Design of a Miniaturized RFID Antenna Integrated with Sensor for Wireless Agricultural Applications

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Abstract— **in this paper, designs of an RFID-enabled tag antenna as well as two other miniaturized antennas are proposed for wireless sensors for agricultural applications, all of which are based on patch antennas around the resonant frequency of 2.45 GHz. With the use of the simulation tool CST MWS, these antennas were designed and optimized. They allow not only the integration of a microchip but also of a sensor commonly used in the agricultural field such as a humidity/temperature sensor.**

Keywords- RFID, miniaturized antenna, slot antenna, wireless agricultural applications, RFID-enabled sensor.

I. INTRODUCTION

For the past few years, RFID- enabled automatic identification has become a very interesting technology finding ever increasing application in different industries like supply chain tracking, retail stock management, libraries, space, healthcare, anti-counterfeiting [1]...

RFID is a means of storing and retrieving information through electromagnetic transmission. Besides its main function, RFID is able to give information about the surrounding environmental conditions even the condition of the object it is attached on. RFID technology is widely used in different applications and when it is combined with sensing abilities, its applications can be extended to bio-monitoring. RFID are a very interesting choice due to the tags' miniaturized size, low profile and easy fabrication [2].

II. ANTENNA DESIGN AND SHAPE

A. Antenna geometry and sructure

Various studies have exploited the patch antennas. There are different analytic models that allow calculating the different dimensions of the patches of rectangular, circular and triangular shape [3] [4].

The proposed antenna was inspired by a study realized in [5] [6]. It was modified so as it can allow for the close of a chip and a sensor. The substrate used with this structure is the *polyethylene* of dielectric constant ε_r = 3.9 and los tangent δ=0.003.

The first proposed antenna is shown in Fig.1 and the table 1 contains the dimensions of the patch.

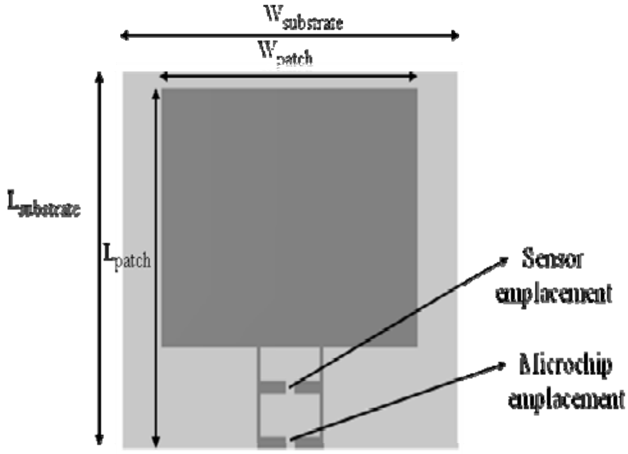

Fig. 1: RFID antenna patch geometry.

TABLE I. Patch Dimensions

Parameter	*Dimension(mm)*
$W_{substrate}$	100
$L_{substrate}$	90
W_{patch}	80
L_{patch}	83

B. Simulation and optimization

To evaluate its performances, numerical simulations were carried out using CST MWS. The following figures show its performances.

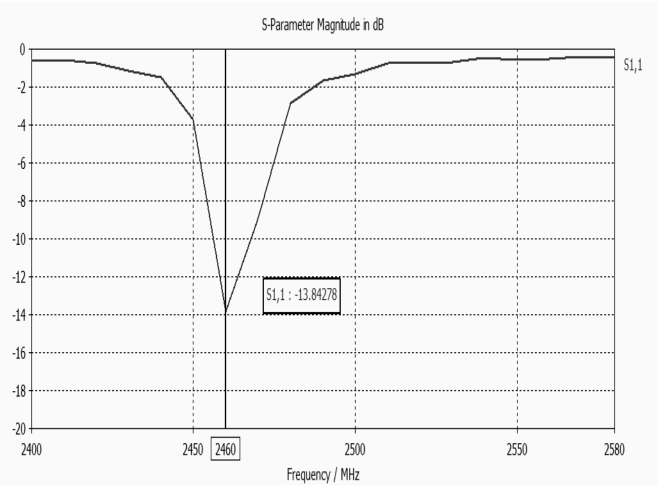

Fig. 2: Return Loss S_{11}.

