CHAPTER 6: CONCLUSION AND FUTURE SCOPE

This chapter concludes the results obtained from the different antenna designs along with research findings in this thesis. The chapter wise contributions and recommendations for future work are also outlined.

6.1 Conclusion

Radio frequency identification is a technology for contactless automatic identification. By using this technology, items can be identified and tracked. During the last decade, researchers have shown a lot of interest in RFID due to its extensive applications in electronic transport payment, access control, automotive security, automated libraries, healthcare industries, livestock management, etc. This thesis is framed within the RFID technology and focused on the antenna design for tag and reader at UHF RFID frequency band. In order to achieve a larger read range with a miniaturized size, two types of potential UHF RFID tag antennas, i.e., circularly polarized cross dipole and dual-band dual-antenna structures have been designed, simulated and measured. The read range between the tag and the reader is enhanced with circularly polarized tag antenna due to the reduction in polarization mismatch. For the conjugate impedance matching between the tag antenna and the microchip, a modified T-match network has been proposed. Further, to mitigate the limitations of the conventional tag antenna, a dual antenna was designed. The dual antenna optimized the UHF RFID tag design by providing a longer read range and continuous power supply to the microchip, simultaneously. Also, a novel circularly polarized meandered cross-shaped slot microstrip antenna has been proposed for the portable UHF RFID reader application. Different perimeter slots have been used for the size miniaturization of the circularly polarized reader antenna.

The content in this thesis has been divided into five chapters (except conclusions and future scope). In chapter 1, a brief study of automatic identification techniques is presented. The superiority of RFID technology over other auto ID techniques is pointed out by comparing them in tabular form. The motivation for carrying the research work along with the antenna for UHF RFID system is described.

In chapter 2, a detailed overview of the RFID system is presented which included the introduction of different system components. Different RFID operating frequency ranges and their working principles are discussed. Furthermore, UHF RFID tag antennas have been analyzed, focusing on the methods of impedance matching, size miniaturization, and impedance measurements. A brief history of RFID is also summarized. The rest of the chapter was devoted to providing a literature review in order to cover the different antennas for RFID tag and reader design that have been presented over the years.

In Chapter 3, a circularly polarized cross dipole tag antenna for UHF RFID applications has been presented. A linearly tapered meander line with rectangular tip loading at the end has been used in each arm of the cross dipole for size miniaturization of the antenna. In order to get the conjugate impedance matching between the antenna and the microchip, a modified T-match structure has been used at the center. In the case of a linearly polarized dipole antenna, the maximum read range was 10.9 m due to the polarization mismatch between the circularly polarized reader and linearly polarized tag antennas. In the case of the proposed CP antenna, there is a good polarization match between the CP reader antenna and tag antenna. Therefore, the proposed CP antenna has 4.7 m longer read range than the analogous linearly polarized dipole antenna.

In chapter 4, a single sided dual band dual antenna for UHF RFID tag applications has been designed. Conventional tags have only one antenna which serves as receiving as well as backscattering antenna. Therefore, a conventional tag antenna would not provide continuous power to the tag IC and the level difference in backscattered signal would not be maximum. To augment the shortcomings of conventional tags, the concept of the dual antenna has been presented. The dual antenna is formed by two independent antennas; one is receiving antenna for continuous power absorption while the second one is backscattering antenna for the maximum level difference in backscattering signal. The differential RCS ($\Delta\sigma$) for the proposed dual-antenna is raised from 2.73 dBsm to 44.60 dBsm at 866 MHz and from 2.67 dBsm to 45.13 dBsm at 915 MHz in comparison to conventional tag antenna. Due to the improved differential RCS, the maximum read range is enhanced from 3.5 m to 4.3 m at 866 MHz and from 5.6 m to 6.8 m at 915 MHz. Performance of the proposed dual antenna in terms of the input impedance and maximum read range is also examined when it is attached to the different size of metallic platforms. The input impedance variation with and without different metallic surfaces is small, which shows that the receiving performance of the proposed antenna remains unchanged and the read range of the antenna is increased when it is mounted on the metallic objects.

In chapter 5, the design and analysis of a circularly polarized antenna for handheld UHF RFID reader is presented. By etching a meandered cross-shaped slot in the first quadrant of the square patch, the antenna generates circularly polarized radiation with compact size. Square-, circular-, cross- and meandered cross-shaped slots have been studied and compared. The compactness of the CP antenna relies on the slot perimeter. For further size miniaturization, diagonally symmetric two- and four- meandered cross-shaped slot circularly polarized antennas are investigated. The operating frequency of the diagonally symmetric slot antenna is shifted towards the lower frequency with an increase in the number of slots. As a result, the size of the antenna is reduced with an increase in the number of slots. For the four slot antenna, the direction of the surface current vector rotates in the clockwise direction with time which demonstrates a left hand circularly polarized radiation in boresight direction.

From these investigations, it is found that all the designed antenna structures have compact dimensions with longer read range in their domain. The cross dipole CP tag antenna provides a longer read range due to the reduction in polarization mismatch. However, the antenna is unsuitable for metallic object tagging and has limitations due to the availability of a single antenna for receiving and backscattering purpose. The limitations of single antenna tag are removed with a dual band dual antenna structure which can also be attached with metallic objects. A single feed CP antenna is designed for handheld UHF RFID reader applications, which provides size miniaturization and simplicity. So all-inclusive, it can be concluded that the present research work has a good potential to implement antennas for RFID tag and reader at UHF band.

6.1.1 Novelty

This thesis puts emphasis on antenna design for passive UHF RFID tag and reader. The present work has been addressed directly to reduce the size and increase the detection range and communication reliability of the RFID framework antennas. In this thesis, two miniaturized antennas for tag and one antenna for handheld reader have been investigated and designed for passive UHF RFID applications. Read range is enlarged by removing the polarization mismatch between the reader and the tag antennas. The detection reliability and the read range are enhanced by 41% by designing a cross dipole circularly polarised antenna. To overcome the shortcomings of conventional tags, dual tag antenna has been proposed which provides continuous power reception with maximum level difference in backscattering signal. For size miniaturisation of the reader antenna, a compact meandered cross-shaped slot circularly polarized antenna for is investigated. The overall size of the antenna is reduced by increasing the perimeter of a slot within one quadrant of the patch.

6.2 Future Scope

In the presented research work of this thesis, there are some possibilities and scope available to extend further this research work. Based on the conclusions drawn and the limitations of the work presented, the following work can be carried out in the future to improve the performance and applications of UHF RFID systems.

- For tagging metallic objects, a microstrip patch antenna has been proposed in chapter 4. For their nature, patches operate on ground planes and in order to perform satisfactorily, patch antennas require a certain thickness of substrate between the upper patch and the bottom ground plane. The height of a patch antenna for optimal operation in the UHF-RFID band makes it bulky and suitable only when a relatively thick tag is available. Moreover, tag ICs are required to be connected between the patch and the ground plane, which can be accomplished by via hole in the substrate. For these reasons, microstrip patch antenna type metal mountable tags are still more expensive and bulky as compared to general-purpose tags. Further research work can be carried out for the development of small-sized dipole type tag antenna for metallic objects.
- The RFID system is more expensive than the barcode for automatic identification due to the use of the tag IC. A chipless RFID tag is less expensive due to absence application specific integrated circuit. Therefore, chipless RFID tags can be explored.

- Another way to decrease the cost of a UHF tag is to scale down the cost of the antenna. So, the graphene ink can be used to print the tag antenna in order to make cost-effective tags as the graphene ink is much cheaper than the copper ink. However, the conductivity of graphene ink is slightly lower than copper ink which results in smaller read range.