Chapter 2
Low Cost Chipless RFID Systems

Abstract This chapter presents a comprehensive overview and novel classification of chipless RFID tags that can be found in the market and reported in peer-reviewed conferences and journals. The problems of achieving low cost chipped RFID are presented along with the proposed solution of chipless RFID for lowering the price of the RFID tag. Two main chipless RFID tag groups are presented: time domain reflectometry-based chipless RFID and spectral signature-based chipless RFID. A comprehensive report on different chipless RFID tags with their pro's and con's is presented. Following the chipless RFID tag classification is a comprehensive classification of chipless RFID readers, which can be found on the market. A system-level view and architectural exploration of RFID readers is presented. The chapter is closed with the presentation of the proposed multiresonator-based chipless RFID tag and reader along with their requirements and specifications.

2.1 Introduction

In the preceding chapter, an introduction to RFID and chipless RFID systems was presented. The proposed chipless RFID system based on multiresonators was presented in block diagram format. The proposed chipless RFID system is a novel spectral signature design, which encodes data in both magnitude and phase.

This chapter focuses on the difficulties of achieving low cost chip RFID systems and the emergence of chipless RFID systems as a cheaper solution. The main issue of chipped RFID tags is the cost of the IC and its assembly to the printed antenna.

S. Preradovic and N.C. Karmakar, *Multiresonator-Based Chipless RFID: Barcode of the Future*, DOI 10.1007/978-1-4614-2095-8_2,

A comprehensive review of chipless RFID transponders available on the market and reported in peer-reviewed journals/conferences is presented. The novel system concept of using chipless transponders results in having new RFID readers, and their system architecture is presented in this chapter.

2.2 Difficulties of Achieving Low Cost RFID

The use of RFID instead of optical barcodes presented in Chap. 1 has not been achieved due to the greater price of the RFID tag (10 cents) compared to the price of the optical barcode (less than 0.1 cent). The arguments for not having a cheap RFID transponder are comprehensively presented by Fletcher [21]. Fletcher advocates that Application Specific Integrated Circuit (ASIC) design and testing along with the tag antenna and ASIC assembly result in a costly manufacturing process. This is why it is not possible to further lower the chipped RFID transponder price. The basic steps for manufacturing a chipped RFID transponder are shown in Fig. 2.1.

The design of silicon chips has been standardized for over 30 years, and the cost of building a silicon fabrication plant is in billions of US dollars [22, 23]. Since silicon chips are fabricated on a wafer-by-wafer basis, there is a fixed cost per wafer (around US $1,000). The cost of the wafer is independent of the IC design; hence, the cost of the RFID chip can be estimated by knowing the required silicon area for the RFID chip. Significant achievements have been made in reducing the size of the transistors allowing more transistors per wafer area [24]. Further on, decreasing the amount of transistors needed results in an even smaller silicon area, hence a lower RFID chip price. As a result, great efforts have been put in by MIT to design an RFID ASIC with less than 8,000 transistors. Although this will reduce the price of the silicon chip, its miniature size imposes limitations and further cost for handling such small chips.

The cost of dividing the wafer, handling the die and placing them onto a label is still significant even if the cost of the RFID chip is next to nothing (which it is not). The cost of handling the die increases with the use of smaller than standard chips simply because the electronics industry is not standardized for them.

Hence, it is safe to say that with highly optimized low transistor count ASICs, implemented assembly processes and extremely large quantities (over one billion) of RFID chips sold per annum a minimum cost of 5 cents is the reality for chipped RFID transponders.

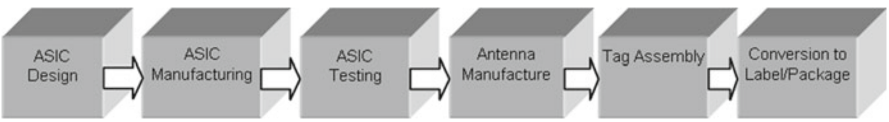

Fig. 2.1 RFID label/transponder manufacturing process

2.3 Chipless RFID Transponders: The Low Cost RFID Solution of the Future

Given the inevitable high cost of silicon chip RFID transponders (when compared to optical barcodes), efforts of designing low cost RFID transponders without the use of traditional silicon ASICs have emerged. These transponders, and therefore systems, are known as *chipless* RFID systems. Most chipless RFID systems are based on using the electromagnetic properties of materials and/or designing various conductor layouts/shapes to achieve particular electromagnetic properties/behaviour. From here on, the main focus of this book will be on chipless RFID systems.

