Optimization of the Radiation Performances of Square Shaped Patch Antenna for RFID Reader

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Abstract: - The main objective of this work is to optimize the radiation performances of square shaped patch antenna. This antenna is excited by microstrip line having a power port adapted to $50\ \Omega$ and intended for RFID reader. The slots inserted at the edges of the radiating element have a direct and positive impact on improving the radiation characteristics of this antenna in terms of reflection coefficient, voltage standing wave ratio, input impedance and radiation pattern around a resonance frequency of $2.45\ GHz$. The simulation results obtained by the two simulators HFSS (High Frequency Structure Simulator) and CST (Computer Simulation Technology) is almost consistent good.

Key-Words: Square patch antenna, microstrip line, RFID reader, reflection coefficient, voltage standing wave ratio, input impedance, radiation pattern, simulators HFSS and CST.

1 Introduction

Recently, radio frequency identification (RFID) technology has been rapidly developing in many service industries, distribution logistics, manufacturing companies and goods flow systems. The range and the scalability of RFID systems are much dependent on the radio frequency. For RFID reader antenna design, challenges lie not only in having a good impedance matching, low axial ratio, and high gain while also keeping low profile but also in other design constraints such as size and cost [1]. Since the RFID tags are always arbitrarily oriented in practical usage and the tag antennas are normally linearly polarized, circularly polarized reader antennas have been used in UHF RFID systems for ensuring the reliability of communications between readers and tags.

The most common frequencies of RFID technology used are low ($125\ KHz$), high ($13.56\ MHz$), ultra-high ($858-930\ MHz$) and microwave ($2.45\ GHz$ and $5.8\ GHz$) [2]. The UHF and microwave bands are widely used due to their advantages of long read range and high data rate, it is favourable to design a single antenna, which operates on both frequency bands.

An RFID application consists of a reader and a transponder. These two components communicate there between through a transmission constituted by the air channel to provide a radio frequency identification solution without physical contact (figure 1). The data contained in the transponder allow the identification of a single object. These data are transmitted to the reader thanks to transmitting or receiving antennas which are in the majority of patch antennas [3]. The design and realization of these antennas require attention and precision in order to obtain clearly coherent communication.

Indeed, the microstrip antennas have appeared in the fifties and have been developed in the seventies. However, several studies have been conducted to arrive at an optimal microstrip antenna that can meet the requirements of the telecommunications industry for aeronautical, aerospace and military applications. This type of antenna is easily adapted to planes surfaces and non-planes and present high strength and flexibility when mounted to rigid surfaces. The antennas are also very efficient in terms of resonance, input impedance and radiation pattern. The major disadvantages of antennas reside in their low polarization purity, low bandwidth and low gain [4].

Among these antennas, this work focuses on the square shaped patch antennas which are the subject of much research and development in recent years [5-10].

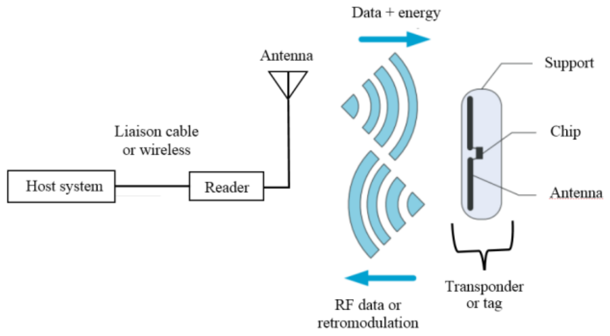

Fig.1 : Functioning of an RFID system [11]

In this work, we propose to design a new structure of square-shaped patch antenna. This antenna is excited by microstrip line having a power port adapted to 50 Ω and intended for RFID reader.

The main objective of this work is to optimize the radiation performances of this antenna in terms of reflection coefficient, voltage standing wave ratio, input impedance and radiation pattern around a resonance frequency of 2.45 GHz.

