Wideband Circularly Polarized UHF RFID Reader Antenna for Indoor Object Identification

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Abstract A wideband circularly polarized L-shaped microstrip antenna with a planar reflector is proposed for Ultra High Frequency RFID readers. The antenna area is 200x200 mm^2 without a reflector and 250x250 mm^2 with a reflector plane. Simulation results show an VSWR bandwidth (VSWR<1.5) of 0.79-1.160 MHz and a 3dB axial-ratio bandwidth (ARBW) of 0.74-0.98 MHz. Both VSWR and ARBW can cover global UHF RFID frequency bands and standards.

Keyword Circular polarization, Directional antenna, Reflector

1. Introduction

Radio frequency identification (RFID) has gained increasing interest as a possible solution in the Internet of Things (IoT) landscape. Any object attached with a RFID tag can be digitally identified within the read range of the combination between a specific RFID reader and tag. Since the Equivalent isotropically radiated power (EIRP) of the reader is limited according to the standard, antenna design for both readers and tags plays an important role in the read range and coverage area of the reader. Whereas inductive HF RFID with a read range of less than one meter is widespread in forms of access cards, e-passports and capsules, radiative UHF RFID provides a longer read range of several meters in case of passive tags and more than ten meters for active tags. Thus, UHF RFID can offer solutions for smart warehouse and retail shops as well as factory automation.

In this work, a UHF RFID reader antenna was designed and simulated. The main challenge is the circular polarization with an axial ratio of less than 3 dB required from the reader antenna in order to cope with unknown configuration of the tags which should be accessible within the read range. This axial ratio as well as a good impedance matching (VSWR less than 1.5) at the antenna feed must be ensured for the entire frequency bands designated in any global region for UHF RFID. This implies a bandwidth of the antenna from 860 to 960 MHz for the impedance matching and the axial ratio.

From the requirements and literature review, it was found that a printed wide-slot antennas (PWSAs) technique can achieve a large bandwidth for both impedance matching and axial ratio [1-5]. Moreover, if a directional antenna is needed, a reflector can also be added to increase the gain [6].

In this paper, a printed wide-slot antenna (PWSA) with a L-type strip and a tuning stub for an enhanced axial ratio bandwidth (ARBW) and a reflector for higher gain and directivity is proposed. The antenna should fulfil the requirements of a UHF RFID reader antenna of the global standard.

2. Antenna Design

A low-cost FR4 substrate with a relative dielectric constant ε_r of 4.2, a loss tangent $tan\delta$ of 0.02, and a thickness h of 1.6 mm is chosen for the proposed antenna design. The first design concept is based on a L-type strip protruding in a square ground ring as shown in Fig.1 (a). With this design, the required bandwidth can be achieved for the impedance matching but not for the axial ratio of less than 3 dB. By widening the L strip and the ground ring, the ARBW can be improved [4] (see fig. 1 (b).). To improve the ARBW further, a ground stub can be added inside the square ground ring [2, 5] (see fig. 1 (c).). The final antenna design of this concept is shown in Fig.2 with all design parameters. By modifying the length Ls of the ground stub, the ARBW can be improved compared to the case without the ground stub. However, the VSWR bandwidth of the input matching is affected by the ground stub. In order to re-optimize the VSWR bandwidth, the length *L1* of the antenna's outer square side, the width *Ws* of the ground stub as well as the dimensions *Lfv* and *Lfh* of the L strip can be modified.

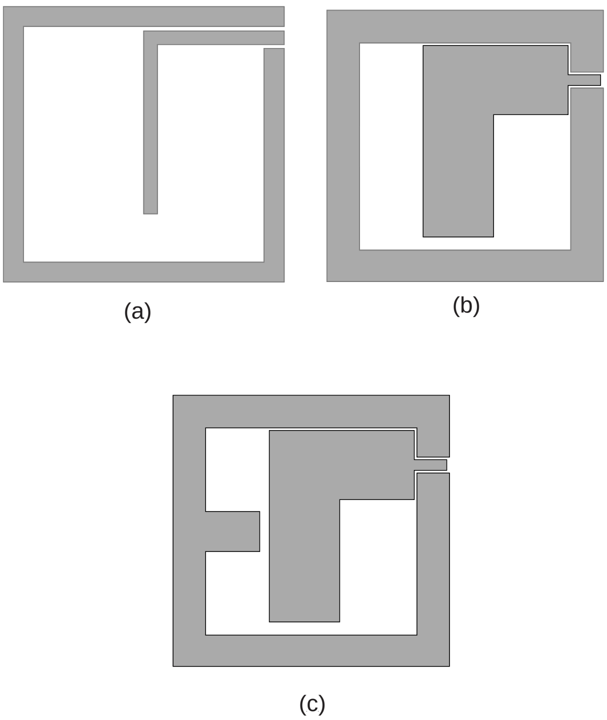

Fig.1. (a) L strip antenna enclosed in a square ground ring (b) Modification for increased ARBW (c) Introduction of the ground stub for further ARBW improvement.

