Multi-band UHF RFID Reader Antenna Design

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Abstract. In this paper, we presented RFID multi-band reader antenna design that is worked in four UHF standard bands to cover all around the world RFID classification frequencies. This design works practically as a circular polarization so it will decrease the tag polarization disadvantage to the minimum effect. In this design, we found that this antenna design works in all the following frequencies (865 - 868 MHz (Europe), 902 - 928 MHz (US and Australia), and 2.4 - 2.4835 GHz (across the world). This antenna is structured as a question mark shape radiating element with modifications. Such as a small half of a circular shape was added to the design to approve multi-band resonance. The antenna was partially grounded, so it doesn't cover all the radiators underneath. Good results were achieved with an improvement and acceptable values of reflection and radiation performance for the targeted frequencies.

Keywords: RFID, Circular Polarization, Multi-band Reader Antenna, UHF.

1 Introduction

In the near field ultra-high frequencies RFID system communications between the reader and the tag there are two main design challenges. The distance and the polarization between the reader and the tags. In addition to that, there is another factor that will limit the applications such as the bandwidth working frequencies. In fact, the further distance communication between the tags and the reader is the best system design we could get. So, one of the biggest challenges in the RFID system design is the radiation of circular polarization [1]. To avoid the tag orientation the circular polarization of the reader design must be applied. Therefore, the present work discusses the design principle of the reader antenna over a multi-band spectrum with acceptable circular polarization, coverage, and power gain.

Globally the UHF was divided into regions in which the usable frequencies or channels can be adapted to operate for such applications, such as 868MHz channel 0 one-channel in Europe. or

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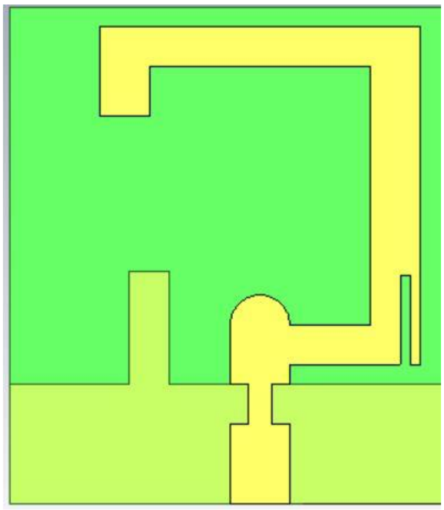
902-928 MHz were 10-channel (1-10) in USA and Australia, and lastly 2.4-2.4835GHz across the world. In this paper, a simplified circular polarized antenna is modified from our previous work in (2)and then redesigned to be able to resonate in all these frequencies. Basically, the advantage of circular polarisation (CP) is reducing the multipath interference and giving better polarisation matching. As a result, a lot of antenna design in CP antenna configuration was achieved. As a result of this, we have nowadays a huge number of wireless contexts, from WiMAX, and WLAN to satellite and beyond (3). The CP multiband or smart band antenna design now is the target of many designer engineers. In the same way, the number of applications is gradually increasing practically in localization applications using RFID systems. These applications are working in different frequencies or regions. So multiband reader antenna will fulfill the needs to meet the wide variety of applications.

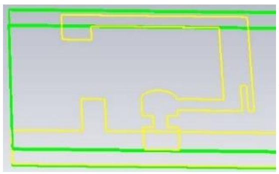
In multi-band antenna design, there are some proposed designs that add some electronic devices to meet the frequencies needed and to cancel other frequencies. On the other hand, there're other designs that meet the frequencies needed without the need to add any electronic component. In this study, the major emphasis is to design a small planer antenna that has wideband CP without adding any electronic components. in contrast to recent experiments researcher, there are some who focused on dual narrow-band CP (5)and others who focused on tri-band CP (6) . In the first group, researchers were able to find designs that meet two required frequency bands. And they are too narrow. While in the second group, the designers were able to find designs that meet a wide range of frequencies, so the three targeted bands were in the range of reader antenna detection (3). To achieve wide axial ratio bandwidth a CP wide slot antenna was developed. In this study, we introduce a multiband circular polarisation antenna with a question mark-shaped patch that is partly shielded by the ground. By adding a rectangular stub and substrate two other rectangular to the ground. And substrate two rectangular from the question mark patch shape and adding a semi-circular to the upper terminal of the feeding line our antenna significantly improved. The simulated results are in good agreement. The design and simulations are presented in section 2, simulation and measured results were obtained using CST microwave studio software in section 3, and finally the conclusion in section 4 was presented.

