



DESIGN, ANALYSIS AND OPTIMIZATION OF A NEW STRUCTURE OF MICROSTRIP PATCH ANTENNA FOR RFID APPLICATIONS

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ABSTRACT

In this paper, we propose a new structure patch antenna excited by two identical microstrip lines having a common feeding adapted to 50 ohm and intended to applications of Radio Frequency Identification (RFID). The slots inserted at the patch antenna have a direct impact on improving the radiation characteristics in terms of reflection coefficient, voltage standing wave ratio, input impedance and directivity over a range of frequencies ranging from 2 GHz up to 2.9 GHz.

The analysis and optimization have been performed using the simulator HFSS (High Frequency Structure Simulator) based on the finite element method. Next, in order to validate our simulation, we use another electromagnetic simulator CST MWS (Computer Simulation Technology- MicroWaves Studio) which is based on the finite integration method. The simulation results of the two simulators agree well practically.

Keywords: *Patch Antenna, Microstrip Line, RFID Application, Reflection Coefficient, VSWR, Input Impedance, Directivity, Simulators HFSS And CST.*

1. INTRODUCTION

The concept of microstrip antennas has appeared in the 1950's with G.A.Deshamps [1], but it will take the 1970's to see the first achievements will be reserved primarily for military applications, and 1990's for a real passage the industrial stage.

Two major advantages have led a very important development of this type of antenna: their low cost implementation and integration capacity. They are now implanted in many electronic devices and constitute the preferred type of antenna to microwave frequencies in modern communication systems.

A lot of researches on microstrip antennas have been published in [2, 3, 4, 5, 6, 7, 8, 9, 10].

Radio Frequency Identification (RFID) is based on radio communication for tagging and identifying an object [11]. It consists of two blocks namely, RFID transceivers (readers) and RFID transponders

(tags). A RFID tag consists of a small integrated circuit for storing information and an antenna for communication. A basic RFID system is based on wireless communication between a reader and a tag (figure 1). RFID readers can read information stored in no line-of sight RFID tags in their vicinity and communicate it to central database system through wired or wireless interface [12]. Over the last few years, RFID has drawn a great deal of attention and it is now widely believed that RFID can bring revolutionary changes [13]. Indeed, applications of RFID systems include supply chain automation, security and access control, cold chain management (temperature logging) and identification of products at check-out points, to name a few. Some of the major retailers have already invested significantly in RFID and mandated their manufacturers to place tags on cases and pallets, which resulted in mass production of inexpensive RFID tags [14].

In recent years, more efforts have been made to implement RFID applications in inventory control and logistics management. RFID based system leads to significant reduction on processing time and labor as inventory in warehouses can be tracked more accurately in a simple, timely and more efficient manner. More importantly, RFID based system provides complete visibility of accurate inventory data, from manufacturer's warehouse, shop floors and brings opportunities for improvement and transformation in various process of the entire supply chain [15].

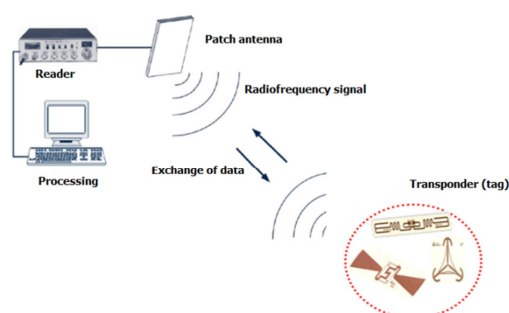


Figure 1: Functioning of an RFID system

In this paper, we propose a new structure patch antenna excited by two identical microstrip lines having a common feeding port adapted to 50 ohm and intended to applications of Radio Frequency Identification (RFID). The use of two supply lines helps minimize energy losses at the excitation port and ensure a better energy transfer injected.

The slots inserted at the patch antenna have a direct impact on improving the radiation characteristics in terms of reflection coefficient, voltage standing wave ratio, input impedance and directivity over a range of frequencies ranging from 2 GHz up to 2.9 GHz.