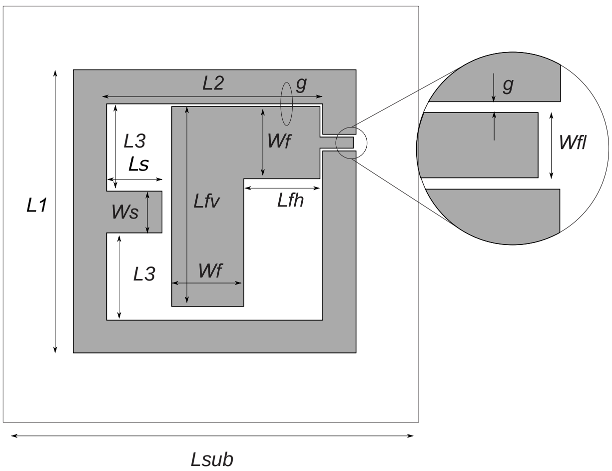

Fig.2. The proposed circularly polarized antenna with all design parameters.

3. Simulation Results

Ansoft HFSS was used to simulate and optimize the design parameters of the proposed antenna in order to cope with the entire global frequency band designated for UHF RFID. In case of a substrate area of 200x200 mm^2, the optimized design parameters are listed in Table 1.

Table.1. Optimized design parameters of the proposed antenna

parameter	size in mm	parameter	size in mm
L1	105	*Lfv*	27.5
L2	83	*Wf*	26
L3	34	*g*	1
Wfl	4	*Ls*	20
Lfh	72	*Ws*	15

Figure 3 shows the simulated reflection coefficient of the proposed antenna. A bandwidth for VSWR<1.5 of 0.76 GHz to 1.16 GHz was provided. Simulated 3 dB ARBW of the antenna is shown in Fig. 4 covering 0.86 GHz to 1.04 GHz. From the results, it is obvious that the proposed antenna can cover the global designated band for UHF RFID (860-960 MHz).

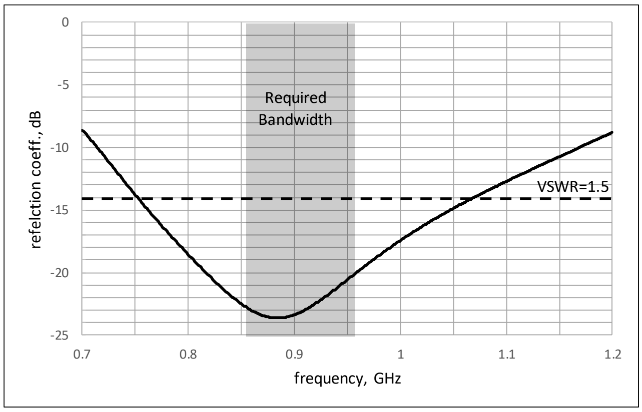

Fig.3. Simulated reflection coefficient of the proposed antenna

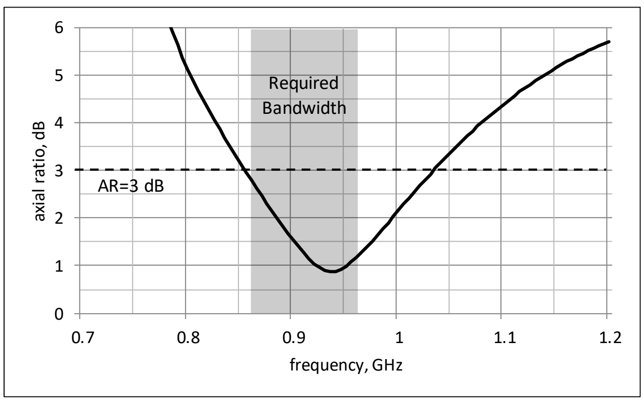

Fig.4. Simulated ARBW of the proposed antenna

The proposed antenna is bidirectional with a left hand circular polarization (LHCP) on one side and a right-hand circular polarization (RHCP) on another side. Figure 5 shows the simulated gain of the antenna with 3.1 dB gain at 910MHz and approx. 3 dB gain for the entire UHF RFID band. In figure 6, the solid line is the simulated radiation pattern of the x-z plane, whereas the dotted line represents the radiation pattern of the y-z plane.

