Broadband U-Shaped RFID Tag Antenna with Quasi-Isotropic Radiation Characteristics

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Abstract

This paper presents a broadband U-shaped RFID tag antenna with quasi-isotropic radiation characteristics in the UHF band. A rectangular-shaped feed located inside the dipole is connected to the bottom of the dipole for broadband conjugate impedance matching with a commercial tag chip. For a VSWR ≤ 2, the tag antenna had a measured fractional bandwidth of 10.58% over the frequency range of 859.5–955.5 MHz. The maximum gain deviation of the antenna in all directions was less than 3.77 dB across that frequency range.

Keywords : RFID antenna, isotropic radiation pattern, gain deviation

1. Introduction

Radio-frequency identification (RFID) applications in the ultrahigh-frequency (UHF) band have been increasing rapidly because this frequency range offers a broad detectable range, fast reading speed, and the ability to read multiple objects [1]. A RFID system consists of a tag attached to an object and a reader that recognizes the tag. The reader in a RFID system uses a circularly polarized antenna to ensure that the tag detection is independent of the direction of the incoming signal. Most tags use linearly polarized antennas such as dipoles or loops. This type of tag antenna reduces the recognition range of the reader or may even result in the tag not being read at all depending on the tag orientation due to nulls or very low gain in certain directions of the tag antenna's radiation pattern. Therefore, the tag antenna must be designed to be readable in every direction to ensure reliable readability. This requires the tag antenna to have a radiation characteristic as close to isotropic as possible [2]. In addition, high radiation efficiency is required to extend the readable range under conditions of restricted system power. The antenna must also have a broad bandwidth to compensate for the frequency shift caused by the presence of unknown objects near the tag.

This paper presents a simple structure for a broadband RFID tag antenna based on a U-shaped dipole antenna [3, 4]. The antenna has a quasi-isotropic radiation pattern with a gain deviation of less than 3.77 dB at any arbitrary angle, resulting in a maximum readable range of between 5.01 and 10.23 m over the entire frequency range of operation.

2. Antenna Structure and Characteristics

Figure 1 shows the structure of the broadband U-shaped RFID tag antenna. The antenna is composed of a U-shaped half-wavelength dipole and a rectangular-shaped feed. The feed, which is located inside the dipole to reduce the overall size of the tag, is connected to the bottom of the dipole for conjugate impedance matching with a commercial tag chip. The tag antenna is printed on a 0.2032-mm-thick RO4003 substrate with a dielectric constant of 3.38. An electromagnetic simulator (IE3D; Zealand Software) was used to optimize the antenna. The design parameters of the optimized tag antenna were L_1 = 68.0 mm, L_2 = 48.0 mm, L_3 = 13.1 mm, L_4 = 7.8 mm, w_1 = 4.0 mm, w_2 = 8.0 mm, w_3 = 1.0 mm, and w_4 = 1.0 mm.

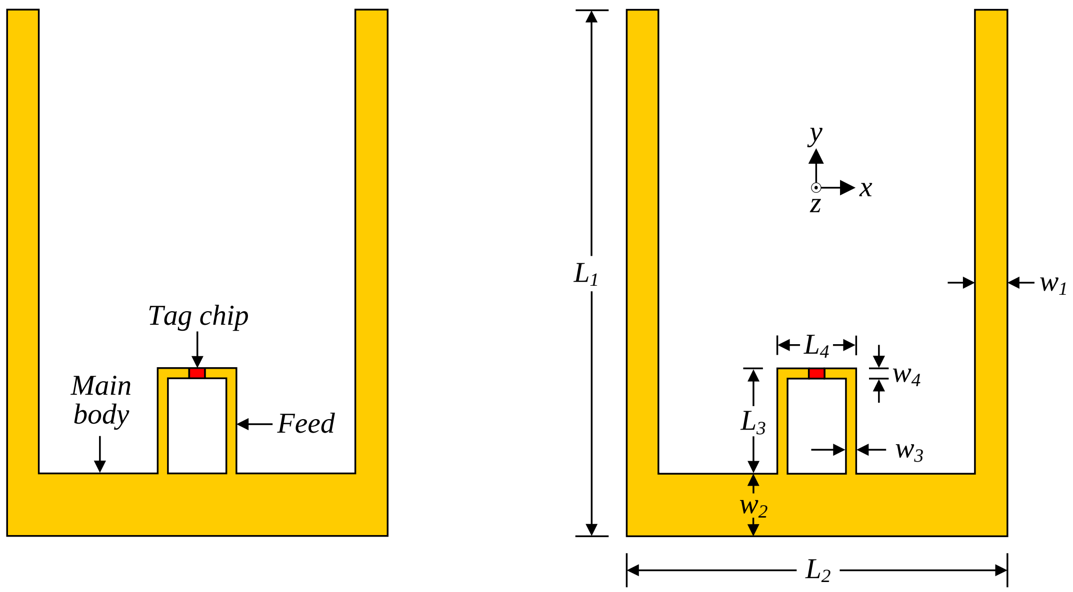

Figure 1. Schematic of the broadband U-shaped RFID tag antenna.