2 Theoretical Study of Patch Antennas

Conventional patch antennas in general have a conducting patch printed on a grounded microwave substrate and have the attractive features of low profile, low transmission power, light weight, easy fabrication, low cost, minimal equipment and conformability to mounting hosts [12-13]. However, patch antennas inherently have a narrow bandwidth, and bandwidth enhancement is usually demanded for practical applications [13]. The generic patch antenna consists of a planar dielectric substrate material with of a radiating patch on one side and a ground plane on the other. The radiating patch can be shaped in any number of geometries depending on the desired electrical and radiation characteristics of the antenna. The patch is fed against the ground at the appropriate point on or near the radiating patch for desired operation. Common feed methods are the microstrip line, coaxial probe and proximity coupled feeds. The simplest patch antenna consists of a square or rectangular radiator.

For the design of microstrip patch antenna, which is shown in figure 2, various geometry parameters and material parameter have to be determined. As it can be seen from figure, three main design parameters should be calculated, width W, length L and finally extended length ΔL which is used to find effective length L_{eff}. First, width of microstrip patch antennas has been found by equation 1 [14].

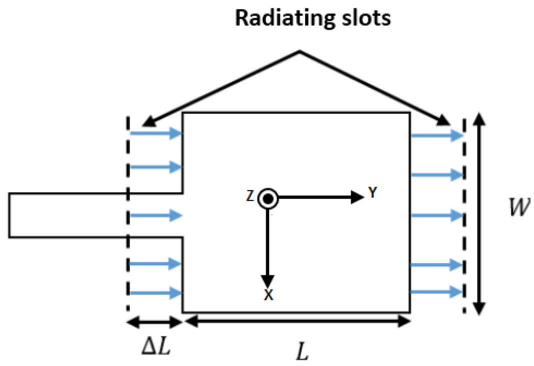

Fig.2 : Microstrip patch antenna [11]

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \tag{1}$$

In this formula, c is the speed of light, ε_r is the dielectric constant of the substrate and f_r is the resonance frequency.

Also, the effective length of the microstrip patch antenna can be calculated by using following equation.

$$L_{eff} = \frac{c}{2\, f_r \,.\sqrt{\varepsilon_{reff}}} = L + 2\Delta L \tag{2}$$

where, ε_{reff} is the effective dielectric constant of substrate, h is the thickness of the substrate and ΔL is given by

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

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+12\frac{h}{W}}}\right] \tag{4}$$

3 Design of Square Shaped Patch Antenna

Throughout this work, we present a modeling and optimization patch antenna around a resonance frequency of 2.45 GHz. This antenna is square shaped linearly polarized and to be integrated into a RFID reader. Before starting detailed modeling of this antenna, we present as a first step the choice of the simulation tool and design methodology that we will adopted.

3.1 Choice of Simulation Tool

A priority of this work is to design and optimize a square shaped patch antenna in microstrip technology to benefit both a small footprint and keep the best characteristics of the antenna from adaptation and gain point of view. For this, we have chosen two tools for simulations with two different methods of calculation, the first is the tool HFSS which is based on the finite element method and the second tool is the CST Microwave Studio which uses the finite integration technique.

3.2 Design Methodology

In a perspective of industrialization, the design of the square shaped patch antenna requires to implement a design methodology which is based on theoretical concepts and passes through several successive steps. Design methodology that we propose is shown in figure 3 below.

3.3 Antenna Base Geometry

Figure 4 illustrates the new patch antenna structure that we have designed. This structure is composed of a square shaped patch, of length $L_p = 41.08\,mm$ and width $W_p = 41.08\,mm$, printed on a substrate Rogers RT/duroid-5880, the relative permittivity of 2.2, the thickness of $1.56\,mm$, the length $L_{sub} = 85\,mm$ and the width $W_{sub} = 50.50\,mm$. The antenna is adapted by a quarter wave line of length $L_{qw} = 24.05\,mm$ and width $W_{qw} = 0.72\,mm$, excited by microstrip line having a power port adapted to $50\,\Omega$, the length $L_m = 15\,mm$ and width $W_m = 4.84\,mm$. The whole is placed on a ground plane of length $L_g = 85\,mm$ and width $W_g = 50.50\,mm$. The square slots inserted at the edges of the radiating element having a width $W_f = 5.3\,mm$ and a length $L_f = 5.3\,mm$, allow to improve the radiation performances of this antenna in terms of reflection coefficient, voltage standing wave ratio, input impedance and radiation pattern.

