# CHAPTER 1: INTRODUCTION AND MOTIVATION

## 1.1 Automatic Identification

With the advancement in wireless communication, automatic identification (Auto-ID) has emerged as one of the most important industries today. Auto-ID is a group of technologies for automatically identifying objects or collecting data without the need for manual input. Some of the common examples of auto-id techniques include barcodes, optical character recognition, biometrics, smart cards and Radio Frequency Identification (RFID) [1]. Figure 1.1 shows the family of automatic identification technologies.

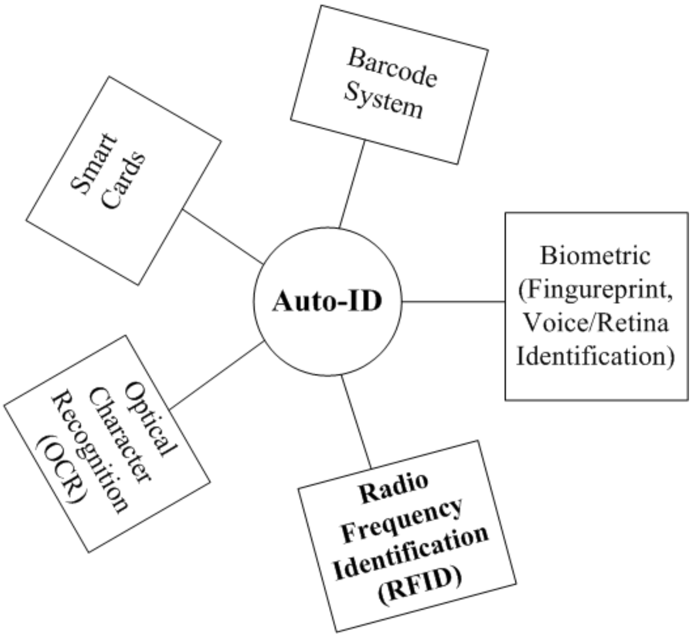


Figure 1.1 Different Auto-ID techniques

Biometric auto-ID, which involves comparison of individual physical characteristics, has two main forms: one is fingerprint and the other is retina identification. Fingerprinting identifies the particular finger patterns of individuals. Applications of biometrics are mostly in access control and security. A common application of fingerprinting is the employee time tracking system at the workplace. However, this technique can be applied to living beings only. Handwritten or printed text can be converted into the machine-encoded language by using an electronic conversion or identification technique called Optical Character Recognition (OCR) in which each character is defined by a different code. Due to higher price and complexity of the system, OCR has failed to gain universal applications. Smart cards are globally used as cash cards, which stores electronic data. Transactions using smart cards require a galvanic connection between the reader and the contact surfaces of these cards to transfer the data. Smart cards are vulnerable to dirt and wear and tear. Although functioning of the RFID systems is closely related to that of the smart cards, the RFID systems do not require any galvanic connection.

Barcodes have ruled the Auto-ID industry since the time of their advent. Barcodes consist of a parallel arrangement of bars and gaps representing a particular binary code. Black bars are put in an order corresponding to a predetermined pattern and produce data elements that refer to a related symbol. The sequence of wide and narrow bars and gaps can be translated numerically. Barcodes are read by an optical laser scanner. Black bars and white gaps generate a different reflection of a laser beam. However, barcodes have been proved incompetent in an increasing number of cases due to their low storage capacity, line of sight operation and the fact that they cannot be reprogrammed. Due to the line of sight operation of barcode, an operator is required to read a barcode. The best solution to increase the storage capacity is to store data in a silicon chip. This paved the way for the emergence of radio frequency identification technology. In addition, RFID technology provides security by means of data encryption, read and write capability, and removes human intervention in the reading process.

Radio frequency identification is a wireless technology having real-time application in localization, identification and tracking of objects using radio frequency signal. A typical RFID system consists of a tag attached to the items to be tracked and a reader connected to a host computer. The tag consists of an antenna and a reprogrammable microchip (to store information about the tagged objects). Communication between the tag and the reader takes place through magnetic (near-field coupling) or electromagnetic fields (far-field coupling) [2]. Over the years, RFIDs have been successfully replaced other commonly used Auto-ID technologies to a large extent as they allow longer read ranges, faster data transfer, non-requirement of line of sight, and simultaneous detection of numerous entities [3]. In recent years, RFID technology has seen significant growth due to cost reduction and wide applications in retail stores, service industries, manufacturing companies, supply chain management. Figure 1.2 represents a schematic diagram of an RFID system. Table 1.1 shows the comparison on strong and weak sides of the above-discussed Auto-ID technologies.

