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통방융합용 소형 모바일 안테나 및 근거리장 특성

Compact mobile antenna and near field characterization for Communication Broadcasting Convergence

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요 약 통방융합서비스가 가시화되면서 성능이 더욱 우수한 안테나 모델을 개발하기 위해 다양한 기술적 접근이 시도되고 있다. 본 논문은 핸드폰에 부착할 수 있고, 통방융합용에 적용할 수 있는 소형모바일 안테나를 제안한다. 모바일 핸드셀용 안테나 설계에서, 크기축소는 중요한 요소 중의 하나이며, 루프안테나의 소형화는 접어진 다이폴을 굽힘으로서 실현된다. 짧은 평면 다이폴은 더 큰 입력저항을 만들기 위해 두 배의 접어진 다이폴과 루프안테나로 변환된다. 그 안테나의 전류분포는 루프 안테나와 같고, 방사패턴은 전방향 특성을 갖는다. 또한 전기광학효과 맵핑 시스템을 이용하여 전류유기 근거리장 방사패턴에 의해 RFID안테나의 성능을 분석한다.

Abstract Motivated by the Communication Broadcasting Convergence service, various technical approaches are being used to develop more efficient antenna models. This paper proposes a compact mobile antenna which is attachable to a cell phone and is applicable for Communication Broadcasting Convergence. In the design of the antennas for mobile handsets, size reduction is a crucial factor. In this paper, the compactness of a loop antenna is realized by bending a folded-dipole. A short planar dipole is transformed to a twice folded dipole and a loop antenna to produce a larger input resistance. The current distribution of the antenna is the same as a loop antenna, and its radiation patterns are omni-directional. We also analyze the performance of the RFID antenna by exploring the current-induced near field radiation patterns using a electro-optic field mapping system.

Key Words : Communication Broadcasting Convergence, Compact dipole antenna, RFID, electro-optic sensing

Ⅰ. INTRODUCTION

Motivated by the Communication Broadcasting Convergence service, various technical approaches are being used to develop excellent efficient antenna models. This paper proposes a compact mobile antenna which is attachable to a cell phone and is applicable for Communication Broadcasting Convergence. Radio-frequency identification (RFID) plays a major role in ubiquitous sensor networks because of its ability to input and output data wirelessly. Active circuitry, one of the main RFID components, is being integrated to minimize the size of the sensor technology, where the dimensions of the antenna are determined by the wavelength of its operating frequency. Much research on minimizing the size of antennas for RFID tags has been done, but research on antennas of RFID readers hasn't been as active[1].

We present the design of, and experimental results on, small planar loop antennas for applications in mobile RFID readers in the Ultra-high frequency band (UHF, 860-960 MHz). A small loop antenna has been realized by bending a folded-dipole, providing the

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advantage that the structure can increase the antenna input resistance. A capacitive load is created inside the loop antenna through a parasitic patch formed in the center of the antenna, lowering the resonance frequency and increasing the electrical length of the structure. The current distribution of the antenna is the same as a loop antenna, and its radiation patterns are omnidirectional. The proposed antenna, a small, planar, rectangular loop antenna with a given perimeter of ~ $\lambda_0/(2\pi)$ at 910 MHz (the center of the UHF band), is easy to tune and it can be formed in various shapes [2, 7, 8].

In contrast to a far-field pattern, the near-field is not typically considered farther away than a few wavelengths from the antenna. Hence, the near-field can not be neglected in the case of RFID analysis because most of the tapping regime is approximately a wavelength (30 cm for 1 GHz) or less from the tap.

We measure the near-fields of the tangential electric field components using photonic-assisted technology known as the electro-optic (EO) sensing. EO sensing has become a viable diagnostic measurement technique for the near field measurement of microwave devices and radiation sources, due to its broad bandwidth (i.e., fine temporal resolution), very low invasiveness, and high spatial resolution [3-6]. A brief methodology will be introduced and two tangential electric field (horizontal and vertical) components, just emerging from the patches, are considered. This method enables analysis of the actual distribution of the fields and current flowing along the transmission lines, which can not be obtained from the conventional network analyzer approach.

