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Antenna Design for UHF RFID Tags Using Two Coupled Patches

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ABSTRACT

In this paper we present a patch antenna with compact low profile for Ultra-High Frequency (UHF) Radio Frequency Identification (RFID), by using two coupled patches by passing C-shaped, wide impedance bandwidth at half power of 152 MHz is obtained for UHF (860-960 MHz) RFID. The lengths of the two patches are slightly different from each other so that they resonate at two different frequencies adjacent to each other to form a wide width strip impedance to cover the entire range of the UHF band. The patch antenna has a planar profile proposed eliminating the need for and against the multilayer structure thus leading to ease of manufacture and reduced cost. The design of the proposed antenna is simulated using HFSS. Simulation results presented show a satisfactory performance when the antenna is mounted on various sizes of metal plate.

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1. INTRODUCTION

Radio frequency identification (RFID) technology is growing tremendous demand in the supply chain management system. RFID is an automatic identification technology [1]. It is a pervasive computing technology for collecting and gathering data from a tagged item. The data is stored in the mobile device called tag. When the tag comes in the reader's reading zone, the data is collected by the reader without any need of physical contact. The data in the tag may be the identification number, location information, or specification of product such as price, brand, date, etc. Unlike bar code technology, the RFID technology does not require lightof-sight and reads longer distance [3]. Such advantages help the supply chain to operate very fast and efficiently.

Each country has its own frequency allocation for RFID. For example, RFID UHF bands are: 866–869 MHz in Europe, 902–928 MHz in North and South America, and 950–956 MHz in Japan and some Asian countries. A typical passive RFID transponder often called "tag" consists of an antenna and an application specific integrated circuit (ASIC) chip. RFID tags can be active (with batteries) or passive (battery less). A passive back-scattered RFID system operates in the following way. Abase station (reader) transmits a modulated signal with periods of unmodulated carrier, which is received by the tag antenna. The RF voltage developed on antenna terminals during unmodulated period is converted to dc. This voltage powers up the chip, which sends back the information by varying its front end complex RF input impedance [2]. The impedance typically toggles between two different states, between conjugate match and some other impedance, effectively modulating the back-scattered signal.

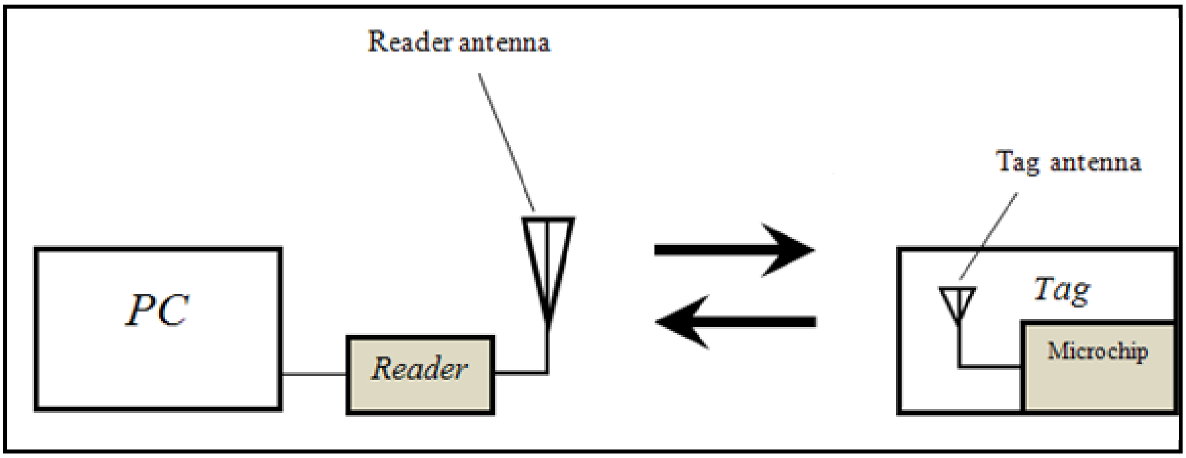


Figure1: Passive RFID system operation

A 900MHz prototype antenna is implemented with the substrate size L x W = 60 mm × 40 mm (substrate FR-4), with dielectric constant ε_r= 4, 3, loss tangent tan δ= 0,02 and thickness h = 1,6 mm. The design parameters as shown in Figure 2 are: A1 = 16,67 mm, A3 = 35mm, A5 = 12mm width = 6mm, θ

