7.
SUMMARY AND CONCLUSION

The RFID systems have become a part of our daily lives, in application such as car key, access control, logistic and supply chain, item level inventory tracking, tool tracking, library systems, RTLS (Real Time Location System), etc. As the antenna is an essential part of the wireless communication systems, there is always demand for an efficient antenna to improve the performance of communication systems. The major function of a passive RFID tag antenna in receiving mode is to harvesting energy generated by reader to provide power to the tag chip. In backscattering mode, antenna sends the modulated backscattering signal to the reader. Therefore, a proper tag design should continuously provide sufficient power to tag chip while exhibiting maximum level difference in the backscattered fields according to the information in the chip. Conventional passive RFID tag uses single antenna for both reception and backscattering. Therefore in backscattering mode, the tag chip alternatively switches between two impedance states i.e., open and short to modulate the output signal. In conventional passive RFID tags, one of the impedance states is chosen to be conjugate matched to the input impedance of the tag antenna to provide maximum power transfer to the tag chip, therefore, the level difference between two impedance states are not the maximum. It results in short read range which limit the application of RFID tag where long read range are required.

In the present thesis endeavour has been made to overcome some of the limitations of the conventional RFID tag antennas using dual antenna structure. Both the simulation and experimental investigations on single sided dual antenna structure, broadband dual antenna structure, dual-band dual antenna structure along with platform tolerant properties have been carried out. Although the various aspects of the investigations are discussed widely in separate chapters, for the sake of convenience, the major findings of the entire work are summarized in this chapter.

The thesis starts with the introduction of the concept of RFID systems and components. Then the classification of the RFID tags based on energy harvesting is presented. Further, the operating frequency bands for RFID applications are discussed. The possible applications of RFID system in different environment are also presented. In addition, the detail literature review about the development of RFID technology and antennas is also presented.

Thereafter, in the second chapter, theoretical background of RFID tag antenna has been present in detail. Further, the concept of dual antenna structure to mitigate the limitation of conventional antenna is reported. The chapter continue by introducing the different methods of impedance measurement of RFID tag antenna. The theoretical background for one of the input impedance measurement technique such as differential probe method has been presented in detail.

The design of single sided meandered dual antenna structure for UHF RFID tags has been presented in the third chapter. The antenna operates at 925 MHz and designed for Alien IC Higgs tag chip with an input impedance of 13.5 −j110Ω. The antenna is fabricated on a low cost FR4 substrate having dielectric constant (ε_r) 4.4, loss tangent of 0.018, thickness 1.6 mm, and overall size 50 mm × 67 mm. The proposed dual antenna consists of two independent antennas for receiving and backscattering, respectively. The parametric study of the shape parameters of antenna element is carried out to optimize the input impedance of the antenna, which is complex conjugate with the chip impedance. The dual antenna structure helps to maximize the quantity of delta RCS from 12 to 110 dBsm which results in increased read range from 2.4 to 4.4 m. Further, to investigate the effect of different material such as plastic, paper, and metallic surfaces attached with the tag antenna has been investigated. The results show that the input impedance of the tag antenna will not change significantly on plastic and paper surfaces. Therefore, the antenna is suitable for attaching on paper, cardboard, and plastic surfaces. The input impedance of antenna is measured using differential probe and simulated and measured results are found in good agreement. The input impedance of antenna is measured using differential probe. The simulated and measured results are found in good agreement. The simulated and measured input impedance of the presented antenna is observed 13+j111Ω and 13+j109Ω, respectively which is close to the complex conjugate of the chip impedance of 13.5−j110Ω.

In the fourth chapter, a broadband dual antenna structure is presented. The antenna operates to cover 915 MHz and 925 MHz, and the bandwidth is about 47 MHz from 913 MHz to 960 MHz and designed for Alien IC Higgs tag chip of input impedance 13−j110Ω at 925 MHz. The antenna is fabricated on 1.6 mm thick FR4 substrate with overall size 44 mm × 82 mm. The receiving antenna consists of two rectangular patch antennas loaded by two asymmetric meandered line slots to obtain two resonance frequencies. A T-matching network has been added to obtain the desirable impedance matching with chip impedance. The backscattering antenna consists of meandered line structure. The parametric study of shape parameters of the antenna is carried out to see the effect on real and imaginary parts of input impedance. Further, it is utilized for the optimization of the input impedance of the tag antenna.

The dual antenna structure helps to maximize the quantity of delta RCS from 13 to 98 dBsm, which results in increased read range from 4.3 to 5.9 m. To investigate the effect of paper, plastic and metal which is attached with the antenna, the input impedance of antenna is investigated. The results show that the input impedance of the antenna almost remains constant on plastic and paper surfaces. The antenna is suitable for attaching on paper, cardboard, and plastic applications. The antenna is measured by using a differential probe. The measured and simulated input impedance at 925 MHz are observed as 16+j97 Ω and 13.5+j108 Ω, respectively. These are close to the complex conjugate of the chip impedance (13-j112Ω). The simulated and measured bandwidth is observed from 913-960 MHz and 913-977 MHz, respectively. It shows that the presented antenna can be operated in the broadband region from 913-960 MHz. During simulation, the input impedance of receiving antenna at 915 MHz is observed

8.69+j102.91Ω. It is close to the conjugate of the chip impedance of AD220 with chip impedance of 8-j91Ω.