II. COMPACT MOBILE ANTENNA

2.1 Design Principle

Three simple types of antennas can be built in a plane: a dipole, a loop, and a patch antenna. A dipole antenna is the best choice among these three antennas to provide the lowest resonant frequency because it can realize the half wavelength length resonance condition in the least space. The proposed design is basically a conventional half wave wavelength dipole antenna that is transformed to a rectangular structure so it is capable of being minimized.

In case of simple folded dipoles, the impedance is mismatched throughout the operating band. Hence, a method to improve the impedance match and reduce the incident power dissipation, which increases the effective bandwidth, is required. There is a way to adjust the input impedance of a planar dipole antenna which adopts the basic structure of a folded dipole antenna. We employ the T-match topology shown in Fig. 1-(a). The T-match can be decomposed into two different modes: the antenna mode, and the transmission line mode. The input impedance of an antenna can be calculated from analyzing currents flowing in both of the modes.

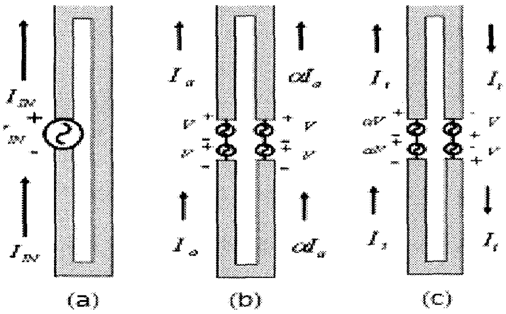


Fig. 1. Folded Dipole Antenna
(a) Antenna Mode
(b) Transmission Line Mode (Ia)
(c) Transmission Line Mode (It)

The currents of the antenna mode and the transmission line mode are expressed as (1-a) and (1-b), respectively.

$$I_a(1+\alpha)=\frac{2V}{Z_a} \tag{1-a}$$

$$I_t=\frac{V(1+\alpha)}{Z_t} \tag{1-b}$$

The sum of the input voltages and currents are calculated by superposition and the input impedance is expressed in (2). The equivalent circuit is shown in Fig. 2.

$$Z_{IN} = \frac{V_{IN}}{I_{IN}} = \frac{2V(1+\alpha)}{I_t + I_a} = \frac{2(1+\alpha)^2 Z_t Z_a}{2Z_t + (1+\alpha)^2 Z_a} \quad (2)$$

If the total length of a folded dipole antenna is close to a half wavelength, then Zt=j∞, and the input impedance is expressed as (3).

$$Z_{IN} \cong (1+\alpha)^2 Z_a \quad (3)$$

The term $(1+\alpha)^2$ plays an important role in increasing the input impedance. It is possible to increase the input impedance of a system to 50Ω by adjusting the distance between two dipole antennas.

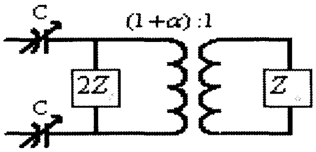


Fig. 2. Equivalent Circuit of Folded-Dipole Antenna

Based on this topology, the input impedance has been noticeably increased. When a dipole antenna and a folded dipole antenna are tested under the same conditions, the higher input impedance (than 50 Ω) of the folded dipole antenna traces into the middle of the smith chart, and the resonant frequency occurs near there. For a 33×44 (mm^2) size T-type matched antenna, the simulated resonant frequency of 0.995 GHz shows a 0.085 GHz difference from the resonant frequency of an ideal folded dipole antenna, which is 0.91GHz. It is proposed to implant a device to control the resonant frequency of the antenna for further optimization.

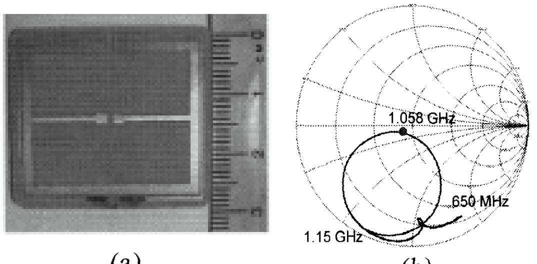
Applying capacitive loading to an antenna is one of many ways to control the resonant frequency of an antenna. An antenna gains extra electrical length and increased resistance against reflection of waves by adding a disk shaped capacitor plate. This forms capacitive loading inside of the antenna and reduces the resonant frequency by providing extra electrical length.