2.3.1 Review of Chipless RFID Transponders

There have been a few reported chipless RFID tag developments in recent years (Table 2.1). However, most of them are still reported as prototypes and only a handful is considered to be commercially viable or available. The challenge that researchers face when designing chipless RFID transponders is how to perform data encoding without the presence of a chip. In response to this problem, two general types of RFID transponders can be identified: time domain reflectometry (TDR)-based and spectral (frequency) signature-based chipless RFID transponders. Figure 2.2 shows the classification of reported chipless RFID transponders.

TDR-based chipless RFID transponders are interrogated by sending a signal by the reader in the form of a pulse and listening to the echoes of the pulse sent by the tag. This way a train of pulses is created, which can be used to encode data. Various RFID transponders have been reported using TDR-based technology for data encoding. We can distinguish between non-printable and printable TDR-based transponders.

Table 2.1 Specifications for chipless RFID tag

Electrical specifications	
Frequency of operation	3.1–10.7 GHz
Tag antenna polarization	Linearly polarized
Tag antenna radiation	Preferably omni-directional
Number of bits	Greater than 20 bits
Mechanical specifications	
Tag Size	Width: 64 mm maximum ; Length: 120 mm
Printability	Fully printable, no semiconductor
Operations	Printed on thin plastic/paper objects
Weight	Less than 5g
Visibility	Preferably transparent
Operating temperature	–20° to 80°C
Commercial	
Cost	Less than 1 cent per tag.

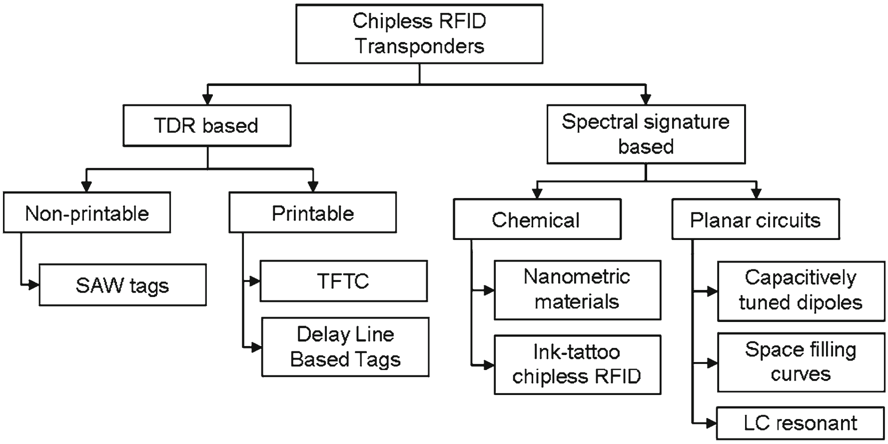

Fig. 2.2 Classification of chipless RFID transponders

The example of a *non-printable* TDR-based chipless RFID transponder is the surface acoustic wave (SAW) tag, which is also the commercially most successful developed by RFSAW Inc. [25]. *SAW tags* are excited by a chirped Gaussian pulse sent by the reader centred around 2.45 GHz [26–30]. The interrogation pulse is converted to a SAW using an interdigital transducer (IDT). The SAW propagates across the piezoelectric crystal and is reflected by a number of reflectors, which creates a train of pulses with phase shifts [31–38]. The train of pulses is converted back to an EM wave using the IDT and detected at the reader end, where the tag's ID is decoded [39–48].

Printable TDR-based chipless transponders can be found either as Thin-Film-Transistor Circuits (TFTC) or microstrip-based transponders with discontinuities. *TFTC transponders* are printed at high speed and on low cost plastic film [49]. TFTC tags offer advantages over active and passive chip-based transponders due to their small size and low power consumption. They require more power than other chipless tags, but offer more functionality. However, low cost manufacturing processes for TFTC tags have not been developed yet. Another issue is the low electron mobility, which limits the frequency of operation up to several MHz.

