A Miniaturized Unidirectional Moxon Antenna for UHF RFID Tags

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Abstract— A unidirectional moxon antenna for UHF RFID tags is proposed. Meander lines are applied in this structure for the size reduction. An inductively coupled feeding loop is used to match the impedance between the antenna and the chip. A gain of 4.48 dBi and an outstanding front-to-back ratio of 17.7 dB are achieved with a very broad frontal lobe (half power beamwidth is 70 degrees in the x-y plane and 150 degrees in y-z plane).

1. INTRODUCTION

RFID (Radio Frequency Identification) technology is a remote automatic identification technology, which enables target recognition and relevant data acquisition through radio frequency signals. The tag antenna is a vital part of the RFID system, and its performance greatly affects the performance of the RFID system. Most tag antennas have omnidirectional radiation patterns or quasi-isotropic radiation patterns. However, in some specific situations a unidirectional tag antenna is much more desired, as it gives a much longer reading range in the required direction than in other directions.

Two kinds of high gain Yagi-Uda UHF RFID tag antennas have been proposed in [1]. The first 5-element Yagi-Uda type UHF tag antenna has an overall size of 180 mm × 140 mm, a maximum gain of 6.6 dB, and a front-to-back ratio of 10 dB. In the second design, the overall size of the 5-element Yagi-Uda type UHF tag antenna has been reduced to 140 mm × 80 mm with a maximum gain of 4.6 dB and a front-to-back ratio of 10.6 dB. The tag antenna size is reduced through a T-matching method.

In this letter, we propose a miniaturized unidirectional moxon antenna for UHF RFID tags. The moxon antenna is a parasitic dual-element array with the ends of each element folded back towards each other for additional coupling. The ends are separated to create a gap, which is mostly responsible for the unidirectional pattern [2]. Meander lines [3] and an inductively coupled feeding loop [4] are applied in this structure for the size reduction and the impedance match between the antenna and the chip, respectively. Our proposed antenna has an overall size of 80 mm × 60 mm, much smaller than the antennas in [1], while the maximum gain is 4.48 dB and the front-to-back ratio is 17.7 dB at 915 MHz. The measured maximum reading range is 18.5 m with a total transmitted power of 4.0 W EIRP at 915 MHz. In addition, the front-to-back ratios are all above 15 dB in FCC band.

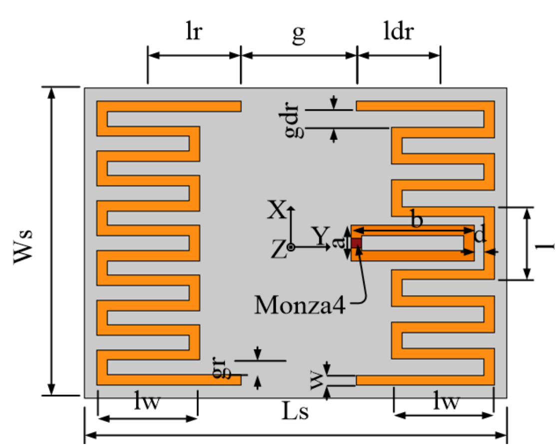

Figure 1: Geometry of the proposed RFID antenna.

2. ANTENNA STRUCTURE AND DESIGN

The configuration of the proposed antenna is illustrated in Figure 1. The antenna consists of a meander driven element and a meander reflector. Both of them are made of 0.01 mm aluminium and printed on a Polyethylene Terephthalate (PET) substrate with a thickness of 0.05 mm and relative permittivity of 3.2. The ends of the driven element and reflector are bent inward. The front-to-back ratio of this antenna is highly affected by the lengths of inwardly bent lines (L_r L_{dr},) as well as the spacing between the driven element and the reflector (g). An inductively coupled feeding loop, inserted in the middle of the driven element, is used instead of directly feeding into this structure. By adjusting the size of the feeding loop and the spacing between the loop and the radiating body of the driven element, the input impedance of the antenna can be conjugate-matched easily to the chip.

The actual overall size of the tag is $L_s \times W_s = 80 \times 60\,\text{mm}^2$. The optimal design parameters are as follows: $l_w = 20\,\text{mm}$, $l = 14.4\,\text{mm}$, $w = 2\,\text{mm}$, $g_r = 2.9\,\text{mm}$, $g_{dr} = 3.2\,\text{mm}$, $l_r = 19.2\,\text{mm}$, $g = 22.4\,\text{mm}$, $l_{dr} = 16\,\text{mm}$, $a = 7\,\text{mm}$, $b = 24\,\text{mm}$, and $d = 2\,\text{mm}$.

3. SIMULATED AND EXPERIMENTAL RESULTS

The prototype antenna is designed and optimised for the FCC band (902–928 MHz). The proposed tag antenna is fabricated in a roll to roll (R2R) process. A Monza 4 chip with an input impedance of $(11 - j143)\,\Omega$ and a threshold power sensitivity of -17.4 dBm at 915 MHz is used in the experiment.

A prototype of the proposed antenna is measured with Agilent E8358A VNA and NI-VISN-100 RFID tester. The tester has an EIRP (effective isotropic radiated power) of 4 W and consists of the RFID reader with a radiation power of 30 dBm and a reader antenna with a gain of 6 dBi.

Figure 2 gives the simulated and measured results of the input impedance, which agree well with each other. The simulated and measured results for the Power Reflection Coefficient (PRC) [5] are plotted in Figure 3. The -3 dB bandwidth is very wide because of the combined effect of the adjacent resonances of the feeding loop, the driven element and the reflector. The small deviation in frequency may be due to fabrication and chip bonding error.