2. PATCH ANTENNA DESIGN

2.1. Design Principles

In general, patch antennas have been the subject many studies and developments that today find themselves in the literature. There are several analytical models useful in sizing antenna geometries such as rectangular, circular or triangular [16], [17].

The first part of the design of an antenna is the estimation its length (L) and it's the width (W) which are calculated using equations (1-4) [18].

$$W = \frac{c}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

With f_r is the resonant frequency of the patch antenna, ϵ_r the dielectric constant of the substrate

and c the speed of light in free space. The effective dielectric constant ($\frac{W}{h} > 1$) is given by:

$$\epsilon_{\text{reff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[\frac{1}{\sqrt{1 + 12 \frac{h}{W}}} \right] \quad (2)$$

The extension of the length of microstrip patch antenna ΔL due to the fringe effect (edge effects) can be obtained by:

$$\Delta L = 0.412h \frac{(\epsilon_r + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_r - 0.258) \left(\frac{W}{h} + 0.8 \right)} \quad (3)$$

So, after taking account the edge effects, the final effective length of the patch antenna can be calculated by:

$$L = \frac{c}{2 f_r \sqrt{\epsilon_{\text{reff}}}} - 2\Delta L \quad (4)$$

2.2. Antenna Configuration

The base antenna is composed of a rectangular microstrip patch of the length $L_p = 50 \text{ mm}$ and the width $W_p = 56 \text{ mm}$, printed on a substrate of Rogers RT/duroid 5880, of the relative permittivity of 2.2, a thickness of 3.2 mm, the length $L_{\text{sub}} = 75 \text{ mm}$ and width $W_{\text{sub}} = 100 \text{ mm}$. The antenna is fed by two identical microstrip lines having a common feeding port adapted 50Ω, of the length $L_m = 41 \text{ mm}$ and the width $W_m = 3.8 \text{ mm}$, the assembly is placed on a ground plane of dimension $(100 \times 75) \text{ mm}^2$ as shown in figure 2.

The calculation made by Matlab gave the results listed in Table 1.

Table 1: Dimensions Of Proposed Patch Antenna

Parameters	Values (mm)
L_{sub}	75
W_{sub}	100
L_g	75
W_g	100
L_p	50
W_p	56
L_m	41
W_m	3.8
L_1	30
L_4	7.5
L_5	12.5
L_6	19.8

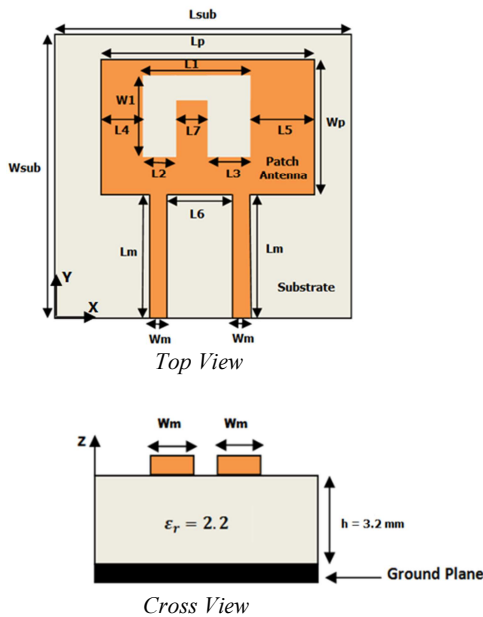


Figure 2: Proposed Microstrip Patch Antenna

3. OPTIMIZATION OF DIMENSIONS THE PATCH ANTENNA

In order to study the performance of our antenna, we will proceed to a series of simulations of the reflection coefficients S_{11} on a frequency range of 2 GHz to 2.9 GHz. We keep the same dimensions shown in Table 1 and we do vary the dimensions of the slots on the radiating element inserted (L_2, L_3, L_7 and W_1). The simulation results in terms of the reflection coefficients and voltage standing wave ratio (VSWR) are presented respectively in figures 3 and 4.

