



High-Gain Circularly-Polarized Square Patch UHF RFID Reader Antenna Design for Smart Factory Applications

Gulbahar Guven^{1*}, Ismail Akdag²

^{1*} İzmir Katip Celebi University, Faculty of Architecture and Engineering, Department of Electrical and Electronics Engineering, İzmir, Turkey, (ORCID: 0000-0002-0155-5011), gulbaharguven44@gmail.com

² İzmir Katip Celebi University, Faculty of Architecture and Engineering, Department of Electrical and Electronics Engineering, İzmir, Turkey, (ORCID: 0000-0001-6470-5892), ismail.akdag@ikcu.edu.tr

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Abstract

In this paper, a UHF (Ultra High Frequency) RFID (Radio-frequency identification) circular polarization reader antenna is presented. The proposed antenna is a low cost, easy to manufacture UHF RFID reader antenna in the European UHF RFID band. The proposed antenna design employs an air-substrate patch antenna. The antenna size of 250x250x7mm. The proposed antenna works from 850 to 874 and 880 to 893 MHz with return loss less than -10 dB, thus covering the European UHF RFID band. The proposed antenna return loss bandwidth is 37 MHz. The gain of the designed antenna is 7.88 dBi at 867 MHz. Also, with a bandwidth of 864-870 MHz, the axial ratio (AR) is less than 3dB. This means that the antenna has circular polarization at 867 MHz. Each result has been calculated on CST Studio Suite 2020. The antenna recommended for use in smart factory applications promises a good antenna among RFID reader antennas.

Keywords: RFID Reader, UHF (Ultra High Frequency), RFID (Radio-frequency identification), Circular Polarization (CP), Axial Ratio

Akıllı Fabrika Uygulamaları için Yüksek Kazançlı Dairesel Polarize Kare Yama UHF RFID Okuyucu Anten Tasarımı

Öz

Bu bildiri, bir UHF (Ultra Yüksek Frekans) RFID (Radyo frekansı tanımlama) dairesel polarizasyon okuyucu anteni sunulmaktadır. Önerilen anten, Avrupa UHF RFID bandında düşük maliyetli, üretimi kolay bir UHF RFID okuyucu antendir. Önerilen anten tasarımı, bir hava-substrat yama anteni kullanır. 250x250x7mm antenin boyutudur. Önerilen anten 850 ila 874 ve 880 ila 893 MHz arasında ve -10 dB'den daha az geri dönüş kaybıyla çalışır, böylece Avrupa UHF RFID bandını kapsar. Önerilen anten dönüş kaybı bant genişliği 37 MHz'dir. Tasarlanan antenin kazancı 867 MHz'de 7.88 dBi'dir. Ayrıca, 864-870 MHz bant genişliği ile eksenel oran (AR) 3dB'den azdır. Bu, antenin 867 MHz'de dairesel polarizasyona sahip olduğu anlamına gelir. Her sonuç CST Studio Suite 2020 üzerinde hesaplanmıştır. Akıllı fabrika uygulamalarında kullanılması önerilen anten, RFID okuyucu antenler arasında iyi bir anten vaat ediyor.

Anahtar Kelimeler: RFID Okuyucu, UHF (Ultra Yüksek Frekans), RFID (Radyo frekansı tanımlama), Dairesel Polarizasyon (CP), Eksenel Oran

* Corresponding Author: gulbaharguven44@gmail.com

1. Introduction

Today, factories are rapidly transitioning to mechanization technologies. The most important improvements made in this process are made with UHF (Ultra High Frequency) RFID (Radio-frequency identification). RFID systems are frequently utilized in industries such as object monitoring, product manufacturing, production tracking, sales, and logistics. [1-4]. Due to the obvious rapid technological discoveries in microwave and millimeter wave component technologies, existing wireless components [5-9] are being replaced by alternative wireless component designs that are targeted to be technically compatible with emerging technology. RFID technology is an automatic identification system consisting of a tag and a reader with an antenna wrapped around it. Data and energy transfer are provided without any contact between the tag and the reader. As in every wireless communication system, the antenna is one of the vital parts of in RFID systems [10]. A circularly polarized antenna is required to ensure reliable communication between the reader and the tag [11]. Air-substrate can be used to obtain circularly polarized characteristics, increase impedance bandwidth and reduce antenna dielectric loss [12-14]. In recent years, different architectures have been proposed to generate broadband circular polarization radiation [10-15]. In [15], a reader antenna with a maximum gain of 8.9 dBi in the 890 - 944 MHz range is presented. The disadvantage of this antenna is that the antenna does not have circular polarization and its dimensions are large (305x3025x7mm). In [12] presents an L-shaped ground plane powered antenna with a maximum gain of 8.6 dBi in the 836 and 986 MHz range. The disadvantage of this antenna is its large dimensions (250x250x60mm). In [16], a reader antenna with a maximum gain of 4 dBi is presented in the 618- 998 MHz range. The Dimension size of the antenna is 120x120x0.8 mm. In [17], a reader antenna with a maximum gain of 5.62 dBi is presented in the 850 - 1060 MHz range. The disadvantage of this antenna is that the antenna is very thick and has a more complex structure because it is multi-layered. (150x100x10mm). However, these antennas are either large, have a small bandwidth, or have a small gain compared to the antenna.