A single sided dual antenna structure for UHF RFID Tags is presented for both metallic and non-metallic surfaces in the fifth chapter. The proposed dual antenna (Antenna-I) consists of square patch loaded with a cross-shaped slot and two L-shaped open-ended microstripline with different length, connected to two terminals of tag chip and terminated by a shorting pin which is capacitively coupled to the patch. The longer arm of the L-shaped microstripline is designed in such a way that the maximum power is coupled to the patch and it acts as receiving antenna. Whereas the small arm of L-shaped microstripline along with patch acts as backscattering antenna. The proposed antenna is designed for Impinj Monza Gen2 tag chip with an input impedance of 33-j112Ω for operate at 915 MHz. Further, excitation of the surface waves is one of the major limitations of the microstrip antennas which reduce the antenna efficiency, gain, and read range. To mitigate the limitation of microstrip antennas electromagnetic band gap (EBG) structures can be used to enhance the gain and read range of the RFID system. Therefore, to increase the gain of Antenna-I, EBG like structures are placed around the antenna which is referred as Antenna-II. The parametric study of the antenna shape parameters which affects the real and imaginary parts of input impedance is investigated and presented in detail. With the help of the dual antenna structure, the quantity of delta RCS increased from 15 to 93 dBsm which results in increased read range from 3.6 to 4.3 m in Antenna-I. Thereafter, by surrounding Antenna-I by EBG like structures, the read range increased from 4.3m to 5.5 m. Further, the effect of mounting the RFID tag antenna with surfaces of different materials like metallic surface, glasses, plastic, and wood, simulation studies are carried out. The results show that the gain and read range of the proposed antenna increases remarkably when attached with a metallic surface, though the best performance occurs when the surface is made of glass which has maximum relative permittivity comparatively. Both Antenna-I and Antenna-II has been measured by using differential probe. The measured complex input impedances for the receiving antennas of Antenna-I and Antenna-II are obtained as 25.4+j115.18Ω and 24+114.35Ω, respectively, which are close to the complex conjugate of the chip impedance i.e. (33+j112Ω). The measured reactance values of the backscattering antenna for Antenna-I and Antenna-II are observed as −0.49 Ω and −1.121 Ω, respectively which are close to zero. The simulated and measured results are found in good agreement.

After that in chapter six, a single sided dual-band dual antenna structure for ultra and super high frequency RFID tags has been presented. The proposed antenna is designed for Impinj Monza Gen2 tag chip with input impedance of 33−j112Ω at 915 MHz. Due to single sided antenna structure with complete ground plane the proposed tag antenna can also be used with metallic objects without performance degradation. The proposed tag antenna is a dual antenna structure at UHF band and conventional single antenna at SHF. For 915 MHz application, proposed antenna consists of two independent antennas one for receiving (Antenna-I) and the other for backscattering (Antenna-II) which enhances the read range. Whereas for 2450 MHz application, proposed antenna behaves like conventional single antenna in which receiving and backscattering operation are performed by same antenna (Antenna-I). Due to which Antenna-II is not utilized at 2450 MHz. The actual overall size of antenna is 70 mm × 80 mm.

The parametric study of antenna element is carried out to see the effect on real and imaginary parts of the antenna and presented in detail. With the help of the dual antenna structure, maximize the quantity of delta RCS from 4.39 to 63 dBsm which results in increased read range from 4.1 to 5.5 m in antenna at 915 MHz and the read range observed at 6 m at 2.45 GHz. Further, the RFID tag antenna is also investigated on a metallic surface of size 150×150mm^2. The results show that the performance of the antenna do not affects severely. However, some shifting of the resonance is observed towards lower and higher frequency side for UHF and SHF. The antenna is measured by differential probe at two frequency bands. The simulated and measured results are found in good agreement. The simulated and measured input impedance of the Antenna-I at UHF and SHF are observed as 32+j104Ω and 47.8+j164Ω. The simulated values are in proximity of the complex conjugate of the chip impedance i.e., 33–j112Ω while the measured impedance changes due to fabrication tolerances of the differential probe.

From the present endeavour made in this thesis, there are many scopes to work in the future. The effect of materials on which tag to be attached has been investigated in the present thesis and accordingly platform tolerant dual antenna structures have been investigated for UHF and SHF bands. The resonant characteristics based artificial materials including electromagnetic band-gap structures, artificial magnetic conductors, etc. to be used to reduce the size of the RFID tag antenna. Further, these materials can also be utilized to make platform tolerant RFID tag antennas.