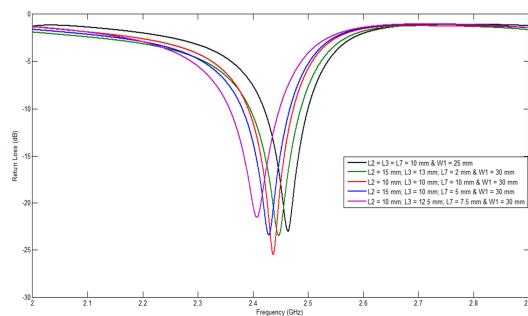


Figure 3: Reflection Coefficients For Different Values Of L_2, L_3, L_7 And W_1 In Function Of The Frequency

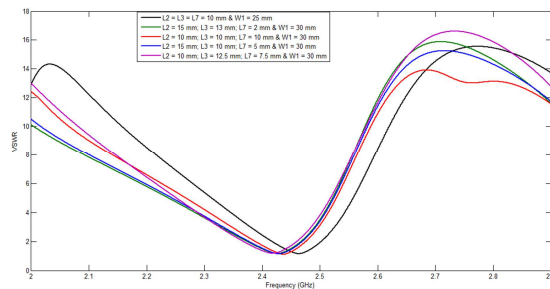


Figure 4: Voltage Standing Wave Ratio For Different Values Of L_2, L_3, L_7 And W_1 In Function Of The Frequency

The results of optimization show that of the reflection coefficients S_{11} at the input of the microstrip patch antenna exhibit a single frequency band for each variation of the dimensions of the slots. Note also that when changing the length and width of the slots, the levels of reflection coefficients successively change, which causes a decrease in the levels of the resonance frequencies found in the whole band considered.

For the dimensions of the slots ($L_2 = 10 \text{ mm}, L_3 = 12.5 \text{ mm}, L_7 = 7.5 \text{ mm}$ and $W_1 = 30 \text{ mm}$), we see that the reflection coefficient reaches a level of -21.54 dB to a resonance frequency of 2.4 GHz with a bandwidth of approximately 4.42. This means that the reflected power is minimal and therefore it will have a positive impact on increasing the level of the power transmitted by the microstrip antenna.

Table 2 below represents the optimization results of the proposed microstrip patch antenna.

Table 2: Optimization Results

Parameters	Frequency (GHz)	S_{11} (dB)	VSWR
$L_2 = 10 \text{ mm}$ $L_3 = 10 \text{ mm}$ $L_7 = 10 \text{ mm}$ $W_1 = 25 \text{ mm}$	2.46	-23.01	$1.15 < 2$
$L_2 = 15 \text{ mm}$ $L_3 = 13 \text{ mm}$ $L_7 = 2 \text{ mm}$ $W_1 = 30 \text{ mm}$	2.44	-23.47	$1.14 < 2$
$L_2 = 10 \text{ mm}$ $L_3 = 10 \text{ mm}$ $L_7 = 10 \text{ mm}$ $W_1 = 30 \text{ mm}$	2.43	-25.47	$1.11 < 2$
$L_2 = 15 \text{ mm}$ $L_3 = 10 \text{ mm}$ $L_7 = 5 \text{ mm}$ $W_1 = 30 \text{ mm}$	2.42	-23.43	$1.14 < 2$
$L_2 = 10 \text{ mm}$ $L_3 = 12.5 \text{ mm}$ $L_7 = 7.5 \text{ mm}$ $W_1 = 30 \text{ mm}$	2.40	-21.54	$1.28 < 2$

4. OPTIMIZATION RESULTS AND DISCUSSION

We present in this section, for comparison, the simulation results obtained using simulators CST and HFSS.

Note that the electromagnetic simulation software CST Microwave Studio is a specialized tool for three-dimensional electromagnetic simulation of high frequency components. It is dedicated primarily to microwave and RF communications such as wireless applications, but also can simulate measures electromagnetic compatibility and electromagnetic interference.

