRAY STRUCTURE

Variables	*Values (mm)*
L_{sub2} (2*1 array antenna)	38.77
W_{sub2} (2*1 array antenna)	59.44
W_f	4
W_2	3.23

III. SIMULATION RESULTS AND DISCUSSION

In this part, we present a comparative study between a simple patch antenna and a 2*1 array patch antenna by two simulators: HFSS and CST microwave studio. The first simulator employs the Finite Element Method (FEM) and the second one is based on the Finite Integration Method [11, 12].

The simulation has been accomplished to reach the wanted results in terms of S_{11}, VSWR, Z_{in}, gain and directivity at the resonance frequency (5.8 GHz).

A. Return loss

Fig.4 shows the comparison between the two designs (Simple antenna and array patch antenna 2*1) in term of return loss.

The value of return loss passes from -30.58 dB (for simple antenna) to -40.11 dB (for 2*1 array antenna). The values of S11 found by CST simulator are almost same.

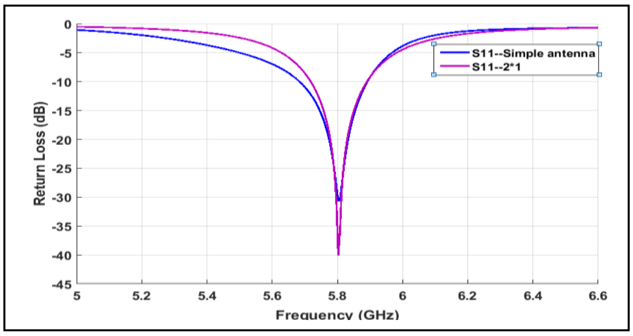

Fig. 4. Return loss versus frequency of the two designs.

B. Voltage Standing Wave Ratio

The antenna adaptation quality is defined either by its input impedance or its VSWR which must be less than 2, at the resonance frequency, for the antenna to be well adapted..

The Voltage Standing Wave Ratio variance for the two designs is shown by Fig.5.

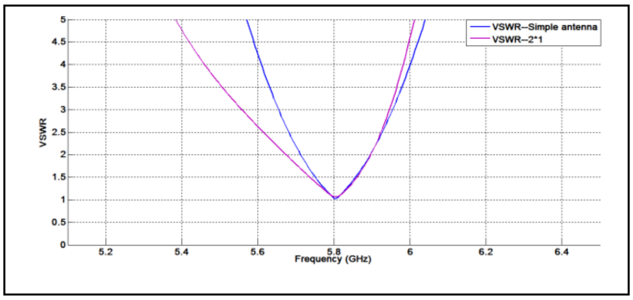

Fig. 5. VSWR versus frequency of a two designs.

The obtained values of Voltage Standing Wave Ratio VSWR= 1.01 at 5.8GHz for simple antenna and VSWR= 1.06 at 5.8GHz for 2*1 array antenna (The values of VSWR found by CST are almost the same).

It can be remarkable that the value of the VSWR in the interest band is less than 2 which proves that each proposed design is well adapted to its transmission line.

C. Input impedance

In the addition of the VSWR, the input impedance is considered as an important parameter to study the antenna adaptation.

The following figure shows the values obtained of input impedance for the simple antenna and the 2*1 array antenna.

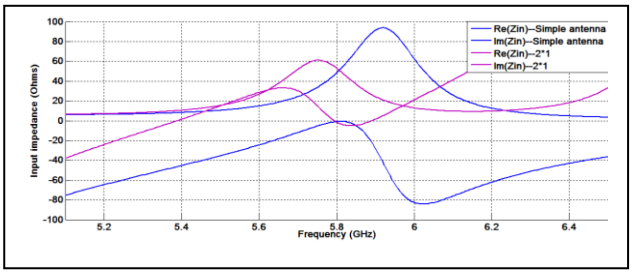

Fig. 6. Input impedance versus frequency of the two designs.

At the resonance frequency 5.8 GHz Zin = (49.44-j0.8)Ω for a simple antenna and Zin = (50.68-j1.43)Ω for 2*1 array antenna.

These values show that the two designs are well adapted to 50Ω.

D. Radiation pattern

The radiation pattern is a characteristic which helps to comprehend the designed antennas behavior.

Fig.7 and Fig.8 show respectively the radiation pattern in the two plans E (φ=0deg) and H (φ=90deg) of a simple antenna and a 2*1 array antenna respectively.

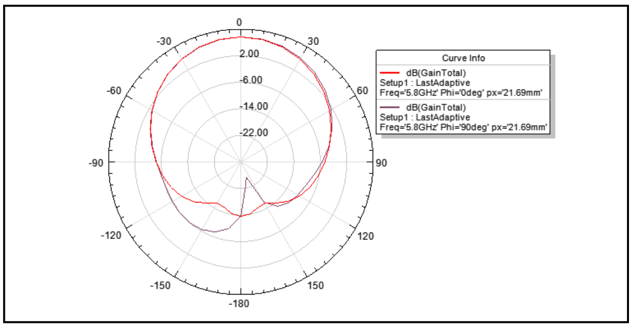

Fig. 7. Radiation pattern of a simple antenna.