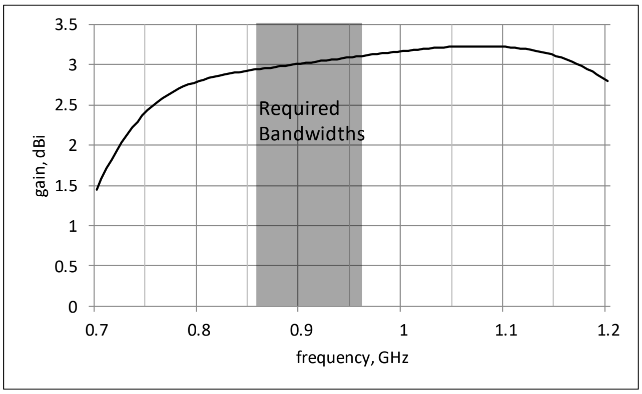

Fig.5 Simulated gain of the proposed antenna

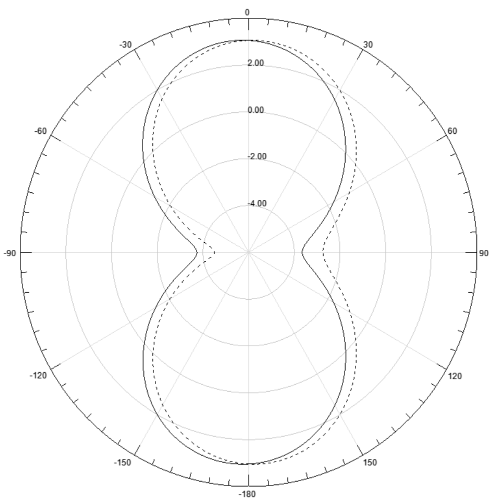

Fig.6 Simulated radiation pattern

4. Combination of the proposed antenna with a reflector

In order to increase the gain, a reflector can be added to the proposed antenna, so that it becomes a directional antenna instead of a bi-directional one [6]. In order to reflect the signal and obtain a maximum power in the front direction, the reflection plane should be located at a distance *h1* which is approximately equal to a quarter wavelength from the main radiating element (see Fig. 7).

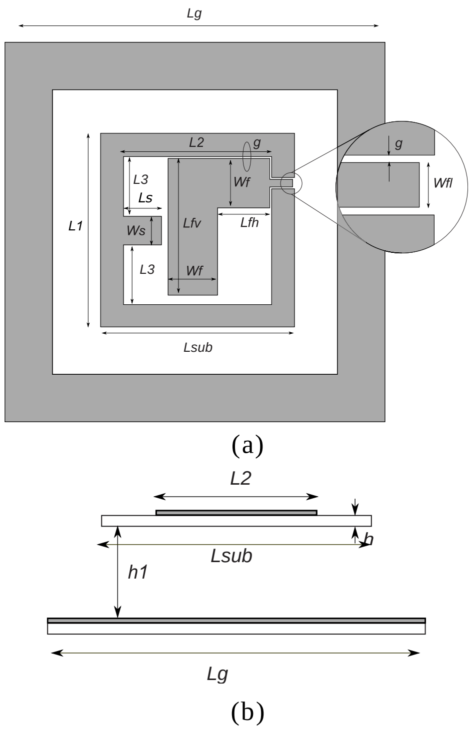

Fig.7. (a) Top view and (b) side view of the proposed antenna with a reflector

The size of the reflector plane (*Lg*) should be large enough to reflect the signal. From the design point of view, it is of interest to have a small antenna without a degradation of performances. Therefore, size reduction of the antenna element and the reflector have been studied. In case of a large reflector, the size of the radiating antenna element is determined by the size of the FR4 substrate. Figures 8 and 9 depict the reflection coefficient bandwidth and ARBW over the frequency, when the substrate size of the radiating element is varied.

Considering Figure 8, it is obvious that the size of the FR4 substrate does not have a significant effect to the reflection coefficient of the antenna, but more to the axial ratio as seen in Fig.9.

