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# Design of dualband antenna for RFID applications

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**ABSTRACT**

This paper focuses on the design and fabrication of dual band antenna for UHF RFID and ISM RFID applications. The U-shaped patch loaded with dipole is introduced and investigated. The antenna can be performed dual-band frequencies at 0.915 GHz and 2.4 GHz required in RFID applications with reflection coefficient is less than -10 dB. The lower band can be varied by adjusting both dipole arms length and upper band is tuned by U-shaped patches. The gains of the design with a size 130x45x1.6 mm$^3$ are performed 1.89 dB and 3.65 dB for single and dual band respectively. This compact and low cost dual band antenna also performed total efficiency greater than 80%. The design methodology and antenna measurement results are both presented and discussed in this letter.



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## 1. INTRODUCTION

Multiband Radio Frequency Identification (RFID) antenna has led to great demand in the commercial wireless and service industries. Most of RFID antennas were designed to operate at one or more frequency bands, such as Low Frequency, High Frequency, Ultra High Frequency, and Microwave. Recently, UHF and ISM bands have become more attractive because of their suitability for long-range applications and reconfigurability [1-2]. The dual-band antennas developed conform to various communication protocol standards and established operating frequency bands in one system [3-6]. For that reason, more designs of dual-band antennas for RFID readers were developed to fulfill the requirement of the RFID industry. In [7] a dual band frequency was obtained by controlling the shape and size of the diamond shape patch. The bandwidth was 18 MHz (902–920 MHz) in UHF band and 80 MHz (2.42–2.5 GHz) in ISM band with 150 mm×127 mm×5 mm size antenna. The antenna bandwidth was expanded by utilizing the coupling effect between the notched patch and the resonant aperture for dual-band RFID reader antenna 155 mm×230 mm in size [8].

Several methods were approached in designing the multi-frequency antenna from a single frequency antenna [9-14]. In the study by [9] the dual band functionality was achieved though a perturbation method by electrically coupling a two-turn spiral resonator to the antenna. The position of the resonators along the line affects the impedance characteristic. Dual operating frequencies were also achieved by loading two pairs of narrow slots in the triangular patch [11]. By adjusting the slot, protruding a narrow slot out of embedded slots close to the side edges; broad-band radiation was obtained. A triple band was also experimented by placing a cross slot in the ground plane. By embedding a small circular patch into a dual stub loaded on annular ring structure was able to reduce the size by 50% compared to the conventional annular ring patch and broad impedance bandwidth at 1.17 GHz, 1.428 GHz and 1.9 GHz was obtained [12]. In [13] dual band antenna with high gain was achieved by applying U-shapped feeding strip excites the rectangular ring. In addition, some studies have developed the optimisation performance techniques of RFID antennas regardless of its size such as miniaturized antenna using meander-line [15-17], artificial transmission lines [18] and complementary split ring resonator (CSRR) [19]. Moreover, photo paper with silver nanoparticle conductive ink [20] and biopolymer substrate [21] have been proposed due to flexibility and low cost.

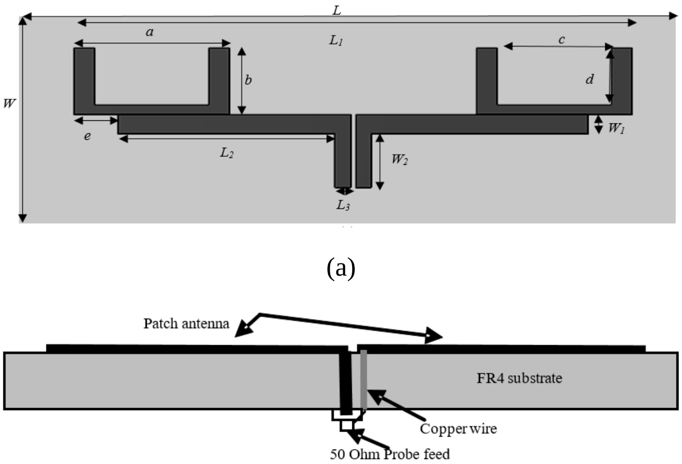
Techniques used to design multi band antenna with dipole configuration were also studied [20-24]. In [22], the dipole was made of two concentric hallow cylinder with different radius anf length. Another method tested is by integrating two patches with the dipoles printed on the same substrate to perform triple band with directional radiation pattern [23]. It consists of a top loaded dipole for lower frequency, two longer dipoles for middle frequency and two shorter dipoles for upper frequency. The antenna was performed in direction patter with antenna gain 7.5 dBi at lowest band, 8.5 dBi at middle band and 9-10 dBi at highest band. Thus, the integration by two patches was adopted in this study to achieve two frequency bands. The length slot of radiating patch integrated with dipole antenna proposed by [24] able to adjust the desired upper frequency and the bandwidth. By varying the dipole arms for both elements, the lower frequency was obtained.