2.2 Fabrication and Measured Results

The capacitive load is mounted on an antenna by plating metal traces with an open-circuit gap. This is the complete proposed dipole antenna, and its full manufactured dimensions and the Smith Chart Trace are presented in Fig.3.

As presented in Fig.3-(b), the manufactured antenna has its resonant frequency at 1.058 GHz, which is 0.15 GHz higher than the results from simulation. It is believed that this is a common error that any simulation tool based on FDTD makes while simulating small sized antennas. Also, the actual physical size of the antenna has been fabricated ~10% smaller than desired. However, as discussed before, the resonance frequency can be tuned by manipulating the electrical length of capacitive loading and the size of the parasitic patch on the other side of the substrate. The matching quality was observed to be good, giving approximately 23 dB return loss at the resonance frequency. The experimental result after tuning is presented later. The capacitive loading has extra advantages. This not only increases the capacitance but also gives an extra 0.04 dBi gain.

A capacitively-loaded transmission line added in the middle of the antenna reduces the resonant frequency by providing extra electrical length.



(a) (b)

Fig. 3. (a) Manufactured Antenna with Capacitive Loading (Before Tuning) (b) Measured the Smith Chart Trace (0.65 ~ 1.15 GHz)

The RFID antenna consists of two major dipole antennas. The primary one is the folded dipole, at the top of the structure in Fig. 3(a), and the secondary one is the capacitive loading patch in the middle of the substrate. With a 20-dBm input power, comparable peak signal levels of -48 dBm ± 3dB are observed on the lock-in amplifier at the two terminal ports for both the x and y components of the electric field (depending on the polarization of the tangential component and slight changes of the probe height or the spectral bias). This is the electrical power in the demodulated, amplified, and downconverted signal channel.

Fig. 4 shows the Smith plot, and Fig. 5 is the radiation pattern of the proposed antenna, As is shown in figure 5, it has a characteristic non-directional pattern in the xy and yz planes. The loop antenna has the same radiation patterns as the folded dipole antenna, because the current densities are equal if their sizes match.

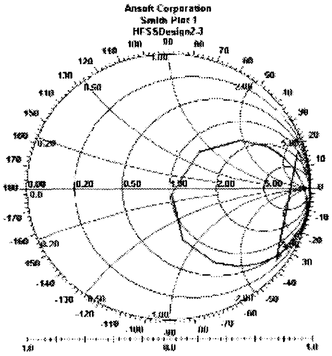


Fig. 4 Smith plot

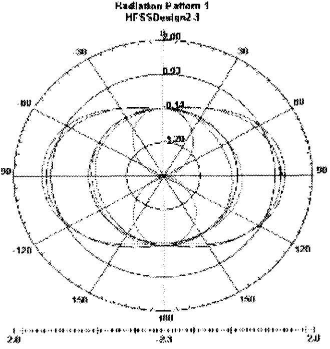


Fig. 5 Radiation Pattern Elevation plane (0°, 45°, 90°, 135°, 180°)

III. NEAR FIELD CHARACTERIZATION

3.1 Measurements using Electro-Optic Sensing

Electro-optic sensing (EOS) is emerging as a promising technique for the near-field measurement of electronic devices and radiation sources, due to its large bandwidth, low degree of intrusiveness, and high spatial resolution [3]. The sensing mechanism, which relies on the Pockels effect to modify the refractive indices of an EO crystal using an applied electric field, perturbs the polarization of the light within the EO medium. The modulated light contains the information of the applied electric field which interacts with the light through electro-optic crystals. Since this configuration is made of a photonic assisted all-dielectric embodiment, practical non-invasive measurements of near fields sensing are feasible with less EMI/EMC associated field distortions [4].

