

# Small Ceramic Patch Antenna for UHF RFID Tag Mountable On Metallic Objects

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**Abstract:** A very small UHF band RFID tag antenna using ceramic material mountable on metallic objects is presented. The proposed tag size is 25x25x3 mm. The impedance of the antenna can be easily matched to the complex conjugate of the tag chip impedance from the size of the shorting plate of the side patch and the size of the feeding loop. The antenna satisfactorily operates on metal plates, so it is applicable in many applications. The proposed design is verified by simulation and measurements which show good agreement.

## 1. Introduction

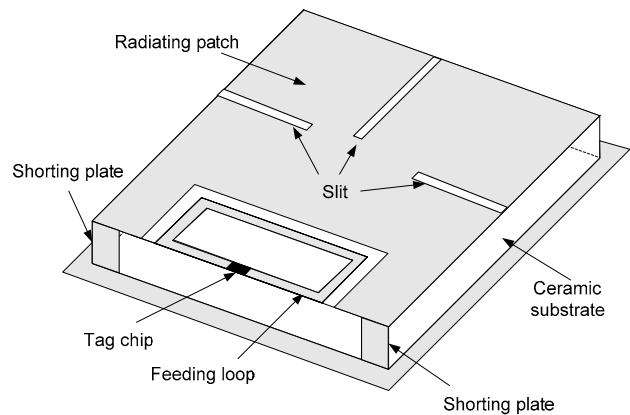
Radio frequency identification (RFID) has been widely used in supply chain, services industries, distribution logistics, and manufacturing companies to identify goods. In special RFID applications such as metallic components, the general label tags cannot operate in the surface of the conducting materials because of the degradation of tag antennas. Proper antenna design for RFID tag applications is becoming essential for the maximization of RFID system performance. Recently, there have been many studies on RFID tag antennas in the UHF band, especially at 900 MHz. In many applications, RFID tags need to be placed on metallic materials and to be very small. To meet this application requirement, the planar inverted-F antenna (PIFA) which can be used on metal has been proposed as a tag antenna [1], [2]. To reduce the size of the patch antenna, two symmetric shorted microstrip patch antennas and a feed loop is studied [3]. To expand the bandwidth of the metal tag antenna, there have been studies which proposed using orthogonal proximity coupled patch antennas in RFID tags [4]. Metal tags applied in specification fields have to be manufactured to a smaller size than the existing metal tags. Also, the tag antenna must be directly matched to the tag chip, which may have a complex impedance which differs from  $50\Omega$ . The impedance matching technique using inductive coupling has been studied in relation to RFID tag antennas [5].

In this paper we discuss a very small tag antenna, which uses a ceramic material, an inductively coupled feed and patch antenna with a shorting plate suitable for the UHF band RFID tag which can be placed on the conducting materials and can be used in specified applications. A rectangular tag with a height of 3 mm and an area of 25x25 mm is proposed.