## 2. ANTENNA DESIGN

In this paper, U-shaped patch loaded with dipole antenna is being proposed. This design will be able to perform dual band antenna inspired by [25]. Li described that the performance of the dipole antenna was not affected by the size condition of Koch fractal. However, the electric dipole's performance is only related to its heights. Thus, the disturbance of dipole height may perform the multiband or wideband antenna. Therefore, the rectangular patch is proposed to be loaded on top of arm length $L_2$. The characteristics and the performance of dipole antenna loaded U-shaped patch is studied.

### 2.1. U-shaped Patch Antenna Geometry

The parameters of $L_1$, $W_1$, $L_2$, $L_3$ and $W_2$ are shown as basic dipole design. For the dual band frequencies, the U-shaped patch structure is loaded with the dipole on the arm length of dipole symmetrically as shown in Figure 1. Analysis is based on the parametric study of parameters *a*, *b*,*c*, d and *e* as U-shaped patch configuration .




(a)

(b)

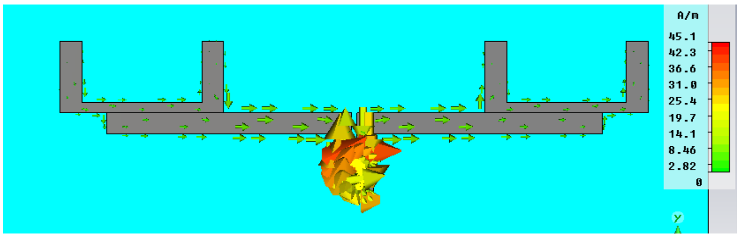
Figure 1. (a) Geometry of dipole intergrated with U-shaped patch on top view
(b)The structure of FR4 board of proposed antenna on side view

The configuration of dipole is unchanged. Therefore the effects of U-shaped patches is discussed. There are two parts to be investigated which are the effect of loading the rectangular patch without slot and the slot configurations. The reflection coefficient curves results are studied when the parameters are varied. The resonance frequency of dual band performance is compared within 0.915 GHz and 2.4 GHz.

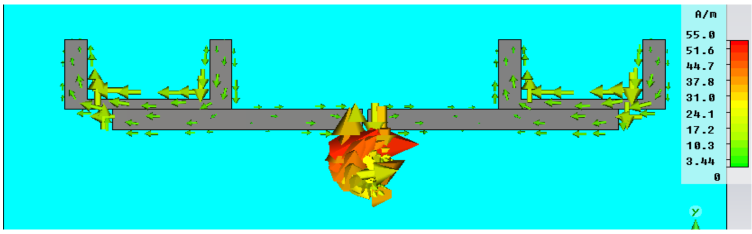
### 2.2. Current distribution

The arm length of the basic dipole is 45 mm has performed the reflection coefficient with −22.64 dB at 1.2275 GHz. By integrate the rectangular patch $a \times b$ mm$^2$ with the basic dipole, dual band is performed. The resonance frequency first band is shifted from 1.2275 GHz which is the reading from basic dipole to 0.915 GHz. The reading is decreased because of the length of dipole has increased ($L_2$+ $e$+ $b$). Consequently, the geometrical path for current resonates is increased. As shown in Figure 2 (a) the lower band of 0.915 GHz, the current strongly distributes along the arm dipole geometry.

