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A New Design of a CPW-Fed Dual-Band Monopole Antenna for RFID Readers

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ABSTRACT

This paper comes with a new dual-band planar monopole antenna fed by Coplanar Waveguide (CPW) line designed for RFID readers and it operates at 2.45 GHz, 5.80 GHz. This antenna is designed with reasonable gain, low profile and low cost production. The designed antenna based on theoretical equations is simulated and validated by using ADS from Agilent technologies and CST Microwave Studio electromagnetic solvers. A parametric study of the proposed antenna has been carried out by optimizing some critical parameters. The antenna has a total area of 35×38 mm2 and mounted on an FR4 substrate with dielectric permittivity constant 4.4 and thickness of 1.6 mm and loss tangent 0.025. The comparison between simulation and measurement results permits to validate the final achieved antenna structure in the desired RFID frequencies bands. Details of the proposed antenna design and both simulated and experimental results are described and discussed.

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1. INTRODUCTION

Nowadays radiofrequency identification (RFID) has been deployed in a wide range of applications such as logistics, intelligent trace, asset tracking, electronic passports and tale health, for these reasons RFID has become more popular and gained much interest [1], [2]. An RFID system is basically composed of two principal elements; a tag, comprising an antenna and a microchip circuit which is remotely interrogated and supplied by a reader responsible for gathering all the information from the detected tags. The tags use the backscattering modulation technique to communicate their data to the reader based on a magnetic or electromagnetic coupling. The block diagram of an RFID system is illustrated in Figure 1 [3].

Several frequency bandshave been assigned to the RFID technology such as the Low frequency (LF, 125,134 kHz) and high-frequency (HF, 13.56 MHz) applications are most matured and worldwide accepted. These applications are based on magnetic flux 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) offer a communication link at longer distance with high data rates [4].

Recently, monopole antennas have found widespread applications in wireless mobile communication systems such as RFID systems.The CPW is the feeding which side-plane conductor is ground and center strip carries the signal [5]. CPW-fed antennas have many attractive features, such as no soldering points, easy fabrication and integration with monolithic microwave integrated circuits, and a simplified configuration with a single metallic layer, low cost, wide bandwidth and flexibility towards multiband operation. Thus, the designs of the CPW-fed antennas have recently received much attention. Many compact printed monopole antennas were manufactured for wireless applications and reported in the literature [6-8]. Some of these monopole antennas have been investigated especially for RFID applications [9-16].

In this paper, we propose a new design of uni-planar dual-band F monopole antenna fed by a CPW line (see Figure 2). The proposed antenna is particularly simple in manufacturing owing to its single dielectric and single metal layer. The two operating modes of the proposed antenna are associated with various lengths of two monopoles, in which the longer monopole works for the first resonant mode and the shorter monopole works for the second mode. In this study, several designs are investigated by simulation, and the characteristics of the return loss and radiation patterns are analysed and discussed.

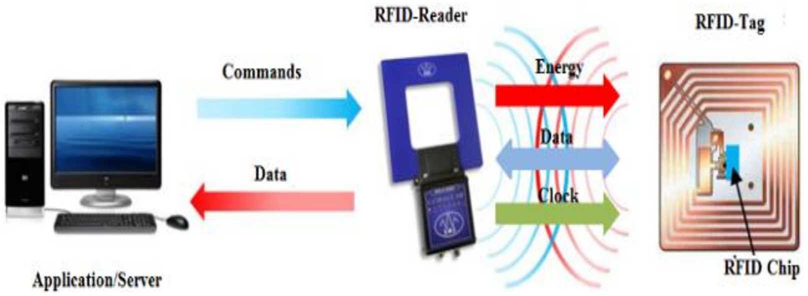
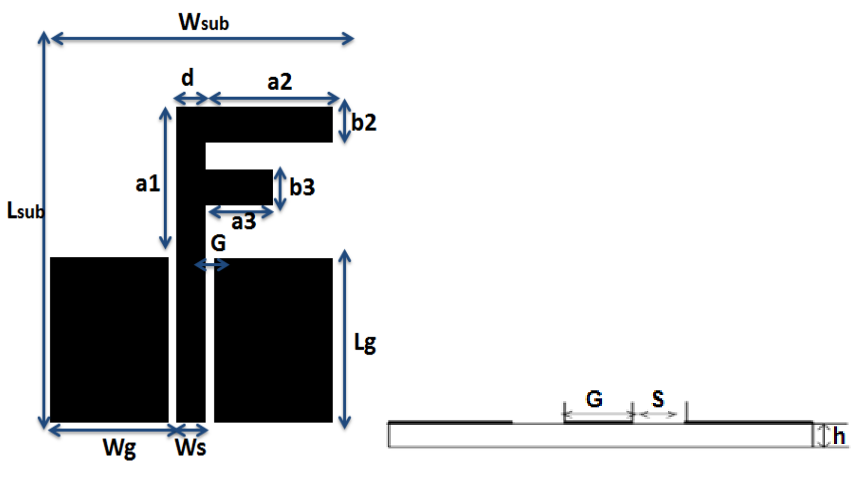


