A Circular Polarization RFID Tag for Medical Uses

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***Abstract*—The aim of this paper is to present Radio Frequency Identification (RFID) Tag. The use of this kind of antennas in the medical field has a great importance in making people's life easier and improving the way to get medical information. This article is dedicated to explain the details of the method used to obtain the circular polarization using a shaped cross slot. A simulation study with the SAR values is performed to obtain an idea about the effects of the electromagnetic waves. In this study, a specific diode pin CPINUC5206-HF has been used in order to obtain a high frequency (3 GHz). Two fabrication methods have been adapted: the printed circuit board method (PCB) and metal cutting through laser ablation method (MCTLA). A comparison study between the two methods has been also conducted.**

***Keywords*—Radio Frequency Identification (RFID); circular polarization; metal cutting through laser ablation method**

I. Introduction

RFID is an innovative technology that can be used to identify a person or an object and track tags attached to objects using electromagnetic fields. The RFID antenna uses a radio frequency to read information from a small device called tag which contains information stored electronically [1] and [2]. Compared to bar-code, the RFID system represents many advantages, such as remote communication, high safety and an important mass information processing. That is why this technology has been quickly developed in the few recent years [3] and has become one of the most useful technologies in the medical applications [4, 5, 6]. To be able to monitor his own health status, the patient needs a practical device like the wearable mobile medical monitoring which is increasing quantities in the economic market [7].

As a matter of fact, the use of RFID technology in medical applications can offer patient tracking, safe guarding [8] and even physiological monitoring [9]. According to the advancements in the field, the RFID technology is used whether as a standalone system or in combination with other wireless technologies [10]. Various factors are considered for wearable medical instruments such as, performance, design and the safe use on the human body. Many researchers are also studying the ability to use wearable medical instruments and health-monitoring systems [11]. According to [12] and-[13], radio frequency (RF) engineers have developed wearable antennas in many forms, for example wristbands or attachments to clothing. In order to obtain wearable antennas, the radiation pattern reconfigurable antennas, which have many advantages like the ability to adjust beam directions [11] can be used.

According to [14] and [15], there exists a switching technique that helps to adapt the beam directions. For this reason, many switches such as pin diodes and FET switches have been used. Beam-steering techniques are realized by using different structures [11]. The examples [16] and [17] present antenna using double loops and folded dipoles. The presence of beam-reconfigurable antennas in the domain of wearable antennas can help to improve this field especially in the use of communication systems [11].

The present paper depicts the realization of a radiation-pattern reconfigurable antenna to be used in medical applications [2]. According to [11], the performance of the antenna is improved after adding beam-switching skills. This study compares two antennas with the same method to obtain the circular polarization (having an arrow shaped cross slot [1]), yet with two different methods of fabrication, namely the ordinary PCB method and the MCTLA method. In addition, the paper presents the antenna return loss, the directivity and the specific absorption rate (SAR) results. The antenna performance and the specific absorption rate simulation results help to have an idea about whether the electromagnetic waves have a negative effect on the human body [11].

The goal of the present study is to have a CP (circular polarization), which helps to reduce the loss of polarization misalignment between the signals of transmitter and receiver antennas [18]. The polarized antenna is used, in different systems, to reduce the multi-pass effect between the transmitter and receiver antennas.

Also, there exist, the systems of wireless data links and radar [19]. Many techniques and shapes of micro strip antennas such as: log spiral [19], spiral antenna for wide bandwidth [20] and corner truncated ground for narrow band application [21], have been used. The spiral shape and truncate forms of the patch, in these methods, control the current distribution on the surface of the antenna, with the aim of achieving the CP [19-21]. In this study, the raison to obtain a circular polarized patch antenna is to benefit from its various advantages such as: low cost, light weight, ease of integration and compatibility [22].

In the present paper, a proposed RFID TAG is studied and simulated using CST with the aim of converting a linear polarized antenna to circular one.

This study took into consideration that the SAR value shall be acceptable and not exceed the limit value in order to guarantee a safe use in medical field and to ensure an acceptable rate of axial ratio necessary to prove the circular polarization existence.

