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A New Compact CPW-Fed Dual-Band Uniplanar Antenna for RFID Applications

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Abstract

*In this paper a new dual-band uniplanar monopole antenna fed by Coplanar Waveguide (CPW) line is proposed for Radio Frequency Identification (RFID) applications. The antenna structure includes a CPW fed line and the dual-band operation is achieved from the G-shaped folded antenna. The antenna parameters have been investigated and optimized by using CST Microwave Studio. To validate the CST Microwave Studio results before the antenna achievement, we have conducted another study by using ADS. The final circuit was achieved, measured and validated. Experimental results show that the proposed antenna with compact size of 30*45 mm^2 is simple in design and compact in size. It exhibits broadband impedance matching, consistent omnidirectional radiation patterns and appropriate gain characteristics suitable for the microwave RFID applicartions.*

Keywords: *antenna, RFID (Radio Frequency Identification), Coplanar waveguide (CPW) fed, dual-frequency operation, monopole antenna*

1. Introduction

Radio Frequency Identification (RFID) technology defines the system that transmits the identity of an object or a living being automatically by using radio waves. This system is being widely used in inventory control systems, manufacturing industries, goods flow systems, electronic toll-collection systems which made wireless RFID more popular [1-2].

RFID System consists of a microchip (tag) enwrapped by an antenna and a reader. Data and energy transfer are provided without any contact between tag and reader. Therefore, they continuously spread the information on them from a radio frequency. The antennas receive the electromagnetic waves sent by the reader and activate the circuits on the tag. The tag modulated the waves and sent them back to the reader, and the reader converts the new wave into digital data. A sample RFID system is shown in Figure 1.

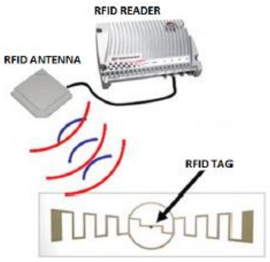

Figure 1. Block diagram of RFID System

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The RFID technology can operate at different frequencies. The Low-frequency (LF, 125,134 kHz) and high-frequency (HF, 13.56 MHz) applications are most deployed. These applications involve magnetic field coupling between the reader's and tag's coils. RFID systems at Ultra-high frequency (UHF, 860; 960 MHz) and microwave (2.4 GHz and 5.2 GHz) based on electromagnetic coupling between antennas and offering a high readable range, fast reading speed, large information storage capability and low cost [3-4].

The main bottleneck in RFID reader design is the cost associated with the antenna part, in order to make them suitable for integration in variety of application, avoiding to be affected by their environment, especially by metallic objects, and finally providing adequate gain for seamless operations, especially in case of RFID handheld reader.

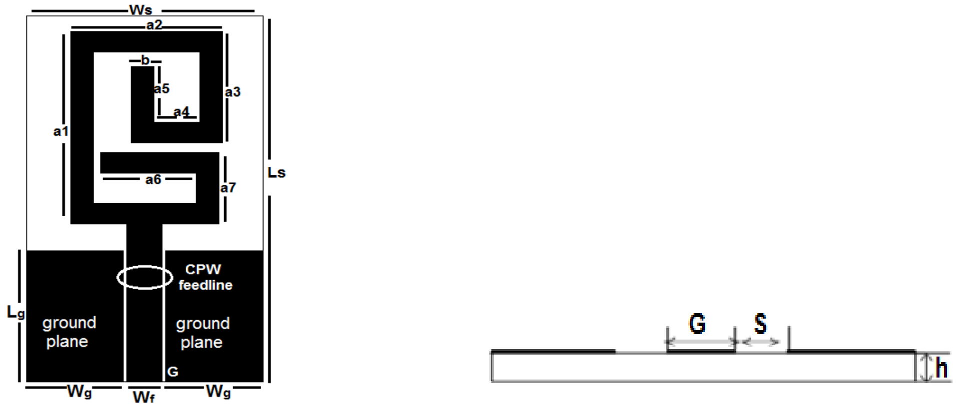
In order to satisfy the rapid development of wireless communication, multi-band antennas with large impedance bandwidth and excellent radiation performance have been designed. Because of their low cost, light weight, and good radiation characteristics, the printed monopole antennas have been widely used in wireless communication terminals. Recently, the printed monopole antennas with different schemes for wireless communication systems have been reported [5-14]. The handheld RFID reader antenna also has been designed and reported in a few letters [15-19]. Some of the proposed antennas are large three-dimensional size which possibly limit the integration size of the wireless communication devices and impact the portable characteristics.

