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Dual-Band UHF Folded Dipole RFID Tag Antenna Loaded With Spiral Resonator

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1. Abstract

In this paper, a dual-band UHF RFID tag antenna operating at 867 MHz and 956 MHz has been proposed. Perturbation method is used to obtain dual-band response by loading a 2-turn spiral resonator (2-SR) to a single band folded dipole antenna (FDA) operating at 912 MHz. The 2-SR perturbs the electrical length of the FDA and splits the resonant frequency at 912 MHz into the two resonant frequencies of interest. Reflection coefficients of -13.25 dB and -13.34 dB have been recorded with corresponding read ranges of 5 m and 3.3 m in 866-869 MHz band and 950-956 MHz band respectively.

2. Introduction

Advancement in wireless communication has led to the emergence of automatic identification technology. Although barcodes have ruled the automatic identification industry since their inception, however they have been found to be inadequate in an increasing number of cases due to their low storage capacity. Recently, Radio Frequency Identification (RFID) systems have gained huge popularity because of their increased storage capacity, hence replacing barcodes and other commonly used automatic identification technologies to a large extent.

A typical RFID system consists of a tag attached to the item to be tracked and a reader connected to the host computer. The tag has an antenna and a reprogrammable microchip to store information about the tagged object. Communication between the tag and the reader takes place through electromagnetic fields [1].

Different parts of the frequency spectrum are used for RFID applications, like low frequency (LF, 125-134 KHz), high frequency (HF, 13.56 MHz), ultra-high frequency (UHF, 860-960 MHz) and microwave frequency (2.45, 5.8 and 24 GHz) [2]. UHF RFID systems are more advantageous as they offer longer read ranges, and need smaller antennas compared to LF and HF RFID systems. Moreover, they are less prone to multipath interference and signal diffraction compared to RFID systems used in microwave frequency band [3]. Different parts of the UHF band have been allocated for RFID use by each county worldwide, viz. 866-869 MHz in Europe, 902-928 MHz in North and South America, and 950-956 MHz in Japan [4]. RFID tags which can simultaneously operate at any two of these allocated UHF bands are referred to as the UHF dual-band tags. The most challenging aspect of designing a dual-band tag antenna is to attain conjugate impedance matching with the tag chip at the two operating frequencies of interest for enabling maximum power transfer between the tag chip and the antenna. Some of the many techniques to obtain dual-band response reported in the literature involve the use of impedance matching network [5], AMC (Artificial Magnetic Conductor) ground plane [6], and the use of perturbation method [7].

In this letter, a miniaturized dual-band passive UHF RFID tag antenna resonating in the 866-869 MHz band and 950-956 MHz band has been proposed. Perturbation method has been used to obtain dual-band response in which the electrical length of a single band folded dipole antenna is perturbed by a 2-turn spiral resonator. The proposed antenna uses commercially available Impinj Monza 4 IC chip (P_{th}=-17.4 dBm) with impedances of 13-j151 Ω at 866 MHz and 10-j137 Ω at 956 MHz.

3. Antenna Design

To design a dual-band tag antenna using perturbation method, initially it is necessary to design a mono-band tag antenna that can operate at the intermediate frequency between the two required frequencies of operation. The frequency in between 867 MHz and 956 MHz is approximately 912 MHz. A folded dipole antenna (FDA) is designed to resonate at 912 MHz to suffice the requirement. Figure 1 illustrates the geometry of the designed FDA. The antenna design consists of a dipole with M=3 turns. The antenna is printed on a low cost 1.6 mm thick FR-4 substrate (εr=4.4, $\tan\delta$=0.002) of area= 20×66 mm^2. Finite Element Method based Ansoft HFSS software has been used for the purpose of simulation.

The impedance of the FDA depends on the number of turns (M) as well as on the arm width. At the feed point of the FDA impedance is given by,

$$Z_{in}=M^2Z_0 \qquad (1)$$

where Z_0 is the impedance of the dipole with M=1 turn. At 912 MHz, the Impinj Monza-4 IC chip has an impedance of 11.16 – j143.65 Ω. Thus, to achieve conjugate impedance matching with the chip at 912 MHz, the number of turns is chosen to be M=3. The extended arm of length 17.3 mm is taken to further improve the impedance matching.