2. ANTENNA DESIGN

Parameter often used to calculate the impedance mismatch between the antenna and the chip yield loss, RL. In general, the yield loss is a measure of the effectiveness of the supply of energy from a transmission line to a load, in this case where the transmission line is represented by the tag antenna chip as filler. Return Loss (dB) is defined by the equation:

$$RL = 10\ \log_{10}\left(\frac{P_{in}}{P_{ref}}\right)$$

Γtag, between the complex antenna impedance and microchip complex input impedance is given by Eq:

$$\Gamma = \frac{Z_{chip} - Z_A^*}{Z_{chip} + Z_A}$$

From a compromise between gain, bandwidth and antenna volume is unavoidable, careful study design is made to meet the design requirements of the antenna. For the evaluation of the performance, bandwidth impedance half the power (RL ≥ 3 dB), which represents half of the radiated power absorbed by the antenna of the tag is adopted in this study [3]. Impedance matching is of great importance in the design RFID tag antenna. A good impedance match provides sufficient power is supplied to the electronic chip allowing it to function. We know that the microchip inherits capacitive reactance due to its ownership of energy storage. Therefore, the tag antenna is present inductive impedance at its input terminal to provide corresponding combined impedance. There are several varieties of chips available tag whose input impedance varies from another [4].. In this study, tag chip made from Alien Technology, Alien Higgs-3 EPC Class 1 Gen 2 RFID chip is chosen as a reference. The exhibition complex impedance of the smart tag is Zchip = (31- J212) Ω at 915 MHz.

In this design, the technique of inductive coupling loop power supply is used to achieve impedance matching between the antenna and the proposed chip. In the radiating element of the antenna, two C-shaped spots are used. The two patches are fed by the same supply network and simplifying the adjustment element [5].. The lengths of the two patches are slightly different from each other so that they resonate at two different frequencies adjacent to each other to form a wide width strip impedance to cover the entire range of the UHF band.Both the resonant frequencies, the reactance and resistance of the tag antenna are given by the equation:

$$R_{A,0} = R_A(f_0) = \frac{(2\pi f_0 M)^2}{R_{rb,0}}$$

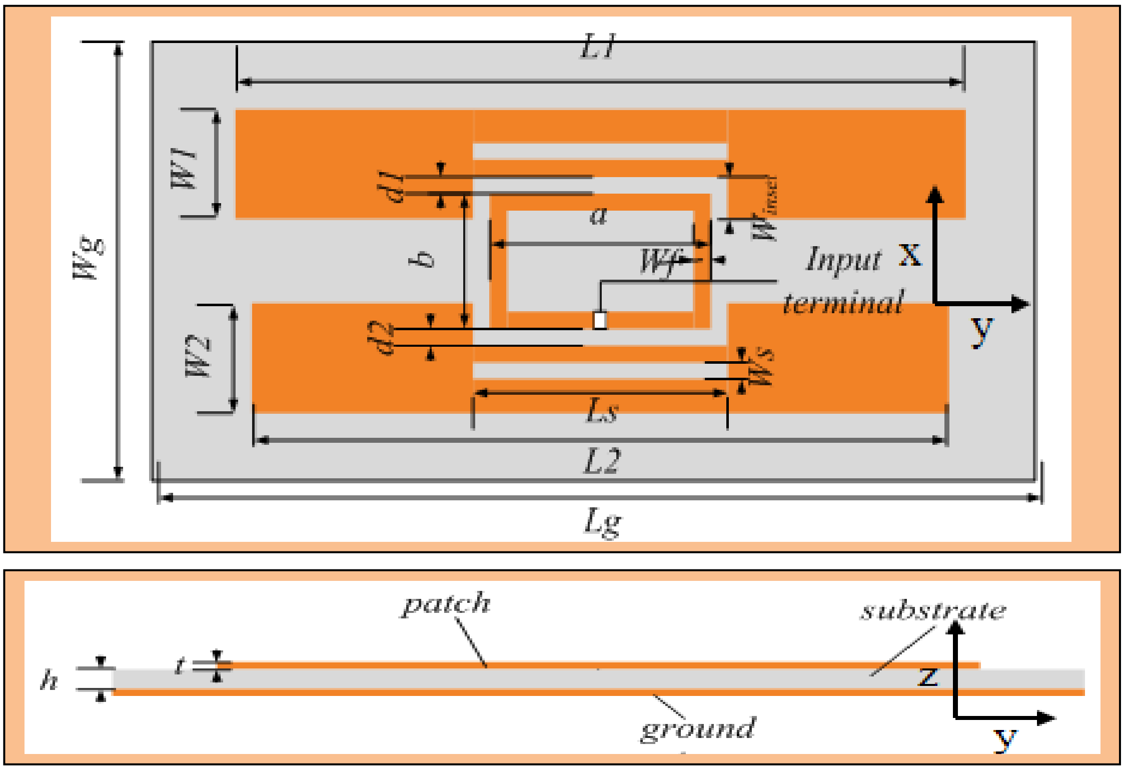


Figure 2: The geometry of the antenna

$$X_{A,0} = X_A(f_0) = 2\pi f_0 L_{loop}$$

f_0 : the resonant frequency of the patch
M: is the mutual inductance between the patch and the loop
R_{rb}: Represents the resistance of the patch
L_{loop}: is the self-inductance of the feed loop

It is apparent that $R_{A,0}$ and $X_{A,0}$ can be adjusted independently to match the impedance of the microchip.

Figure 3 illustrates the geometry of the proposed antenna. The C-shaped patch can be derived from a rectangular microstrip antenna in which a slot is cut along one of its non-radiating edges [6]. To calculate the initial resonant frequency of the rectangular part without cutting slot shows the relation:

$$f_0 = \frac{c}{2\sqrt{\varepsilon_e}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{1/2}$$

Where L and W are the length and width of the room, respectively and m and n are the modes along L and W.
Ɛe effective dielectric constant is with:

$$\varepsilon_e = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r - 1)}{2}\left[1 + \frac{10h}{W}\right]^{-1/2}$$

It is observed that the calculated resonant frequency of the rectangular piece to be reduced once a rectangular slot in one side of the non-radiating edge is cut to form C-shaped patch. This is due to the increase in the electrical path of the antenna. Therefore, the physical length of the antenna can be reduced to achieve smaller form factor compared to the design of typical rectangular patch [7].

Inexpensive FR-4 epoxy glass with a relative dielectric constant, $\varepsilon r=4.4$ and tangential loss $\tan\delta=0.002$ is chosen as a substrate. The high loss tangent of the substrate reduces the Q value of the antenna, thus increasing the bandwidth. The thickness of the substrate, h = 1.6 mm is selected to keep mm low profile [8]. The size of the substrate and the ground are both 87 mm x 45 mm. As for the patch and the ground plane, with a thickness of copper, t = 0.0358 mm is used. The design of the proposed antenna is simulated using Ansoft HFSS.