Delay-line based chipless RFID tags operate by introducing a microstrip discontinuity after a section of delay line as reported in refs. [50–52]. The transponder is excited by a short pulse (1 ns) EM signal. The interrogation pulse is received by the transponder and reflected at various points along the microstrip line creating multiple echoes of the interrogation pulse. The time delay between the echoes is determined by the length of the delay line between the discontinuities. This type of tag is a replica of the SAW tag using microstrip technology, which makes it printable. Although initial trials and experiments of this chipless technology have been reported, only 4 bits of data have been successfully encoded, which shows limited potential of this technology.

Spectral signature-based chipless transponders encoded data into the spectrum using resonant structures. Each data bit is usually associated with the presence or absence of a resonant peak at a predetermined frequency in the spectrum. So far, five types of spectral signature-based tags have been reported and all five are considered to be fully printable. We can distinguish two types of spectral signature tags based on the nature of the tag: chemical tags and planar circuit tags.

Chemical transponders are designed from a deposition of resonating fibres or special electronic ink. Two companies from Israel use *nanometric materials* to design chipless tags. These tags consist of tiny particles of chemicals, which exhibit varying degrees of magnetism and when electromagnetic waves impinge on them they resonate with distinct frequencies, which are picked up by the reader [53]. They are very cheap and can easily be used inside banknotes and important documents for anti-counterfeiting and authentication. CrossID, an Israeli paper company, claims to have such 70 distinct chemicals, which would thus provide unique identification in the order of 2^{70} (over 10^{21}) when resonated and detected suitably [54]. Tapemark also claims to have “nanometric” resonant fibres, which are 5 μm in diameter and 1 mm in length [55]. These tags are potentially low cost and can work on low grade paper and plastic package material. Unfortunately, they only operate at frequencies up to a few kHz, although this gives them very good tolerances to metal and water.

Ink-tattoo chipless tags use electronic ink patterns embedded into or printed onto the surface of the object being tagged. Developed by Somark Innovations [56], the electronic ink is deposited in a unique barcode pattern, which is different for every item. The system operates by interrogating the ink-tattoo tag by a high frequency microwave signal (>10 GHz) and is reflected by areas of the tattoo, which have ink creating a unique pattern which can be detected by the reader. The reading range is claimed to be up to 1.2 m (4 feet) [57, 58]. In the case of animal ID, the ink is placed in a one-time-use disposable cartridge. For non-animal applications, the ink can be printed on plastic/paper or within the material. Based on the limited resources available for this technology (still in experimental phase), the author has assumed that it is spectral signature based.

Planar circuit chipless RFID transponders are designed using standard planar microstrip/co-planar waveguide/stripline resonant structure, such as antennas, filters and fractals. They are printed on thick, thin and flexible laminates and polymer substrates. *Capacitively tuned dipoles* were first reported by Jalaly [59]. The chipless tag consists of a number of dipole antennas, which resonate at different frequencies. When the tag is interrogated by a frequency sweep signal, the reader looks for magnitude dips in the spectrum as a result of the dipoles. Each dipole has a 1:1 correspondence to a data bit. Issues regarding this technology would be: tag size (lower frequency longer dipole—half wavelength) and mutual coupling effects between dipole elements.

Space-filling curves used as spectral signature encoding RFID tags were first reported by McVay [60]. The tags are designed as Peano and Hilbert curves with resonances centred around 900 MHz. The tags represent a frequency selective surface (FSS), which is manipulated with the use of space-filling curves (such as Hilbert curve, etc.). The transponder was successfully interrogated in an anechoic chamber. Only 3 bits of data have been reported so far. However, the tag requires significant layout modifications in order to encode data.