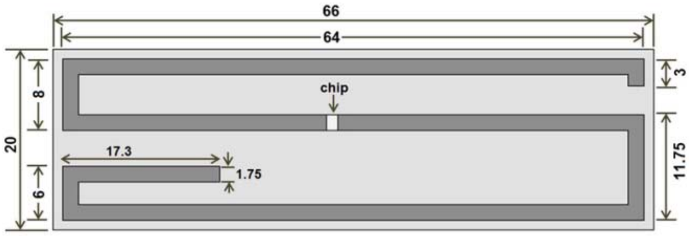

Figure 1. Geometry of the folded dipole antenna resonating at 912 MHz (all dimensions are in mm).

To obtain dual-band response from the mono-band FDA, perturbation method has been employed. In this method a 2-turn spiral resonator (2-SR) is loaded with the FDA without changing its dimensions. The 2-SR alters the electrical length of the FDA and leads to conjugate impedance matching with the chip at the desired frequencies, i.e. one below 912 MHz (at 867 MHz) and another beyond 912 MHz (at 956 MHz). As a result, the resonant frequency of the antenna at 912 MHz gets split into two resonant frequencies, leading to dual-band response at 867 MHz and 956 MHz. The 2-SR used for the design is 16 mm in length and 6 mm in width. The arm width of the 2-SR is 0.4 mm with a spacing of 0.3 mm in between the turns. The proposed antenna design with all the optimized dimensions have been displayed in Figure 2. Figure 3 shows the simulated reflection coefficients of the mono-band FDA and the FDA loaded with 2-SR.

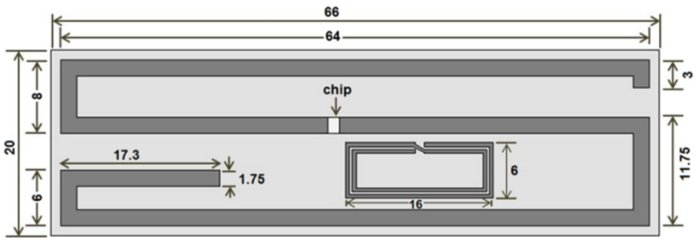

Figure 2. Geometry of the proposed antenna (all dimensions are in mm).

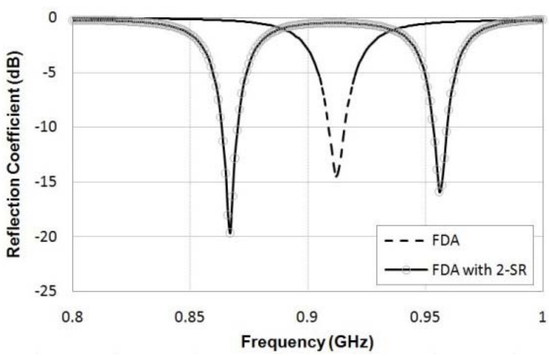

Figure 3. Simulated reflection coefficients of the mono-band FDA and the FDA loaded with 2-SR.

4. Results and Discussion

The proposed antenna is fabricated and the complex S-parameters are measured using Anritsu VNA through differential probes. Figure 4 depicts the fabricated antenna connected to differential probes.

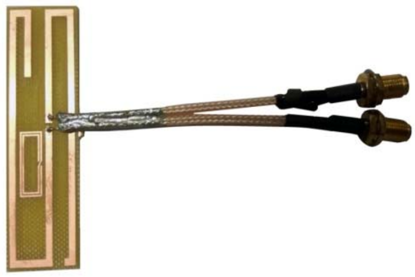

Figure 4. Fabricated prototype of the antenna with differential probes.

Once the S-parameters are measured, the differential impedance is calculated using the conversion formula given in [8]. At 867 MHz, the measured and simulated impedances are found to be 18.8 + j154.5 Ω and 15.6 + j148.5 Ω, whereas at 956 MHz the corresponding values are obtained to be 14.9 + j139.2 Ω and 13.8 + j136.6 Ω respectively. The simulated and measured reflection coefficient plot is shown in Figure 5. The simulated values of the reflection coefficient are -19.67 dB and -15.91 dB at 867 MHz and 956 MHz respectively and the measured values at 867 MHz and 956 MHz are -13.25 dB and -13.34 dB respectively.