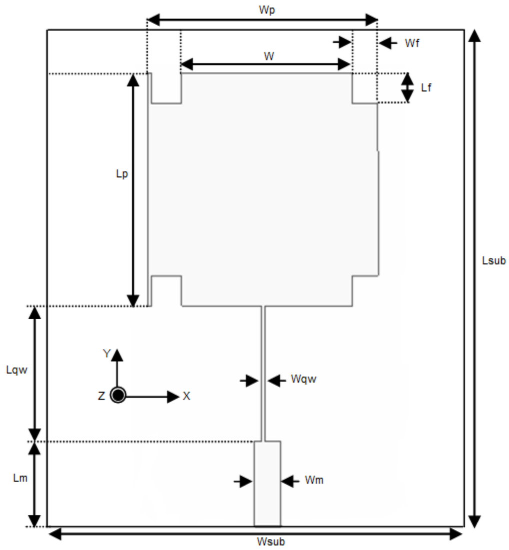

Fig.4 : Geometry of the square shaped patch antenna

Table 1 below shows the dimensions of the square shaped patch antenna.

Table 1: Dimensions of square shaped patch antenna

Parameters	Values (mm)
L_{sub}	85
W_{sub}	50.50
L_{g}	85
W_{g}	50.50
L_{p}	41.08
W_{p}	41.08
L_{m}	15
W_{m}	4.84
L_{qw}	24.05
W_{qw}	0.72
L_{f}	5.3
W_f	5.3
W	29.79