2 Design and simulations

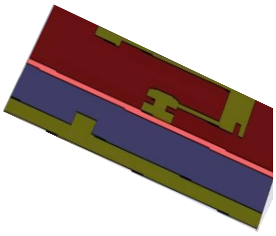
This section is showing the stages of the design that lead to the final geometry of the proposed multiband UHF RFID reader antenna. we start with the initial design of our previous work (2). In fact, we work on a different frequency range, so our design needs to change in measurements. Figure 1 shows the basic diagram of the design Antenna. There are two Main FR4 substrates with a dielectric constant ($\epsilon_r = 4.3$, $tg\delta = 0.025$). The dimension of both substrates is 250x250 x 1.6 mm^3. A question mark patch shape is designed on the top of the paper substrate while the partial ground is on the top side of the lower substrate. The general antenna structure consists of a 50Ω microstrip feed line connected to a ?-shaped patch to form a wideband planar monopole antenna. A stub with a length equal to L_{st} has been attached to the ground plane to improve the axial ratio bandwidth (ARBW) of the proposed antenna. Further enhancement in the ARBW has been acquired after engraving a slit with a length equal to L_s on the patch of the proposed antenna in addition to attaching a semicircular stub with a radius r at the top of the feed line. Figure 2 shows the Initial result of the design Antenna as the design work on operating at the dual band from 0.42-090 and 1.35-2.53 GHz Frequency.



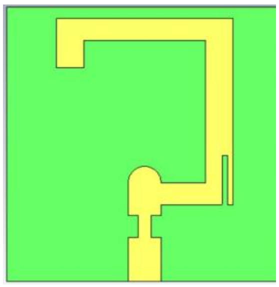
a. Antenna Diagram with Upper and lower design



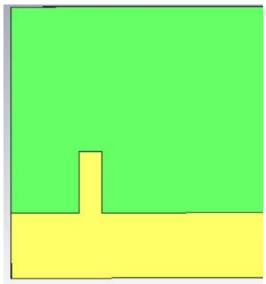
b. Transparent View



c. Side View



d. Top View with |Upper Substrate



e. Lower Substrate with ground

Figure 1. The basic antenna design model.

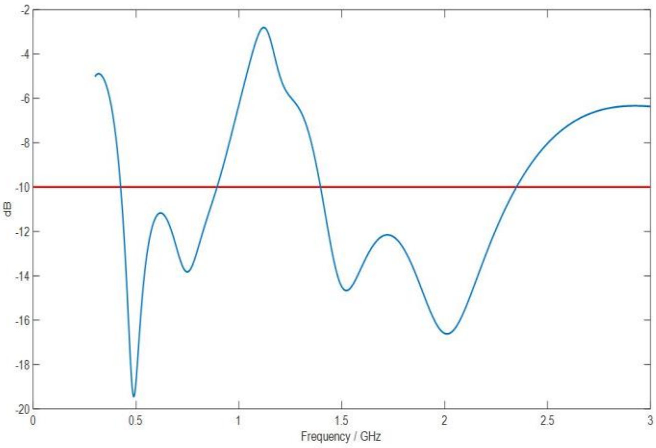


Figure 2. The variations of the input reflection coefficient of the basic model in Figure 1.

The procedure that has been followed until obtaining the final structure (Ant.1-7) is demonstrated in Fig. 3, while the resulting reflection coefficient (S_{11}) and the axial ratio (AR) corresponding to each structure are exhibited in Fig. 4 with the aid of CST Microwave Studio simulation suite.