We have implemented a fiber-based sensing probe to realize a photonic-assisted dielectric antenna with improved scanning ability for field mapping. In this measurement, we used a novel resonance-based probe which not only simplified the optical systems but also improved the sensitivity up to ~ 20 dB by increasing the resonance structure of the sensor. This methodology is extended to high frequency sensing using a photonic mixing technique which down-converts the high frequency information into the lower frequency band of a slow detector. Fig. 6 describes an optical heterodyne down conversion EO sensing system. Using a low-cost cw pigtailed laser diode and an all fiber-guided embodiment, the resonant-based probe provides a reliable and simplified optical realization, eliminating the need for the analyzers. A modulated 8mW cw beam with a polarization control was applied to the resonant probe made of a thin EO crystal and the re-routed EO modulated-reflection beam was delivered to the detector. This simple configuration gives a suitable minimum detectable RF power level for most of the RF device characterizations.

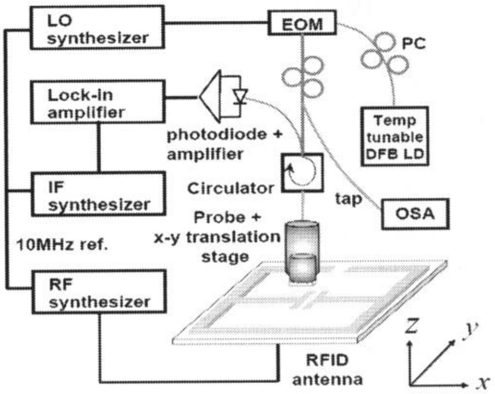


Fig. 6 Experimental setup of the all-fiber resonance-based EO sampling system using cw modulated light. (EOM: electro-optic modulator, PC: polarization controller, DFB LD: distributed feedback laser diode, OSA: optical spectrum analyzer), The gray and black lines are optical fibers and electrical connections, respectively.

The cw beam is modulated by an electro-optic modulator (EOM) providing flexible local oscillator (LO) modulation frequencies for arbitrary radio and intermediate frequencies (RFs and IFs). The RF feeding frequency is set to 1.058 GHz and the LO modulation of the light and the detector IF frequencies are set to 1.061GHz and 3 MHz, respectively.

3.2 Results and Discussion

The EO system provides an electric field mapping over the antenna. The amplitude and phase of the tangential x electric field component are presented in Fig.7. The strongest field components are observed at the two terminals of the antenna, which are the top side of the folded antenna and the middle capacitive terminal. In addition, two minor components are also observed at the top edge sides where the impedance is relatively mismatched due to the bending of the structure. Besides these regimes, no fields are found because the guided signals are efficiently delivered through the transmission lines and finally broadcasted to the air at two final guided destinations. Furthermore, the system provides phase information, so the directions of each signal field can be recognized. For example, the 180^0 shift between signals (light blue and light green in Fig.7-(b)) indicates the opposite direction to each other.

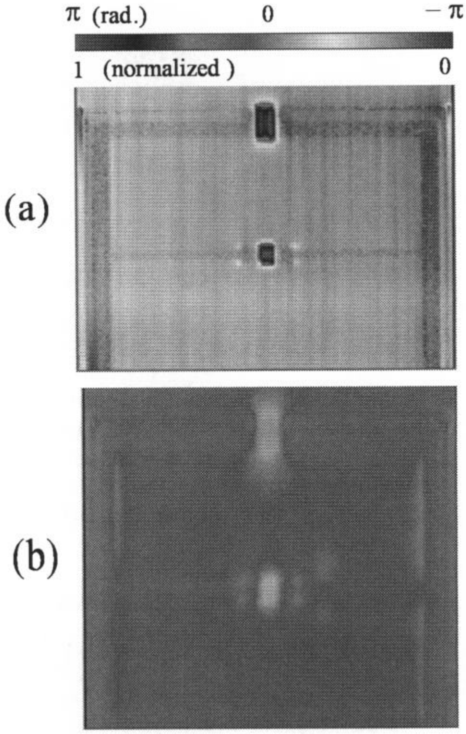


Fig. 7 Tangential x (horizontal) electric field distribution over the RFID antenna. (a) amplitude (b) phase (The probe scanned ~0.1mm above the DUT with a 0.2 mm step resolution)

The detailed full tangential electric fields for the primary and the capacitive loading terminals are presented in Fig.7 and 8, respectively. The strong fields at the two terminals indicate 'the evidence of efficient radiation' associated with good matching quality. The field is basically 'the seminal fountain' of the far field radiation. Based on the electric field, the directionality and pattern of the near field radiation components can be extracted.