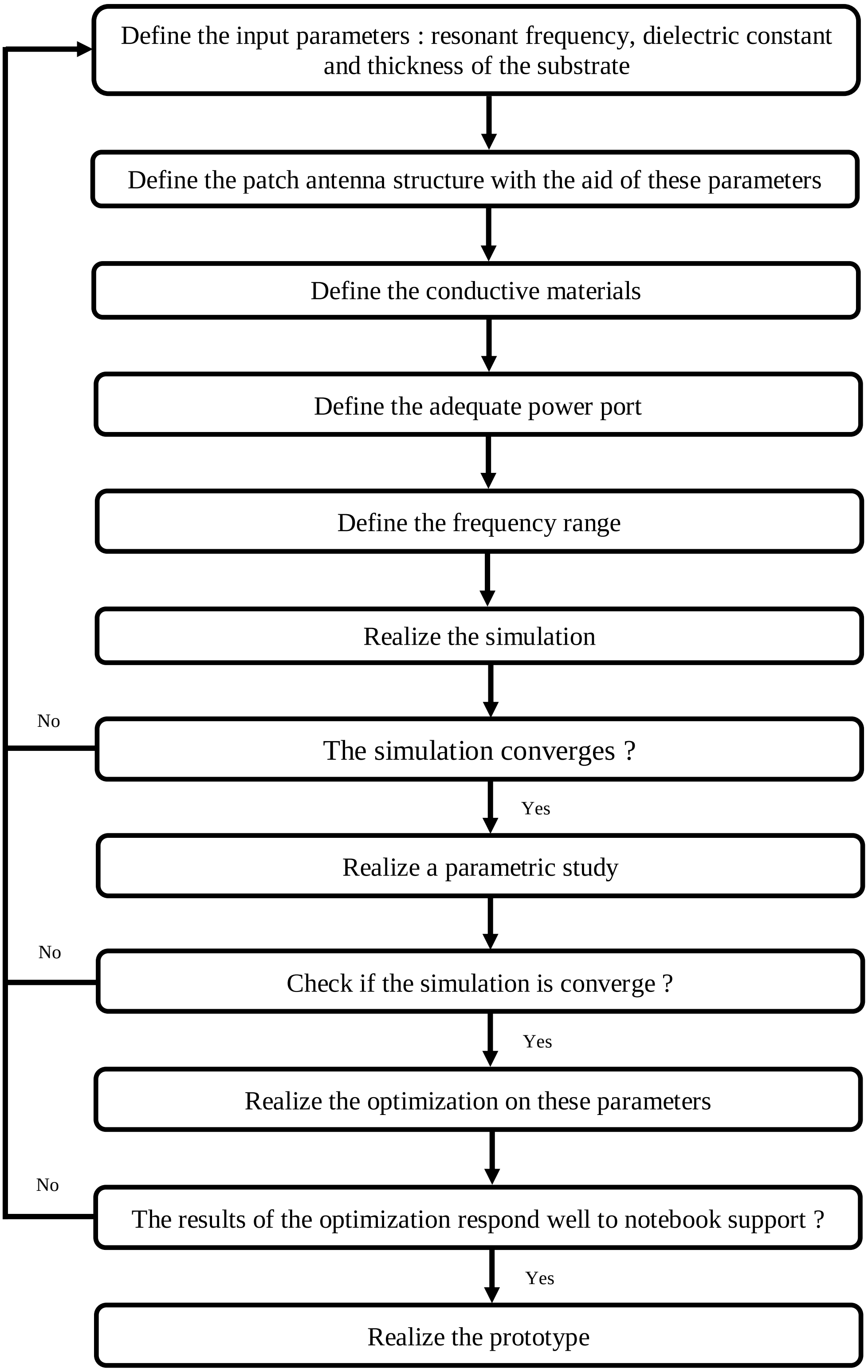

Fig.3 : Design methodology of square shaped patch antenna

4 Results and Discussion

In this section, we present the simulation results obtained in terms of reflection coefficient, voltage standing wave ratio, input impedance and radiation pattern around a resonance frequency of $2.45\ GHz$. These results are shown respectively in figures 5, 6, 7, 8 and 9.

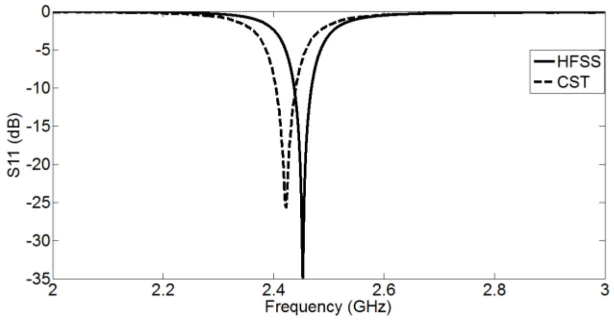

Fig.5 : Reflection coefficient of the square shaped patch antenna

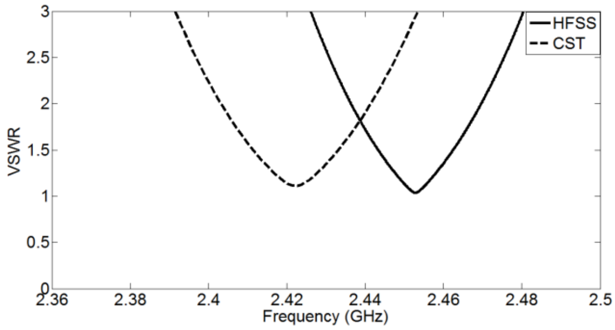

Fig.6 : Voltage standing wave ratio of the square shaped patch antenna

The simulation results obtained by the simulators HFSS and CST are almost similar. The slight difference recorded in terms of levels reflection coefficients, voltage standing wave ratios and resonant frequencies is due to the simulation step and the mesh used for each simulator during the simulation.

The agreement between these results is quantitatively evaluated by the average of the resonance frequency relative error as indicated in Table 2.

