Eccentric Circular Ring RFID Tag Antenna for Dual-Band Operation

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1. Abstract

In this letter, a dual-band ultra high frequency (UHF) passive RFID tag antenna covering the 865-868 MHz band and 950-956 MHz band is proposed. The antenna has two eccentric circular rings, each of which resonates at one of these two bands. Both the rings are simultaneously excited by an arc-shaped short-circuited microstrip line by the coupling-feed technique. The proposed structure exhibits good impedance matching at both the bands with the Impinj Monza-4 tag chip used in the design. The measured return losses at 866 MHz and 952 MHz are around -12.25 dB and -12.99 dB respectively. Bidirectional radiation patterns suitable for RFID applications are obtained at both the frequencies.

2. Introduction

Advancement in the semiconductor industry in 1990s led to the commercialization of Radio Frequency Identification (RFID) in supply chain management, product tracking, transportation and logistics. Today RFID has been successful in replacing some of the ubiquitous automatic identification technologies like smart cards, magnetic stripe cards and barcodes, as it offers non-line of sight communication and increased storage.

The three basic components of an RFID system are the tag, the reader and the application software. Ultra-high frequency (860-960 MHz) RFID systems have become more popular compared to low frequency (125-134 KHz) and high frequency (13.56 MHz) systems as they require smaller antennas and enable simultaneous detection of multiple tags [1]. Different parts of the UHF band are allocated by different countries for RFID use, viz. 865-868 MHz (Europe), 902-928 MHz (North and South America), 920-926 MHz (Australia) and 950-956 MHz (Japan) [2]. A dual-band tag can operate at any two bands simultaneously. For a dual band tag, the antenna impedance must have conjugate matching with the impedances of the IC chip at both the desired frequency bands to achieve maximum power transfer. Several dual-band UHF RFID tag antennas have been presented earlier in the literature [3-6].

In this article, a dual band RFID tag antenna with two eccentric circular rings, resonating at 865-868 MHz and 950-956 MHz bands, is presented. Each of these two rings is responsible for resonance at one of the two frequencies. An arc-shaped microstrip line feeds the two rings simultaneously using coupling-feed techniques [7]. Impinj Monza 4 tag chip with impedances of 13-j151 Ω at 866 MHz and 10-j137 Ω at 956 MHz is used for the design.

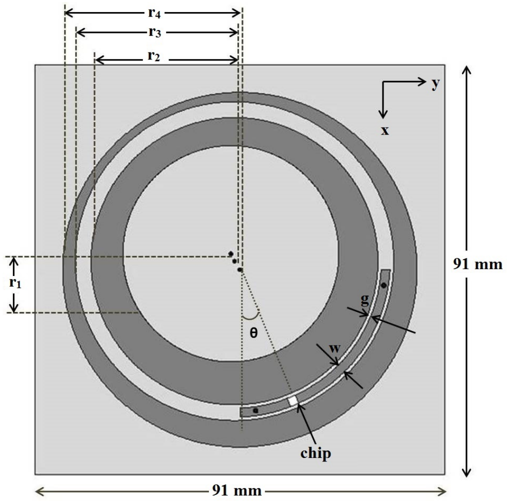
3. Antenna Design

The proposed antenna structure is shown in Figure 1(a). It consists of two eccentric circular ring patches of different radii and an arc-shaped short-circuited microstrip feed-line printed on a 1.6 mm thick FR-4 substrate (dielectric constant, ε_r=4.4 and loss tangent, tanδ=0.002), with a ground plane on the opposite side. The total size of the structure is 91 × 91 mm^2. Simulation of the design is performed using the Ansoft HFSS software.

On taking the two rings individually and exciting them by the microstrip feed-line, the larger ring is found to resonate at 866 MHz and the smaller ring at 956 MHz. Dual-band response is obtained on inserting the smaller ring (inner radius, r_1=24 mm and outer radius, r_2=31.9 mm) inside the larger ring (inner radius, r_3=35.4 mm and outer radius, r_4=39.4 mm) and exciting both the rings simultaneously by the short-circuited microstrip feed-line. Eccentric circular rings store less energy beneath it compared to a regular circularly shaped patch owing to its smaller area. This reduces the quality factor leading to increased bandwidth. The arc-shaped short-circuited microstrip line (width, w=2 mm), in between the two rings, houses the IC chip at an angle $\theta=22^0$ with the x-axis. The imaginary part of the antenna impedance is mainly contributed by the length and width of the short-circuited microstrip line and is given by the relation [7]:

$$l = \frac{\lambda}{2\pi}\tan^{-1}\left(\frac{143.65}{Z_o}\right) \qquad (1)$$

Where, Z_0 is the characteristic impedance of the microstrip line and is calculated to be 63.6 Ω for a 2 mm thick microstrip line. The value of the imaginary part of the chip impedance is j143.65 Ω at 911 MHz (intermediate frequency between 866 MHz and 956 MHz). The real part of the antenna impedance can be achieved on varying the coupling distance between the arc-shaped microstrip line and the two rings. Here, the coupling distance is taken to be g=0.75 mm to obtain a real impedance of 11.16 Ω at 911 MHz.