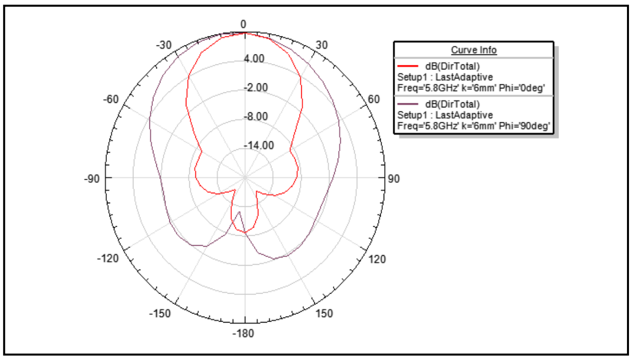

Fig. 8. Radiation pattern of a 2*1 array antenna.

The figures above present respectively radiation pattern of simple antenna and 2*1 array antennas. It can be seen that the both structures offer a directional radiation pattern at 5.8 GHz with maximum gain of 7.67dB and 9.88dB, respectively.

The values obtained make it possible to conclude that the 2*1 array patch antenna produces more intensity in the center of the radiation than the simple patch antenna.

E. Gain and Directivity

Fig.9 and Fig.10 present respectively, the comparison between the gain and directivity of the simple antenna and the 2*1 array antenna.

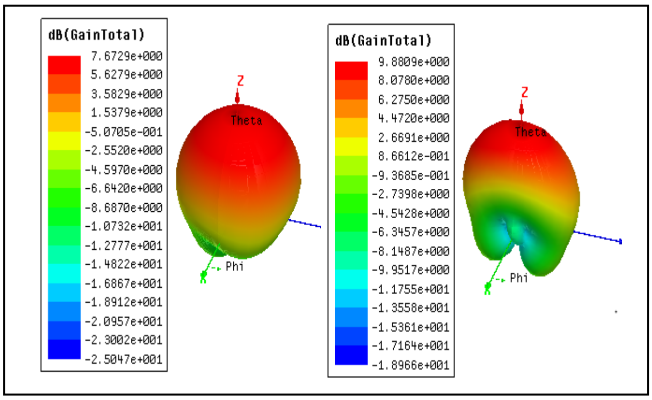

Fig. 9. Gain of a simple antenna and 2*1 array antenna.

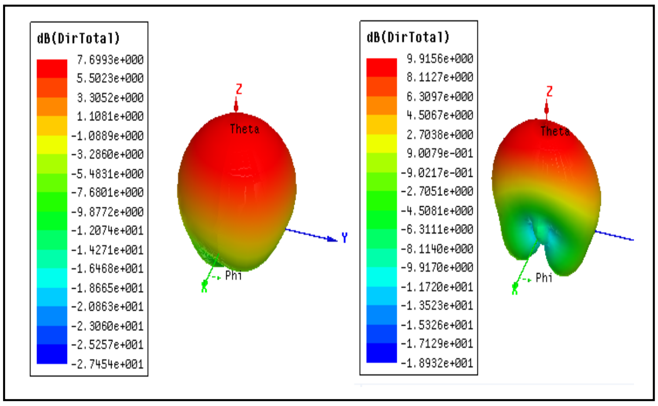

Fig. 10. Directivity of a simple antenna and 2*1 array antenna.

The simple antenna gain and directivity are respectively equal to 7.67dB and 7.69dB on HFSS (The values of gain and directivity found by CST are almost the same).

The 2*1 array antenna gain and directivity are respectively equal to 9.88dB and 9.91dB on HFSS (The values of gain and directivity found by CST are almost the same).

From the figures 9 and 10 we notice that the use of two elements has increased the antenna gain and directivity than the simple element.

The following table presents the advantages of our proposed array antenna comparing to others in the literature. It can be seen that our proposed array antenna is miniaturized and represents a significant gain and a good adaptation.

TABLE III. RESULTS COMPARISON BETWEEN OTHER RESEARCH PAPERSAND OURS.

Variables	*Size (mm^2)*	*Gain (db)*	*Return Loss (db)*
Proposed antenna	38.7*59.4	9.88	-40.11
Reference[9]	105*165.5	6.51	-31.42
Reference[10]	63*68	5.05	--------------

CONCLUSION

This paper mainly focuses on design of the simple antenna and the 2*1 array patch antenna with 5.8 GHz working frequency using HFSS and CST Microwave Studio.

From obtained results, gain and directivity were improved when we passed to a 2 * 1 array antennas. It is clear that increasing the number of patches is a solution to further improve radiation performances and obtain a more directive beam. However, the position of patches in array antennas must be carefully chosen to avoid mutual coupling. Methods to minimize mutual coupling will be exploited in a future work.

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