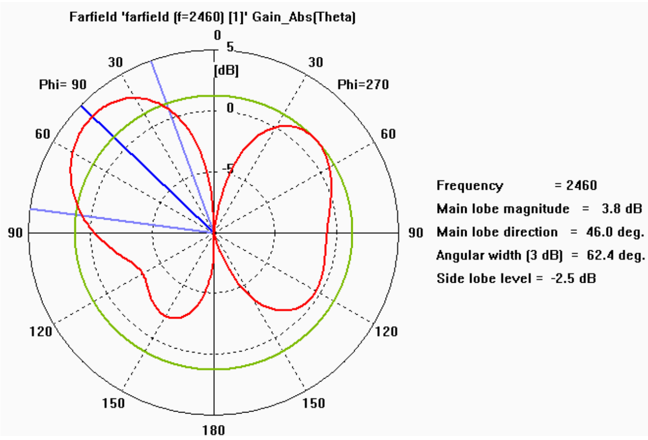

Fig. 3: Radiation pattern in H-plane.

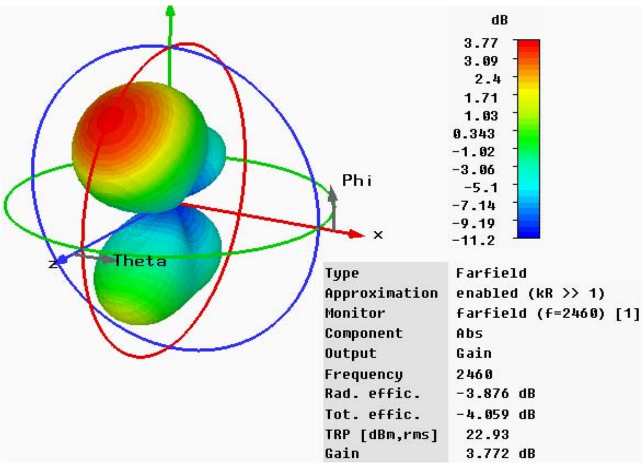

Fig.4 : 3D radiation pattern.

We notice that we have got a Return Loss S_{11} of -13,8dB and a butterfly shape radiation pattern with a gain of 4.7 dB. This value of gain is considered acceptable because the communication between tag-reader relies on the power of the RFID reader antenna.

The proposed antenna features an acceptable performance, but in order to be applicable for practical RFID tags, its size has to be significantly reduced as shown in the next section.

III. The Miniaturized Antennas

To miniaturize the above antenna, we initially introduced two slots within the patch antenna as shown in Fig.5. These slots aim to reduce the size of the tag antenna with a shift in the resonant frequency. To rectify this lag, it is possible to change the dimensions of the patch to control the resonant frequency and to get it back to 2.45GHz [6] [7].

A. Miniaturized antenna shape with two U-shape slots

As we have mentioned before, this antenna will include slots in its structure. There are mainly two slots of U-shape like it is shown in Fig. 5

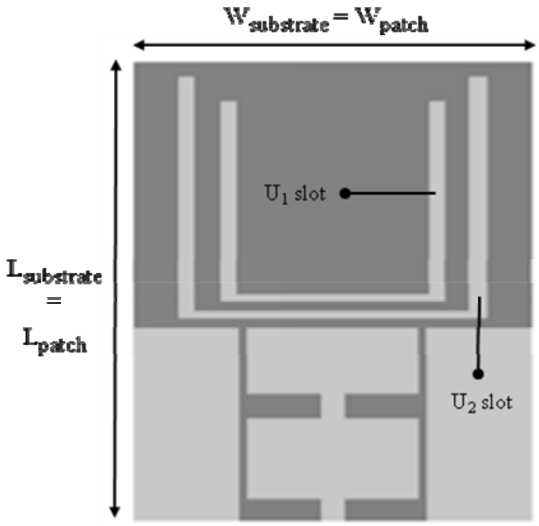

Fig. 5: Miniaturized antenna with two U-shape slots.

The new dimensions are gathered in *Table II* below.

TABLE II. U-Shape Slots Antenna Dimensions

Parameter	***Dimension(mm)***
$W_{substrate}$	46
$L_{substrate}$	57.1
W_{patch}	46
L_{patch}	57.1
W_{U1}	35.6
L_{U1}	29.05
W_{U2}	26
L_{U2}	25

The results of the miniaturized antenna simulations such as Return Loss S_{11}, radiation pattern and 3D radiation pattern are illustrated in the following figures.