LC resonant chipless tags comprise a simple coil, which is resonant at a particular frequency. These transponders are considered 1-bit RFID transponders. The operating principle is based on the magnetic coupling between the reader antenna and the LC resonant tag. The reader constantly performs a frequency sweep searching for transponders. Whenever the swept frequency corresponds to the transponder's resonant frequency, the transponder will start to oscillate producing a voltage dip across the reader's antenna ports. The advantage of these tags is their price and simple structure (single resonant coil), but they are very restricted in operating range, information storage (1 bit), operating bandwidth and multiple-tag collision. These transponders are mainly used for electronic article surveillance (EAS) in many supermarkets and retail stores [61].

In the following section, the general RFID reader architecture and modern RFID reader review will be presented.

2.4 Modern RFID Readers

RFID readers are devices that perform the interrogation of RFID transponders. In a chipless RFID system, the RFID reader detects the tag by using signal processing demodulation techniques to extract data from the transponder's signal. A chipless tag cannot generate a signal without the reader sending an interrogation signal to the transponder. Therefore, the reader and transponders are in a master–slave relationship, where the reader acts as a master and the transponders as slaves. Nevertheless, RFID readers themselves are in a slave position as well. A software application, also called middleware, processes data from the RFID reader, acts as the master unit and sends commands to the reader [62] as shown in Fig. 2.3.

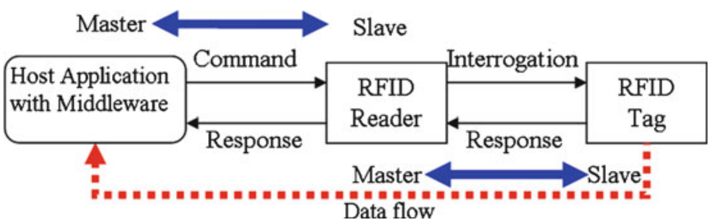

Fig. 2.3 Master–slave principle between the application software and reader, and the reader and transponders

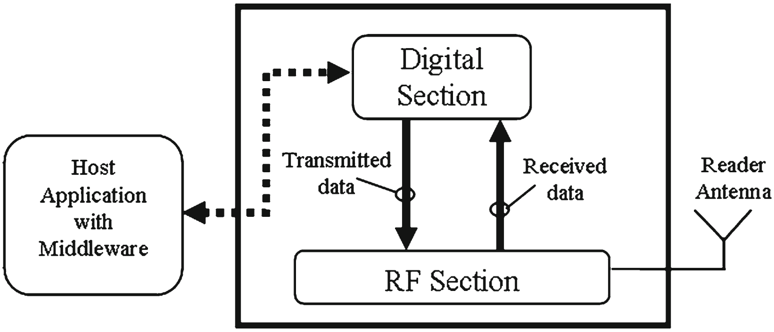

Fig. 2.4 Block diagram of a typical RFID reader

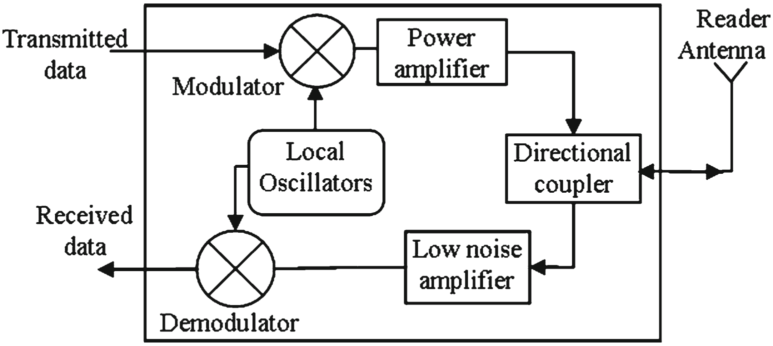

Fig. 2.5 Block diagram of the RF section of an RFID reader

2.4.1 RFID Reader Architecture

An RFID reader consists of three main parts as shown in Fig. 2.4. These main three components are:

1. Digital/control section.
2. RF section.
3. Antenna.

The digital section of the RFID reader performs digital signal processing over the received data from the RFID transponder. This section usually consists of a microprocessor, a memory block, a few analogue-to-digital converters (ADCs) and a communication block for the software application.

The reader's RF section is used for RF signal transmission and reception and consists of two separate signal paths to correspond with the two directional data flows as shown in Fig. 2.5.