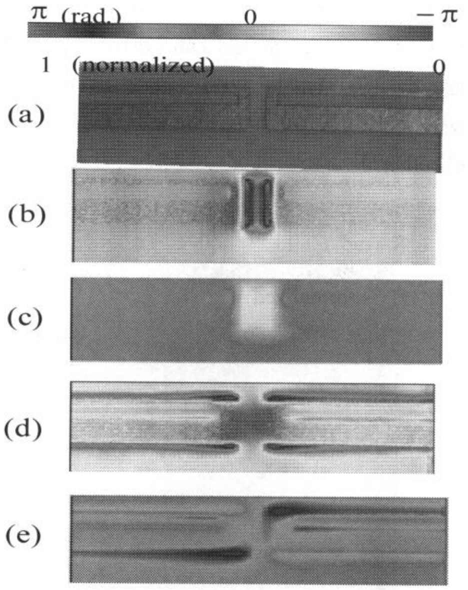


Fig. 8 Tangential electric field distributions over the primary antenna terminal. (a) picture (b) x − amplitude (c) x − phase (d) y − amplitude (e) y − phase (The probe scanned ~0.1mm above the DUT with a 0.1 mm step resolution)

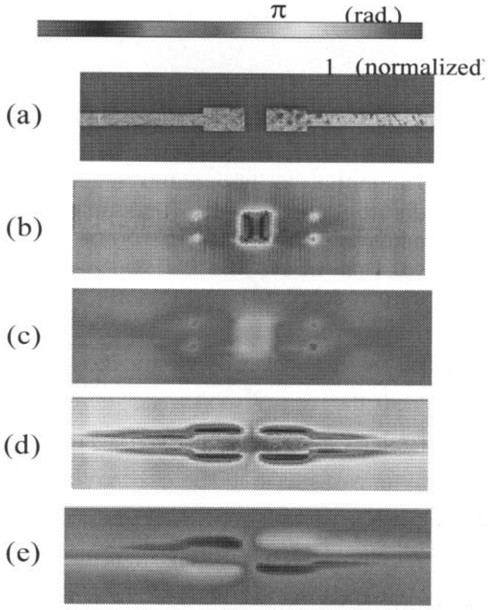


Fig. 9 Tangential electric field distributions over the capacitive loading terminal. (a) picture (b) x − amplitude (c) x − phase (d) y − amplitude (e) y − phase (The probe scanned ~0.1mm above the DUT with a 0.1 mm step resolution)

IV. CONCLUSIONS

This paper proposes a compact mobile antenna which is attachable to a cell phone and is applicable for Communication Broadcasting Convergence. We have confirmed that a dipole antenna is most suitable to the proposed antenna compared to other known types of antennas such as a loop and a patch antenna. To increase the low input impedance of a planar dipole antenna, we adopted a folded dipole structure, and included capacitive loading to stretch the electrical length to lower the resonant frequency. The proposed antenna has a gain of 0.04 dBi, and an 8 MHz bandwidth. The manufactured antenna has been evaluated by exploring the near electric fields from the radiation port. The field was measured through a non-invasive electro-optic field mapping system which is suitable for characterizing the matching and near field distribution. The near field analysis is key to exploring radiation evolution from the port to mid and far radiation patterns which are non-directional in the xy and yz planes. It is also possible to lower the resonant frequency of the proposed antenna by including capacitive loading. If the antenna goes through proper optimizations, this small antenna will work below 0.91 GHz. It is also possible to use it anywhere by adjusting the input impedances and capacitive loading.

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