Figure 1. Block Diagram of an RFID System

2. ANTENNA DESIGN

Figure 2 shows the geometry of the proposed dual band CPW-fed printed monopole antenna for RFID applications.



(a) (b)

Figure 2. (a) Geometry of the proposed antenna top view and (b) side view

The strip width (Ws) and gap (G) of the Coplanar Waveguide (CPW) feed are derived using standard design equations for 50Ω input impedance, in order to match the characteristic impedance of transmission line.The characteristic impedance of a conventional coplanar waveguide structure can be computed using standards equations [17]. Due to the presence of different lengths of the two elements, the first resonant frequency of the proposed antenna is expected to be controlled mainly by the length of the longer element, and the second resonant frequency is greatly dependent on the length of the shorter element. The final optimized dimensions of the antenna through EM simulations are presented in Table 1.

Table 1. Dimension of the proposed antenna

Parameter	Value (mm)
Lsub	38
Wsub	35
Lg	22
Wg	15.8
a1	12.6
a2	14.6
a3	4.6
b2= b3	2
d	2.7

The antenna performance was studied by using the computer simulation technology (CST) microwave studio [18]. To validate our use of design software CST, we designed and simulated the same structure using ADS "Advanced Design System" simulator software [19]. Figure 3 illustrates the reflection coefficient obtained from both simulation tools.

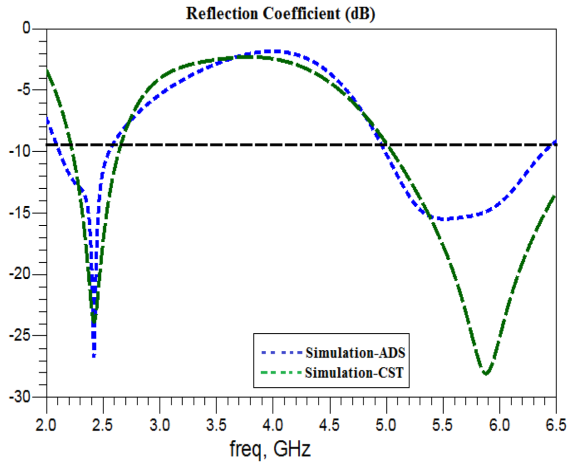


Figure 3. Simulated return loss ofthe proposed antenna versus frequency

The reflection coefficient curve shows that the designed antenna resonates at 2.45 GHz with a bandwidth of 120 MHz (2.4–2.52 GHz) and at 5.8 GHz with an impedance bandwidth of 1.4 GHz (5.1–6.5 GHz). The maximum return loss of -27dB and -28.5dB is obtained at the resonant frequencies of 2.45 GHz and 5.85 GHz respectively.

We can observe a difference in return loss obtained with CST and ADS due to the technique of calculation used in each simulation software. CST is 3D EM simulator based upon Finite Integration Technique (FIT) while ADS is 2D EM simulator based upon the Method of Moment (MoM).

A parametric study of the proposed antenna has been conducted in order to study the effects of different elements of the antenna on return loss. The parametric study of the proposed antenna is performed by using computer simulation technology (CST) microwave studio. The results for the case of a single element of length a_2 are shown in Figure 4. It is clear to see that when the antenna uses a single element, only one resonant mode is excited at about 2.3 GHz for a_2=15.2 mm and 3.1 GHz for a_2=7 mm. While for the antenna having two elements we obtain the two resonant frequencies of 2.45 GHz and 5.8 GHz with good matching input impedance.