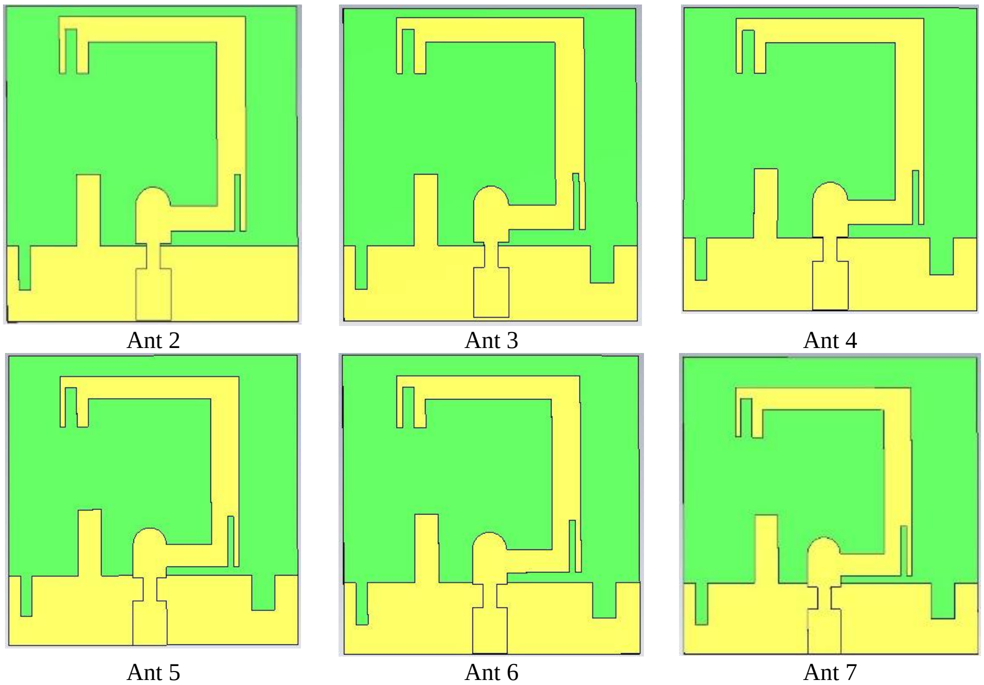


Figure 3. The antennas design steps

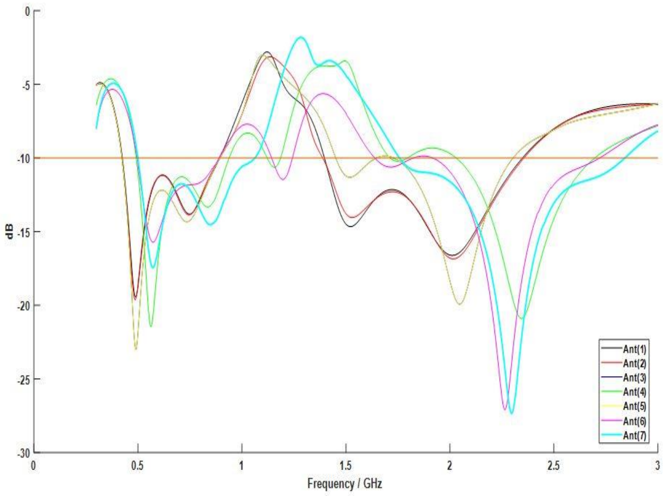
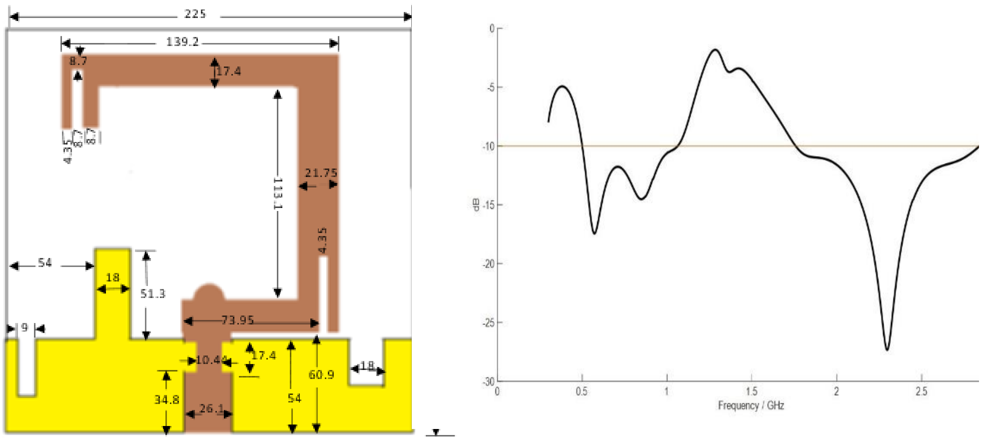