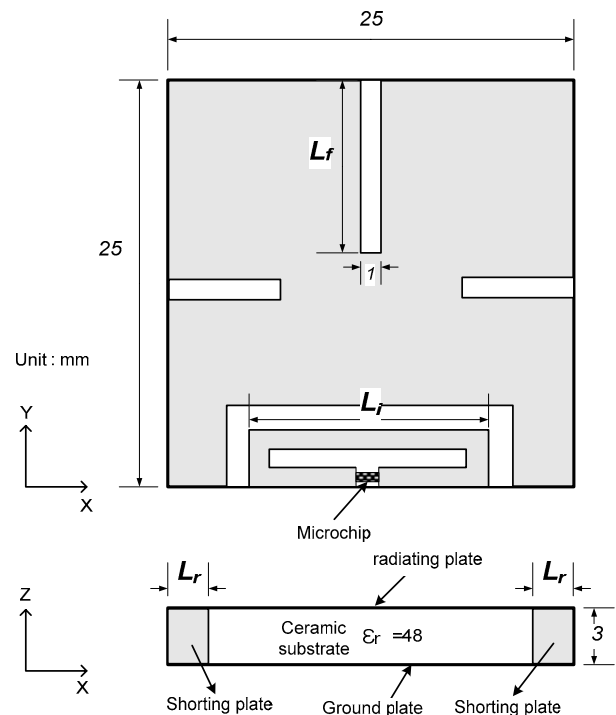
## 2. Tag Antenna Design

The geometry of the proposed antenna is presented in Fig. 1. The proposed tag consists of a tag chip, a inductively coupled feed line, a radiating patch with a shorting plate,

the substrate filled with ceramic material ( $\epsilon_r = 48$ ) and the ground plate. The radiating patch is a metal plate with the horizontal and vertical slit for adjusting radiation frequency.



(a) Geometry of the proposed antenna



(b) Top and side view of the proposed antenna

Fig. 1 Structure of the proposed antenna

The vertical slit has length of  $L_r$ . The tag chip is electrically connected to the feed line, which is located in the same plane of radiating patch. The horizontal length of the feed line is  $L_i$  and the width of the shorting plate is  $L_r$ . In many applications, the resistance of the characteristic impedance of the tag chip is found to be in the range of 3 to  $150\Omega$ , and

the reactance is in the range of  $-200$  to  $-50\Omega$  (capacitive). In this paper the antenna is designed for a tag chip (commercial RFID tag chip : Alien higgs chip) with an impedance of  $Z_c=(12-j140)\Omega$  at a resonant frequency of  $910\text{MHz}$ . The conjugate match is achieved between the impedance of the proposed antenna and the tag chip by adjusting the width of the shorting plate and the feed line length. The operating frequency is adjusted by varying the slit length of the radiating patch, while the impedance of the antenna is almost unaffected..

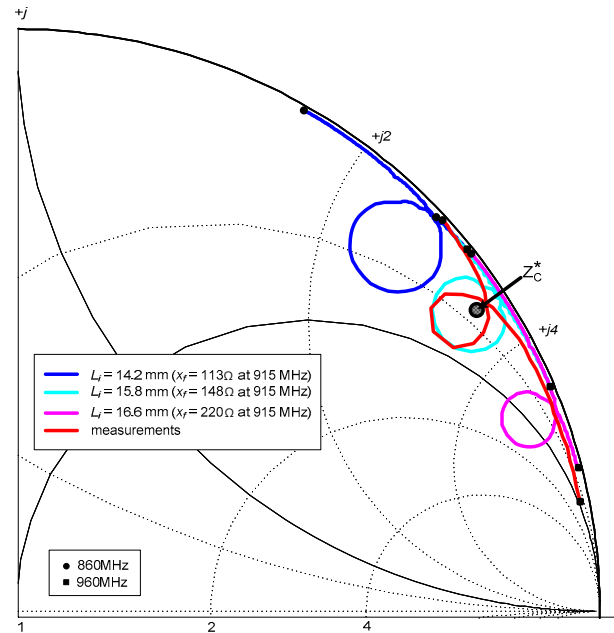
### 3. Simulation and Measurements

A prototype antenna has been designed and implemented for a tag chip with an complex conjugate impedance of  $Z_c^*=(12+j140)\Omega$ . The overall size of the antenna is only  $25\times 25\times 3$  mm and the operating frequency is  $910\text{MHz}$ .