Figure 5 shows the simulated reflection coefficient of the antenna as a function of frequency for the different values of a_3 while other parameters are fixed. It can be seen from the Figure 5 that the length of a_3 has a clear effect on the position of the second resonant frequency. When increasing the length of a_3, we notice that the second resonant frequency gets lower.

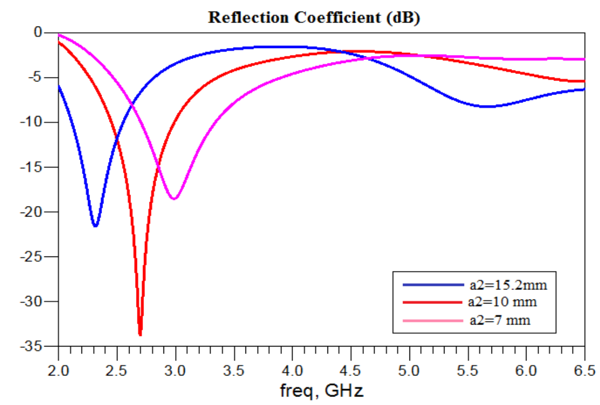


Figure 4. Simulated Reflection coefficient for different lengths of (a_2) parameter versus frequency with other parameters fixed

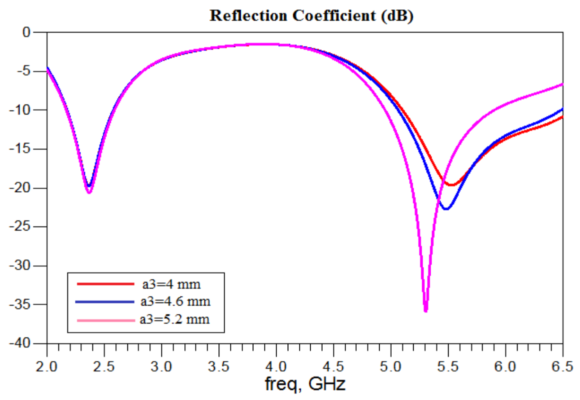
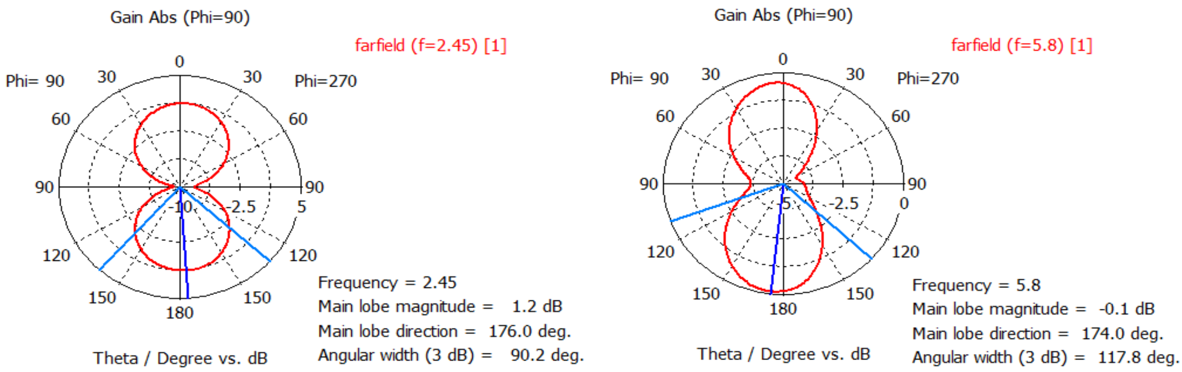