During this research, two fabrication methods were done and are represented in the following sections: the first is the PCB method which is the most used in antenna manufacturing while the second is the MCTLA which is not well known in this field but it gives a more flexible antenna, more comfortable and more suitable for medical use.

II. Antenna Design

In [11], three proposed antennas have been proposed and presented with different theta angles 30, 90 and 150 degree. Every antenna consists of a monopole and a loop antenna, where the loop is opened at the point of contact with the pole. Two p-i-n diodes have been used as switches in an open circuit [11]. In addition, a pole is loaded on the top of the monopole, which is referred to as top loading [11]. The two main reasons behind the use of the top of the monopole are realizing the antenna miniaturization and controlling the beam direction by changing the angle (30°, 90° and 150°) of the top .Based on the theta angle , both sides of the top-loading poles are bent [11]. The simulation results are acceptable for theta 30 and 150. That's why this study has been conducted using these two angles. Fig. 1 presents the antennas design for theta 30 and 150. There are two states and two switches in case 1, the switch 1 is in the ON state while the switch 2 is in the OFF state, with the voltage measured at 1.2 v. Case 2 is exactly the opposed of case 1,where the switch 1 is in the OFF state and the switch 2 is in the ON state [11].

As a first step of this study, the dimensions of antenna were modified with conservation of the same design. The cases of theta (30) and theta (150) yields acceptable results.

The schematic diagram of the PIN diode connections is shown in Fig. 2. The Vc is a DC voltage, which is the control voltage of the switch. It is obtained by using a battery of 1.2V and can be valued at +1.2 or -1.2 following the direction of a battery connection. The RF signal Vs is connected through a DC block to protect the RF measuring device [23]. The antenna consists of a loop and a fire where the loop behaves as a folded dipole and the open wire as a reflector [24]. The use of a reconfigurable antenna can control a beam in the direction where the strength of the signal is stronger or in a direction that can avoid noise sources [25, 26].

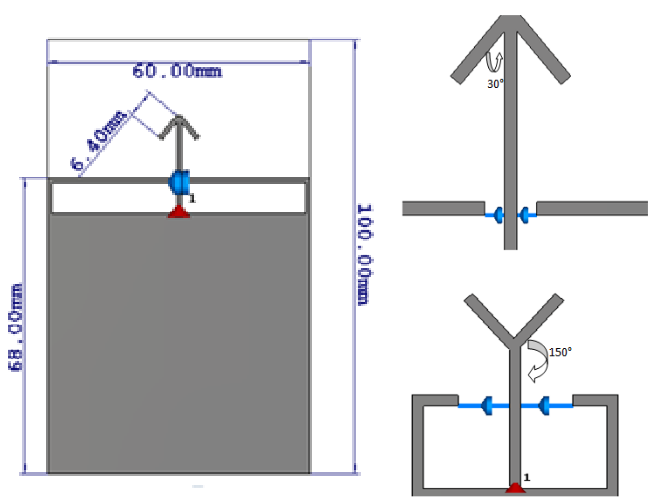

Fig. 1. Geometry of the Linear Polarization Antennas.

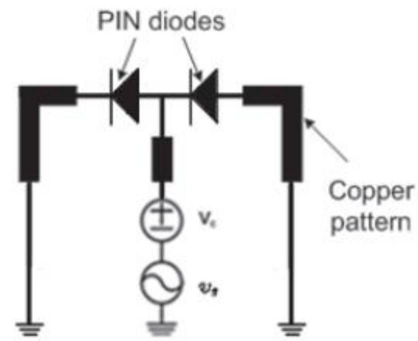

Fig. 2. Schematic Diagram of the PIN Diode [23].

Fig. 3 shows the antenna return loss of the three proposed simulated antennas in the two cases: case 1 and case 2. As shown in Fig. 3, there is a little deviation in the results and there is no big difference between the two cases.