In this paper, we present an uniplanar dual band G monopole antenna fed by a CPW line for RFID reader applications.The proposed antenna benifits from the advantages of the CPW transmission line to achieve a simple structure with a single metal layer and to have an easy integration with microwave integrated circuit. The performances of the antenna are verified by experimental data obtained from fabrication and measurement. The design of the proposed structure is described in the second section. Moreover, simulations are conducted to investigate the influences of the geometry parameters on the dual-band behavior and the characteristics of the return loss and radiation patterns. The experimental results are discussed in Section 4.

2. Antenna Design

The proposed antenna is designed on a low cost FR4_epoxy substrate with a relative permittivity of 4.4. The thickness of the substrate is H=1.6 mm and total area of 30×45 mm^2. Figure 2 shows the geometrical parameters of the antenna and its dimensions are shown in Table 1.

The exitation of the designed structure is based on the use of a 50-CPW transmission line, having a strip conductor of width W_f and a gap of distance G [20]. The characteristic impedance of a conventional coplanar waveguide structure can be computed by using standards equations [21-22].



(a) Top view of the designed antenna

(b) Side view antenna

Figure 2. Geometry of the proposed antenna

Table 1. Dimension of the Proposed Antenna (unit in mm)

Parameter	Value
Lsub	45
Wsub	30
Lg	12
Wg	12.6
a1	28
a2	20.5
a3	17
a4	8
a5	11
a6	13.6
a7	10
b	2.5
Wf	3.8
G	0.5

Two finite ground planes with equal length Lg and width Wg are symmetrically inserted on each side of the CPW feed line. The use of these two elements through adjusting the length Lg permits the control of input impedance level at the two working frequencies.

The first resonance frequency f_1 of the printed monopole antenna is a function of the total length L_1 composed of the elements a_1, a_2, a_3, a_4, a_5 and can be adjusted to obtain a frequency band centered at 2.45 GHz while the second resonant frequency f_2 depends on the total length L_2 of the elements a_6, a_7 and it is chosen to be centered at 5.8 GHz. It demonstrated that without inserting the element of length $L_2=a_6+a_7$ the antenna is only resonating at one frequency close to f_1, whereas by including this element in the structure, the second resonant frequency is obtained. By tuning the dimensions of the antenna, the two resonances modes can be achieved at 2.45 GHz and 5.8 GHz respectively. The length of the two monopoles can be expressed as a function of the guide wavelength (λ_g) which given by:

$$L_i = k.\lambda_g = k.\frac{\lambda_0}{\sqrt{\varepsilon_e}}$$

where λ_0 is the wavelength of f_1 or f_2 in free space, ε_e is the effective dielectric permittivity. According to the previous equation, the length L_1 of the longer element is given to be about 0.75 wavelength at f_1=2.45 GHz, and the length L_2 of the shorter element corresponds to about 0.6 wavelength at f_2=5.8GHz.

3. Antenna Performances

The aim of this study is to design a new compact antenna structure for dual-band RFID applications. The design evolution of the proposed antenna is presented in Figure 3 the conception of the planar antenna with dual frequency operation capabilities is due to the multiple resonances introduced by the combination optimization of the geometry antenna, length of the two monopoles and CPW-feed line dimensions.

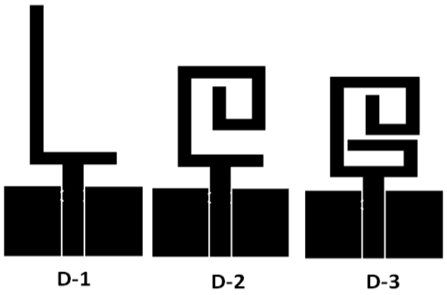


Figure 3. Design evolution of the proposed antenna

Figure 4 shows the simulated return losses for successive cases of the conception of the final dual-band antenna. From Figure 3, we can clearly see that the proposed antenna is designed through three steps. Firstly, we start with a straight rectangular monopole (Figure 3.D-1). Secondly by folding the monopole the dimension of the antenna was reduced (Figure 3.D-2). At the end, the final dual-band antenna is achieved by inserting a second monopole (Figure 3.D-3). Thus, the matching input impedance of the final antenna structure is achieved respectively in frequency bands 2.45GHz and 5.8GHz with a return loss less than -10dB. Figure 4 shows the simulated return loss for each design.