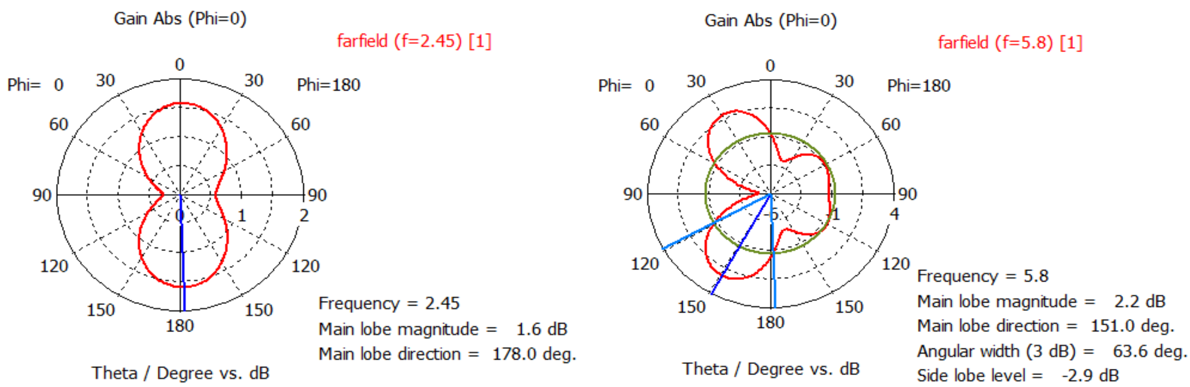
Figure 5. Simulated Reflection coefficient for different lengths of (a_3) parameter versus frequency with other parameters fixed

The 2D radiation patterns are given by Figure 6 and Figure 7 respectively in the plane E and plane H, in the low frequency 2.45 GHz and the high frequency 5.8 GHz.



(a) (b)

Figure 6. 2D radiation pattern in E –plane for the designed structure at resonant frequency, (a) fr of 2.45 Ghz, (b) fr of 5.8 Ghz



(a) (b)

Figure 7. 2D radiation pattern in H–plane for the designed structure at resonant frequency, (a) fr of 2.45 Ghz, (b) fr of 5.8 Ghz

3. 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 8.

The return loss was measured by using Vectorial Network Analyzer (VNA) PNA-X from Agilent Technologies. 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 (Figure 9).

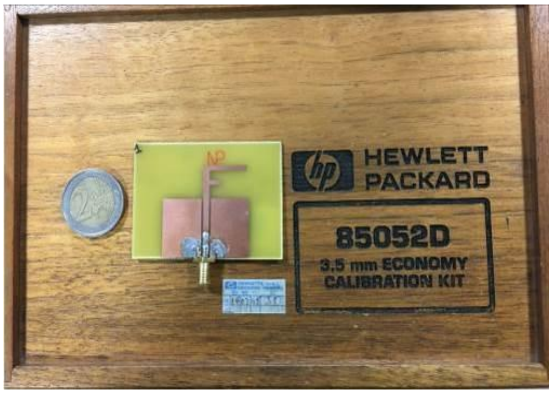


Figure 8. Photograph of the fabricated structure

Figure 9. Calibration Kit 3.5 mm

After the calibration, the return loss for the achieved antenna as shown in the Figure 10 is tested. In the same time, both the simulations on ADS and CST with measurement results are compared.

Small discrepancies between the measured and simulated results areobserved, 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 400 MHz (2.2–2.6 GHz) and at 5.8 GHz with an impedance bandwidth of 1300MHz (5.2–6.5 GHz).

The radiation patterns were measured in anechoic chamber as shown in Figure 11.