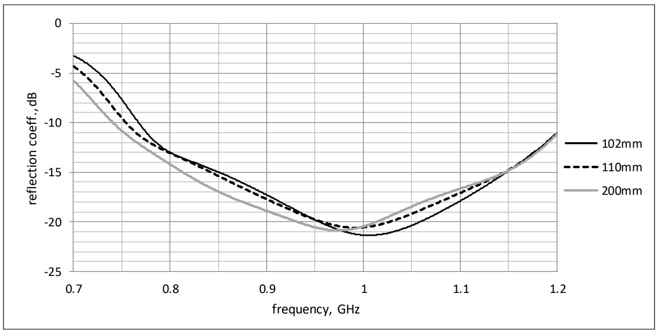

Fig.8 Effects of the substrate size to the reflection coefficient

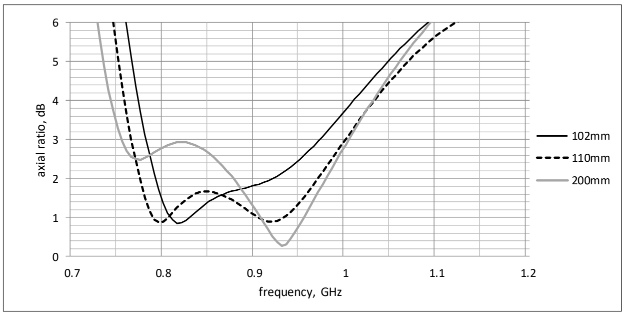

Fig.9. Effects of the substrate size to axial-ratio

In case of the reflector, the size does not cause a significant impact to the reflection coefficient as well as to the axial ratio as shown by Fig. 10 and 11.

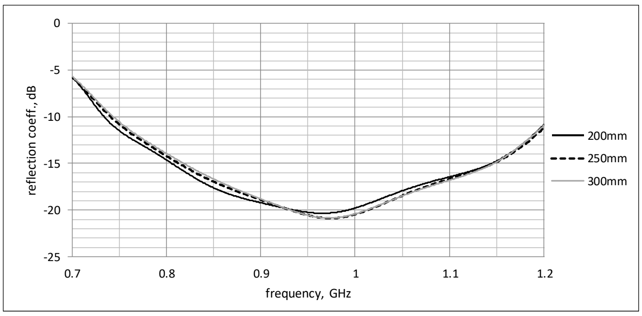

Fig.10. Effects of the reflector size to the reflection coefficient

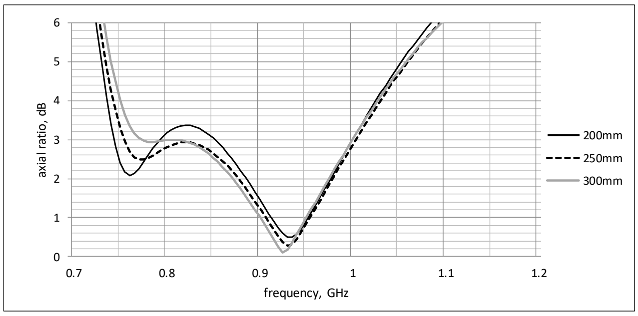

Fig.11. Effects of the reflector size to the axial ratio

The proposed antenna with a reflector has been optimized with the radiating element size of *Lsub*=200 mm and a reflector size *Lg* of 250 mm. The distance *h1* between the radiating element and the reflector is 80 mm. Other design parameters are optimized, so that the VSWR of less than 1.5 and the axial ratio of less than 3 are ensured in the entire range of the global UHG RFID band. The values of the optimized design parameters of the proposed antenna with a reflector are listed in Table 2.

Table.2. Optimized design parameters of the proposed antenna with a reflector

parameter	size in mm	parameter	size in mm
L1	102	*Lfv*	27.5
L2	78	*Wf*	26
L3	31.5	*g*	1
Wfl	4	*Ls*	20
Lfh	72	*Ws*	15

The radiation pattern was simulated to confirm that the reflector has fulfilled its function by reinforcing the main beam of the antenna into just one direction (see Fig. 12). The proposed antenna with a reflector is left-handed circularly polarized with a flat gain over the required bandwidth of approx.7.5 dBi (see Fig. 13).

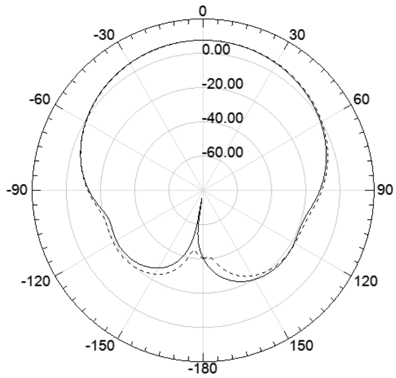

Fig.12 Simulated radiation pattern of the proposed antenna with a reflector plane. Solid line: xz-plane pattern, dotted line: yz-pattern.