3. RESULTS AND DISCUSSION:

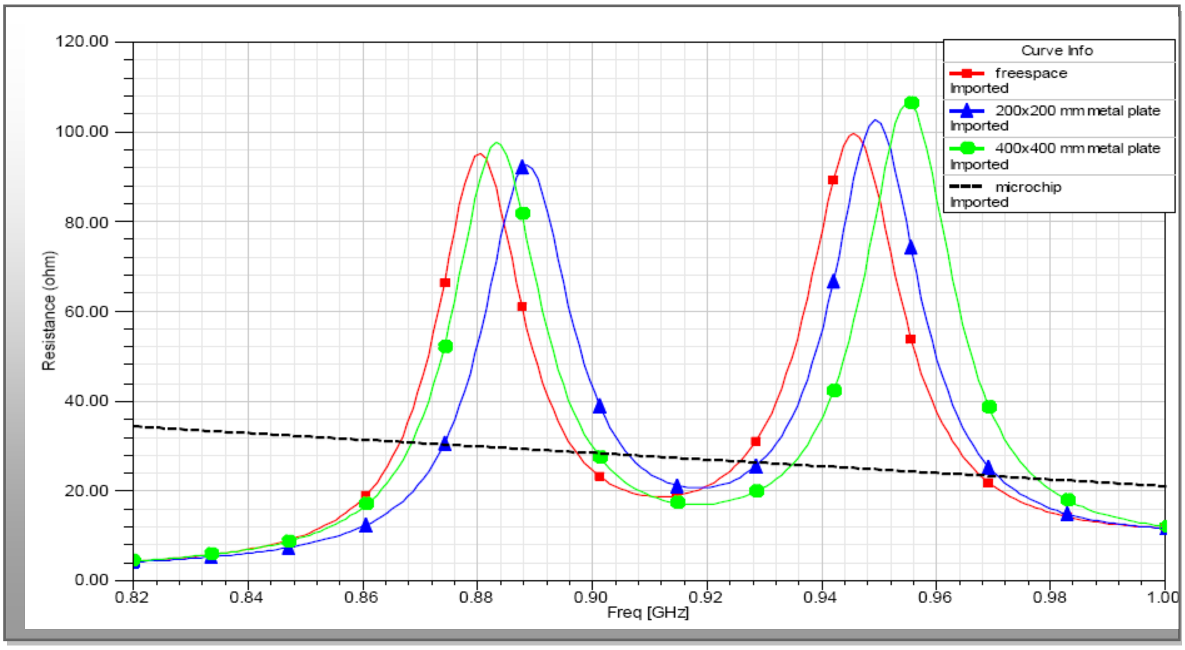
To realize a wide band characteristic, good impedance matching between the antenna and the proposed whole frequency range UHF chip is necessary. To do this, two C-shaped patches having modes of resonance close to the other is adopted [9]. To feed the two plates, inductive coupling loop power is sandwiched between them. This allows only a single feed network to be used to power both of the radiating body. The input reactance of the antenna can be adjusted to match that of combining the capacitive impedance of the chip by changing the dimensions of the loop, a and b. On the other hand, the distance between the two patches supply loop, d1 and d2 may be adjusted accordingly to present a good correspondence with the resistance value of the chip [10].

A thin slit is cut at the center of these two patches to increase the strength of coupling between the loop and the patch where significant increase in resistance is made to the antenna input terminal [11]. The advantage of using this matching technique is that independent adjustment can be made for the resistance value and the desired inductance. Parametric refinement was performed using the simulator to find the optimized values for good impedance matching over the entire range of UHF RFID [12]. Since the objective of this study is to design the antenna broadband tag is capable of being used for metal applications, two scenarios where the antenna are mounted on two different sizes of the metal plate were simulated to observe its effects on the performance of the antenna. The dimensions of the metal plate are taken to be 200×200 and 400×400 mm^2 respectively.The parameters of the optimized antenna are summarized in Table 1.