We will proceed by following a series of simulations on the radiation characteristics of the microstrip patch antenna namely: the reflection coefficient, the input and the radiation pattern of impedance in plans E and H.

Table 3 represents the optimized dimensions of the microstrip patch antenna.

Table 3: Optimized dimensions of the patch antenna

Parameters	Values (mm)
L_{sub}	75
W_{sub}	100
L_g	75
W_g	100
L_p	50
W_p	56
L_m	41
W_m	3.8
L_1	30
L_2	10
L_3	12.5
L_4	7.5
L_5	12.5
L_6	19.8
L_7	7.5
W_1	30

4.1. Reflection Coefficient

The first simulation result is the reflection coefficient on the frequency range from 2 GHz to 2.9 GHz. This result is shown in figure 5.

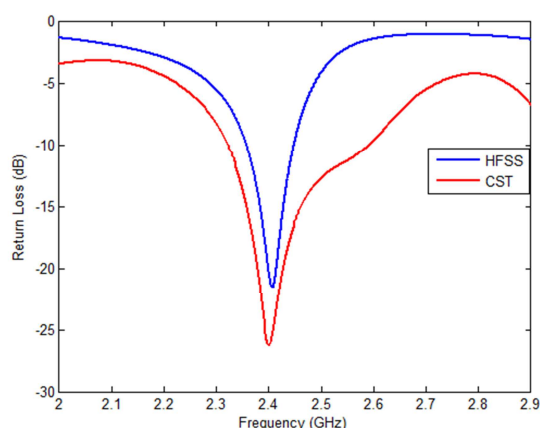


Figure 5: Comparison between parameters S_{11} found by simulators HFSS and CST

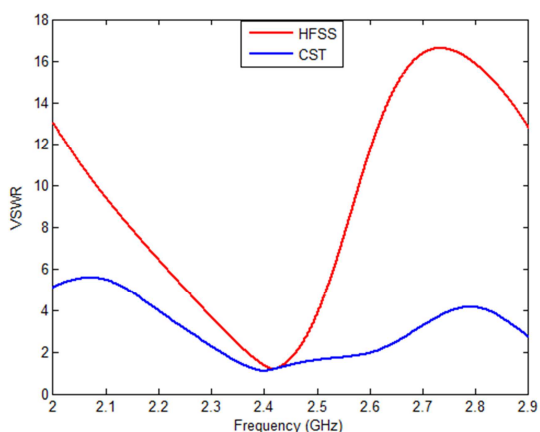


Figure 6: Comparison between voltage standing wave ratio found by simulators HFSS and CST

Table 4: Comparison Of Simulation Results Obtained With HFSS And CST

Simulators	Frequency (GHz)	S_{11} (dB)	VSWR	Bandwidth (%)
HFSS	2.406	-21.54	1.28 < 2	4.42
CST	2.400	-26.27	1.09 < 2	11

It can be observed in figures 5-6 and Table 4, a good agreement between the results obtained by HFSS and by those CST in terms of resonance frequencies, reflection coefficient and voltage standing wave ratio. The difference between the bandwidths is not due to the mesh used in simulation and during the simulation.

4.2. Input Impedance

Impedance matching allows optimizing the transfer of electric power between a source and a load. Figure 7 represents the input impedance of this microstrip antenna.

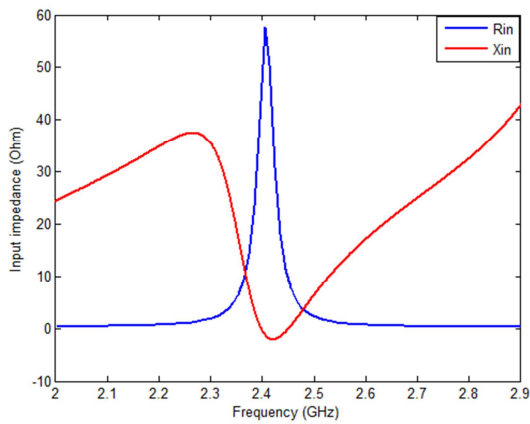


Figure 7: Input Impedance Of The Patch Antenna As A Function Of Frequency

As shown figure 7, the input impedance of the microstrip patch antenna is equal to $Z_{in} = (57.67 - j1.24) \Omega$ at the resonant frequency of 2.406 GHz. Indeed, the input impedance of the antenna has a resistive portion of 57.67 Ω and another reactive of -1.24 Ω at the same resonant frequency of 2.406 GHz, this means that it is suitable for almost source feeding.