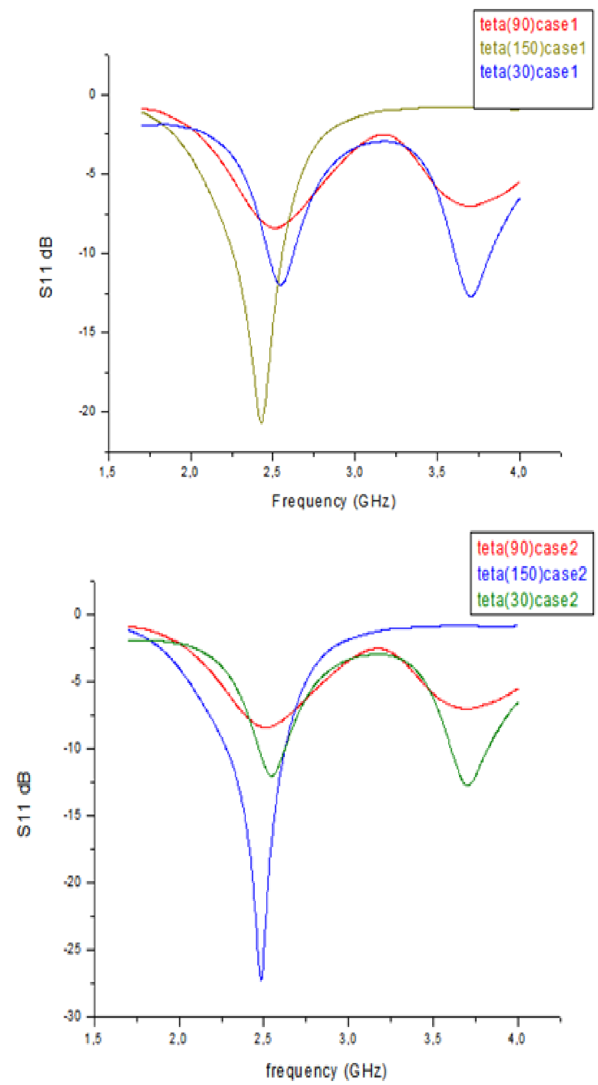

Fig. 3. Simulation's Results of the Proposed Antennas. (a) CASE1 (b) CASE2.

The return loss of the antenna in case1 depend on the theta angle .When the theta angle is equal to 150°, the resonant frequency is valued at 2.47GHz and when the theta angle is 30°, the resonant frequency is measured at 2.53 GHz and 3.7GHz. Fig. 3(b) presents the return loss depending on the theta angle 150° and 30° for case2. In this case, the resonant frequency is 2.5 GHz and 3.68 GHz for the (30°) degree angle and 2.5GHz for the (150°). At the beginning; the study should be based on an antenna with a linear polarization (which is the case here), then circular polarization study is conducted. According to the simulation results, both theta angles of 30° and 150° yields acceptable results.

For the rest of this study, theta angle was fixed at 30° since this value gave the best results.

Fig. 4 reveals that the antenna directivity is measured at 4.47 dBi for a frequency of 2.45 GHz and the energy distribution is located in the plan y. Fig. 4(b) presents the beam main lobe direction which is 149 degrees with a beam width of 52.1 degrees.

Fig. 5 presents the method used following [27] to obtain the circular polarization. The design of the slot is presented in [27].

The antenna is simulated when the theta angle is equal to 30°. From the feed line, the patches are capacitive and coupled. An arrow shaped coupling slot is used here to provide the ground plane. The arrow shaped coupling slot with an angle of 45° is inclined with the upper cross slots [27].

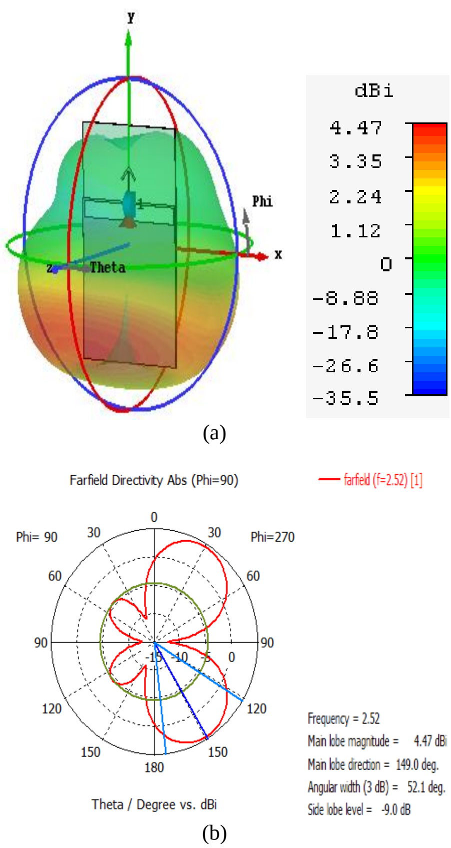

Fig. 4. 2.52 GHz Radiation Pattern (a) 3D Antenna Directivity (b) Polar Slot of the Antenna.

