Design of Flexible CPW-Fed Folded-Slot Monopole Antenna for 5.8 GHz RFID Tags

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Abstract

A flexible planar monopole antenna is proposed for use in the radio frequency identification (RFID) tags at 5.8 GHz. The antenna was fabricated on an 13×15 mm^2 thin laminate dielectric substrate and fed by using a coplanar waveguide (CPW) stripline to thereupon provide a low-profile and flexible antenna prototype for suitable use as a tag antenna. By embedding a folded slot into the proposed antenna, good radiation characteristics of about 480 MHz impedance bandwidth, monopole-like radiation patterns, and ≥ 5 dBi average antenna gain, for operating at 5.8 GHz can be obtained. In addition, the antenna performance for the proposed design with different curvatures are also examined and discussed.

Key Words: Flexible, CPW-fed, Folded-slot, Monopole antenna, RFID.

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Ⅰ. Introduction

Recently, from security and control point of view, the radio frequency identification (RFID) systems have received much attention for use in efficiently tracking and identifying objects in the various supply chains such as logistics, automatic billing, access control and work tracking for factory automation, inventory management and bio-engineering applications. The RFID system basically consists of a read/write device and a tag, and data is transferred between the tag and the read/write device wirelessly by means of electromagnetic waves at the assigned bands of 125 kHz, 13.56, 869,902-928 MHz, 2.45 and 5.8 GHz[1]. However, for a tag which includes the antenna and a microchip transmitter antenna, it always produces difficulty and distortions from sticking the tag over a corner of an object or attaching it on goods without smooth surfaces or with soft packages (e. g. plastic bags and papers). The distortion caused from attaching the tag to an un-smooth structure will generally seriously change the radiation performance of the tag antenna and thus result in performance degradation to the RFID system, especially when operating in microwave frequency. Therefore, the installed antenna of a tag must have a thin, low profile, low cost, small size and especially flexible structure for valuable and easy use when it is attached to an identified object, which may not have a smooth surface.

So far, several antenna designs for use in a RFID tag have been proposed, including the meander line structures[2], the aperture-coupled structure[3], and the CPW-fed folded-slot structure[4, 5]. Though these designs have advantages of either small size or broad bandwidth, however, they are either complex in antenna structure or inflexible for attaching to goods with an un-smooth or a soft surface.

In this paper, a new design of a thin, low-profile, and flexible planar monopole antenna consisting of a slotted radiating patch and a CPW feeding structure, which are both printed on a single-layer laminate dielectric substrate, is presented. By properly selecting the structure of the CPW-fed slotted antenna, good radiation characteristics and sufficient impedance bandwidths suitable for use as a flexible 5.8 GHz RFID tag antenna could be achieved. In addition, the effects on antenna performance for the proposed design with different curvatures are also examined. Details of the antenna design and experimental results are presented and discussed.

Ⅱ. Antenna Design

Based on the CPW-fed slotted monopole antenna[5], the thin and flexible CPW-fed antenna for 5.8 GHz RFID tag is developed in this paper. Figure 1 is the configuration of the proposed antenna. The antenna has a very simple structure and is extremely different from using a conventional FR4 substrate. The antenna is printed on a thin laminate dielectric substrate of thickness h=0.11 mm and relative permittivity ε_r=2.8. These make the antenna not only with easy fabrication but also with a very thin and flexible structure for possible mounting on a curvature surface. A rectangular metal layer of thickness 35 μm with dimensions of $W\times L$ mm^2 was printed on one side of the laminate substrate. The antenna is arranged in symmetry with respect to the longitude direction (i. e. z-axis direction). We embedded a folded slot to the rectangular metal layer to therefore form a monopole structure with an inverted U-shaped strip fed by a CPW feeding line. Clearly, the radiating strip of this antenna is thus separated from the ground plane by the folded slot. Here, for simplicity, the width of the folded slot was selected to be a fixed value of g. The inverted

U-shaped strip with a fixed strip width of s has lengths of w_s and ℓ_s for its horizontal section and two vertical sections, respectively. The inverted U-shaped strip was fed from it central position by a CPW strip line with a length of ℓ_f and a fixed strip thickness of w_f. The gap distance between the signal strip and the coplanar ground plane is g, same as the width of the folded slot. We adjusted the dimensions of the antenna by experiment. Finally, the dimensions of the fabricated antenna were chosen to be: W=15 mm, L=13 mm, s=1 mm, w_s=12 mm, ℓ_s=6 mm, ℓ_f=10.2 mm, w_f=1 mm, and g=1 mm.