4.3. Radiation Pattern

The radiation pattern of the antenna characterizes the variation of radiated power over long distances in different directions in space. Figures 8 and 9 respectively represent the radiation pattern in 3D and 2D at frequency of 2.4 GHz.

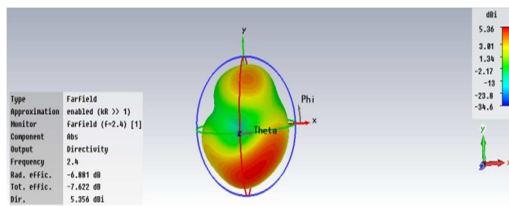


Figure 8: Radiation Pattern Of Proposed Antenna Showing Directivity Of 5.35 Dbi

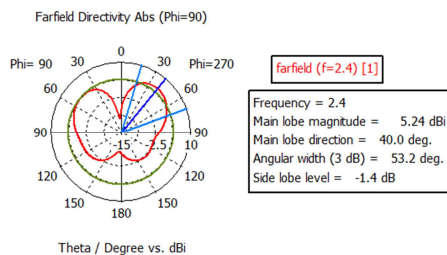


Figure 9: Directivity Of Patch Antenna Alone (Polar View)

The Directivity plot (3D View) represents amount of radiation intensity is equal to 5.35 dBi. The simulated antenna radiates more in a particular direction as compared to the isotropic antenna which radiates equally in all directions, by an amount of 5.35 dBi. From polar plot view of the directivity, it can be seen that at a frequency of 2.4 GHz, directivity is 5.24 dBi, radiation pattern obtained is omnidirectional with main lobe directed at an angle of 40 degree, having angular beam-width of 53.2 degree. The magnitude of the main lobe is 5.24 dBi.

Order to supplement the previous simulations, we propose to introduce the electromagnetic field distribution in the two E and H planes to know the levels of radiation far fields that propagate at the antenna and totaled values $1.26 \cdot 10^4$ V/m for E and 25.6 A/m for H.

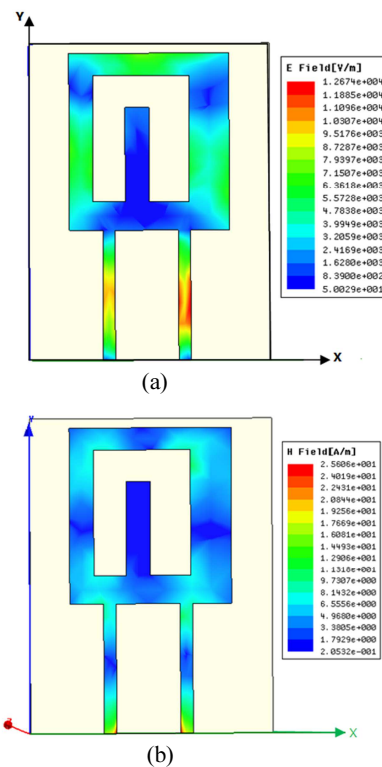


Figure 10: Field distribution, (a) E-field and (b) H-Field

5. CONCLUSION

In this paper, we presented a new structure of microstrip patch antenna and intended for RFID applications.

The results presented throughout this work are optimized in terms of reflection coefficient, VSWR, bandwidth, input impedance and radiation pattern.

The proposed antenna is a simple structure which can be easily manufactured with a low cost. It is a good solution for many wireless applications.

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