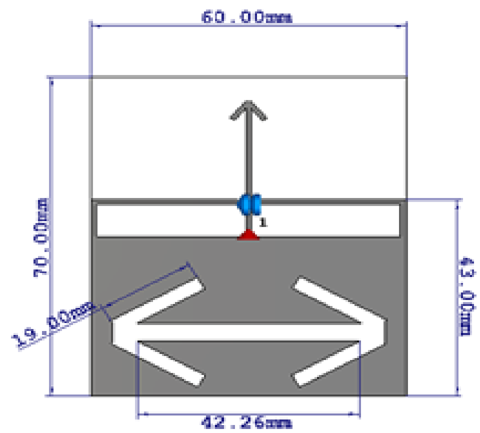

Fig. 5. Geometry of Circularly Polarized Patch Antenna.

The dimensions of the coupling slot are shown in Fig. 5. The coupling slot is selected to be narrow and is etched on the ground plane [28].

Fig. 6 presents the antenna which is fabricated with the PCB method and consists of: the FR-4 substrate. The pin diode CPINUC5206-HF is used as a switch, and a SMA connector is deployed to obtain 50ohm.

In the present study, an antenna is designed with two fabrication techniques the PCB and MCTLA methods [29].

The use of these methods helps to get a flexible antenna which can be useful in the medical field. Fig. 7 presents the fabricated antenna. To design this latter, in this method there are few steps to follow.

The dimensions of a small piece of ceramic covered with the scotch are first fixed. Second, the liquid silicone is mixed with n. Heptan by using two syringes for fifty times as shown in Fig. 9. After that a machine called (Laurell spin-coater) shown in Fig. 8 is used, to distribute the mixture on the ceramic plate.

Then the procedure is repeated for 3 times, and each time with 6 mm of solution. In the end, the metal stainless steel (strainless stell), on which the dimensions of the patch antenna will be fixed using the laser set up machine is added.

Fig. 6. Fabricated Antenna with PCB Method.

Fig. 7. Antenna manufactured using Laser Method.

Fig. 8. The Laurell Spin-Coater Machine.

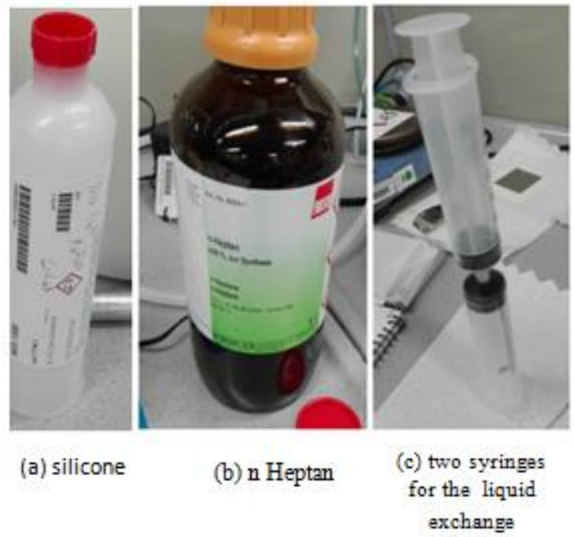

Fig. 9. The Substrate Liquid Constituted of Silicone with n.Heptan.

III. Results and Analysis

A. Simulation Results

1) Pre-incorporation of the human phantom: The simulated return losses (S11) of the antenna are shown in Fig. 10. A resonant frequency of 3.07 GHz is found with an attenuation of - 23.39 dB and a bandwidth band of 82 MHz.