To study the influence of different parameters of the proposed antenna which affect the dual-band performances, CST simulation software has been applied to guide this design [23]. Figure 5 shows the simulated reflection coefficient of the antenna as a function of frequency for the different values of the length of the first monopole a_1 while other parameters are fixed. The center frequency of the first band decreases with the increase of a_1, whereas the second band knows a slight shift.

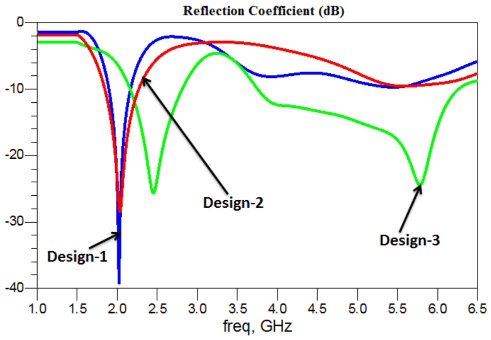


Figure 4. The return loss vs frequency of the proposed antenna for different cases on CST

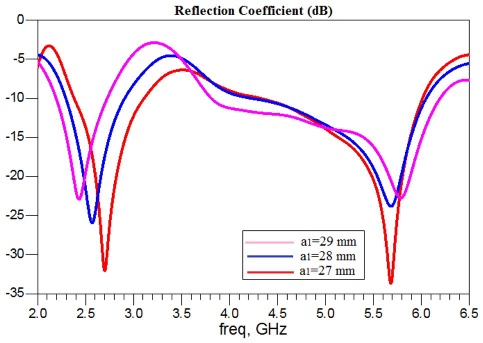


Figure 5. Simulated reflection coefficient of the proposed dual band antenna with varied a_1 while other parameters fixed

Figure 6, illustrates the simulated reflection coefficient curves with varied length of the second monopole a_6. As can be seen from Figure 6, the center frequency of the second band decreases with the increase of a_6.

Figure 7 shows the simulated reflection coefficient of the antenna as a function of frequency for the different values of Lg while other parameters are fixed. It can be seen from the Figure 7 that the length Lg permits to obtain a good impedance matching at both operating frequencies.

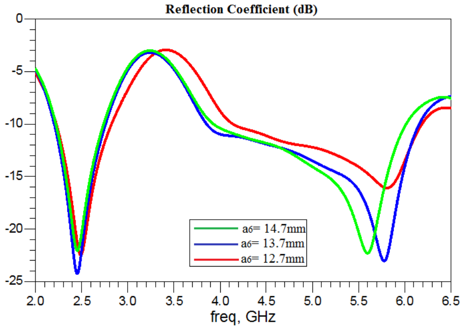


Figure 6. Simulated reflection coefficient of the proposed dual band antenna with varied a_6 while other parameters fixed

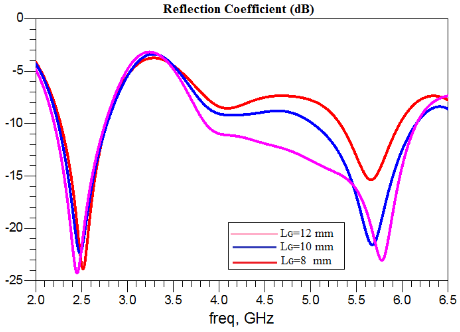


Figure 7. Simulated reflection coefficient of the proposed dual band antenna with varied Lg while other parameters fixed

In order to compare the results in Figure 4, another electromagnetic solver ADS software "Advanced Design System" [24] is used. Figure 8 shows a comparison of the simulated return loss versus frequency for the proposed antenna using CST and ADS.