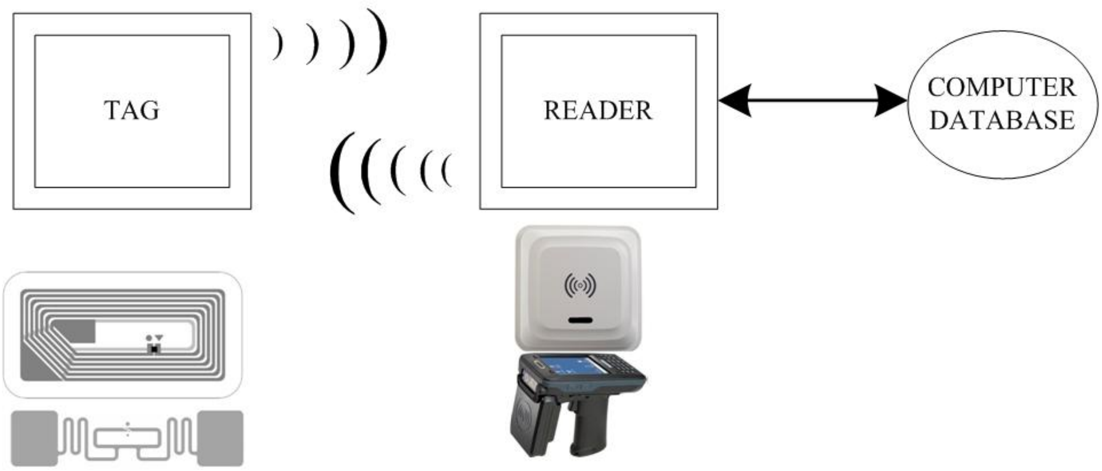


Figure 1.2 Schematic diagram of an RFID system

Table 1.1 Comparision of features of Auto-ID techniques[1]

| **Auto-IDs ⇒** <br> **System Parameters ⇓** | **Barcode** | **OCR** | **Biometry** | **Smart Card** | **RFID** |
|---|---|---|---|---|---|
| **Data storage (bytes)** | 1-100 | 1-100 | - | 16-64k | **16-128k** |
| **Human readability** | Limited | Easy | Difficult | Impossible | **Impossible** |
| **Influence of dirt** | Very high | Very high | - | Possible | **No influence** |
| **Purchase cost** | Very low | Medium | Very high | Low | **Medium** |
| **Operating cost** | Low | Low | None | Medium | **None** |
| **Unauthorised copying** | Slight | Slight | Impossible | Impossible | **Impossible** |
| **Response Time** | Low (4 s) | Low (3 s) | Very Low (>5-10 s) | Low (4 s) | **Very fast (0.5 s)** |
| **Read range** | 50 cm | <1 cm | Direct contact* | Direct contact | **Up to 20 m (Passive)** |
| **Line of sight** | Required | Required | - | - | **Not required** |
| **Simultaneous identification** | Single item at a time | Single item at a time | Single item at a time | Single item at a time | **Multiple tags per second** |

*For fingerprint

## 1.2 RFID Applications

Radio frequency identification supports two essential abilities such that improved visibility and quick detection. Therefore, the RFID technology is able to detect high speed moving tagged objects that are not necessarily in the line of sight. RFID system has a number of applications such as stock management in retail stores, in logistics supply chain for tracking of goods to reduce theft and loss of goods, access control using college ID cards, E-passport for airport security, electronic toll payment for vehicles, ignition keys for anti-theft feature in high end cars, livestock identification and management in animal product industry, etc. [4]. Some applications of RFID are discussed below:

1. **Retail:** Retail stores can electronically interrogate the shelves with the support of item-level tagging, which provides critical real-time information about the list of stock and tendency in sales. The real-time supervision with RFID tagging facilitates stores to maintain stock and reduces mismanagement due to erroneous shelving or misplacement of objects.
2. **Contactless Transactions:** Contactless payment by smart cards supports transactions without physical contact between the card and the system. The system uses RFID, which allows the cardholder to show the RFID card in front of a contactless payment machine to complete a transaction. Compared to chip-and-signature smart cards, contactless RFID cards are faster, more convenient and more secure.
3. **Automotive industry:** The charm of RFID technology in the automotive industry is safety protection. An electronic immobilizer is a protection accessory that is equipped in a vehicle to make it much more difficult for illegal use. In a vehicle immobilization system, a transponder is combined with the ignition key, and the reader antenna is integrated with ignition lock. Thus, when only the authorized key is inserted, then the magnetic coupling between the reader antenna and transponder is optimized.
4. **Transportation:** RFID systems can be practiced in various areas in the transportation industry such as electronic toll collection (ETC), electronic vehicle registration (EVR), automatic vehicle identification (AVI) and fleet management. RFID technology can also be used in car parking and access control.