The simulated gain pattern and measured reading range pattern are shown in Figure 4 for comparison. The outlines of the simulated and measured results are generally similar to each other, which indicates the agreement of the simulated and measured results.

The front-to-back ratio is obtained by:

$$\text{FBR}\,(\text{dB}) = 10\log_{10}\frac{G_f}{G_b} = 20\log_{10}\frac{R_f}{R_b} \tag{1}$$

where G_f and G_b are gains in the front and back directions, respectively, and R_f and R_b are reading ranges in the front and back directions, respectively.

With a simulated gain of 4.48 dB in the front direction and -15.6 dB in the back direction, the simulated front-to-back ratio is 20 dB at 915 MHz. The measured front-to-back ratio is 17.7 dB, and the measured reading range is 18.5 m in the front direction and 2.4 m in the back direction at 915 MHz. The measured half power beamwidth is 70° in the x-y plane and 150° in the y-z plane while the half power beamwidth of the dipole antenna is about 70° in usage plane.

The reading ranges in the front and back directions as a function of the frequency are shown in Figure 5. As in the grey zone, the front-to-back ratios in the FCC band are all above 15 dB. Good directivity can be achieved in the FCC band.

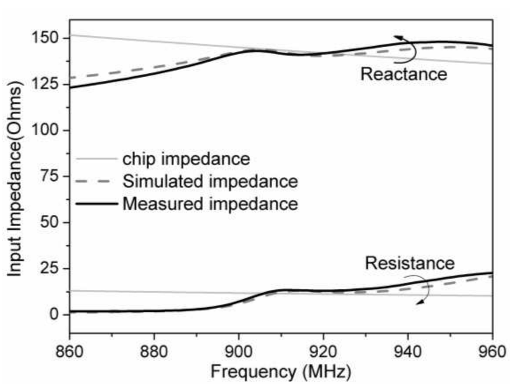

Figure 2: Simulated and measured input impedances of the proposed RFID antenna.

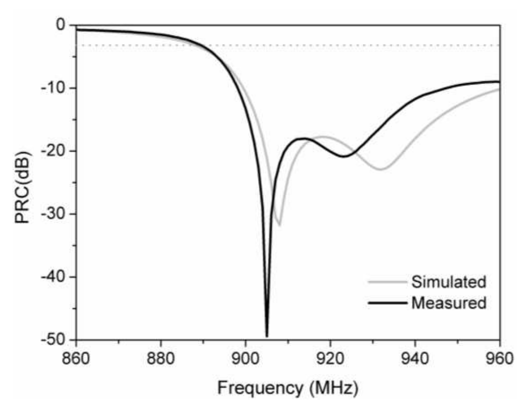

Figure 3: Simulated and measured results of PRC of the proposed RFID antenna.

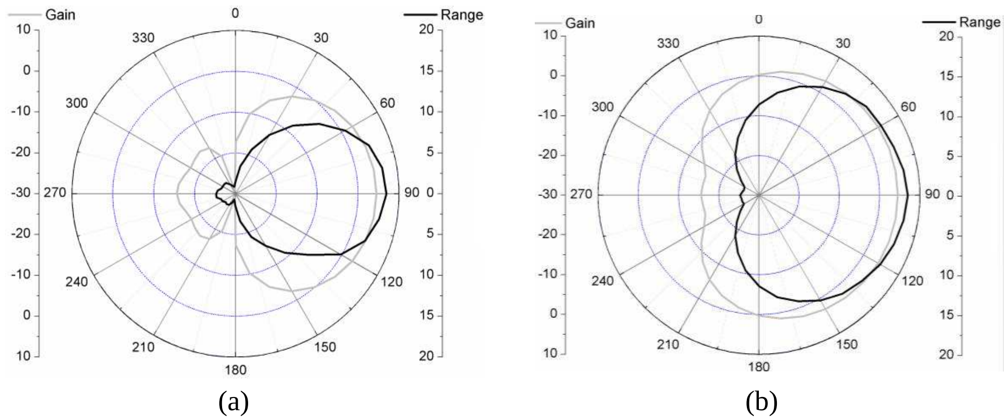

Figure 4: Simulated gain (dB) pattern and measured reading range (m) pattern at 915 MHz of the proposed RFID antenna. (a) Patterns in the x-y plane. (b) Patterns in the y-z plane

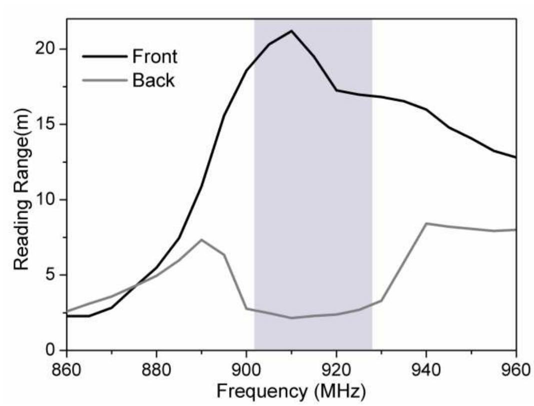

Figure 5: Measured reading ranges in front and back directions.

4. CONCLUSION

A unidirectional moxon RFID tag antenna has been proposed. The proposed antenna is very unidirectional with a long reading range, an outstanding front-to-back ratio, and a very broad frontal lobe in the FCC band. Meander lines and an inductively coupled feeding loop have been applied to make the antenna more compact and to match the impedance between the antenna and the chip.

ACKNOWLEDGMENT

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