For upper band at 2.4 GHz, it can be observed that the current is intensely travelling around the edge of U-shaped slot of $c \times d$ mm$^{2.}$ The distance between the feeding point and the rectangular patch has influenced the resonance frequency. The shorter the distance, thus the higher the operating frequency. The slot can be varied the upper band without changes the performance of lower band. This optimized parameter values of RFID application are shown in Table 1.




(a)




(b)

Figure 2. Current distribution of dipole antenna loaded with U-shaped patches antenna (a) 0.915 GHz at lower band (b) 2.4 GHz at upper band

Table 1.Optimized parameters of the proposed dual band antenna for UHF and ISM RFID applications

| Parameter | Value (mm) | Parameter | Value (mm) |
|---|---|---|---|
| $L$ | 130 | $W_2$ | 11 |
| $W$ | 45 | $a$ | 30 |
| $L_1$ | 108 | $b$ | 13.65 |
| $W_1$ | 4 | $c$ | 22 |
| $L_2$ | 45.5 | $d$ | 11.65 |
| $L_3$ | 3 | $e$ | 8.5 |

## 3. RESULTS AND ANALYSIS

The optimized parameters of the proposed dual band antenna are shown in Table 1. Antenna prototype of proposed dual-band antenna is performed as depicted in Figure 3 for measuring. Based on the Table 2, the operating frequencies for lower and upper band are same. However, the reflection coefficients of lower band and upper band have shown differently. At lower band, reflection coefficient is excited at 0.9 GHz with -25.05 dB and measured result is -16.5 dB. For upper band, measured return loss is -14 dB as compared the simulated result is -41.23 dB. The bandwidth is increasing for both resonance frequencies. The lower band is 196 MHz with 8% increment from the simulated result. In addition, 73% differences of upper band as compared with the simulated bandwidth at the 87.3 dB shown in Figure 4. The gain and directivity at 0.915 GHz are 1.89 dBi and 1.99 dB respectively. However, the gain and directivity for the upper band is greater than lower band which is 3.65 dBi and 4.37 dB respectively. At lower band, the efficiency is 97.23% and 84.72% at upper band.

Lastly, the radiation patterns of E-plane and H-plane patterns are discussed as shown in Figure 5 to describe the performance of the antennas. Omnidirectional radiation pattern is performed at 0.915 GHz and 2.4 GHz in H-plane. At lower band, bidirectional in E-plane like a dipole. Besides, the radiation pattern in E-plane is distorted a bit at 2.4 GHz as the current travel around the slot of the U-shaped patches.

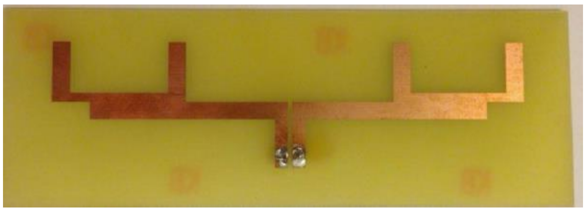


Figure 3. Prototype antenna

Table 2. Comparison result

| C-shaped patches loaded with dipole antenna | Simulated result Lower band | Simulated result Upper band | Measured Result Lower band | Measured Result Upper band |
|---|---|---|---|---|
| Frequency Resonance (GHz) | 0.9 | 2.46 | 0.914 | 2.42 |
| Reflection coefficient (dB) | –25.05 | –41.23 | –16.5 | –14 |
| Bandwidth (MHz) | 109 | 87.3 | 196 | 150 |