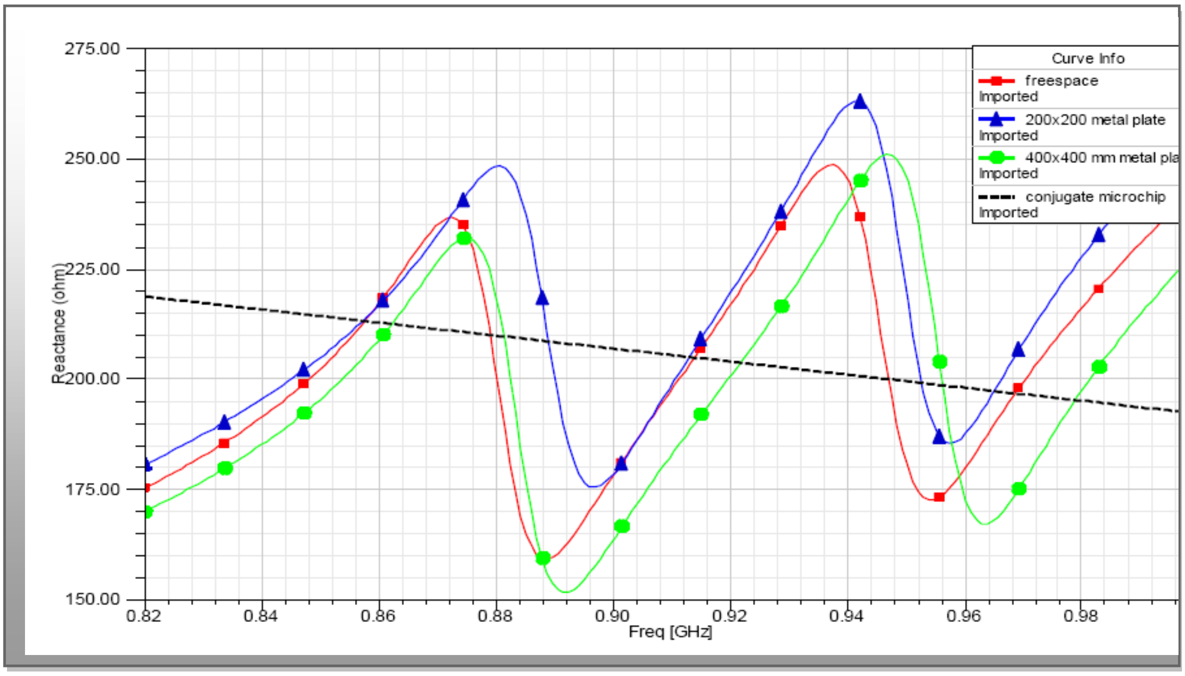
Parameter	**Value (mm)**
W1	**10**
L1	**74**
W2	**10**
L2	**69**
W_S	**1**
L_S	**30**
d1	**2**
d2	**2**
W_{inset}	**4**
T	**0.0358**
H	**1.6**
Wf	**2**
a	**29**
b	**10**
Ground plane and substrate	**87×45**

Table 1: Design parameters of the antenna

Figure 4 shows the simulated complex impedance of the antenna and the impedance value of the corresponding conjugated microchip. As predicted, due to the excitation of the two modes of resonance of the radiating plate, a large part of the resistance and the reactance between the antenna and the microchip proposed is obtained throughout the frequency range width thus producing impedance bandwidth [13]. Only slight difference in frequency is observed when the antenna is mounted on a metal plate. This is probably due to the reduction of the field of fringes which is fixed on the metal plate with respect to the condition without metal plane [14].



