Chapter XXI
Smart Antennas for Automatic Radio Frequency Identification Readers

Nemai Chandra Karmakar
Monash University, Australia

ABSTRACT

Various smart antennas developed for automatic radio frequency identification (RFID) readers are presented. The main smart antennas types of RFID readers are switched beam, phased array, adaptive beamfsorming and multiple input multiple output (MIMO) antennas. New development in the millimeter wave frequency band—60 GHz and above— exploits micro-electromechanical system (MEMS) devices and nano-components. Realizing the important of RFID applications in the 900 MHz frequency band, a 3×2-element planar phased array antenna has been designed in a compact package at Monash University. The antenna covers 860-960 GHz frequency band with more than 10 dB input return loss, 12 dBi broadside gain and up to 40° elevation beam scanning with a 4-bit reflection type phase shifter array. Once implemented in the mass market, RFID smart antennas will contribute tremendously in the areas of RFID tag reading rates, collision mitigation, location finding of items and capacity improvement of the RFID system.

INTRODUCTION

The Radio Frequency Identification (RFID) system is a new wireless data transmission and reception technique for automatic identification, asset tracking, security surveillance and many other emerging applications. An RFID system consists of three major components: a reader or integrator, which sends interrogation signals to an RFID **trans**mitter res**ponder** (transponder) or tag, which is to be identified; an RFID tag, which contains the identification code; and middleware, which maintains the interface and the software protocol to encode and decode the identification data from the reader into a mainframe or a personal computer. Figure 1 below illustrates a generic block diagram of the RFID system. At the dawn of the new millennium, as barcodes and other means for identification and asset tracking are becoming inadequate for recent demands, RFID technology has been facilitating logistics, supply chain management, asset tracking, security access control, intelligent transportation and many other areas at an accelerated pace. A recent Google search of the terminology 'RFID' brought up thirty eight million hits. This large huge number of URLs represents the significant activities and applications of RFID in various sectors in either commercial domains or government agencies.

RFID technology is an off-shoot miniaturized version of the 'identification, friend or foe (IFF)' radar system developed by British defence during World War II. This radar technology used backscattered signals to identify and/or discriminate friendly targets from enemy targets and enabled decisions to attack appropriate targets. While low frequency RFID tags use strong magnetic coupling by being in proximity to the RFID reader's coil antennas, all ultra high frequency (UHF) and microwave RFID readers and tags are based on the radar principle of sending far-field electromagnetic (EM) interrogating signals from the readers and receiving the back-scattered modulated signals with the unique identification code of the tag. Thus identification of items, human beings and animals is possible in all weather conditions and off line-of-sight communication.

RFID was first proposed by H. Stockman (Stockman, 1948) who introduced the RFID system in his landmark paper "Communication by Means of Reflected Power". Stockman advocated that considerable research and development work was required to solve the basic problems of wireless identification by means of reflected power. A complementary article on the history of RFID can be found in Landt (2001).

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."

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 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. 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. The advent of smart antennas has brought many benefits for the communications industries as many value added

Figure 1. Generic RFID system