Preface

Radio Frequency Identification (RFID) is a wireless data capturing technique for automatic identification, tracking, security surveillance, and logistic and supply chain management. In the modern time RFID is one of the top ten technologies that have tremendously impacted society. RFID offers flexibility in operation and higher data capacity compared to that for optical barcodes. Therefore, RFID has gained momentum to be used in all possible applications. The most visible application of RFID is Electronic Article Surveillance (EAS) in superstores. Expensive items are tagged so that the unpaid items give warning signals at the entry and exit points of stores. EAS is a 1-bit tag, can only respond to 'yes' or 'no' situation. More expensive and high capacity tags carry much more useful information that an optical barcode can offer. Therefore, RFIDs offer not only flexibility and capacity but also item level tagging, tracking, and surveillance. However, the bottleneck of mass deployment of RFIDs for low cost item tagging is the cost of the tag. The cost of the conventional RFIDs has been decreasing day by day. However, there is a limit due to the silicon chip attached to the tag. These chips are application specific integrated circuits (ASICs) and the price of the chip can be tens of cents. To alleviate this cost problem, researchers are envisaging alternatives such as chipless tags. Thin film transistors (TFTs) on organic substrates and fully printable tags are the two commercially viable solutions that can compete with optical barcodes in mass implementations. If the cost of the tags can be reduced to less than a cent, the tags will find many potential applications. This book has addressed the most recent development of chipless and conventional tags—their systems and applications.

According to the respected research institute IDTechEx (2009), chipless RFID tags will occupy more that 60% market share of RFID markets within a few years time if the tags can be made less than a cent. The market of RFID technology surpassed $5B in 2009 and is projected to be more than $25bn in 2018. The accelerated pace of RFID tags, middleware, and reader development will address many technological challenges as well as provide many new solutions in printing techniques, algorithm and reader architectures. Anti-collision will also play an important role in mass deployments of chipless RFID technology in multi-faceted applications. Chipless RFID will change the culture of the way we do transactions in our businesses and livings. Like chipped RFIDs, chipless RFIDs have the capability to provide flexibility in operations with its salient features of non-line-of-sight (NLOS) and all-weather reading capability without much human intervention. It has the potential to replace trillions of optical barcodes printed each year. Therefore, many research activities on chipless RFID tags have been conducted not only in academia but also in industries. In this regard, printed electronics technologies shall play the vital role. Again according to the market analyses by IDTechEx, a few hundred industries are engaged in printed electronics for identifications, tagging and telecommunications markets. As quoted

by Harrop, Reuter, & Das (2009), "This organic and printed electronics is growing to become a $300 billion market and, in 2007 alone, many factories came on stream to make "post silicon" transistors, displays and solar cells using thin films and, increasingly, printing. Most of the action is taking place in East Asia, Europe and North America..…*There is also the prospect of replacing 5-10 trillion barcodes yearly with printed RFID that is more versatile, reliable and has a lower cost of ownership*."

RFID is an emerging technology which has been going through various developmental phases in terms of technological developments and businesses (applications), the potential as well as the challenges are huge. As for the example of the implementation of the RFID in Monash University's Library above, the bottleneck is the cost of the tag and its mass deployment. The answer to the problem lies in the development of new materials and printing technologies which can appropriately address the problem and bring forth a sustainable solution in terms of economy and technological advancements.

When the tags become dumb, the reader should be smart. The smartness will come from the smart signal capturing capabilities from the dumb tags and the post-processing of the returned echoes which are the signals from the uniquely identifiable tags. Significant advancement has been made in the new design of RFID systems and detection techniques of RFID tags, discrimination of tagged items and protocols developed for wireless sensors network applied to RFID systems. The book includes a full section on these topics.