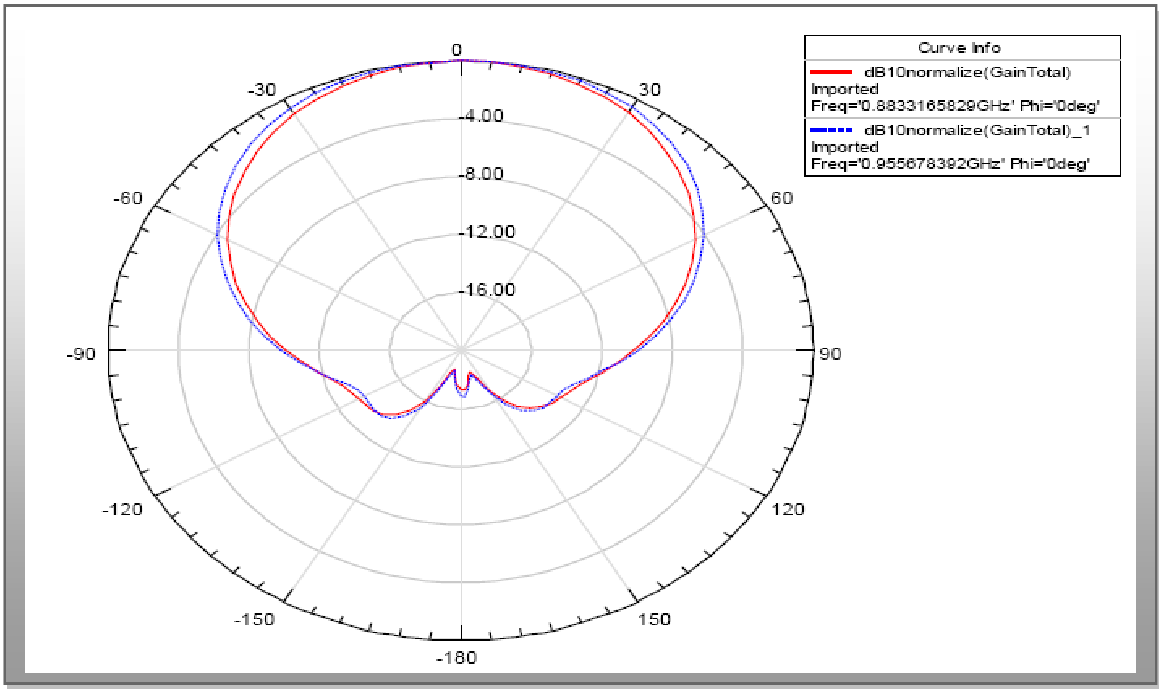
(a)



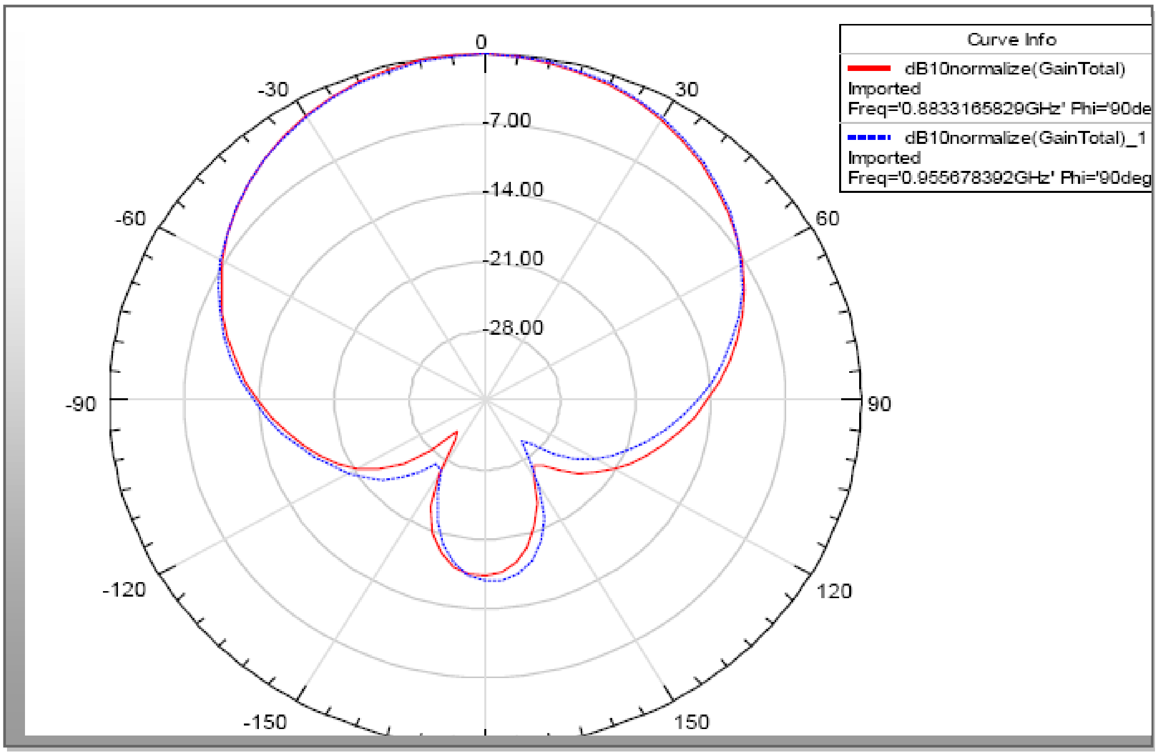
(b)

