Design of CP Antenna with a Fenced Ground for a Handheld RFID Reader

Seok-Jin Hong[1] · Yeon-Sik Yu[1] · Dong-Hyun Lee[1] · Sungtek Kahng[2] · Jae-Hoon Choi[1]

Abstract

A design of circular polarized(CP) microstrip antenna with a fenced ground is proposed and the equivalent circuit is derived. The antenna consists of a square radiating patch with a pair of truncated corners, a bottom ground and a fenced ground. From conducted experiments, a patch size reduction using the metal fence as large as 25 % from the conventional patch structure, has been obtained. The input admittance of the extracted equivalent circuit is shown to agree with that of the measurement. And the design parameters and performance of the proposed antenna are examined by analyzing the fields and circuit behaviors.

Key words : Circular Polarized Antenna, Fenced Ground, Microstrip Antenna, RFID Reader Antenna.

Ⅰ. Introduction

Nowdays, there is a phenomenal growth in demand for wireless RF systems such as wireless local area network(WLAN), radio frequency identification(RFID)[1] and point-to-point communication systems. RFID systems are gaining popularity in manufacturing units, purchase departments, access control and transportation. In these applications, data are contact free transferred to a local querying system from a remote transponder. The RFID reader antenna is one of the important components in an RFID system[2]~[4]. In most RFID applications, compact and small wireless devices are highly preferred. For RFID reader applications, the small and light component is an important requirement for portable communication equipment, such as handheld RFID reader equipment.

Recently, many types of RFID antenna have been proposed[5],[6]. However, those antennas are either too large in size or complex in structure for practical applications.

Many designs of single-feed, circularly polarized(CP) microstrip antennas with square patches are known[7]. Lately, various CP techniques have been reported. In these designs, the CP techniques used include inserting slits or spur lines at the patch boundary[8]~[9], embedding a Y-shaped slot of unequal arm lengths[10], and truncating the corner of square patch in [11].

In this paper, a CP antenna with a fenced ground surrounding a radiating element is suggested for Korean RFID application for a handheld RFID Reader. The method to produce a single-feed CP operation of a square microstrip antenna is by truncating a pair of patch corners. The design to reduce the size of antenna is mainly used by attaching a fenced ground. Also, to increase the gain of the proposed antenna, the air layer is placed between the dielectric substrate and the ground plane.

The equivalent circuits of the antenna with and without the fenced ground are derived, on the basis of the rational function fitting technique introduced in [12], in order to investigate how the metallic fence influences the physics of the designed antenna. Going over the elements of the circuit models that correspond to the change in the fringing field concerning the fenced geometry, the improvement in the radiation as well as the input impedance of the operating frequency resonance will be explained. This is helpful to determine the key parameters in the design.

In sections Ⅱ and Ⅲ, respectively, the details of the design are described about the proposed patch antenna structure along with finding the equivalent circuits, and the experimental results of a constructed prototype showing CP bandwidth and good radiation characteristics are presented.

Ⅱ. RFID Antenna Design

The geometry of the proposed RFID CP antenna with a fenced ground is illustrated in Fig. 1. A square radiating patch has a side length of L_2 and a pair of truncated corners. A circularly polarized radiation can be