Figure 2 shows the reflection coefficient of the optimized broadband U-shaped antenna as a function of frequency. For a voltage standing wave ratio (VSWR) ≤ 2, the measured and simulated bandwidths agreed very closely and were about 10.58% (859.5–955.5 MHz) and 9.41% (866.0–951.5 MHz), respectively. The proposed antenna covered the entire bandwidth used in UHF RFID systems worldwide. Figure 2 also shows the gain deviation of the tag antenna as a function of frequency. The gain deviation is defined as the difference between the maximum and minimum gain in any direction at a given frequency. The simulated gain deviation was less than 3.77 dB within the bandwidth for a VSWR ≤ 2. Figure 3 shows the efficiency of the optimized tag antenna measured using the Wheeler cap method. The measured results showed that the antenna had a radiation efficiency of more than 80% within the bandwidth for a VSWR ≤ 2.

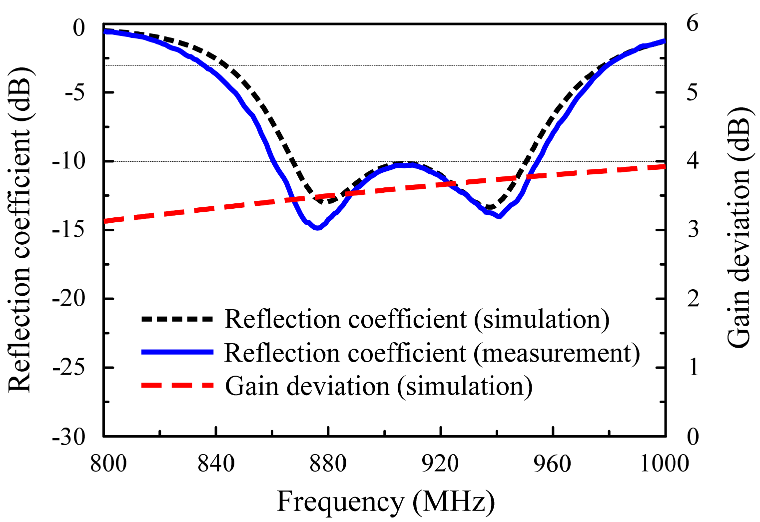

Figure 2. Reflection coefficient and gain deviation of the tag antenna as functions of frequency.

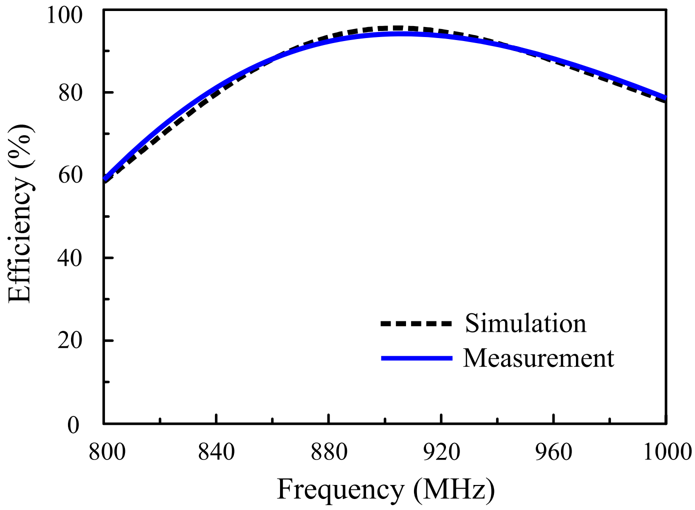

Figure 3. Efficiency of the tag antenna as a function of frequency.

Figure 4 shows the readable range with respect to the representative direction in the three principal planes (*xz*, *yz*, and *xy*) of the tag antenna at 870, 910, and 950 MHz measured using a circularly polarized reader antenna in an anechoic chamber. Table 1 summarizes the measured readable range with respect to the direction of the tag antenna, and shows that the proposed antenna had a stable readable range throughout the wide range of its operational frequencies. Figure 5 shows the simulated three-dimensional radiation patterns of the tag antenna at 870, 910, and 950 MHz. The radiation pattern in each representative plane agreed closely with the measured readable range shown in Fig. 4.