Figure 4. $S_{11}$for all steps design

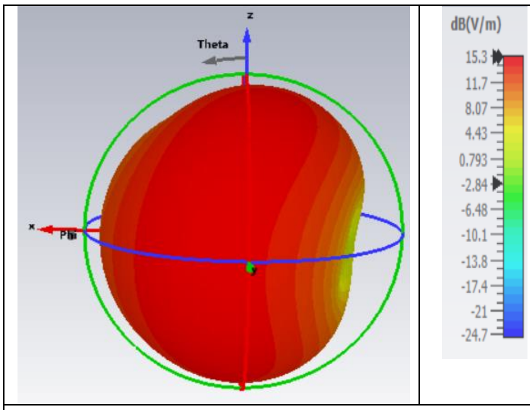
The geometry of the proposed RFID multiband antenna is depicted in **Figure 5**, along with the values that have been optimised for each parameter. Both antenna contents are covered by an FR4 dielectric substrate that has a height of h=1.6 mm, a dielectric constant of $\epsilon_r = 4.3$, and a loss tangent of 0.025. The antenna has overall dimensions of 225 millimeters height by 225 millimeters width. To produce a wideband planar monopole antenna, the general antenna structure is made up of a microstrip feed line with a 50 Ω impedance that is connected to a patch in the shape of a question mark. In order to increase the axial ratio bandwidth (ARBW) of the proposed antenna, another FR4 is attached to the ground plane and has the same length, same width, and same depth as the first FR4 layer. After cutting a slit on the patch of the proposed antenna with a length equal to 41mm and adding a semicircular stub with a radius r = 15 at the top of the feed line, an additional enhancement in the ARBW was obtained. And all measurements are shown in **Figure 5a** below. By using CST software, the designs were simulated and all values of S_{11} are presented in **Figure 5b**.



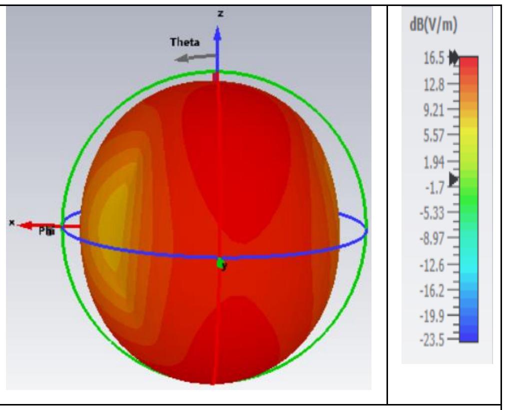
(a) (b)

Figure 5. Final antenna design structure (a), Input reflection coefficient (b).

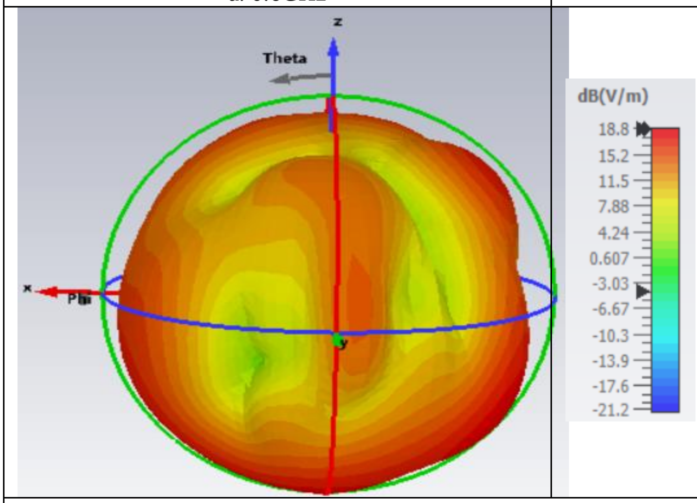
In order to demonstrate the radiation characteristics of the proposed antenna, Figures 6 and 7 show the 3-D and 2-D radiation patterns at various frequencies such as 0.6, 0.85, and 2.30GHz. The proposed antenna can provide sufficient radiation analysis for individual radiators.