Manuscript received May 31, 2007 ; June 14, 2007. (ID No. 20070531-016J)
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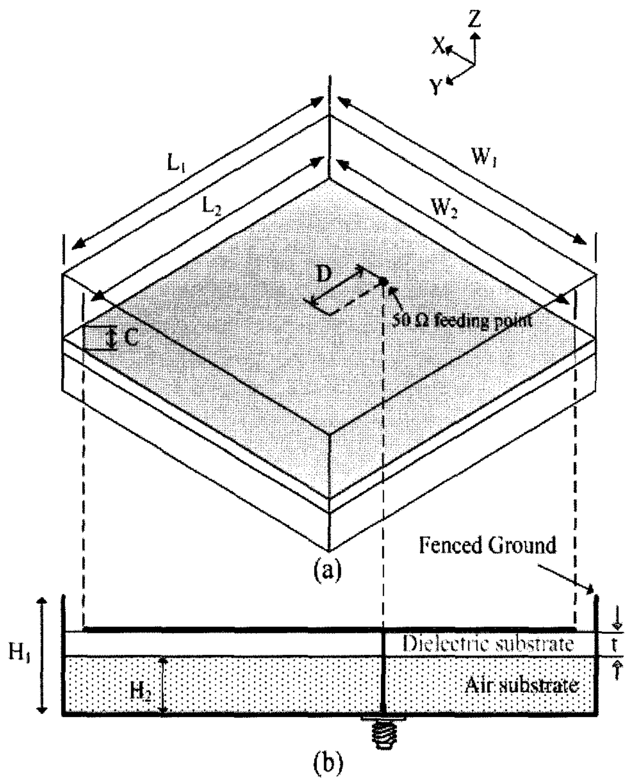


Fig. 1. Geometry of the proposed RFID antenna (a) 3-D view, (b) side view.

obtained by truncating two opposite corners of the patch in an appropriate amount to excite two orthogonal near degenerate resonant modes for CP radiation. Thus C is dependant on axial ratio required.

The antenna is fed from a coaxial probe, which is positioned at a distance D from the center of rectangular patch. The air layer(H_2) is placed between the dielectric substrate and bottom ground plane to enhance the radiation efficiency. Four walls of a fenced ground which have the same size($H_1 \times W_1$), which is simulate the actual ground of the handheld RFID reader, are connected to the bottom ground($L_1 \times H_1$).

The proposed antenna is designed using the well known commercial software High Frequency Structure Simulator(HFSS)[13]. The optimized design parameters for the proposed antenna are $L_1=W_1=100$ mm, $L_2=W_2=$ 92 mm, $H_1=$ 13 mm, $H_2=5$ mm, $D=23$ mm, $C=7$ mm, and $t=3.17$ mm.

In order to investigate the effect of a fenced ground on the performance of an antenna, the antenna is represented by a rational function, equivalent to Fig. 2. The input admittance of equivalent circuit in Fig. 2 can be written as,

$$Y_{in}(s) = y_{dc} + \sum_{n=1}^{N_{max}} \frac{a_{rn}}{s - p_{rn}} + \sum_{m=1}^{M_{max}} \frac{a_{cm}}{s - p_{cm}} \tag{1}$$

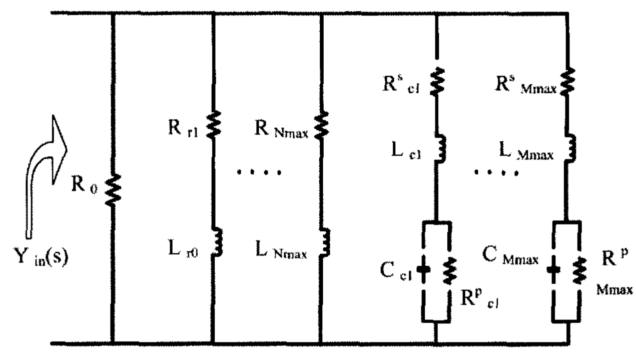


Fig. 2. The proposed equivalent circuit.

where y_{dc}, a_{rm}, a_{cm}, and p_{cm} are static-conductance, real coefficient, real pole, complex coefficient, and complex pole, respectively. The second and third terms represent R-L and R-L-C resonators in Fig. 2. The equivalent circuit element values in Fig. 2 can be obtained from the measured input admittance data. Using this scheme, we analyze how the fenced ground affects the circuital behavior of the antenna in the next section.