As an enabling technology, RFID encompasses multiple disciplines. Similar to radar technology, RFID is a multi-disciplinary technology which encompasses a variety of disciplines: (i) RF and microwave engineering, (ii) RF and digital integrated circuits, (iii) antenna design, and (iv) signal processing software and computer engineering. The latter encodes and decodes analog signals into meaningful codes for identification. According to Lai et al (2005), "The fact that RFID reading operation requires the combined interdisciplinary knowledge of RF circuits, antennas, propagation, scattering, system, middleware, server software, and business process engineering is so overwhelming that it is hard to find one single system integrator knowledgeable about them all. …. In view of the aforesaid situation, this present invention (RFID system) seeks to create and introduce novel technologies, namely redundant networked multimedia technology, auto-ranging technology, auto-planning technology, smart active antenna technology, plus novel RFID tag technology, to consolidate the knowledge of all these different disciplines into a comprehensive product family." The book has incorporated these multi-disciplinary contents in seven different sections: (i) Security, (ii) Middleware, (iii) Anti-collision Protocol, and (iv) Applications.

Due to the flexibility and numerous advantages of RFID systems compared to barcodes and other identification systems available so far, RFIDs are now becoming a major player in retail sectors and government organisations. Patronization of the RFID technology by organisations such as Wal-Mart, K-Mart, the USA Department of Defense, Coles Myer in Australia and similar consortia in Europe and Asia has accelerated the progress of RFID technology significantly in the new millennium. As a result, significant momentum in the research and development of RFID technology has developed within a short period of time. The RFID market has surpassed the billion dollar mark recently (Das & Harrop, 2006), and this growth is exponential, with diverse emerging applications in sectors including medicine and health care, agriculture, livestock, logistics, postal deliveries, security and surveillance and retail chains. The book includes application in tracing systems on the integrity of pharmaceutical products, near field authentication, monitoring system for sleep apnoea diagnosis in wireless body sensor network (WBSN)

using active RFID and MIMO technology, chipless RFID based temperature and partial discharge (PD) detection sensors and finally, wireless sensors network and their applications in RFIDs.

Today, RFID is being researched and investigated by both industry and academic scientists and engineers around the world. Recently, a consortium of the Canadian RFID industry has put a proposal to the Universities Commission on the education of fresh graduates with knowledge about RFID (GTA, 2007). The Massachusetts Institute of Technology (MIT) has founded the AUTO-ID centre to standardize RFID, thus enabling faster introduction of RFID into the mainstream of retail chain identification and asset management (McFarlane & Sheffi, 2003; Karkkainen & Ala-Risku, 2003). The synergies of implementing and promoting RFID technology in all sectors of business and day to day life have overcome the boundaries of country, organisation and discipline.

As a wireless system, RFID has undergone close scrutiny for reliability and security (EPCglobal, Inc., 2006). With the advent of new anti-collision and security protocols, efficient antennas and RF and microwave systems, these problems are being delineated and solved. Smart antennas have been playing a significant role in capacity and signal quality enhancement for wireless mobile communications, mobile ad-hoc networks and mobile satellite communications systems. Smart antennas are used in RFID readers where multiple antennas and associated signal processing units are easy to implement (Lai et al, 2005). Even multiple antennas are proposed in RFID tags to improve reading rate and accuracy (Ingram, 2003).

Besides the contributions from outside, this book editor's research group at Monash University have contributed significantly in the physical layer development of RFID reader architectures for chipped and chipless RFID tag systems, RFID smart antennas, wireless sensor network protocols for RFID, and anti-collision algorithm. The research group has been supported by the Australian Research Council's Discovery Project Grants *DP665523: Chipless RFID for Barcode Replacement* and *DP110105606: Electronically Controlled Phased Array Antenna for Universal UHF RFID Applications*; the Australian Research Council's Linkage Project Grants *LP0989652: Printable, Multi-Bit RFID for Banknotes*; *LP0776796: Radio Frequency Wireless Monitoring in Sleep Apnoea (particularly for paediatric patients)*; LP0669812*: Investigation into improved wireless communication for rural and regional Australia*; *LP0991435: Back-scatter based RFID system capable of reading multiple chipless tags for regional and suburban libraries*; and *LP0989355: Smart Information Management of Partial Discharge in Switchyards using Smart Antennas*; and finally, Victorian Department of Innovation, Industry & Regional Development (DIIRD) Grant: *Remote Sensing Alpine Vehicles Using Radio Frequency Identification (RFID) Technology* within the Department of Electrical and Computer Systems Engineering, Monash University from 2006 to date. The dedication of former postgraduate students Drs. Sushim Mukul Roy, Stevan Preradovic and Isaac Balbin and current research staff and PhD students under my supervision has brought the chipless RFID tag and reader system as the viable commercial products for Australian polymer banknotes, library database management systems, access cards, remote sensing of faulty power apparatuses in switchyards and the wireless monitoring of sleep apnoea patients. The RFID and smart sensor related research projects supported by Australian Research Council's Discovery and Linkage Projects and Victoria Government are worth approximately three million dollars. More than twenty researchers have been working in various aspects of these projects. The book contains three chapters on our research findings in the above research topics.