5. **Animal Identification:** RFID technology can be used in the livestock industry for automatic feeding and measuring productivity. It can also be used to keep track of pets and their vaccination record and for easy retrieval of pets by owners.
6. **Museums and Libraries:** Libraries use RFID tags in books and other materials to track circulation. Product information such as book title and author name is stored electronically, which helps in inventory management and also provides security from theft. Librarians at the circulation desk read the tags with RFID readers to check books in and out. The process is faster and more accurate than with traditional optical barcode labels.
7. **Sporting Events:** In huge sporting occasions such as a marathon, the runner who starts from the last position is always at a loss, because his time is measured from the moment the race is commenced. For many participants, it takes a large amount of time before they can actually cross the beginning line. To amend this unfair measurement of time, all participants carry an RFID tag with them, which provides the individual timing.
8. **Baggage Handling:** Baggage handling in airports comprises transferring the passenger bags to either connecting flights or baggage claim terminals for pickup. RFID readers placed with the conveyor belts interrogate the tagged bags and make routing decisions based on the destination information stored in the transponders.

## 1.3 Motivation

In the last decade, radio frequency identification technology has emerged as a promising technique for identifying and tracking objects. The cost of RFID devices is becoming more and more competitive, making the technology affordable even for the identification of low-value consumable items. In particular, passive RFID systems have been experiencing fast growth over the last decade, being currently used for hundreds of applications and further expansion is predicted for the near future. Nevertheless, to fully develop its potentiality as a worldwide leading solution for identification, passive RFID technology must deal with a set of challenges, which strongly depend on the specific application scenario [5].

Among the various types of RFID systems, which will be discussed in chapter 2, passive UHF RFID systems are more attractive than others due to fast data transfer speed, more storage capability and higher reading range [6]. For RFID applications, the UHF (Ultra-High Frequency) band is defined from 840 MHz to 960 MHz. The term passive implies that there is no internal power source available for the tag.

An RFID system is a complex system which involves various areas of study such as antenna design for tag and reader, microwave communication analysis, signal processing and integrated circuit design. The thesis puts emphasis on antenna design for passive UHF RFID tag and reader.

UHF RFID systems have some inherent deficiencies:

1. Due to the working Spectrum of UHF RFID system (840 – 960 MHz), the wavelength is in the range of 312 mm to 357 mm, and the size of the antenna resonates within UHF band has to be proportional to half of the wavelength in order to achieve good radiation characteristics, which makes antenna size relatively large.
2. In all practical applications, the tag design must be focused on maximizing the reading distance. Therefore, the design of RFID tags with an optimized reading distance represents another interesting research subject within the frame of RFID technology.

3. Due to different worldwide regulations, the UHF RFID frequency bands have different locations in the spectrum and vary in the different world regions. Each country has allocated a different specific frequency band for UHF RFID system. Therefore, the design of RFID tags that are able to cover at least two of the regulated UHF bands with appropriate read range is very promising for inter-country UHF RFID applications like import-export industry.
4. Conventional passive tags have only one antenna which serves as receiving as well as backscattering antenna, thereby giving rise to two crucial drawbacks. Firstly, the power reception by the tag chip would not be continuous. Secondly, the level difference in the backscattered signal would not be maximum. For an impeccable tag design, there should be continuous power reception in order to keep the chip activated and to obtain a longer read range. Furthermore, the difference in the level of the backscattered field should be maximum. It is a research challenge to augment these shortcomings of conventional tags.
5. In passive UHF RFID systems, the backscatter signal is weak and therefore vulnerable to metallic objects. There is only one normal component of the electric field and tangential component of the magnetic field on a perfect electric conductor. Thus, the dipole type RFID tag antennas, whose performance relies on a tangential component of the electric field, may suffer from severe performance degradation when it is mounted on the conductive surface. To have reliable communication, RFID tags should be made more resistant to metallic surfaces.

## 1.4 Objective

The antenna plays a fundamental role in passive RFID tag design. Advancement of RFID technology is, therefore, dependent upon the research efforts and accomplishments in the field of antenna design. The main objective of this thesis is aimed at exploring new antenna design solutions for passive RFID systems, working at the UHF band, which can be employed to overcome the challenges as mentioned above, thus contributing to the progress of RFID technology. Further, in accordance with the objective, three important tasks have been attempted in the present research, which are as follows:

- Design of a circularly polarised cross dipole tag antenna for longer read range.
- Design of a dual band dual antenna for metallic objects to overcome limitations of conventional tag.
- Design of a miniaturised circularly polarised antenna which covers at least one regulated UHF band for handheld RFID readers.