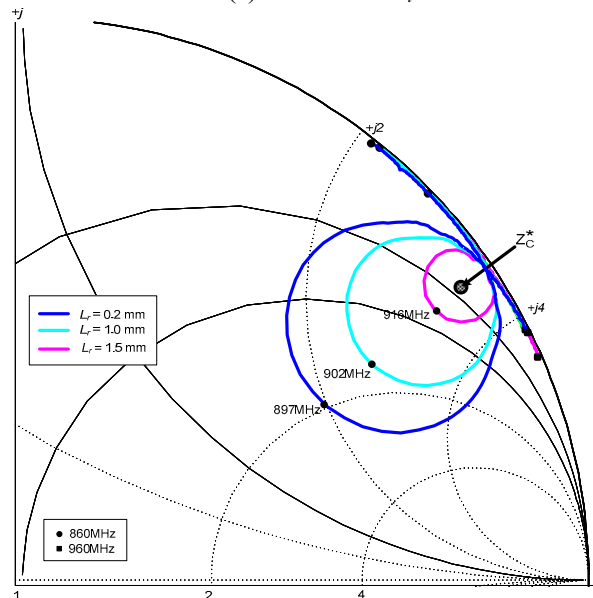
Figure 2 shows the simulated and measured data for the input impedance of the antenna when it is attached to an infinite metal plate. The simulation is performed using CST Microwave Studio. The locus of the input impedance of the antenna has a  $\alpha$  - shaped feature in the smith chart. This is because the reactance component of the coupled impedance of the radiating patch and the self-reactance of the feed line cancel each other around the resonance frequency of the radiating patch in a similar manner to the inductively coupled feed[5]. The reactive component of the input impedance is dependent on the self-reactance of the feed line  $X_f$  and can be easily matched to the conjugate of the tag chip impedance by varying the length of the feed line  $L_i$  and the resistive component of the input impedance has simple dependence on the width of the shorting plate  $L_r$ . The reactive and resistive component of the input impedance characteristics of the antenna for different values of  $L_i$  and  $L_r$  are shown in Fig2(a),(b). As the value of  $L_i$  increases, the reactance of the input impedance increases and as the value of  $L_r$  increases, the resistance of the input impedance decreases while the resonant frequency is not changed. Fig2(c) shows the vertical length of the slit  $L_f$  in the radiating patch has the effect of moving the  $\alpha$  - shaped locus with varying the resonant frequency. Fig2(a) shows that the measured impedance locus agrees well with the simulated results. The measurement was carried out with the antenna placed at the center of a  $40 \times 40$  cm<sup>2</sup> metal plate. Figure 3 shows the return loss of the proposed antenna with the simulation and measurement results with respect go  $Z_c$ . The 3dB return loss bandwidth is  $21\text{MHz}$  which covers the bandwidth of the Korean RFID frequency band( $908.5\text{MHz} \sim 914\text{MHz}$ ).

Fig. 4 shows the simulated radiation pattern of the proposed antenna mounted on metallic surface at  $910\text{MHz}$ . The radiatin pattern in  $y$ - $z$  plane and  $x$ - $z$  plane has fairly good omni-directional performance.

To study the effect of the size of the metallic object for the proposed antenna, the radiation pattern is simulated with different size of metal plate (mounted on free space,  $20\times 20$  cm and  $40\times 40$  cm) in Fig 5. Fig. 5 represents that the main



(a) variation in  $L_i$



(b) variation in  $L_r$

Fig. 2 Input impedance characteristics of the proposed antenna

beam direction is not steered by metallic plates and the antenna has omni-directional radiation pattern

The simulated directivity of proposed antenna with metal plate is about  $5.21\text{dBi}$  and the radiation efficiency is about  $35\%$  because of the small antenna size and high dielectric constant of the substrate. The size of the proposed tag is very small and the structure is very difficult to measure the radiation pattern and antenna gain, so the characteristics of the antenna is verified from the maximum reading distance of the tag in the RFID applications.

