Preface

Radio frequency identification (RFID) is a modern wireless data transmission and reception technique for applications including automatic identification, asset tracking and security surveillance. As barcodes and other means of identification and asset tracking are inadequate for recent demands, RFID technology has attracted interest for applications such as logistics, supply chain management, asset tracking and security access control. With the continuous development of RFID technology, we can see that new applications of RFID have been emerging from all wakes of our day-to-day lives. The vast majority of RFID transponders (or tags) are usually composed of an antenna and integrated circuit (IC). The IC performs essential data processing tasks. For passive RFID tags, ICs are powered by the energy emitted from the interrogation signals of RFID readers. RFID transponders which use on-board power supplies (such as batteries) are called active RFID tags. Passive RFID tags are low in cost with the expense of short reading range (up to 3 m). Active RFID tags need on-board batteries, have higher cost and can be read even over 100 m. The most expensive component of an RFID tag is its application-specific integrated circuit (ASIC). The cost of RFID limits their potential for the replacement of trillions of barcodes each year. According to the market analysis of IDTechEx, chipless RFID will occupy more than 60% of the total RFID market by 2018 (in 2009 total market value of RFID exceeded $5 billion). Therefore, researchers have been developing chipless RFID tags that can be made much cheaper and comparable to the optical barcodes.

Scientific and technological development has a trade-off between the cost and performance. Chipless RFID is going through the various development phases to maximise the trade-off. Chipless tags offer a low-cost tagging solution at the expense of significant technical challenges. The challenges are non-conventional data encoding techniques, reading distances, collision of proximity tags and printing techniques. All these factors may result in a reduced number of bits that can be encoded in a chipless RFID tag when compared to that for a chipped RFID tag. Since chipless RFID tags have no ASIC chip, data encoding and decoding, frequency of operation and reading methods are very different and unique. In this book, we present a comprehensive review of the latest reported chipless RFID circuits presented in peer-reviewed journals and conferences and open resources such as the internet. The chipless RFID tags are classified based on how they encode data. We distinguish between two types of chipless tags: time domain reflectometry-based and spectral signature-based tags. The chipless RFID tags are classified based on how they encode data. The TDR-based tag encodes data in the time domain by creating a train of echo pulses backscattered to the reader when interrogated. The spectral signature-based tag encodes data in the frequency domain by filtering out certain frequencies using resonant structures. As both types of tags have their pros and cons, it is important to decide which tag is suitable for which application. In this book, we focus on the design and optimisation of spectral signature-based chipless RFID.

A novel RFID system composed of a chipless RFID tag and an associated reader is reported in the book. The chipless tag is a fully passive microwave circuit and uses spectral signatures for data encoding. The tag consists of a multi-resonator coupled to transmitting and receiving antennas. To accommodate multiple bits, the tag operates over the ultra wideband (UWB) frequency spectrum. UWB antennas are used to receive the interrogation signal sent from the reader and transmit the signal back to the reader after performing modulation of the frequency spectra with the multi-resonator. Modulation is performed in both amplitude and phase of the spectrum. A chipless tag up to 35 bits, which operate over 3–7 GHz band, has been designed.

After the successful design of the chipless tag, three prototype readers have been developed. The Gen1 reader was designed to validate the chipless RFID concept using 6-bit chipless tag reading based on amplitude-only detection in S-band; the Gen2 reader is an upgraded version of Gen1 with both amplitude and phase detection capability; and the Gen3 reader is a UWB reader capable of reading up to 35-bits in the UWB band. The integrated reader is a complete system with analog RF and digital control sections, RS232 interface and a PC loaded with graphical user interface (GUI) and software protocol. Both the hardware and software design of the RFID reader and field trials of the designed chipless RFID system have been validated in the real-world environment. Investigation into reader antenna systems in order to enhance reading range has also been performed. A read range up to 70 cm was achieved.

The unique features of the developed chipless RFID system are: (a) a low cost, fully printable tag and (b) a dedicated chipless RFID tag reader. The importance of this concept lies in the fact that chipless RFID tags become comparable to barcodes in terms of the substrate material used and the cost of fabrication. The main application of this chipless RFID system is in short-range tagging of extremely low-cost items such as the Australian polymer banknote. The chipless tag can also be used in other applications such as hand tags for appeals, library access cards, etc.

So why would this book be of interest to a reader? Well the vast majority of RFID books describe the conventional types of RFID systems (active, semi-active and passive) and they focus on the design of the rectifier circuit for the tag, antenna design and improving reading range. This book, on the other hand, presents a completely unique research finding on a chipless RFID tag technology—a multi-resonator-based paradigm chipless RFID tag and its dedicated reader. The main hindrance of mass deployment of the RFID technology is the cost of the tag. Various efforts are envisaged to reduce the cost of the conventional tag. They are designed with reduced number of silicon transistors required in the RFID tag chipset and reduced cost of the IC design process. However, these approaches will not bring the RFID technology near to the optical barcodes with regard to cost. Our approach is to get rid of the silicon chip in the tag completely and fully eliminate the above two items (ASIC and relevant processing) that determine the cost and reading range of a RFID system. To the best of the authors' knowledge, no single book has been published on chipless RFID. The book features the detailed design of a chipless RFID system with a comprehensive overview of other chipless RFID systems as well. Therefore, the RFID community will be tremendously benefited knowing the new technology in details.

Since this book presents novel RFID design pathways and encoding techniques (such as chipless RFID) which provide solutions for low cost and robust tagging, we hope that this book will be welcomed by the scientific community and create a significant impact in future RFID development. Since the majority of RFID systems found on the market are HF (13.56 MHz) and UHF (around 900 MHz) RFID systems, it is possible that an illusion could be created among researchers that nothing else besides system level design and performance characterisation of implemented RFID systems is left for engineers/researchers in the RFID field. However, this is far from the truth and this book is intended to present a comprehensive review of chipless RFID technology that is on the market but also prototyped by research institutions around the world using unconventional data encoding techniques, circuits and operating frequencies to tackle some of the issues that current chipped RFID tags have which prevent it from completely replacing the optical barcode: cost below 1 cent, operating in high temperatures, full printability and zero power requirements and power supply.

The findings, design and measurements presented in this book have been the result of a 4-year PhD research project conducted by Dr. Stevan Preradovic under the supervision of Dr. Nemai Karmakar at the Department of Electrical & Computer Systems Engineering at Monash University in Melbourne, Australia. The project was financed by the Australian Research Council Discovery Grant "*Chipless RFID for barcode replacement.*" The outcomes of the PhD research project have been also presented at the ARC Major Grant Expo 2008 held in Canberra as one of the top ten projects predicted to have a significant impact on society. The chipless RFID tag has been patented as an international patent "RF Transponder." The authors would also like to acknowledge the support of Dr. Sushim Roy and Dr. Isaac Balbin to the development of the chipless RFID technology presented to this book.

The book will be of primary interest to RF/microwave engineers specialised in RFID design, transceiver design, antenna design and passive filter design. However, engineers involved in mixed signal design and embedded system design will find this book interesting as well since the book covers topics in passive and active RF/microwave circuit design along with some digital circuit design.

Endeavour Hills, VIC, Australia — Stevan Preradovic
Melbourne, VIC, Australia — Nemai Chandra Karmakar

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