The design of a UHF RFID high-gain circularly polarized RFID reader antenna is presented in this article. The proposed new antenna offers high gain for better readability of tags along with good impedance matching in the 864-870 MHz UHF RFID band. The proposed antenna circular polarization design is preferred because circular polarization provides distance gain over linear polarization and facilitates communication between antennas that are not in direct line of sight [19]. In addition, a suitable size design has been made for the reader antenna and the use of FR4 has been presented for a low cost.

2. Material and Method

2.1. Antenna Design

Figure 1 shows the geometry and size of the proposed antenna. The air-substrate thickness used in the proposed antenna is 5.42 mm. Used FR4 A 0.8 mm thick and FR4 substrate with permittivity =4.4, and loss tangent =0.02.

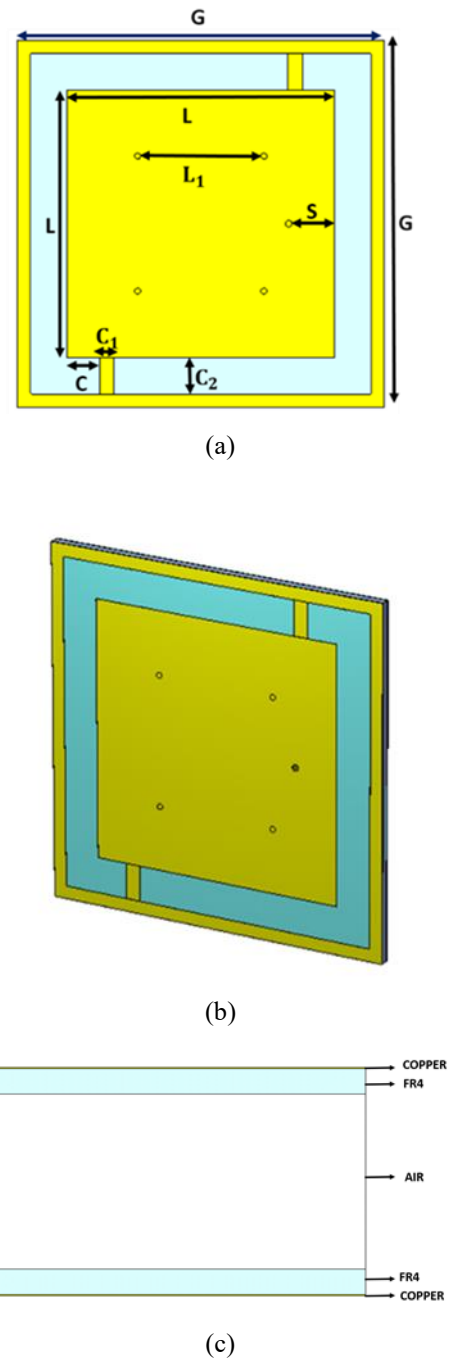


Fig.1: Geometry of proposed antenna. (a) top view, (b) antenna view (c) side view.

Fig.1 (e) shows the simplified version of the antenna from the side. Fig.1 (c), the antenna has 0.035 mm thick copper ground, 0.8 mm thick FR4, 5.42 mm air, 0.8 mm thick FR4, and 0.035 mm thick copper, from bottom to top, respectively. The patch and ground plane are connected by four copper pins. The antenna is fixed with these copper pins, which force the radiation patch to connect directly to the ground plane, increasing the antenna's impedance bandwidth. The antenna is fed by a 50 Ω SMA connector. The parameters used are $G=250$ mm, $L=183$ mm, $L_1=82$ mm, $C=22.50$ mm, $C_1=24.50$ mm, $C_2=10$ mm, $S=30$ mm.

3. Results and Discussion

3.1. Results

The proposed antenna was constructed and simulated using CST Studio Suite 2020. Antenna dimensions are optimized to achieve desired performance in reflection coefficient, bandwidth, axial ratio, and gain. The S parameters of the proposed antenna are shown in Fig.2. When Figure 2 is examined, the proposed antenna offers a bandwidth of 37 MHz in the frequency range of from 850 to 874 and 880 to 893 MHz. When Fig.3 is examined, the antenna provides 7.88 dBi gain at 867 MHz.