Ⅲ. Results

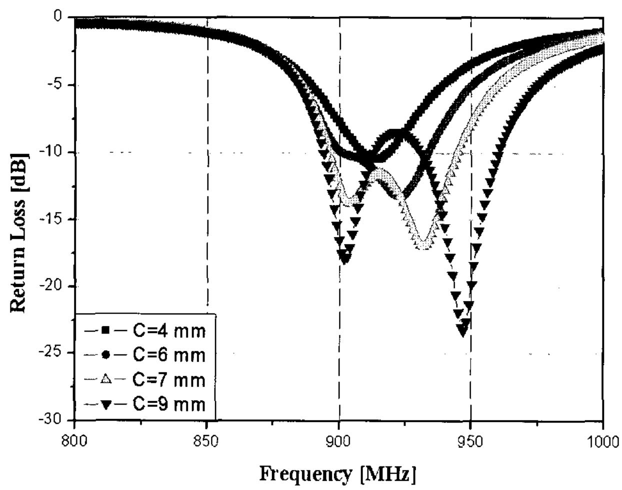
Fig. 3 illustrates the simulated input impedance for various values of feeding point distance(D) and corner truncated length(C), respectively. It is found that the feed position and corner truncation play a critical role in deciding the bandwidth and CP operation. Through the process of parametric study, we can end up with the optimal dimensions of the feed position and corner truncation.

By changing the height(H_1) of a fenced ground, the resonant frequency of the proposed antenna can be controlled as shown in Table 1.

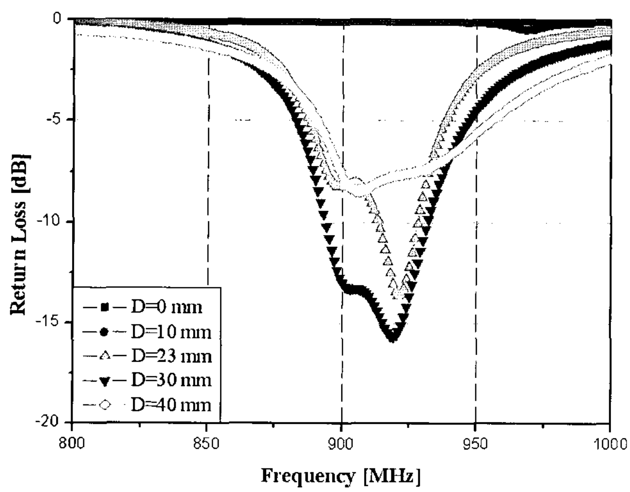
Fig. 4 shows the measured return loss of the manufactured antenna with and without a fenced ground. This indicates that the antenna with a fenced ground can lessen resonant frequency about 25 % compared to ante-

Table 1. Resonant frequency for different values of a fenced ground height.

Height of a fenced ground (mm)	Resonant frequency (MHz)
$H_1=0$ (without a fenced ground)	1,163
$H_1=3$	1005
$H_1=5$	935
$H_1=13$	912
$H_1=15$	880



(a) Feed position distance



(b) Truncated length change

Fig. 3. Return loss with respect.

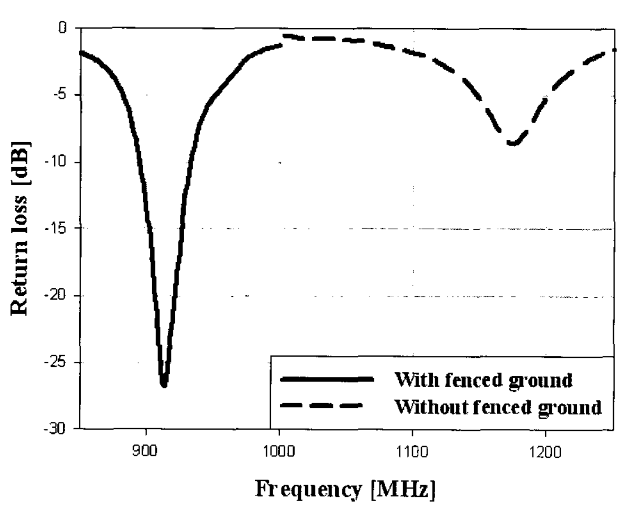


Fig. 4. Comparison of measured return loss characteristics for the proposed antenna with and without a fenced ground.