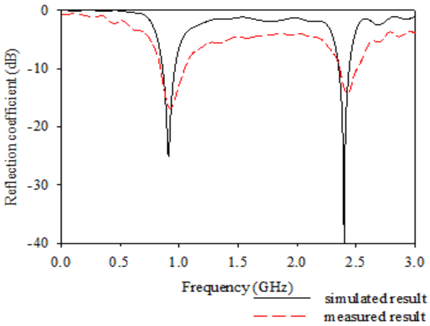



Figure 4. Reflection coefficient curve of proposed antenna

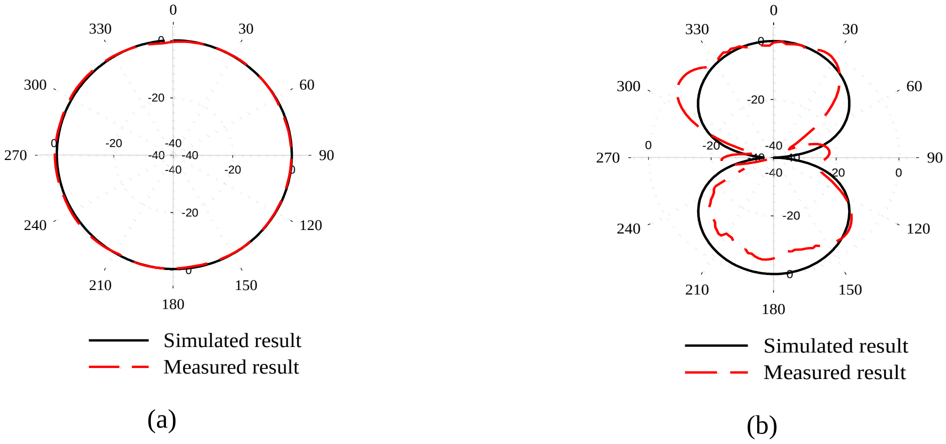



Figure 5. Radiation patterns of prototype when both switches are ON (a) H plane at 0.915 GHz (b) E plane at 0.915GHz

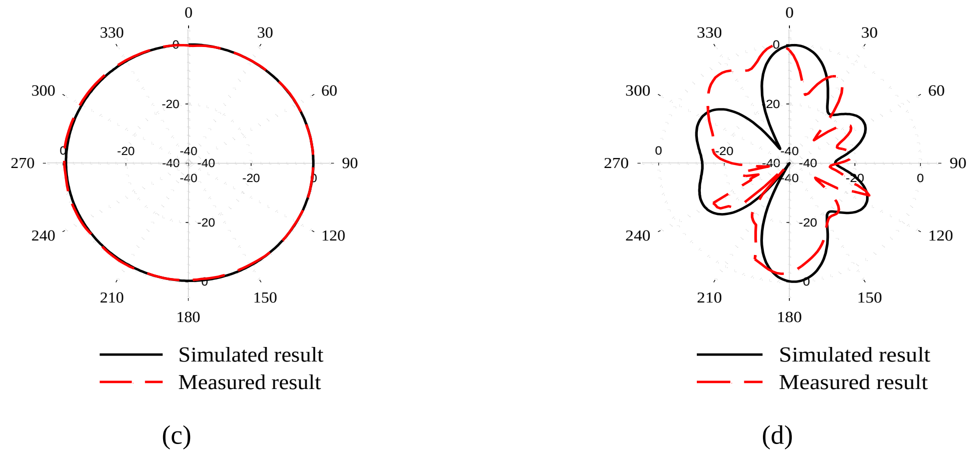



Figure 5. Radiation patterns of prototype when both switches are ON (c) H plane at 2.4 GHz (d) E plane at 2.4 GHz

## 4. CONCLUSION

This paper presents the investigation into the basic dipole antenna with the U-shaped patch antenna without a ground plane. Without ground plane, the antenna performance can be improved when RFID integrate with any material [24]. The antenna configuration is initially designed from the basic dipole as planar antenna with coaxial feeding method to achieve low profile and compatibility with printed circuit board. The configuration of U-shaped patches has been placed on the arm length of dipole. It has found that in designing the lower band at 0.915 GHz, the parameter of *e* was affected the arm length which was integrated with the rectangular patch. This was resulted the increment of the geometry of arm length. After the parameters of rectangular of length, *b* was determined, the slot can be modified to design the upper band. It has been observed that by adjustment of slot length *d*, the upper band was adjusted but the lower band has no changes. Based on the results, the dual band antenna for RFID applications was achieved.

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