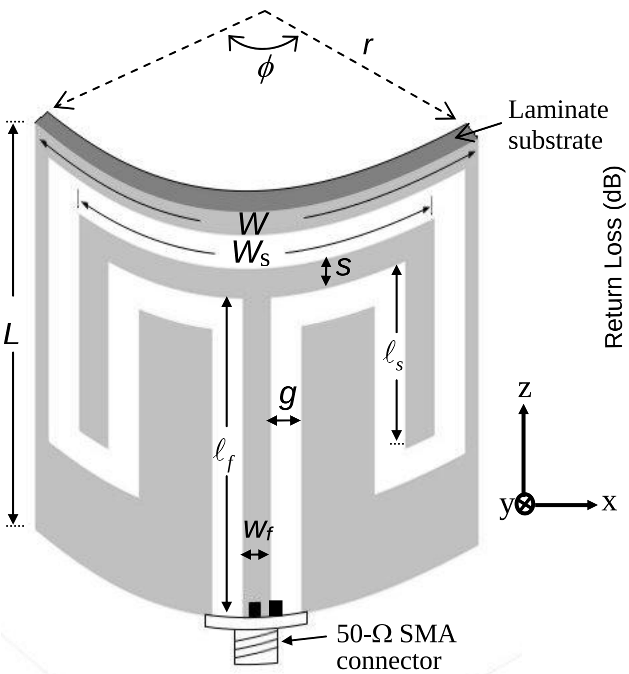


Figure 1 Configuration of proposed flexible CPW-fed folded-slot monopole antenna for 5.8 GHz tag

In this design, the dimensions of the fabricated antenna were chosen to be of height 13 mm and width 15 mm, and the length of the folded-strip arm ($w_s/2+\ell_s$) was found about 12 mm, which are all very close to one quarter wavelength in free space at resonant frequency of 5.8 GHz (≅13 mm), and these indicate that the antenna can effectively excite a 5.8 GHz resonant mode. Moreover, to investigate the effects of curving the proposed antenna on radiation performance, the measured results for the proposed antenna design with a curvature angle of ϕ, which provides an appropriate radius of r according to the fixed patch width W (i. e. $W=r\theta$), are presented and discussed in more detail in the following section.

Ⅲ. Measurement and Discussion

The prototype of the proposed flexible CPW-fed folded-slot antenna for 5.8 GHz RFID tag use as depicted in Figure 1 was constructed and tested. Figure 2 shows the measured frequency responses of return loss for the proposed design without curvature.

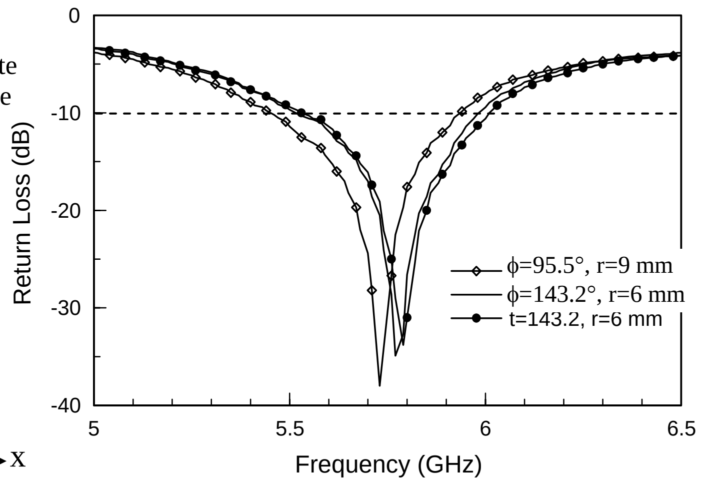


Figure 2 Measured frequency responses of input return loss for proposed antenna without and with two different curvatures