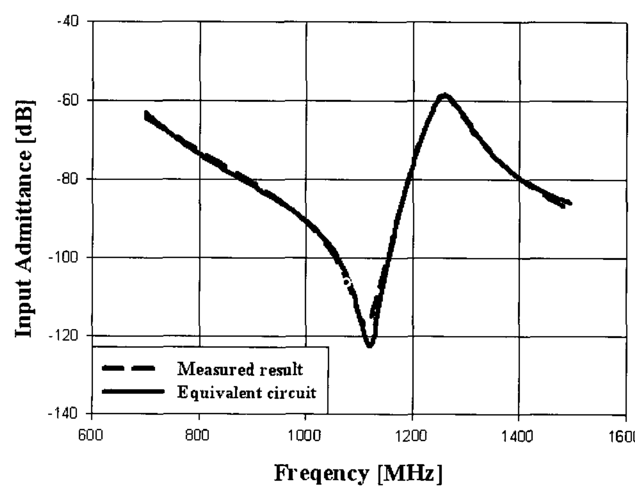
nna without a fenced ground at a fixed size.

This may due to the prominence of the mode excited by the fenced ground enclosure over that of the patch resonance and fringe field distortion.

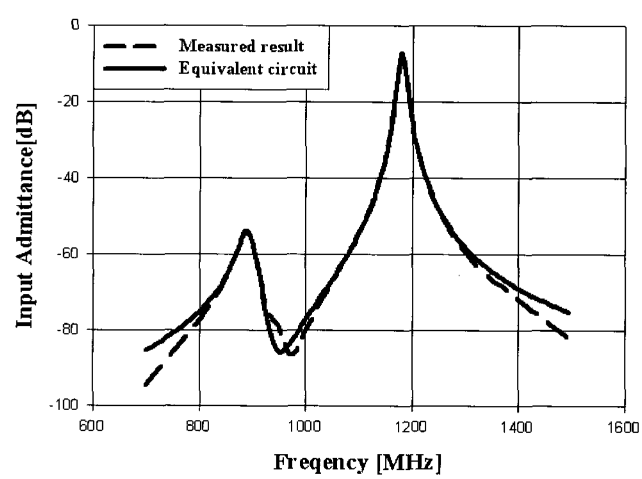
The input admittance is used to find the circuit parameters. As shown in Fig. 5, good agreement between measured result and equivalent circuit data is observed.

Using the equivalent circuits for the two cases, we are able to find the influence of facilitating fences around the patch. For this purpose, we show the major circuit parameters and their change over the two cases. The obtained parameters of circuit modelling are summarized in Table 2.

Seeing the trend of the change in circuit values in Table 2, it is noticed that the metal fence increases the shunt L's in a relatively large scale, while shunt C's undergo negligible change. This coincides with the physical meaning that the series C's are lowered by the



(a) Without a fenced ground



(b) With a fenced ground

Fig. 5. Input admittance of the equivalent circuit.

Table 2. Comparing the representative R-L-C groups of the antenna. [Unit: Ω, μH, pF]

	Element group 1			Element group 2		
	R	L	C	R	L	C
Without fenced ground	5	12	0.688	625	10	0.01
With fenced ground	112	74	0.407	40013	1470	0.068

occurrence of fringing fields in between the patch and the ground.

Fig. 6 shows the measured radiation patterns at center frequency(912 MHz) of Korean UHF RFID band in x-z plane. In the forward direction(near 0 degree), the amplitude of the left hand circular polarization(LHCP) component is less than 20 dB lower than that of the right hand circular polarization(RHCP) component.

Fig. 7 presents the measured axial ratio and antenna gain across the CP bandwidth. The antenna peak gain is found to be about 4.6~4.63 dBi and the measured 3-dB axial ratio bandwidth of about 10 MHz(905~915 MHz) is obtained, which covers the required bandwidth.