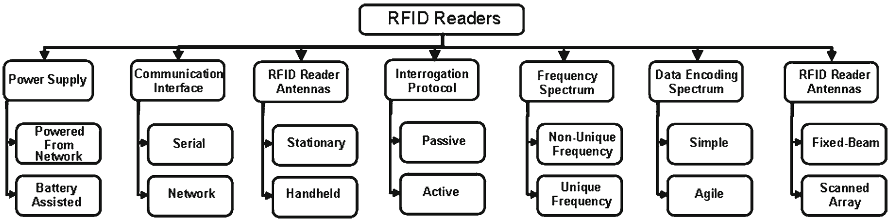

Fig. 2.6 Classification of RFID readers available in the market and open literature

The local oscillator generates the RF carrier signal, a modulator modulates the signal, the modulated signal is amplified by the power amplifier, and the amplified signal is transmitted through the antenna. A directional coupler separates the system's transmitted signal and the received weak back-scattered signal from the tag [63]. The weak back-scattered signal is amplified using low noise amplifiers (LNA) before the signal is decoded in the demodulator. Different demodulation techniques are used when decoding the data received from the transponder. Most RF sections are protected from EM interference using metal cages.

Depending on the RFID system's applications, the RFID reader can be designed in different ways, where the antenna's resonating frequency, gain, directivity and radiation pattern can vary. Adaptive antennas act as spatial filters and a promising technique for implementing this spatial diversity into RFID readers [64]. The antenna reported in ref. [63] is a 5-element rectangular patch antenna array with an intelligent beam forming network at 2.45 GHz. A number of different reader antennas have been developed during the years based on microstrip patch antennas [65–67].

Following is a detailed discussion on various RFID reader systems available in the market and reported in open literatures.

2.4.2 Review of RFID Readers

Figure 2.6 shows the classifications of RFID readers available in open literature and commercial markets. The classification is done after an analysis and synthesis of a comprehensive literature review on RFID readers. The classification is based on the power supply, communication interface, mobility, tag interrogation, frequency response and the supporting protocols of the reader.

The classification of the RFID reader based on their power supply brings forth two types of readers: readers supplied from the power network and battery-powered (BP) readers.

Readers supplied by the *power network* generally use a power cord connected to an appropriate external electrical outlet. Most readers that use this type of power supply are fixed stationary readers and their operating power supply ranges from 5 to 12 V [68], but there are examples of readers that operate at voltage levels as high as 24 V [69].

Battery-powered readers are light in weight and portable. The battery is mainly used to power up the motherboard of the reader. Most BP readers are hand-held, but there are stationary readers that are battery assisted as well. BP readers use from 5 V up to 12 V batteries for their power supply [70, 71].

Based on their *communication interface*, readers can be classified as serial and network.

Serial readers use a serial communication link to communicate with their host computers or software applications. The reader is physically connected to a host computer using the RS-232 [72], RS-485, I2C or USB serial connection [73–75].

Network readers are connected to the host computer via a wired or wireless network. These types of readers behave like a standard network device. Today's RFID readers support multiple network protocols, such as Ethernet, TCP/IP, UDP/IP, HTTP, LAN, WLAN and others [76, 77]. This allows easier tracking, maintenance, data rate and results in a smaller number of hosts for installing a large number of readers in comparison with serial readers.

The next classification of RFID readers can be made on their *mobility*. Hence, we distinguish two types of readers: stationary and hand-held RFID readers.

Stationary RFID readers are also known as fixed readers. This term comes from the reader's ability to be mounted on walls, portals, doors or other objects, where they can perform effective transponder readings and are not meant to be moved or carried. Fixed RFID readers are mainly used for wireless data capture in supply chain management, asset tracking and product control [78], but can also be found in personnel identification and authentication for restricted access areas [79–81] as well.

Hand-held RFID readers are mobile readers that can be carried and operated by users as hand-held units. Hand-held readers have built-in antennas and usually do not have connectors for additional antennas. They are BP and are light weight (from 82 g up to 700 g). They have shorter reading ranges than fixed readers [82, 83] and are mainly used for tracking live stock, locating items in stores and in stock, etc.

Another classification of RFID readers can be made upon the reader's *interrogation protocols* in terms of being passive and active.