a. 0.6GHz

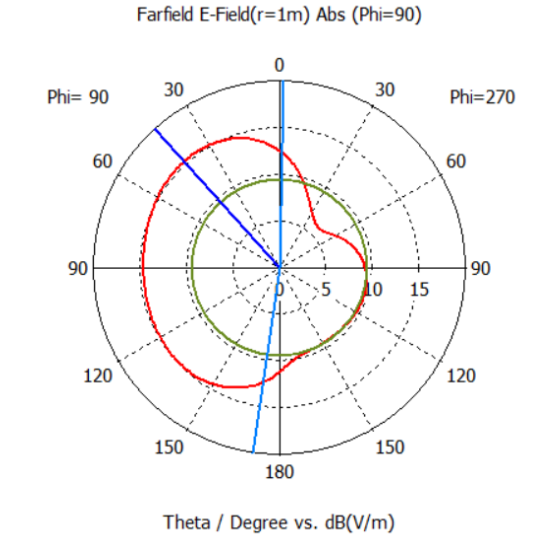


b. 0.85 GHz

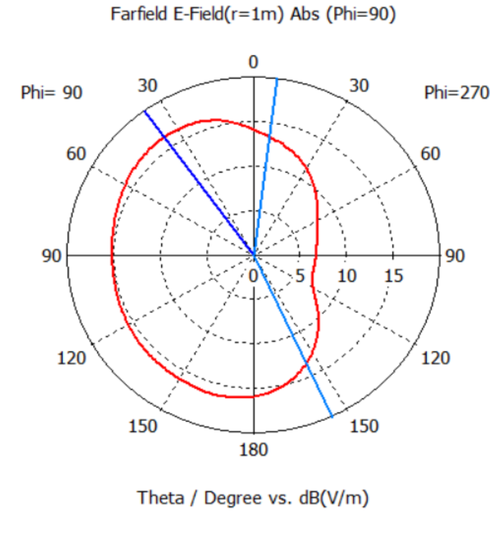


c. 2.30 GHz

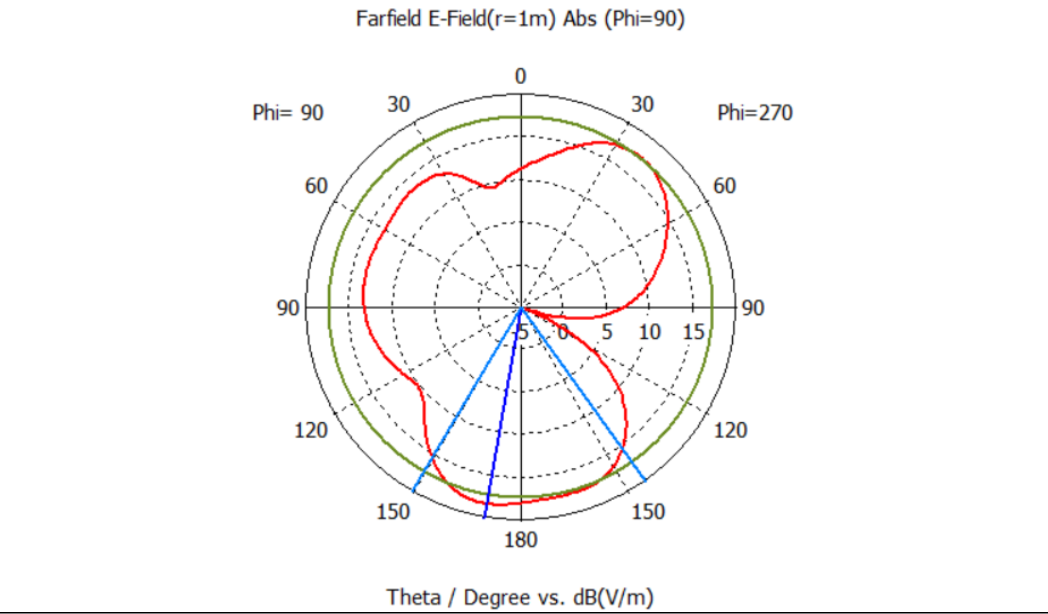
Figure 6. 3D Radiation Patterns.



a. 0.6 GHz



b. 0.85 GHz



c. 2.30 GHz

Figure 7. 2D Radiation Pattern

3 Conclusion

Circularly polarised patch antenna that was developed specifically for use with RFID readers. This design is capable of operating on all available UHF frequencies for RFID usage applications. The following acceptable results that this antenna achieved, for S_{11} are as follows: S_{11} = -11.883 when the frequency is set to 0.868 GH, S_{11} = -11.085 when the frequency is set to 0.902 GH, S_{11} = -10.477 when the frequency is set to 0.928 GH, S_{11} = -16.83 when the frequency is set to 2.4 GHz, and S_{11} = -13.2585 when the frequency is set to 2.4835 GH.

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