As shown in Fig. 11(a), the directivity is valued at 4.39 dBi and the energy distribution is localized in the Z+ plan where there is the slit with an arrow form. The beam main lobe direction for the proposed antenna is 10 degrees with a beam width of 94 degrees as shown in Fig. 11(b).

In order to validate the circular polarization of the designed antenna, the axial ratio shall be identified based on a CST simulation. Fig. 12 presents the axial ratio result, which is acceptable in the frequency range between 3.06 GHz and 3.11 GHz (in a frequency band of 41.2 MHz).

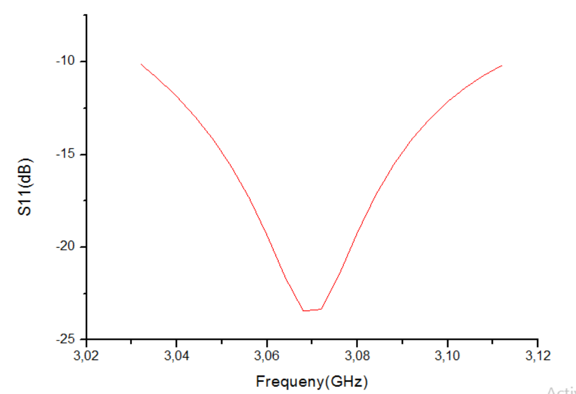

Fig. 10. Reflection Coefficient S11 of the Designed Antenna before Incorporation of the Phantom.

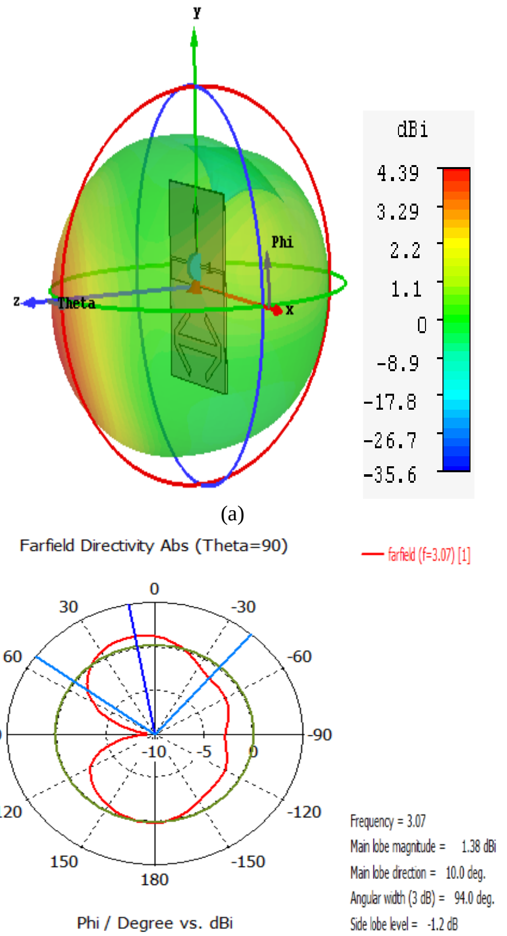

Fig. 11. 3.07 GHz Radiation Pattern (a) 3D Antenna Directivity (b) Polar Slot of the Antenna.

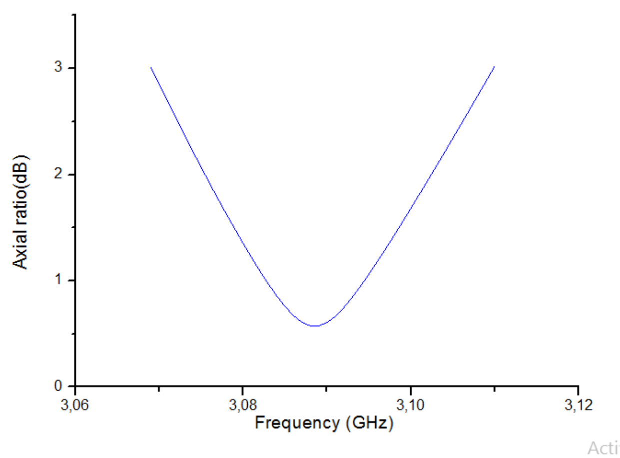

Fig. 12. The Antenna' Axial Ratio before Incorporation of the Phantom.