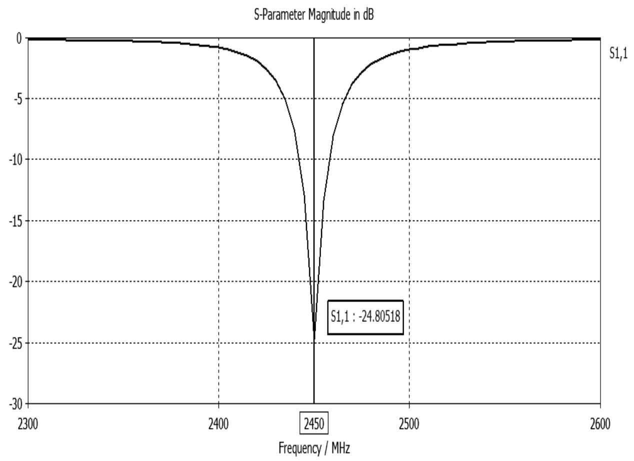

Fig. 6: Return Loss of the U-shape slot antenna.

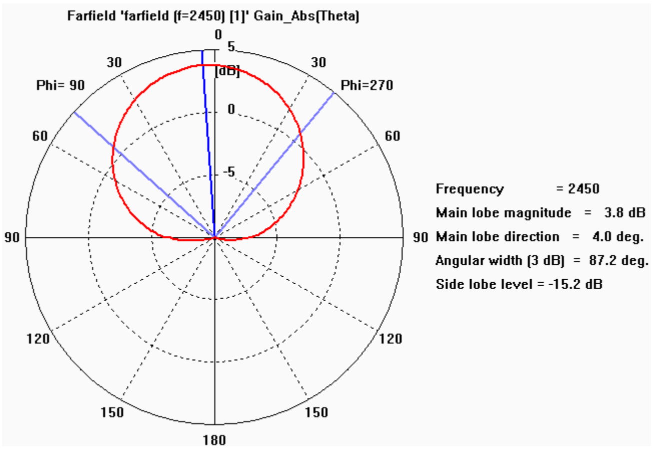

Fig. 7 : Radiation pattern of the U-shape slot antenna in H-plane.

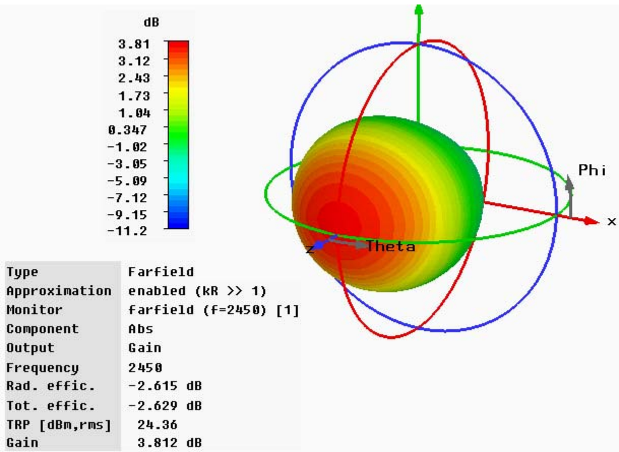

Fig. 8: 3D radiation pattern of the U-shape slot antenna.

These simulations show that the miniaturized antenna has a better return loss with -24,8 dB at operating frequency and in this case the radiation pattern becomes omnidirectional. The new gain is 3.8 dB.

B. *Miniaturized antenna shape using the Snake-shape slot*

The second miniaturized antenna has also two slots. The outer slot has a U form and the inner slot has a Snake form as it is illustrated in the following figure.

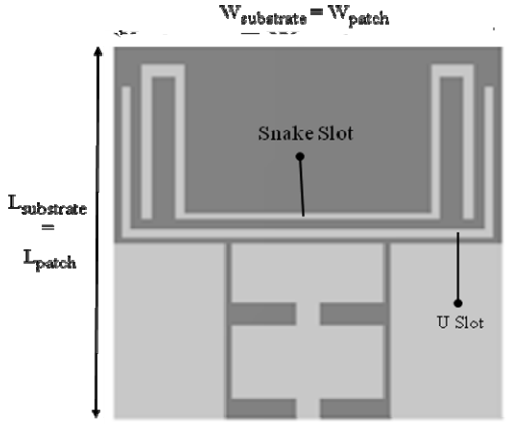

Fig. 9: Miniaturized antenna with Snake and U-shape slots.

The dimensions of this antenna are gathered in the table below.

TABLE III. Dimensions of the antenna with Snake and U-Shape slots

Parameter	***Dimension(mm)***
$W_{substrate}$	46
$L_{substrate}$	50,75
W_{patch}	46
L_{patch}	50,75

The new dimensions, as shown in *TABLE III*, are smaller than those of the previous antennas. To make sure that this antenna is better, we are going to look closely to the following simulation results.