Passive readers are limited to only "listening" and do not perform additional tag interrogations. When interrogating the tags, the reader sends CW signal as a power source for the RFID transponder, which becomes activated. Upon activation, the RFID transponder transmits its unique ID back to the reader [84].

Active readers are true interrogators, which interrogate and listen to tags. Active readers perform data transmission towards the tags, which is implemented, in most cases, as a modulation of the carrier signal. Therefore, transponders must have a demodulating circuitry enabling them to decode the reader's command. These readers can perform both listening and calling out to the tags and can even achieve

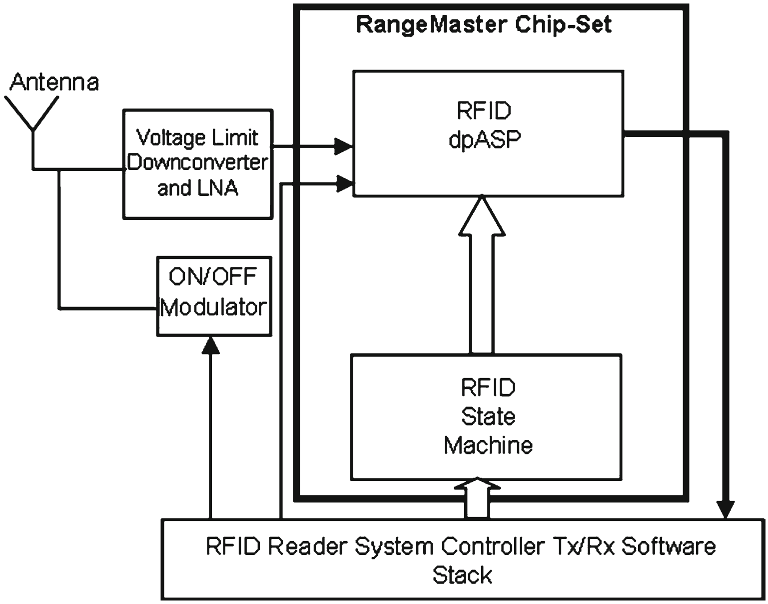

Fig. 2.7 System-level overview of the RangeMaster-embedded RFID reader

successful area location of the transponder based on the amplitudes of the transponders respond to the reader's interrogation [85].

We can classify readers based on the *transponder frequency responses* that they listen to as unique frequency response and non-unique frequency response-based readers.

Unique frequency response-based readers operate at a unique (or short bandwidth <80 MHz) frequency range and use this frequency for both data transmission and reception. The vast majority of RFID readers that can be found on the market today are unique frequency response-based readers.

None-unique frequency response-based readers operate using one frequency for sending a command or just provide a carrier signal at a certain frequency and listen for an integer multiple of its carrier frequency, generally in the form of a second harmonic, or a frequency-divided signal as the transponder's response [86]. Two RF frequencies used for communication by the reader to the RFID system allow fast and reliable full-duplex communication, but this system needs a more complex RF front end for both the reader and transponder module [87]. Figure 2.7 shows a multi-frequency RFID system.

We can distinguish between two types of RFID readers based upon their ability to communicate with transponders in regards to *data-encoding protocols*: simple RFID readers and agile RFID readers.

Simple RFID readers use a unique protocol for communication and data transmission between transponders in the reader's interrogation zone [88, 89]. When a transponder that supports the reader's interrogation protocol is set in the interrogation area of the reader, the tag is automatically recognized and detected. When a transponder that operates using a different protocol is put into the interrogation area, no data transmission will occur because of the unfamiliarity of the reader's interrogation protocol to the transponder.

Agile RFID readers can operate and perform interrogations and data transmission with transponders using multiple protocols. The most commonly used protocols for data transmission between transponders and readers are EPC Gen1 [90], EPC Gen2 [91], ISO 18000 [92], TIRIS Bus Protocol, etc. The majority of RFID readers that can be found in the market are designed for multiple protocols and multi-tag readings [93].

We can distinguish between two types of RFID readers based on their *antennas*: fixed beam RFID readers and scanned array RFID readers.