Ⅳ. Conclusion

In this paper, a compact and novel UHF RFID reader antenna was designed and manufactured for PDA application. By using a fenced ground, the antenna size is reduced by about 25 % compared to that without a fenced ground. The optimized antenna has the gain of about 4.6~4.63 dBi with such a small dimension and the measured 3 dB axial ratio CP bandwidth of about 10 MHz is obtained for Korean UHF RFID band.

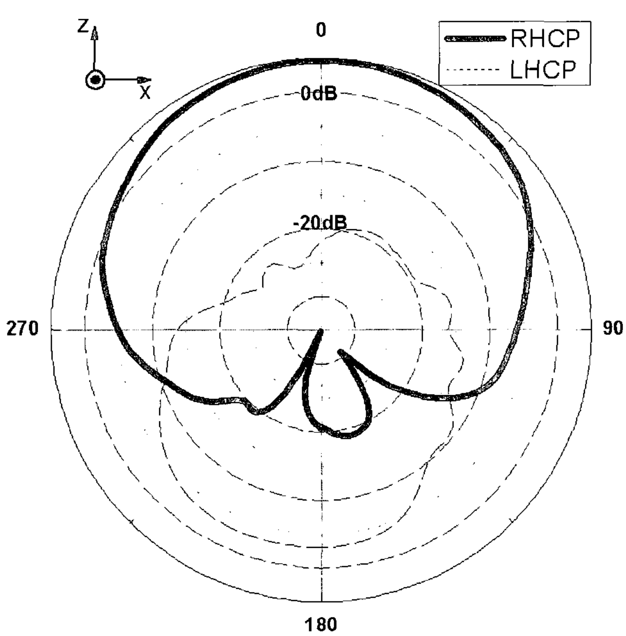


Fig. 6. Measured radiation pattern in x-z plane at 912 MHz.

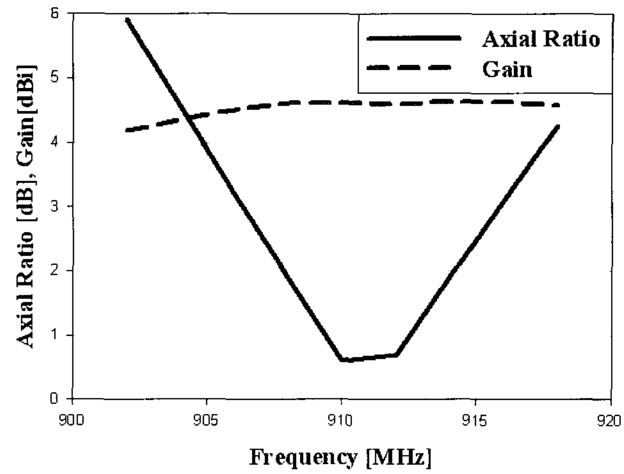


Fig. 7. Measured axial ratio and antenna gain.

This research was supported by the MIC(Ministry of Information and Communication), Korea, under the ITRC(Information Technology Research Center) support program supervised by the IITA(Institute of Information Technology Advancement) (IITA-206-(C1090-0603-0019).

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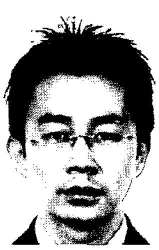

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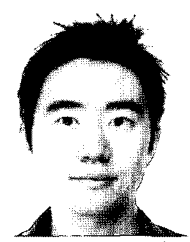

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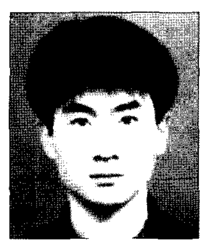

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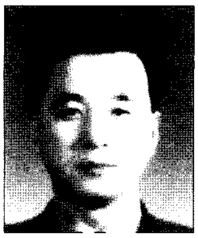

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