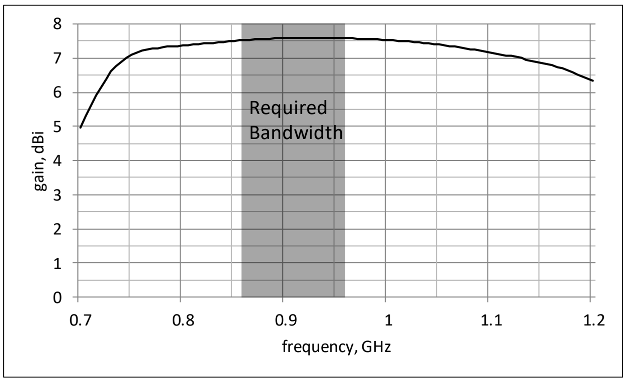

Fig.13 Simulated gain of the proposed antenna with a reflector.

By optimizing other design parameters, it was ensured that the antenna can be used as a UHF RFID reader antenna for any global standard. The simulated reflection coefficient and the axial ratio are depicted in Fig. 14 and 15, respectively. For VSWR<1.5, the bandwidth of the proposed antenna with a reflector ranges from 0.79 to 1.16 GHz. In case of an ARBW<3 to ensure a circular polarization, the bandwidth ranges from 0.74-0.98 GHz. Both VSWR bandwidth and ARBW can cover the frequency range of all UHF RFID global standards.

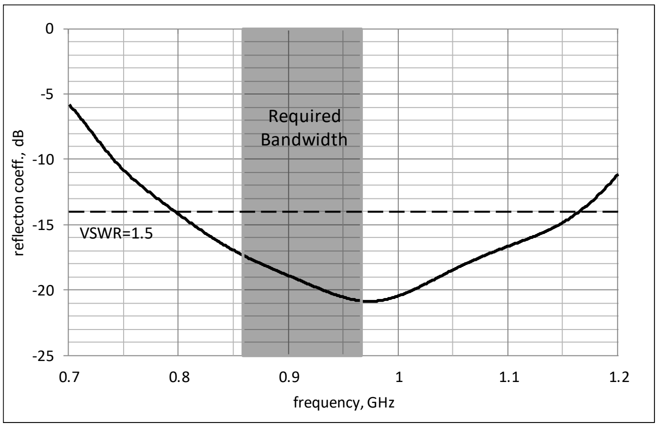

Fig.14. simulation of reflection coefficient of CP square antenna with reflection plane

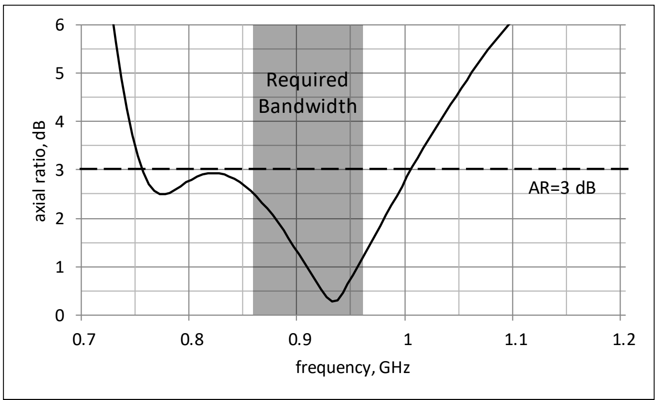

Fig.15. simulation of axial-ratio bandwidths of CP square antenna with reflection plane

5. Conclusions

A wideband circularly polarized UHF RFID antenna has been proposed. The design concept is based on a L-shaped microstrip antenna surrounded by a square ground ring. The widths of the L-shaped antenna and the ground ring can be optimized to achieve a good axial ratio bandwidth over the frequency band designated for global UHF RFID standards. Further improvement of the axial ratio bandwidth can be realized using a ground stub added to one inner side of the ground ring. Without a reflector, the proposed antenna showed a bi-directional radiation pattern with a gain of approx. 3 dBi within the required bandwidth. With a reflector, the gain can be increased to 7.5 dBi within the required bandwidth with a directional radiation pattern. For both cases, the design parameters can be optimized, so that the axial ratio of less than 3 dB and a VSWR of less than 1.5 can be ensured for the global frequency standards of UHF RFID applications.

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