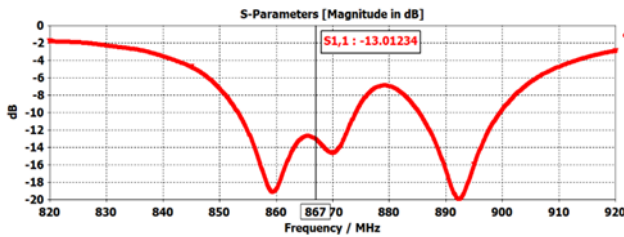


Fig.2: |S11| of a proposed reader antenna

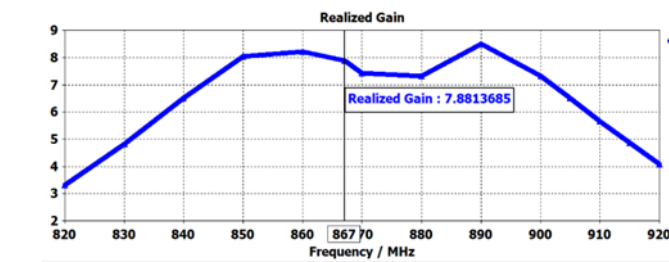


Fig.3: Realized gain of a proposed reader antenna

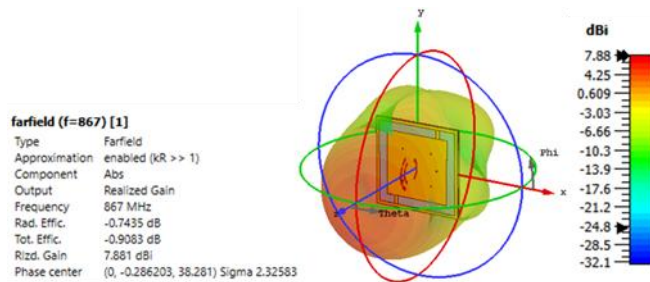


Fig.4: Realized gain of the proposed reader antenna

The 3D radiation patterns of the designed antenna are illustrated in Figure 4. The realized gain of the antenna is 7.88 dBi at 867 MHz.

When Fig.5 is examined, the axial ratio is below 3 dB in the range of 864-870 MHz. In the frequency range where the axial ratio is above 3 dB, the antenna exhibits circular polarization.

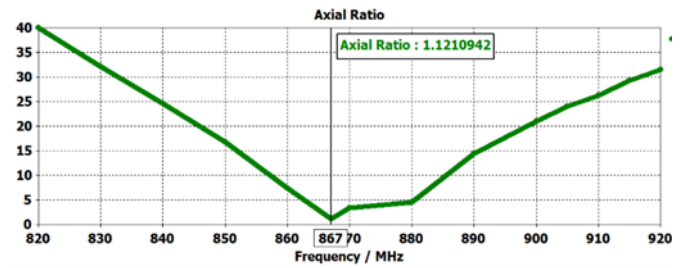


Fig.5: Axial the ratio of a proposed reader antenna

3.2. Discussion

As seen in Table 1, the proposed reader antenna is better when compared to the reader antennas in the literature. Different studies have been examined in different working ranges and gains created with different parameters and methods. The proposed antenna is more applicable and usable than other antennas in terms of size and gain.

Table 1. Comparison of the performance parameters of the proposed antenna

Ref.	10 dB Bandwidth (MHz)	AR Bandwidth (MHz)	Gain (dBi)	Dimensions (mm)
[7]	880-960	906-928	9	254x254x18
[8]	890-944	902-928	8.9	305x305x7
[9]	685-1125	836-986	8	250x250x60
[10]	618-998	761-1123	4	120x120x0.8
[11]	850-1060	876-1084	5.62	150x100x10
Prop osed	900-940	911-921	8.64	250x250x7

4. Conclusion

In this paper, a high-gain circularly polarized RFID reader antenna has been proposed. The proposed antenna has a reading range from 850 MHz to 874 MHz, from 880 MHz to 893 MHz, and offers 37 MHz bandwidth. The gain of the designed antenna is 7.88 dBi at 867 MHz. Also, with a bandwidth of 864-870 MHz, the axial ratio (AR) is less than 3 dB. This indicates that the antenna has circular polarization at 867 MHz. The antenna, which is recommended to be used in UHF RFID applications, promises a good and useful antenna among RFID reader antennas.

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