Fig. 4: Simulated impedance of the antenna and the microchip conjugate impedance value against frequency, (a) resistance and (b) reactance value against frequency

To reduce the physical size of the antenna, the rectangular slot was cut on one side of the non-radiating edge of each patch. The existence of the gap causes the bend of the electrical path length which makes longer than that of the rectangular patch without slot. Accordingly, the resonant frequency of the patch is reduced allowing miniaturization of the antenna. The radiation patterns at the E-plane and H-plane are shown in Figure 5:

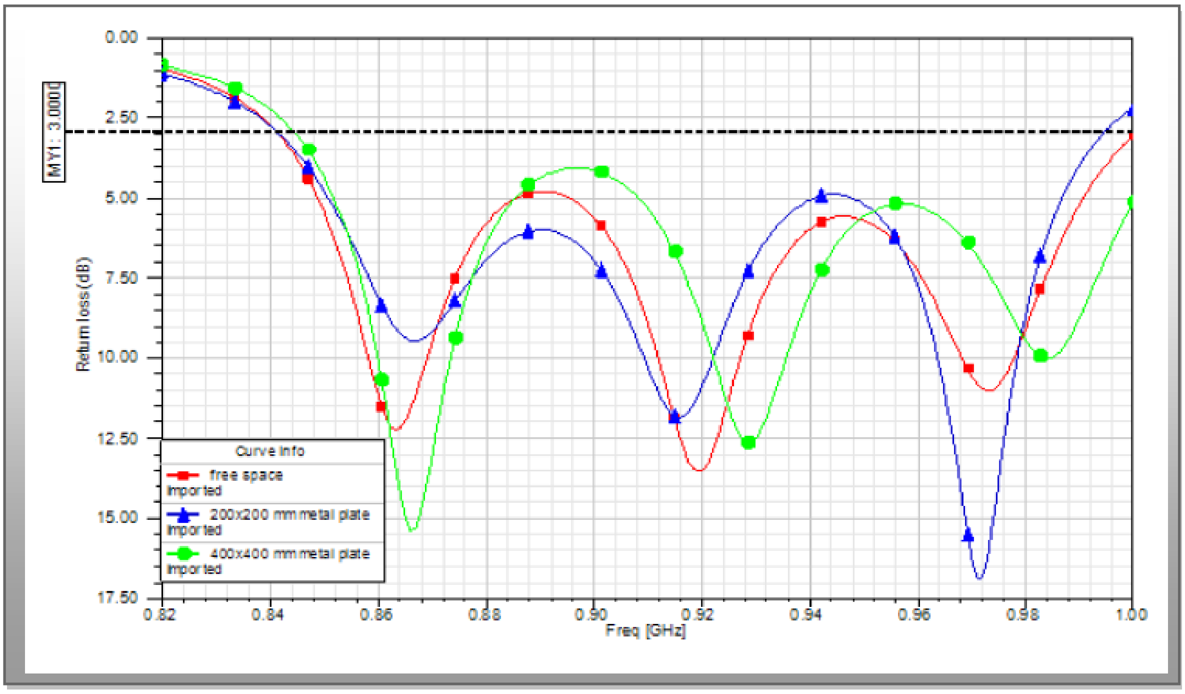


(a)