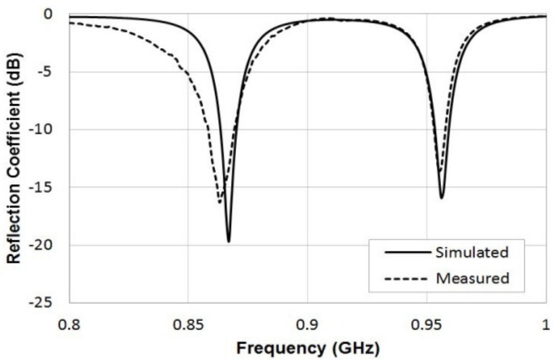

Figure 5. Simulated and measured reflection coefficients of the prototype antenna.

The read range of the antenna is calculated by employing Friis' free space formula given below [4]:

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

λ being the wavelength, P_t is the transmitted power from reader, G_t and G_r are the gain of the transmitting and the receiving antenna respectively. The threshold power of Impinj Monza-4 IC chip is, P_{th}=-17.4 dBm, and τ is the power transmission coefficient which denotes the amount of mismatch between the chip and the antenna. It is given by the equation [4]:

$$\tau = \frac{4\, R_{chip} R_a}{|Z_a + Z_{chip}|^2} \qquad (3)$$

where $Z_{chip}=R_{chip}+jX_{chip}$ is the chip impedance and $Z_a=R_a+jX_a$ is the impedance of the tag antenna. Using the equations (2) and (3), the maximum read ranges are measured to be around 5 m and 3.3 m in the 866-869 MHz band and 950-956 MHz band respectively.

The radiation patterns of the proposed antenna are plotted in Figure 6. It shows that at 867 MHz, the antenna has omnidirectional radiation pattern, whereas at 956 MHz the antenna has bidirectional radiation pattern.

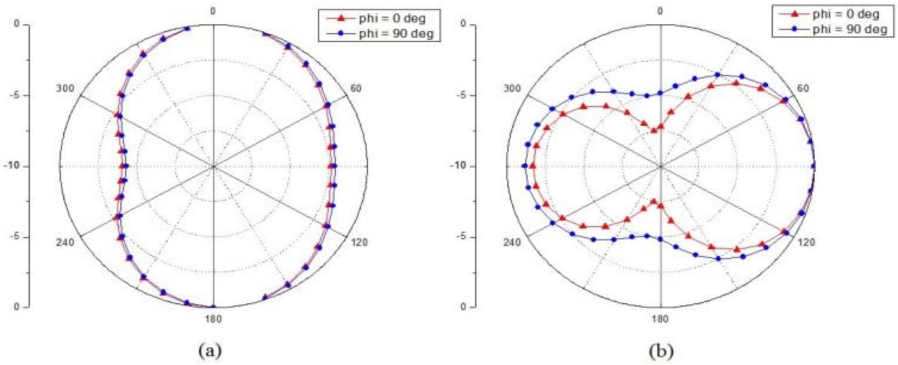

Figure 6. Radiation patterns of the antenna at (a) 867 MHz and at (b) 956 MHz.

5. Conclusion

A miniaturized passive dual-band tag antenna operating in the UHF bands allocated for use in Europe (866-869 MHz) and Japan (950-956 MHz) has been proposed. The antenna uses perturbation method to generate dual-band response. A 2-turn spiral resonator (2-SR) is loaded to a mono-band folded dipole antenna (FDA) which is designed to operate at 912 MHz. The 2-SR splits the resonating frequency at 912 MHz into two resonating frequencies, one at 867 MHz and the other at 956 MHz, by perturbing the electrical length of the single band FDA. At 867 MHz, the simulated and measured values of the reflection coefficients are found to be -19.67 dB and -13.25 dB respectively, whereas at 956 MHz the corresponding values are -15.91 dB and -13.34 dB respectively. Measured read ranges of 5 m at 867 MHz and 3.3 m at 956 MHz have been recorded with omnidirectional and bidirectional radiation patterns at 867 MHz and 956 MHz respectively.

6. Acknowledgements

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7. References

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