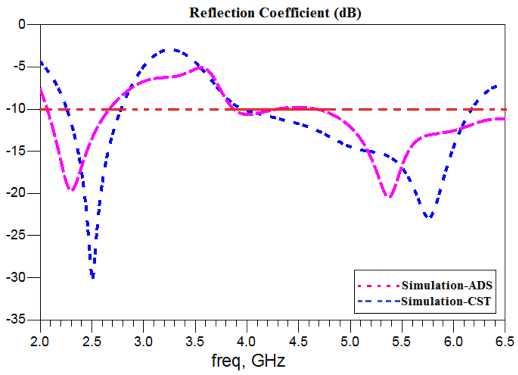
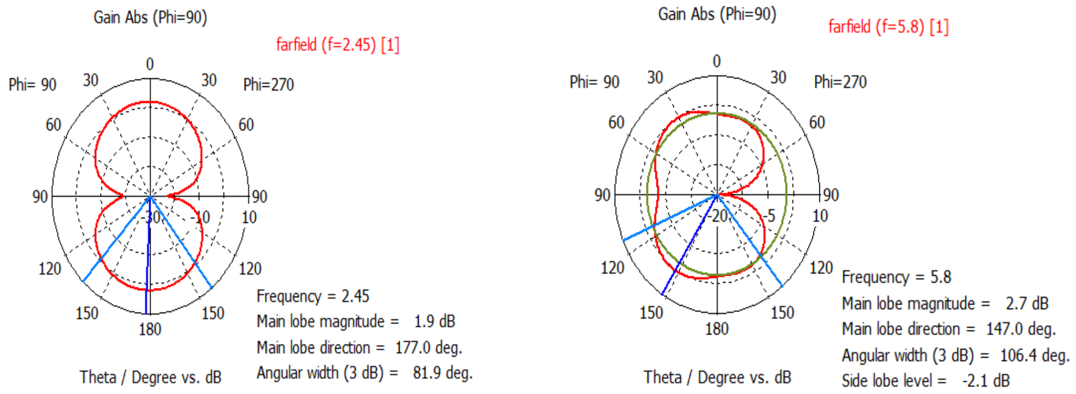


Figure 8. Comparison of simulated return loss S11 for the proposed dual-band antenna using CST and ADS

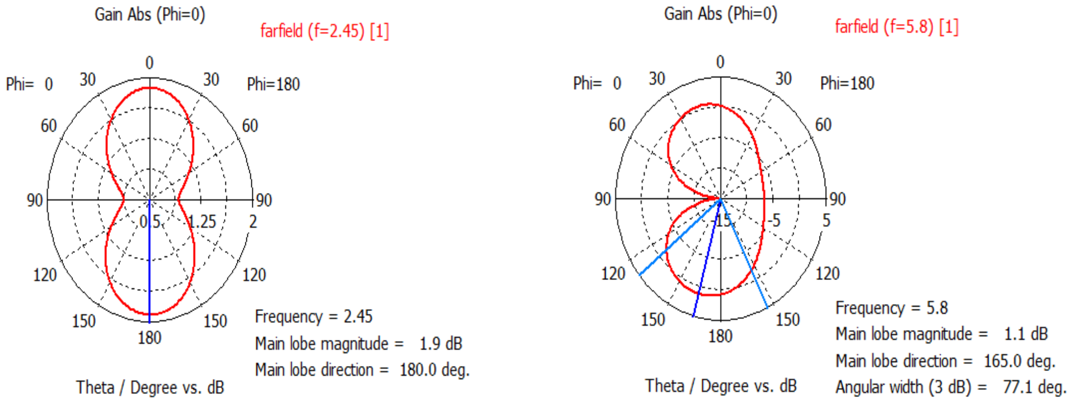
We can notice a slight difference in the return loss obtained by simulation using CST and ADS due to the technique of calculation used in each simulation software. Where CST is 3D EM simulator based on Finite Integration Technique (FIT) while ADS is 2D EM simulator based upon the Method of Moment (MoM). The 2D radiation pattern is given by Figure 9 (a) and (b) in the E-plane, which show a stable and bi-directional radiation pattern for the two resonant frequency bands.



(a) (b)

Figure 9. 2D radiation pattern in E–plane for the designed structure at resonant frequency, for 2.45 GHz (a) and 5.8 GHz (b)

The 2D radiation pattern is given by Figure 10 (a) and (b) in the plane H.



(a) (b)

Figure 10. 2D radiation pattern in H –plane for the designed structure at resonant frequency, for 2.45 GHz (a) and 5.8 GHz (b)

4. Fabrication and Measurement Results

After the conception and optimization of the dual-band antenna by using ADS and CST, the prototype of the investigated antenna was fabricated on FR4 substrate using the Chemical etching machine, then measured to verify the performance of the results obtained from simulation. The photograph of the fabricated monopole antenna is given in Figure 11.

The return loss was measured by using Vectorial Network Analyzer (VNA) PNA-X from Agilent Technologies and the kit of calibration used is 3.5 mm from Agilent Technologies composed from Open, Short and Load components; losses in the different transitions are taken into account. Then after the calibration, the return loss for the achieved antenna as shown in the Figure 12 is tested. In the same time, both the simulations on ADS and CST with measurement results are compared.