## 1.5 Thesis Organization

This thesis can be divided into four parts. The first part includes chapter 1 and chapter 2. Chapter 1 provides the introduction, motivation, and the structure of the thesis while chapter 2 describes the working principle, history, and classification of RFID systems. The second part of the thesis presents UHF RFID tag antennas for longer read range, which includes chapter 3 and chapter 4. The third part is chapter 5, describing miniaturized circularly polarized antenna for UHF RFID handheld reader applications. The last part of the thesis, contained in chapter 6, summarizes the work done in this thesis and makes a recommendation of possible work for future research. The content in each chapter is summarized as below. A tree diagram of the thesis is given in figure 1.3.

**Chapter 1** gives a brief introduction of automatic identification family, which includes biometric, optical character recognition (OCR), smart cards, barcode systems, and radio frequency identification. Some applications of traditional, as well as modern RFID systems, are presented. The motivation of the thesis is also described.

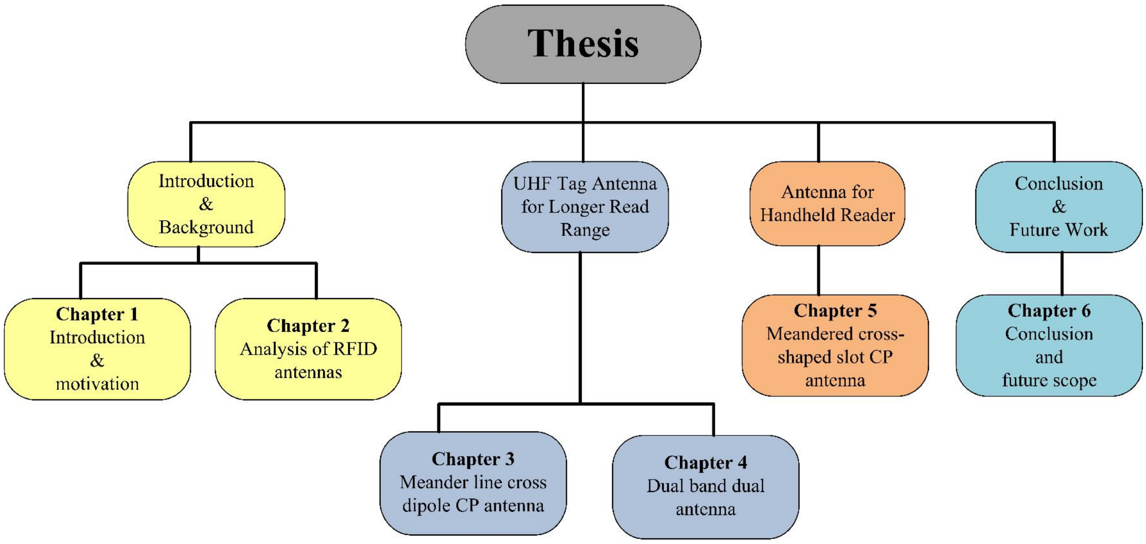


Figure 1.3 A tree diagram of the thesis

**Chapter 2** presents an introduction to RFID system, which includes the principles of RFID system and the operating mechanism of passive RFID tags. The techniques for the impedance measurement of RFID tag antenna are discussed. Recent research progress on passive UHF tag antennas, CP tag antennas, and reader antennas have been investigated and compared.

**Chapter 3** introduces a meandered cross dipole tag antenna with circularly polarized radiation in UHF band. The antenna has a planar geometry with compact size, and the conjugate matching of the complex input impedance between the antenna and the tag IC is realized by using a T-match network. Read range of RFID system is enlarged by removing the polarization mismatch between the reader antenna and tag antenna. The influence of the length of the semi-circular curve on the input impedance and the CP performance of the antenna is also exhibited. The simulated and measured results are discussed and compared.

**Chapter 4** demonstrates a single sided dual band dual antenna which operates at 866 MHz and 915 MHz UHF RFID bands. The presented structure is made up of two separate antennas. One antenna is entirely used for receiving, and other is used for backscattering. Thus, the necessity for a maximum level difference in RCS and uninterrupted power supply to tag IC is fulfilled, simultaneously. The performance of the proposed antenna is analyzed in terms of RCS and read range on metallic objects and free space.

**Chapter 5** focuses on the design of a single feed circularly polarized microstrip antenna for handheld RFID reader in ultra-high frequency band. Circularly polarized radiation has been achieved by etching a slot along the diagonal axis of the square patch. Four different shaped slots (square, circular, cross and meandered cross) are studied and compared for CP radiation. Antenna size miniaturization is realized on increasing the slot perimeter. Two and four meandered slot antennas are investigated for further antenna size miniaturization and compared for a fixed antenna volume.

**Chapter 6** summarizes this work and reports conclusions. Future work recommendations are also provided to further improve UHF RFID tags and RFID system designs.