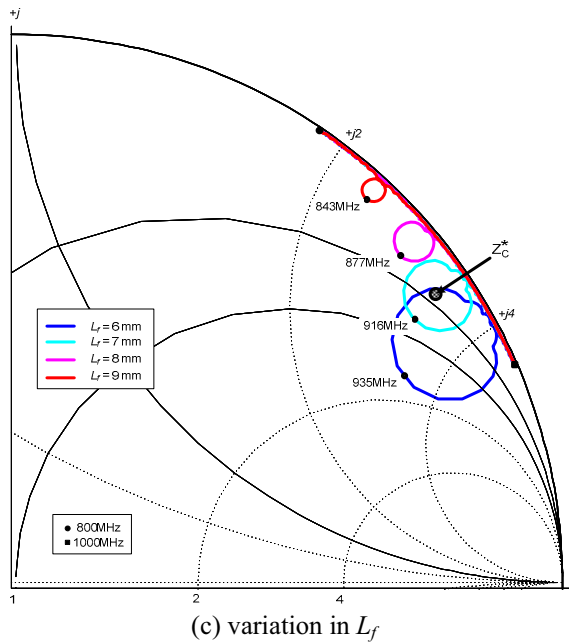


Fig. 2 Input impedance characteristics of the proposed antenna (continue)

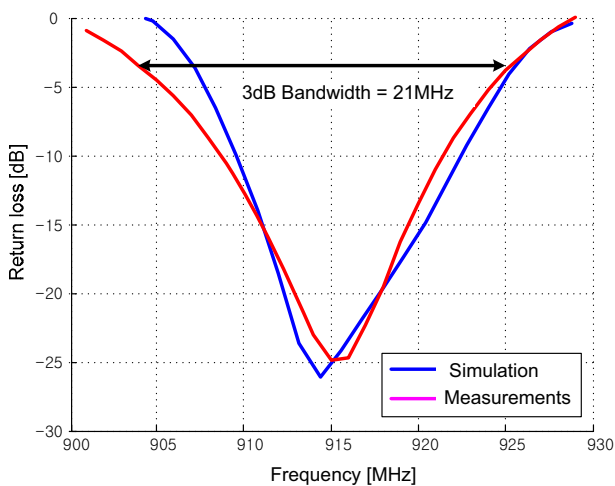


Fig. 3 Calculated and measured return loss of the antenna against frequency

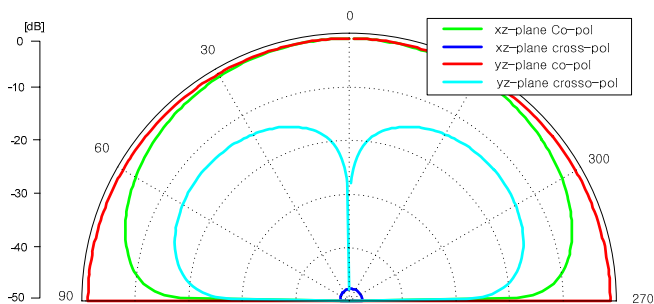
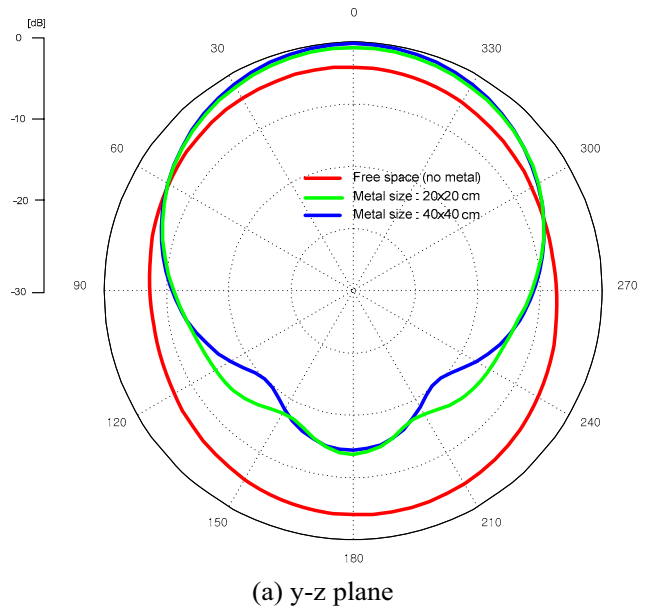
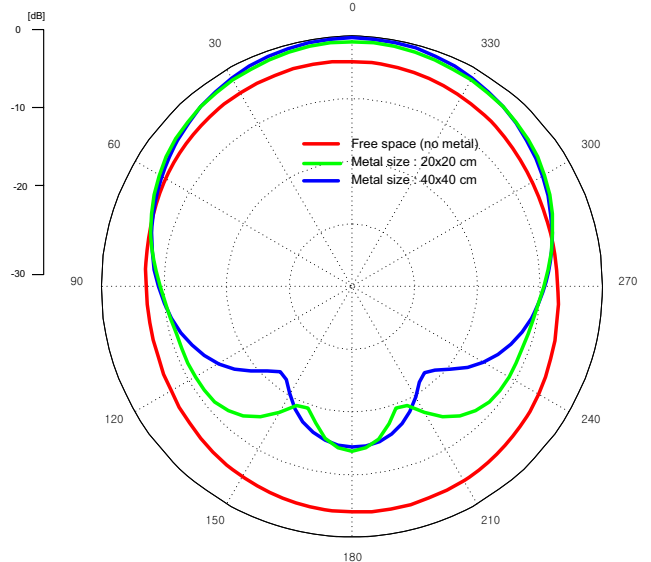