2) Post-incorporation of the human phantom: Fig. 13 presents the constituent of the human phantom. The incorporation of the antenna in the human phantom is done using the CST microwave studio. As shown in Fig. 13, the human phantom consists of: skin of: 2mm (εr=40, Ϭ=1.3) [31], fat of 10mm (εr=5 ,Ϭ=0.06) [31], muscle of 15mm (εr=55 ,Ϭ=1.14) [30]. In this case, a pin diode CPINUC5206-HF is used to get a high frequency (3 GHz), which can help to have an idea about whether this frequency is useful in the medical application. The (Specific Absorption Rate) SAR, which is defined as the rate at which energy is absorbed per mass unit of body tissue [31], can vary from one law to another , the local SAR should not be superior to 2 W/kg in 10g of tissue in the European standard [31].

The antenna resonant frequency is valued at 3.07 GHz with an attenuation of-23.99dB as shown in Fig. 14. In addition, the bandwidth band is measured at 102.3 MHz which is a widened one.

As shown in Fig. 15, an acceptable axial ratio from 3.057 GHz to 3.089 GHz (in a frequency band of 32 MHz) is obtained, which confirms the obtain ability of a circular polarization.

Fig. 16 presents the antenna directivity measured at 5.39 dBi. The above mentioned figure shows also an interesting energy distribution in the position of the slits in the Z+ plan in the two side lobes. Fig.16(b) presents the beam main lobe direction which is valued at 0.847 degree with a beam width of 222.1 degrees.

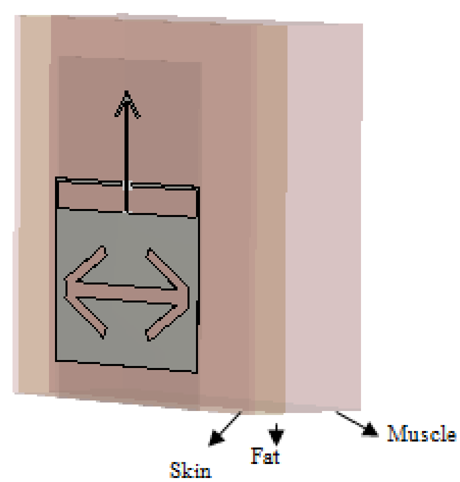

Fig. 13. The Compositions of the Phantom.

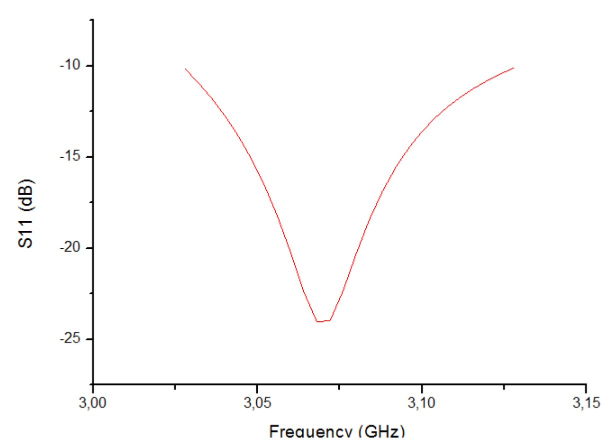

Fig. 14. Reflection Coefficient S11 of the Designed Antenna after Incorporation of the Body Phantom.

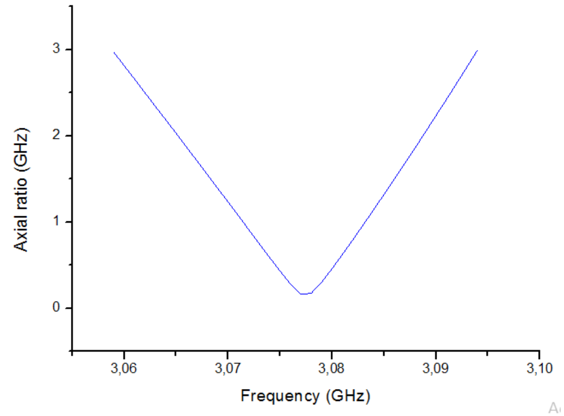

Fig. 15. The Antenna' Axial Ratio after Incorporation in the Phantom.