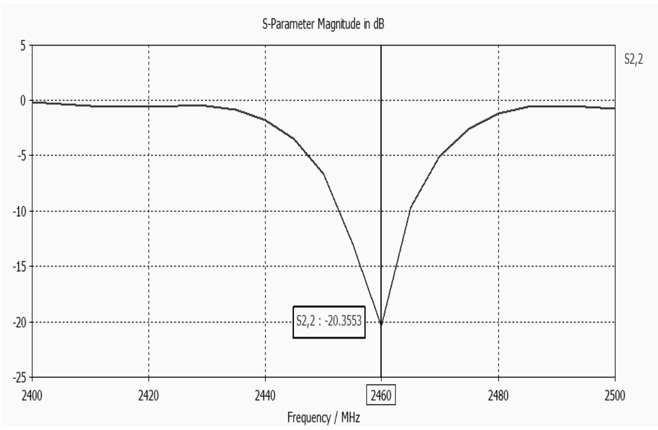

Fig. 10: Return Loss S_{11} of the miniaturized antenna with Snake-Shape slot.

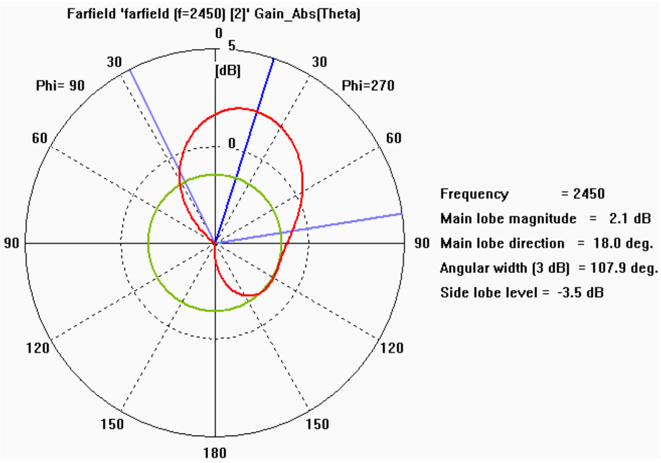

Fig. 11: Radiation pattern of the miniaturized antenna with Snake-shape slot in H-plane.

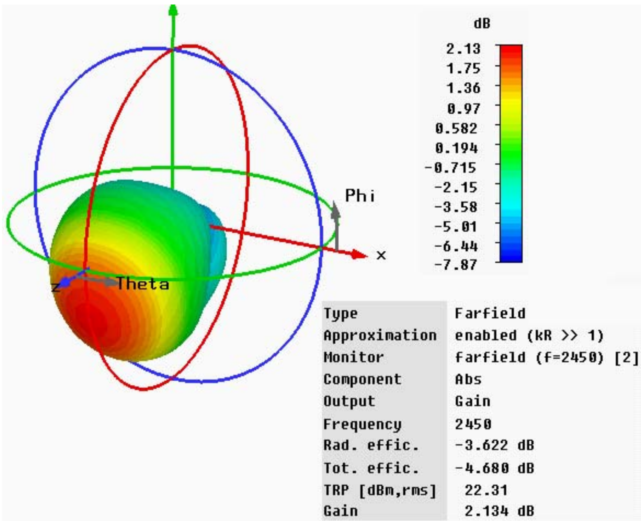

Fig.12: 3D radiation pattern of the miniaturized antenna with Snake-shape slot.

This is an excellent candidate antenna for tree-mounted sensors as the radiation is pointing outwards and away from the ground, thus potentially maximizing the communication range with the reader. Although this antenna has reduced the size compared to the two previously antennas. Its Return Loss S_{11} is around -20.35dB and its gain is equal to 2.13dB. The limited gain value is due to the presence of a big number of slots.

We can summarize the different results in the *TABLE IV* as follows.

TABLE IV. Comparison between the three studied antenna structures

Antenna type	*Dimensions (mm)*	*Return Loss (dB)*	*Gain (dB)*
non-miniaturized antenna	100 x100	-13.84	4.761
Miniarurized antenna with two U-Shape slots	46 x 57,1 (≈51%)	-24,8	3,812
Miniaturized antenna with Snake and U-Shape slots	46 x 50,75 (≈50%)	-20,35	2.13

IV. CONCLUSION

In this paper, we have presented various patch-based antenna topologies for RFID-enabled sensors for agricultural applications.

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