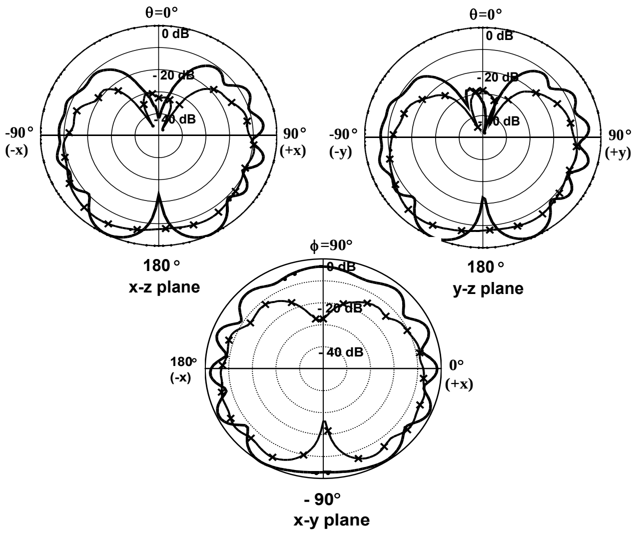
For comparison, the frequency responses of return loss for the proposed antenna with two different curvatures of ϕ=95.5° and 143.2°, which result in an associated radius of 6 mm and 9 mm, respectively, have also been examined and plotted in Figure 2. For the case of the proposed antenna without curvature, as can be seen from the simulation, the antenna has a near resonance occurred at about 5.5 GHz. However, the measured results show that the resonant mode is excited at 5.73 GHz with -10 dB impedance bandwidth of 480 MHz, ranging from 5.45 to 5.93 GHz and simultaneously suitable for 5.8

GHz RFID and 5.8 GHz WLAN (5.725~5.825 GHz) applications. As the antenna is curved, the resonant frequency is slightly moved. The larger the curvature angle, the higher the resonant frequency moves toward. Table 1 has summarized the measured results for the three cases including the proposed antenna design without curvature, θ=95.5° (r=9 mm), and θ=143.2° (r=6 mm). Obviously, the impedance bandwidth seems not affected from curving the antenna.

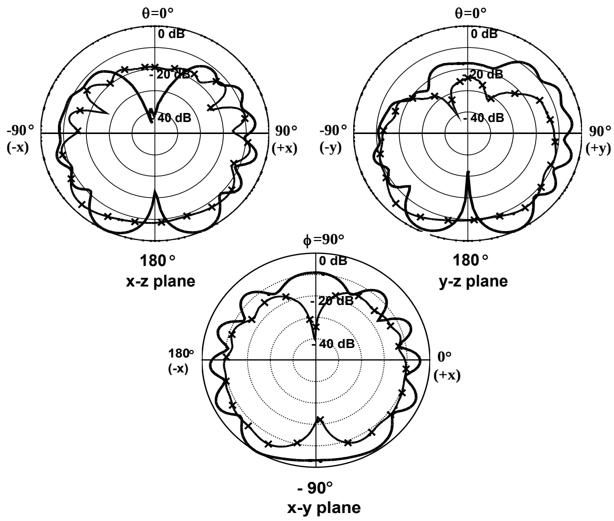
Table 1 Measured impedance bandwidth of the proposed antenna without curvature and with two different curvatures

	Without curvature	ϕ=95.5°, r=9 mm	ϕ=143.2°, r=6 mm
f_c(GHz)	5.73	5.77	5.79
BW (%, GHz)	8.4, 5.45 ~ 5.93	8.3, 5.5 ~ 5.98	8.3, 5.53 ~ 6.01

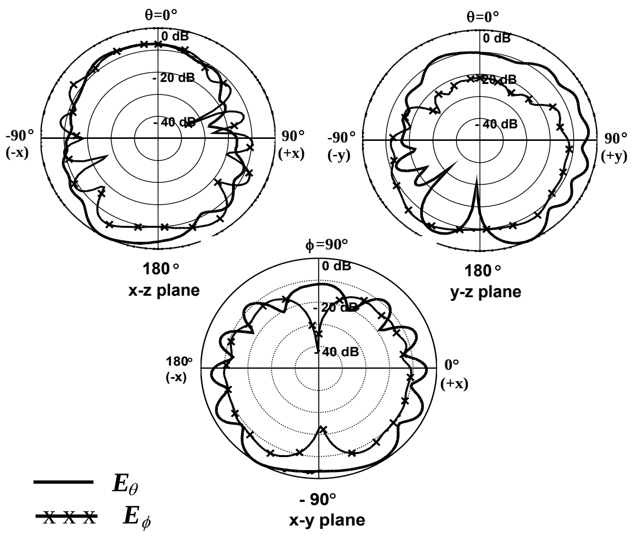
Figure 3 plots the measured far-field radiation patterns including the co-polarization (E_θ) and cross-polarization (E_θ) in the E-planes (x-z and y-z planes) and H-plane (x-y plane) for the proposed antenna without and with two different curvatures at the appropriate resonant frequencies. Clearly, the nearly conical radiation patterns in the E-planes and almost omnidirectional pattern in the H-plane are observed, especially for the cases of without curvature and with a smaller curvature. The antenna in general shows a monopole-like pattern. In addition, we have also found that for the three cases discussed here, both the E_θ and E_ϕ components have comparable intensities in all three planes. These results occurred from the nearly equal length of the horizontal and vertical current paths, $w_s/2$ and ℓ_s, respectively, of the inverted U-shaped antenna. However, this implies that the antenna is capable of receiving arbitrary polarization angles at a constant level. Such a characteristic can alleviate polarization loss and is an advantage for wireless communication applications, such as RFID application, where the wave propagation usually experiences multiple reflection effects due to the complex transmitting-receiving environment or the orientation resulting from the movement of the transmitting or the receiving systems.