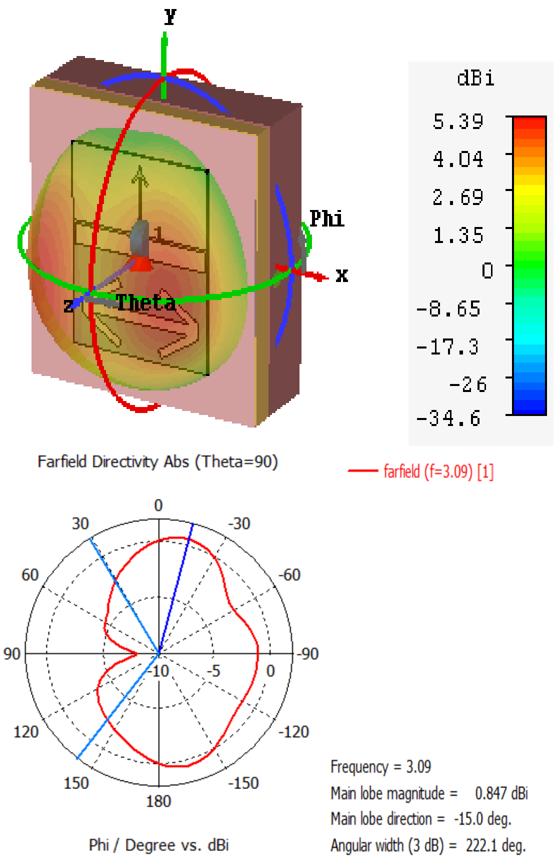

Fig. 16. 3.07 GHz Radiation Pattern (a) 3D Antenna Directivity (b)Polar Slot of the Antenna

As shown in Fig. 17, a value of 1.16 w/kg is obtained in a frequency of 3.07 GHz, which is acceptable according to the European standards.

3) The comparative study according to simulation results: Table I compares the simulation results of the initial antenna and the proposed antenna, where an improvement of 30% for the width and 100.9% for the return loss is noted.

Table II presents a comparison between the results before and after implantation, where an increase in the directivity (from 4.39dBi to 5.39dBi) and in the bandwidth band (from 80 MHz to 102.8 MHz) is noticed, which offers in turn an improvement of 28.25% and 22.77%, respectively.

B. Realization Results

1) The PCB fabrication technique (Printed Circuit Board): Fig. 18 presents a resonant frequency of 3.1GHz for the fabricated antenna (PCB method), with an attenuation of -15.4 dB.

A small deviation was noted while comparing the PCB fabricated antenna with the simulated one which has a resonant frequency of 3.07 GHz.

This deviation is mainly due to experimental procedure.

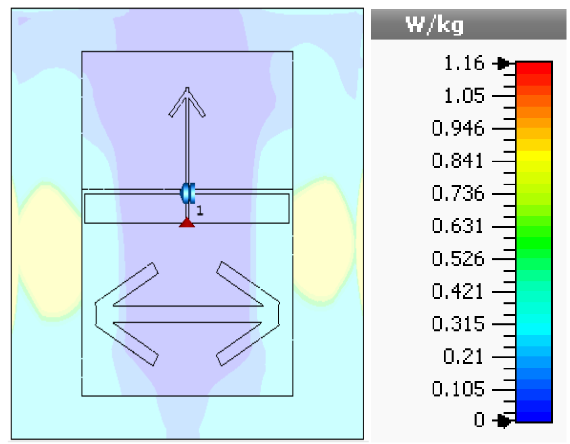

Fig. 17. Antenna's Resulted SAR.