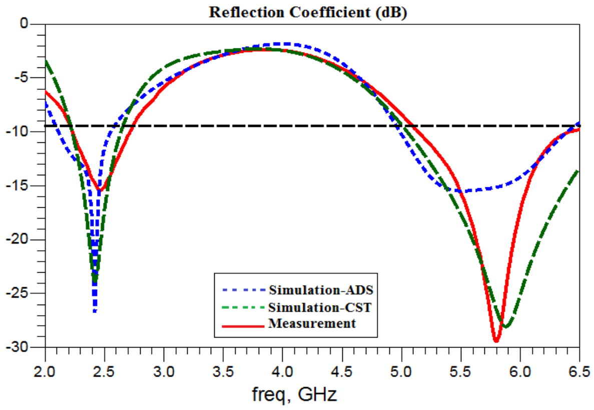


Figure 10. Comparison of simulated and measured return loss

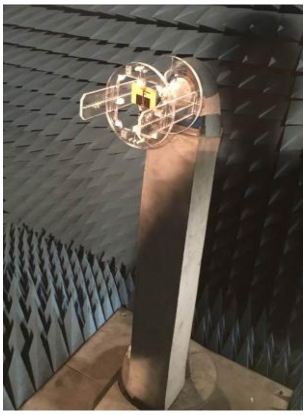
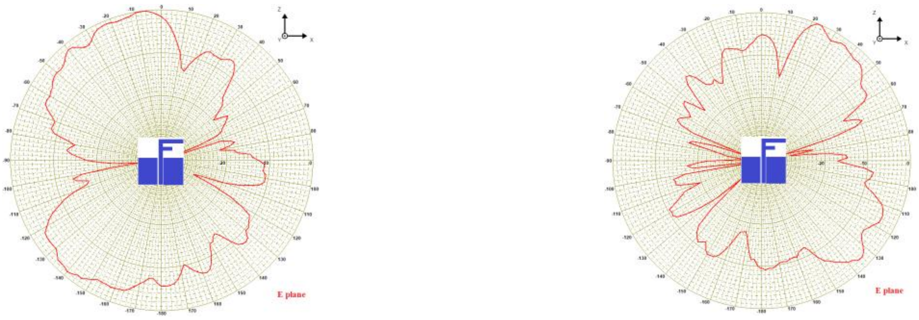


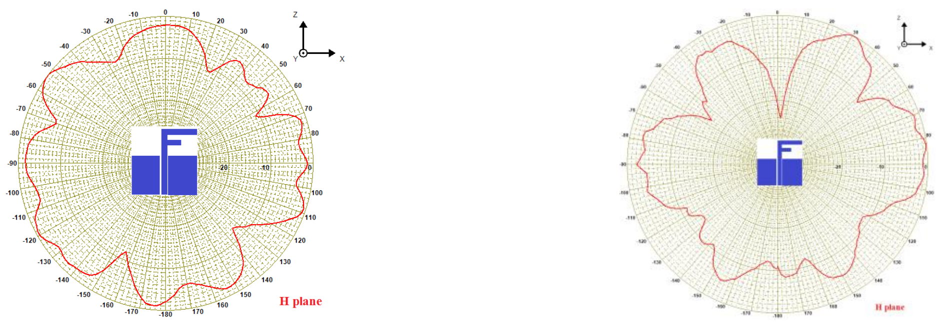
Figure 11. Anechoic chamber

The measured far-field radiation pattern characteristics of the proposed antennas in E-plane and H-plane at 2.45 GHz and 5.8 GHz are presented in Figure 12 and Figure 13. 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) (b)

Figure 12. Measured radiation patterns at 2.45 GHz (a) and 5.8 GHz (b) in the E-plane



(a) (b)

Figure 13. Measured radiation patterns (a) at 2.45 GHz and (b) 5.8 GHz in the H-plane

The following Table 2 presents a comparaison of the proposed antenna with other antennas validated in the literature. It can be seen that the proposed antenna is significantly smaller, offers an important bandwidth and a good gain compared to its dimensions.

Table 2. Comparison between the proposed antenna and other research papers

	S11(dB)		Gain (dBi)		Substrate	Antenna size (mm^2)
	2.45 GHz	5.8 GHz	2.45 GHz	5.8 GHz		
Ref [20]	-11	-18.6	2.2	2.31	FR4	71.6 x 94
Ref [21]	-16	-14	6.30	5.16	Teflon	75x40
Ref [22]	-25	-12	2.4	4.1	FR4	51.3x43.4
Proposed antenna	-16	-29	1.5	2.4	FR4	38x35

4. CONCLUSION

A dual band CPW fed printed monopole antenna for RFID applications has been presented. A dual-band operation is easily achieved by the F-shaped configuration. The proposed antenna is simple to design, light weight and compact in size. It provides good matching input impedance, stable radiation patterns and appropriate gain characteristics in the RFID frequency with a bandwidth of 400 MHz at 2.45 GHz, and 1300 MHz at 5.8 GHz. These results validate the antenna structure for dual-band operations in handheld RFID and WLAN applications.

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