(a)



(b)



(c)

Figure 3 Measured radiation patterns for the proposed antenna without and with two different curvatures at the appropriate resonant frequencies. (a) without curvature at f=5.73 GHz, (b) ϕ=95.5°, r=9 mm at f=5.77 GHz, (c) ϕ=143.2°, r=6 mm, at f=5.79 GHz

The antenna gains were also measured and shown in Figure 4. The peak antenna gains for the proposed design with or without curvature increase with frequency across the operating band. For the case without curvature, the antenna gain varied from about 3.9 to 6.9 dBi. However, as for the cases with curvatures of θ=95.5° and θ=143.2°, both exhibit antenna gain about 2.5 dBi in average higher than that of the case without curvature. Obviously, these experimental results indicate that by curving the proposed antenna, the directional property of radiation can be effectively increased.

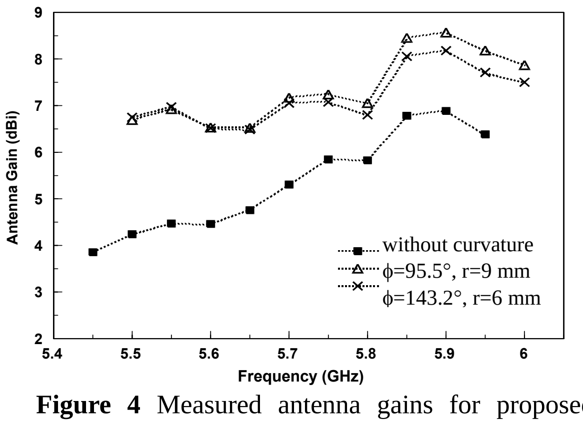


Figure 4 Measured antenna gains for proposed antenna without and with two different curvatures

Ⅳ. Conclusions

A thin low-profile CPW-fed patch monopole antenna with flexible performance has been proposed and implemented. With the use of a thin laminate substrate and the insert of a folded slot to the patch, the proposed antenna can be designed to be flexible and have the bandwidth of 480 MHz, good radiation performance, and average antenna gain of more than 5 dBi, but has only 13×15 mm^2 in antenna size. The antenna is mechanically robust to easily mount it on a curvature surface and integrate it with the application-specific circuit. This design is not only suitable for use in the RFID tag but is also applicable to the WLAN 5.8 GHz communication systems.

Ⅴ. Acknowledgement

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應用於 5.8 GHz 射頻辨識標籤之可彎曲型共面波導饋入折彎槽孔天線設計

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摘　要

本研究提出一種可應用於 5.8 GHz 射頻辨識標籤之可彎曲型共面波導饋入式折彎槽孔天線設計。此天線設計以一大小僅爲 13 毫米x15 毫米之軟性微波膠片爲基材，在基材單一導體面上嵌入一對稱之彎曲形狀槽帶線，使導體面形成一以共面波導饋入作信號饋入方式的雙彎臂線型單極天線結構。所提出之天線設計經實驗量測得知，其具有量好之天線輻射特性，包括操作在 5.8GHz 頻段的 10dB 阻抗匹配頻寬可達 450MHz、具類似單極型的輻射場型及大於 5 ddBi 的平均天線增益。除此，此一天線因具非常輕巧及軟式可彎曲特點，因此相當適合應用於射頻辨識系統中之標籤天線。

關鍵詞：可彎曲、共面波導饋入、折彎槽孔、單極天線、射頻辨識。

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