Figure 11. Photograph of the realized antenna

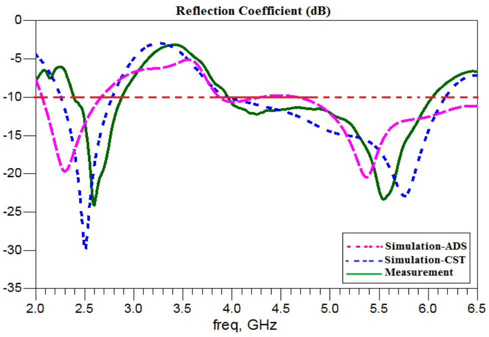


Figure 12. Comparison of simulated and measured return loss

Small discrepancies between the measured and simulated results are observed, due to cable effects, SMA connector and fabrication imperfection.

The reflection coefficient curve shows that the present antenna is fed at 2.45 GHz with a –10 dB return loss bandwidth of 480 MHz (2.39–2.87 GHz) and at 5.8 GHz with an impedance bandwidth of 1890MHz (4.12–6.01GHz). The radiation patterns were measured in anechoic chamber as shown in Figure 13.

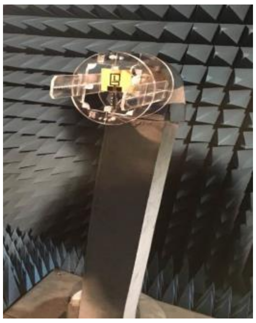
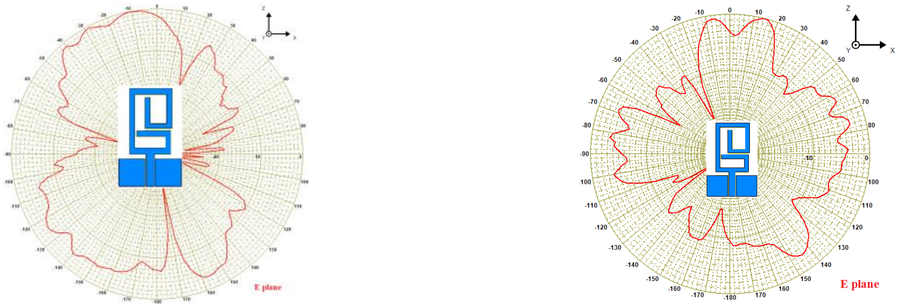


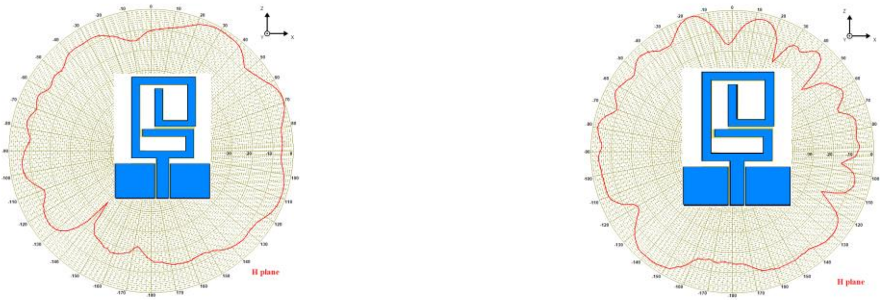
Figure 13. Anechoic chamber

The measured far-field radiation pattern characteristics of the proposed antennas in E-plane and H-plane at 2.45GHz and 5.8GHz are presented in Figure 14 and Figure 15. The measured results shows that the good omni-directional patterns in the H-plane and the nearly bidirectional patterns in the E-plane are obtained for all frequency bands.



(a)F_1=2.45GHz (b)F_2=5.8GHz

Figure 14. Measured radiation patterns at 2.45GHz and 5.8GHz in the E-plane



(a) F_1=2.45GHz (b)F_2=5.8GHz

Figure 15. Measured radiation patterns at 2.45GHz and 5.8GHz in the H-plane

5. Conclusion

In this study, an uniplanar monopole antenna with a 50 Ohm CPW Fed is designed. This validated antenna is suitable for RFID applications which can be used in the released ISM "Industrial Scientific Medical" frequency band 2.45GHz and 5.8GHz. This antenna has been designed and optimized by using CST-MW and ADS electromagnetic solvers. The achieved and tested planar antenna presents a good agreement between simulation and measurement results. These results validate this circuit for the two Microwave RFID bands (2.39–2.87 GHz) and (4.12–6.01GHz) with a compact size of 30x45 mm^2.

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