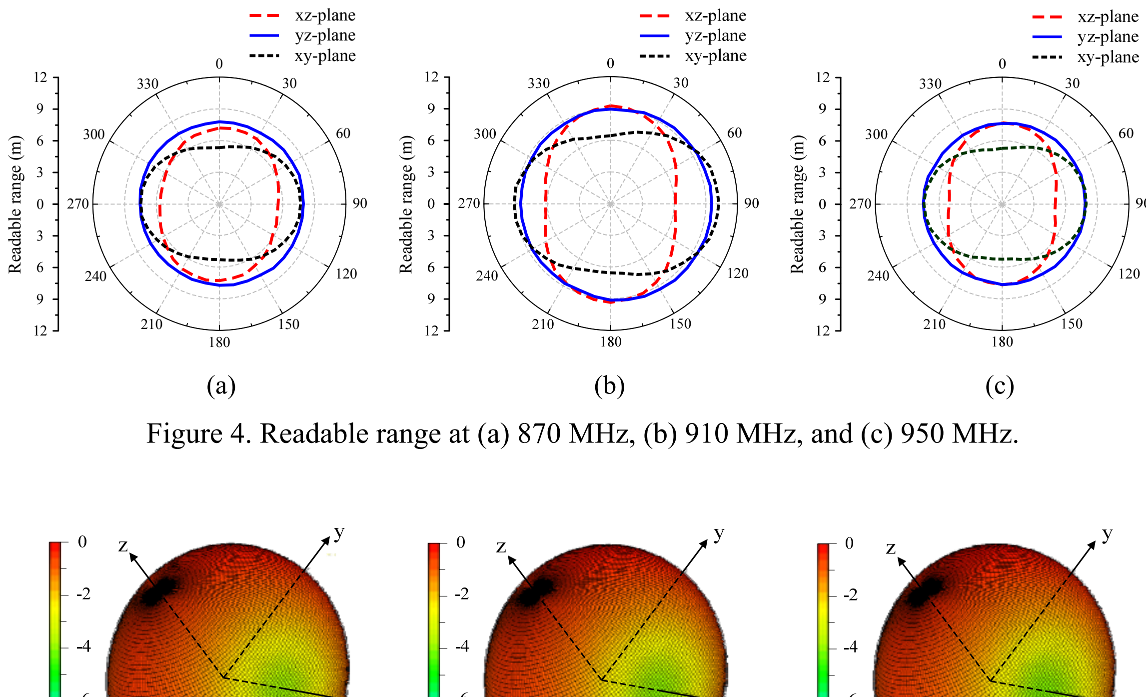

Figure 4. Readable range at (a) 870 MHz, (b) 910 MHz, and (c) 950 MHz.

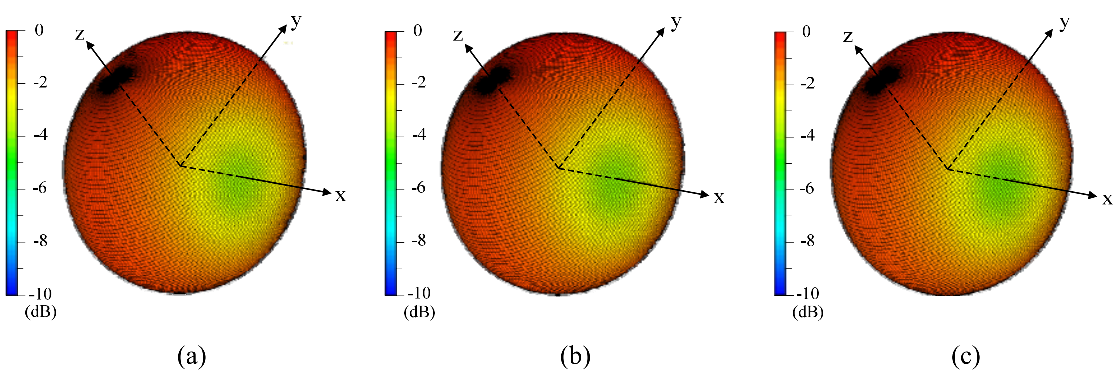

Figure 5. Simulated radiation pattern at (a) 870 MHz, (b) 910 MHz, and (c) 950 MHz.

3. Conclusions

This paper described a broadband U-shaped RFID tag antenna for the stable operation of RFID systems. The tag antenna was composed of a U-shaped half-wavelength dipole and a rectangular-shaped feed. The measured bandwidth was 859.5–955.5 MHz for a VSWR ≤ 2. The antenna exhibited a quasi-isotropic radiation pattern with a gain deviation of less than 3.77 dB for any arbitrary angle. The maximum measured readable range was between 5.01 and 10.23 m in any direction within the frequency range of operation for a VSWR ≤ 2.

Table 1. Measured readable range

	xz-plane		*yz*-plane		*xy*-plane	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
870 MHz	7.31 m	5.56 m	8.04 m	7.51 m	7.69 m	5.29 m
910 MHz	9.34 m	6.10 m	9.56 m	8.52 m	10.23 m	6.40 m
950 MHz	7.68 m	5.01 m	7.93 m	7.32 m	7.95 m	5.20 m

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