TABLE. I. COMPARISON BETWEEN THE INITIAL ANTENNA AND THE DESIGNED ANTENNA

	Comparison Results		
Antenna paramaters	***Initial antenna***	***Proposed antenna***	***The improvement of proposed antenna over initial antenna***
Width	100 mm	70mm	30%
Return loss (S-parameter)	-11.64	-23.39	100.9%
polarization	Linear	Circular	-

TABLE. II. FREQUENCY RESULTS BEFORE AND AFTER INCORPORATION OF THE BODY PHANTOM

	The improvement percentage		
	Before Incorporation of body phantom	*After incorporation of body phantom*	*The improvement*
Bandwidth	82 MHz	102.6 MHz	25.12%
Directivity	4.39 dBi	5.39 dBi	22.77%

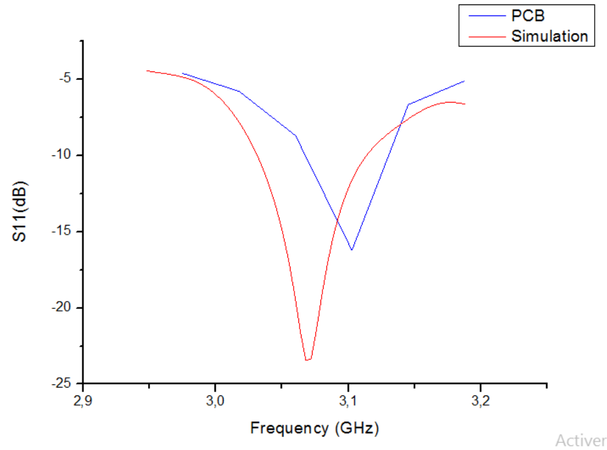

Fig. 18. Reflection Coefficient Comparison between PCB Method and CST Simulation Results.

2) The Metal Cutting Through Laser Ablation Fabrication Technique (MCTLA): Fig. 19 presents a resonant frequency of 3.3 GHz for the designed antenna, with an attenuation of -17.8 dB. Compared to the simulated antenna, we can confirm the similarity in results with a little deviation because of the realization procedure and the difference of the materials used in the manufacture.

3) Analysis of frequency results: Table III presents a comparative analysis of the frequency results; where, there is a similarity between the simulation result and the PCB result. But, a small frequency deviation in the laser result is noted, which can be caused by the use of different compositions (the liquid silicon, the n heptan and the metal stainless steel) in the laser.

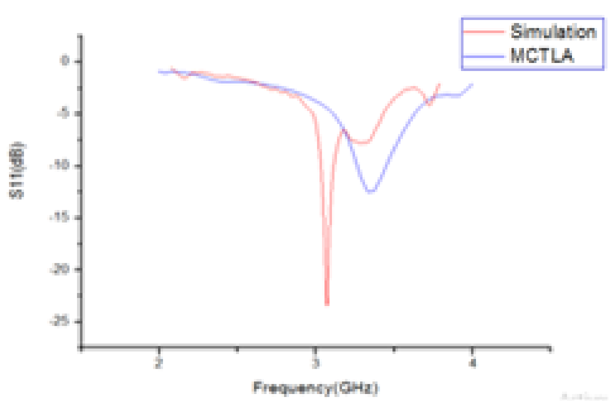

Fig. 19. Reflection Coefficient Comparison between PCB Method and MCTLA Simulation Results.

TABLE. III. THE FREQUENCY COMPARISON

Frequency Comparison Results			
	Simulation	***Realization***	
		PCB	***MCTLA***
Frequency	3.07 GHz	3.1GHz	3.3 GHz

IV. CONCLUSION

In this paper, a circular polarization was obtained by inserting an arrow shaped slot to an antenna initially designed with linear polarization. The simulation results were then noted and analyzed and the fabrication of antennas were made using two different methods. A comparison study was later made between simulation results and manufactured antenna's performances in order to assess any potential difference. The latter revealed that the SAR has an acceptable value even with the use of pin diode with a high frequency (3 GHz). The use of the metal cutting through laser ablation method can help to have a flexible antenna, which is suitable for the medical application. The simulation results and the realization ones are almost equal. Finally, the safety of the antenna use is valorized with the SAR value.

Since the obtained results are acceptable and the SAR is within the admissible values, the next step in the research will include the miniaturization of the antenna's dimensions with the use of more flexible substrate in order to ease the use of the antenna and make it effective, comfortable and easy marketed.

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