The dramatic growth of the RFID industry has created a huge market opportunity. Patronization from Wal-Mart alone has triggered their more than two thousand suppliers to implement RFID system for

their products and services. The motto is to track the goods, items and services from their manufacturing point until the boxes are crashed once the goods are sold. Thus industries can track every event in their logistics and supply chain management and make sound plan for efficient operations and business transactions. The RFID system providers are searching all possible technologies that can be implemented in the existing RFID system (Gen2 becomes a worldwide standard) that can be made cheap, can be implemented to provide high accuracy in multiple tags reading with minimum errors and extremely low false alarm rate, location finding of tags for inventory control and asset tracking. Employing smart information management system in the reader presents an elegant way to improve the performance of the RFID system. The book has covered many technical aspects of these requirements.

The book aims to provide the reader with comprehensive information with the recent development of chipless and conventional RFID systems both in the physical layer development and the software algorithm and protocols. To serve the goal of the book the book features thirteen chapters authored by the leading experts in both academia and industries. They offer in depth descriptions of terminologies and concepts relevant to the RFID systems—the security issues of chipped and chipless tags, development of chipless RFID tags and reader system to address authentications, middleware and applications.

I continuously collect and read books on RFIDs. These books are readily available from on-line book shops such as Amazon.com. Every scientific book publisher has a series of book on RFIDs and their applications in governance, pharmaceuticals, logistics, supply chain managements, retails and original part manufacturing. These books mainly report specific applications, introduce fundamental issues, and gather information on RFIDs, specific technical details that are commonly available from other resources. This book aims to come out of the convention approach of reporting the technology. The book presents the most recent technological development from renowned researchers and scientists from academia and industries. Therefore, a comprehensive coverage of definitions of important terms of RFID systems and how the RFID technology is evolving into a new phase of development can be found in the book. The book covers the state-of-the-art development on RFID in recent years. Seven scientists from five large to medium size industries including Microsoft research Center, USA, Securency Intl. Pty. Ltd, Australia, Unique Microwave Design, Australia, Tata Consultancy Services, India, and fifty academic researchers from Australia, Italy, Mexico, Taiwan, Ukraine, UK and USA, have contributed chapters in the book. Therefore, the book not only delivers the emerging development in a total package of chipless and conventional RFID systems but also provides diversities in topics. The rich contents of the book will benefit the RFID technologist, planners, policy makers, educators, researchers and students. Many universities and tertiary educational institutions teach RFID in certificate, diploma, undergraduate and graduate levels. This book can be served as a textbook or a companion book and a very useful reference for students and researchers in all levels.

The book can be best used as a complete reference guide if an expert wants to design a complete RFID system using either a chipless or a conventional radio frequency identification system. The beneficiaries of the book are the specialists of specific disciplines such system aspects on detection, discrimination, sensor network protocols, security issues and design of security protocols and systems. The readers of the book can maximize their knowledge on a systematic middleware and enterprise software planning, anti-collision protocol designs for multiple tag and reader scenarios such as warehouses, manufacturing plants, supply chain managements, and pharmaceuticals. If some experts and executives want to implement RFID in a particular system in their organizations, they are encouraged to read the last few chapters on design and implementation of RFIDs and RFID based sensors in various emerging applica-

tions. Each section is rich with new information and research results to cater for the needs of specialists in system as well as specific components of the RFID.

In the book utmost care has been paid to keep the sequential flow of information related to the various aspects as mentioned above on the RFID system and its emerging development. Hope that the book will serve as a good reference of RFID and will pave the ways for further motivation and research in the field.

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