Fig. 4 Simulated radiation pattern of the proposed antenna in the case of infinite ground plane



(a) y-z plane



(b) x-z plane

Fig. 5 Simulated radiation pattern of the proposed antenna mounted in the metal plate

We measure the maximum reading distances of the tag on metallic plate with  $20 \times 20 \text{ cm}^2$  and  $40 \times 40 \text{ cm}^2$  using the commercial RFID reader made by Alien Technologies (ALR-9800) in an anechoic chamber. The reading range is approximately 4-5m while the operating frequency of the reader hops onto the frequency band in the range of 908.5 to 914MHz. It is clear that the antenna operates satisfactorily on metal plates, so the tag can be used on metal plates for the best performance in specific applications such as automobile components

## 4. Conclusions

A design for very small tag antenna(25x25x3 mm) using ceramic material at UHF band mountable on metallic objects was implemented. The antenna can be directly matched to the arbitrary complex impedance of a tag chip. It is verified that the proposed tag has good performance by measuring the bandwidth at 3 dB return loss of 21MHz and maximum reading range on metallic plates of 4m. The impedance of the proposed antenna can be easily controlled by using the shorting plate and feeding loop size. The proposed tag is very small, so it may be used with a conducting plate to facilitate mounting it on curved surfaces as cans if necessary..

## Acknowledgement

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## References

- [1] M. Hirvonen, P. Pursula, K. Jaakkola, and K. Laukkanen, "Planar Inverted-F Antenna for Radio Frequency Identification" *Electron. Lett.*, vol. 40, no. 14, July. 2004, pp. 848-850.
- [2] W. Choi, H. W. Son, J. Bae, G. Y. Choi, C. S. Pyo and J. Chae, "An RFID Tag using a Planar Inverted-F Antenna Capable of Being Stuck to Metallic Objects" *ETRI J.*, vol.28, no. 2, Apr. 2006, pp. 216-218.
- [3] H.-W. Son and G.-Y. Choi, "Orthogonally proximity-coupled patch antenna for a passive RFID tag on metallic surfaces" *Microwave and optical Technology Letter*, vol. 49, no. 3, Mar. 2007, pp. 715-717.
- [4] B. Yu, S.-J. Kim, B. Jung, F. J. Harackiewicz, and B. Lee "RFID Tag antenna using two-shortened microstrip patches mountable on metallic objects" *Microwave and optical Technology Letter*, vol. 49, no. 2, Feb. 2007, pp. 414-416.
- [5] H.-W. Son and C.-S. Pyo, "Design of RFID tag antennas using an inductively coupled feed" *Electron. Lett.* vol. 41, Sep. 2005, pp. 994-996.