(a)

(b)

Figure 1. (a) proposed antenna (b) fabricated antenna with differential probe.

4. Results and Discussion

The fabricated structure of the antenna is shown in Figure 1(b). Fabrication is done by etching method. Differential probes are used for impedance measurement using Anritsu vector network analyzer. The simulated values of the antenna impedances are found to be 11.7 + j151.7 Ω at 866 MHz and 7.3 + j136.7 Ω at 956 MHz, whereas the corresponding measured values are 21.2 + j149.2 Ω and 14 + j143.6 Ω. The measured and simulated reflection coefficients are shown in Figure 2. The simulated values of the reflection coefficients are -24.4 dB in 865-868 MHz band and -16.10 dB in 950-956 MHz band. The measured values are -12.25 dB and -12.99 dB in 865-868 MHz and 950-956 MHz bands respectively.

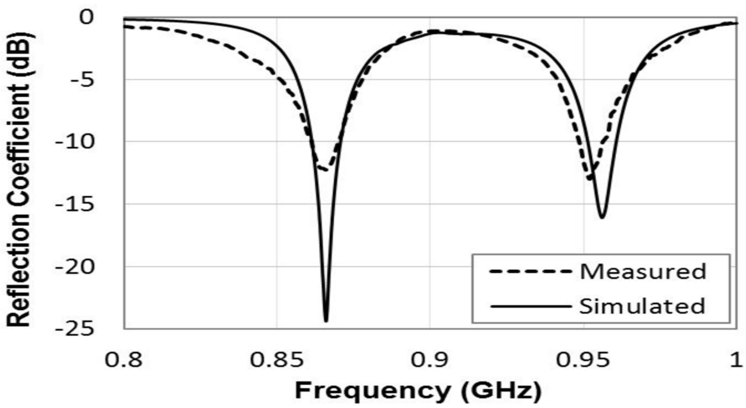


Figure 2. Measured and simulated reflection coefficients of the proposed prototype.

The read ranges (r) of the antenna are calculated using Friis' free space formula [2]:

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r \tau}{P_{th}}} \qquad (2)$$

P_t and G_t are the transmitted power and gain of the tag antenna respectively. G_r is the gain of the reader antenna and P_{th} is the threshold power of the chip (for Monza-4, P_{th}=-17.4 dBm). The power transmission coefficient τ is given by [2],

$$\tau = \frac{4 R_c R_a}{|Z_a + Z_c|^2} \qquad (3)$$

Using (2) and (3), the read ranges are calculated to be around 3 m and 2.6 m in the 865-868 MHz band and 950-956 MHz band respectively.

The proposed antenna has bidirectional radiation pattern at both the frequency bands, which is essential for RFID applications. Figure 3 exhibits the radiation patterns of the antenna at 866 MHz and 956 MHz.

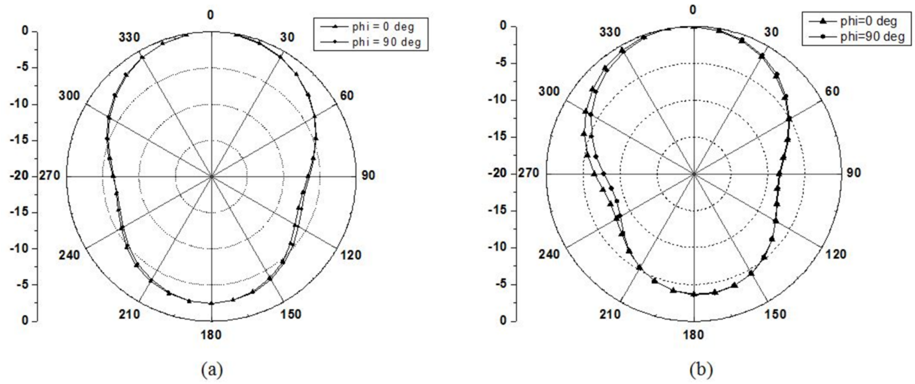


Figure 3. Radiation patterns at (a) 866 MHz (b) 956 MHz.

5. Conclusion

An UHF dual-band RFID tag antenna having two eccentric circular rings is proposed. Coupling-feed mechanism is used to excite the two rings simultaneously with each of the rings resonating at one of the two frequencies. Simulated and measured reflection coefficients obtained from the prototype are -24.4 dB and -12.25 dB respectively in the 865-868 MHz band and -16.10 dB and -12.99 dB respectively in the 950-956 MHz band. Measured read ranges of 3 m at 866 MHz and 2.6 m at 956 MHz are obtained.

6. References

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