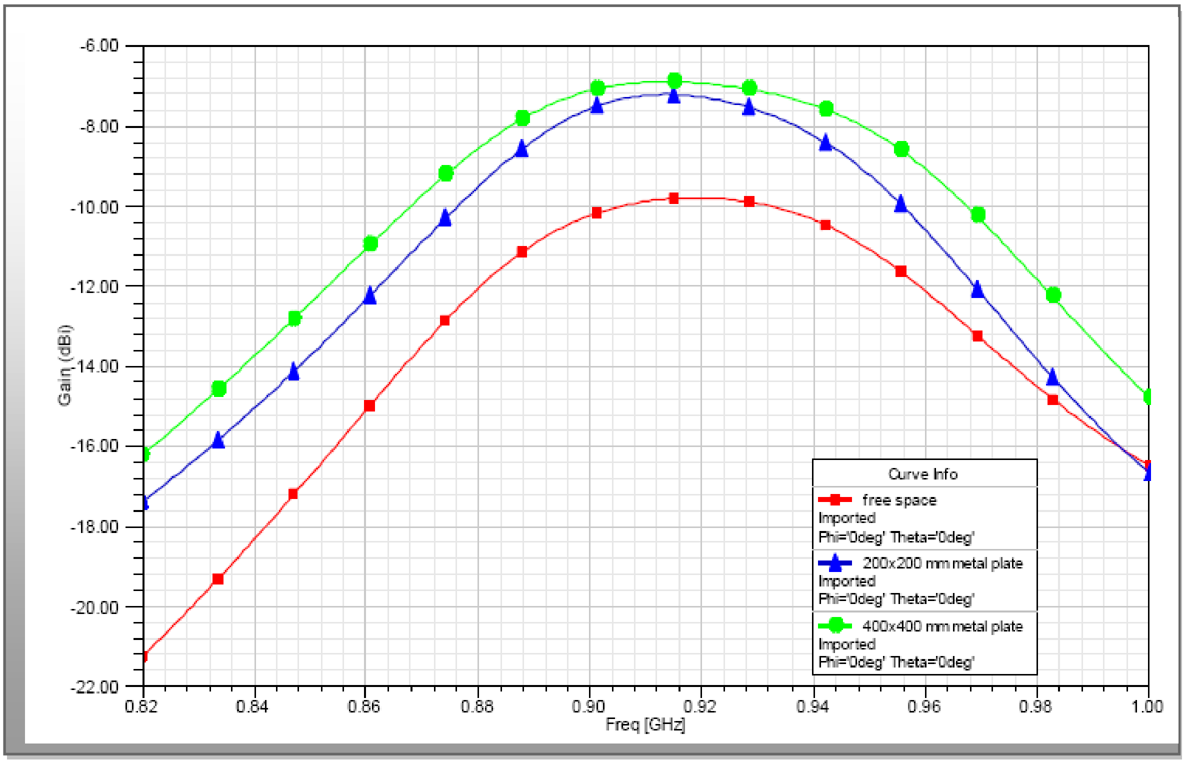


(b)

Figure 5: (a) Normalized E-field and (b) normalized H-field radiation pattern at two resonant frequencies



(a)



(b)

Figure 6: (a) Return loss (dB) of the proposed antenna and (b) Peak antenna gain of the proposed antenna

The impedance bandwidth at half power simulated (RL ≥ 3 dB) of the antenna shown in Figure7-a. It is seen that the impedance bandwidth of all of the three cases, are capable of covering the entire UHF band for RFID use worldwide. The discrepancies of the bandwidth obtained mainly due to the slight difference of the resonance frequencies of the antenna due to the metal plate. To give a better assessment of the performance of the antenna, the simulated total gain is given in Figure 7-b. Low antenna gain is mainly due to the loss and the structure of thin substrate, and its small form factor. However, improving the antenna gain is seen when it was mounted on the metal plate.

4. CONCLUSION

In this study, a new antenna of the RFID tag for metal application is proposed. To achieve impedance bandwidth broadband to the application of the universal UHF band, two shaped patch-C-gap coupled with resonant modes close to each is employed. Power coupled inductive loop is used as a matching system to make the game combined with the chip. The complete structure of the low profile of the proposed antenna eliminates cross and multi-layer construction that would significantly reduce the complexity of the fabrication of the antenna and subsequently lead to potential savings.

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