Table 2 : Comparison of simulation results obtained by HFSS and CST

Simulators	Freq. (GHz)	$\Delta f_r / f_r$ (%)	S_{11} (dB)	VSWR
HFSS	2.453	0.12	-34.68	1.03 < 2
CST	2.422	1.14	-25.63	1.11 < 2

The measurement of precision criterion (error) is defined as the difference of the resonant frequency on each simulator and the appropriate reference frequency. It is determined by the following formula [11] :

$$\frac{\Delta f_r}{f_r}(\%) = 100.\left[\frac{|f_{ref} - f_{simulation}|}{f_{ref}}\right] \quad (5)$$

where, f_{ref} is the resonant frequency of the fundamental mode of our work which is equal to $2.45\ GHz$.

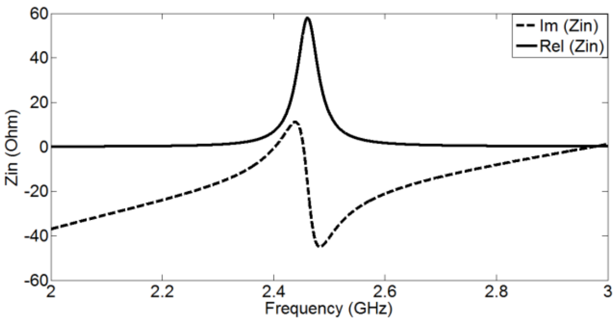

Fig.7 : Input impedance of the square shaped patch antenna

As shown in figure 7, the input impedance of the square shaped patch antenna is equal to $Z_{in} = (50.89 + j0.04)\ \Omega$ for a resonant frequency $2.453\ GHz$. This means it is well adapted to the power source.

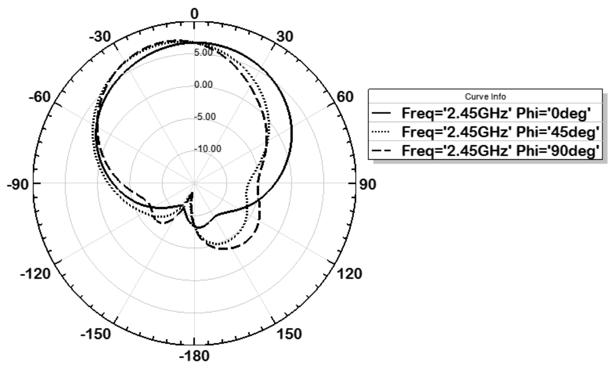

Fig.8 : Radiation pattern of the square shaped patch antenna on the E-plane

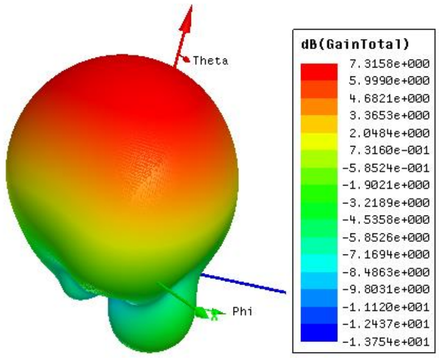

Fig.9 : Radiation pattern 3D of the square shaped patch antenna

We find that the gain of the square shaped patch antenna reaches a maximum value of 7.31 dB for a resonance frequency 2.45 GHz. This result is acceptable to ensure the proper functioning of this antenna.

5 Conclusion

In this work, we have focused on a design methodology and optimization of square shaped patch antenna linearly polarized. This methodology has allowed us to improve the radiation performances of this antenna from adaptation and gain point of view around a resonance frequency of 2.45 GHz.

In perspectives, we are considering to realize our prototype patch antenna in order to validate its performances with experimental measurements. The performances of this prototype antenna from gain point of view could be exploited for the design of antenna arrays to an RFID reader preserving the same patch element optimized in this work for to increase the gain thus that the scope of detection of objects porters passive RFID tags.

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