Fixed beam antennas are characterized with a unique and fixed beam radiation pattern [94]. The use of several fixed beam antennas is used as well and can be commonly found in Alien Technology readers. The advantage of using such antennas is that they are easy to install and do not need any logic to control their radiation patterns. The disadvantage of these antennas is that they pick up multipath signals alongside with the transponders signal, which can result in errors during interrogation.

Scanned Array RFID readers use smart antenna systems in order to reduce the number of transponders within their main lobe radiation zone, thus reduce reading errors and collisions among tags. This technique exploits spatial diversity among tag's locations. The direct beam also reduces the effects of multipathing [95]. This new approach to RFID antenna technology is being incorporated by a few RFID manufacturers, such as Omron Corporation, Japan [95], RFID Inc. [96] and RFSAW, USA [89].

2.4.3 Towards Universal Reader Design

RFID reader designers and manufacturers have gone a step further in the design of independent reader modules [97, 98]. The design of embedded RFID readers has been introduced to the world of RFID in 2005 [99]. In June 2005, Anadigm Inc. announced the birth of the industry's first RFID-embedded reader that can be customized to read different RFID tag types, with different modulation schemes, frequencies and data transmission protocols [100]. The "universal" reader is named RangeMaster. The RangeMaster's system-level block diagram is shown in Fig. 2.7. It comprises a Field Programmable Analogue Array (FPAA) in conjunction with an RFID State Machine, enabling RFID system engineers to develop a universal RFID reader supporting multiple protocols and frequencies for future fixed, mobile and hand-held reader designs [101]. The advantage of embedded RFID readers, such as RangeMaster, when compared to standard readers is that they allow standardization around a single circuit board, simplification and improvement of product development, manufacturing time and cost.

2.5 Chipless RFID System Specifications

Several RFID system design requirements are discussed in this paragraph. These requirements are largely determined by the application for which the RFID system will be deployed.

1. *Cost.* The cost of an RFID system is largely dependent on the cost of the transponder. The chipless RFID tag needs to be extremely cheap—below 1 cent would be preferable in order to be affordable when tagging low cost paper-/plastic-based items. This places restrictions on both transponder design and the choice of materials for its construction. Typical conductors that can be used are copper, aluminium and conductive ink. Typical dielectrics are polyester and PCB substrates.
2. *Size.* The size of the transponder is dependent on both frequency of operation and the size of the tagged item. The size of the transponder should be from several centimetres to approximately a decimetre.
3. *Frequency band.* The frequency band of operation is an important aspect of the proposed system because it directly determines the amount of bits, which can be encoded. The proposal for a UWB system is the chosen option. The UWB frequency spectrum varies from country to country (generally from 3.1 to 10.7 GHz, USA). UWB systems are restricted by the amount of EIRP, which is in the noise level (below −40 dBm outdoors and below −50 dBm indoors).
4. *Read range.* Minimum required reading range is specified based on the reader sensitivity, which is entirely due to the fact that the chipless transponder does not need power supply for operation. Limitations in reading range will be introduced due to the low EIRP and orientation.
5. *Application with mobility.* The chipless RFID system is intended for conveyor belt applications at speeds of 10 m/s. The Doppler shift, in this case, at 10.7 GHz (worse case scenario for UWB system) is less than 400 Hz and does not effect the operation of the chipless transponders. Although the transponder spends less time in the interrogation zone of the reader, since the transponder and reader do not communicate using handshaking or synchronization, this aspect does not present a major issue.
6. *Reliability.* RFID transponders should be reliable devices that can sustain variations in heat, humidity, stress and processes, such as printing, label insertion and lamination. Conductive ink has proven to be extremely robust and when printed on flexible substrates, it maintains its robustness which is a necessity for applications, such as envelope or note-bill tagging.
7. *Security.* The chipless RFID system can provide an extra layer of security against counterfeiting when using transparent conductive inks. A transponder may be printed without visible notice. Another advantage would be the fact that it would be impossible to read multiple tags stacked together (a stack of tagged note bills cannot be read accurately due to the mutual coupling and the inability to differentiate between tags or determining the number of tags).

The following sections will present the proposed chipless RFID transponder and RFID reader circuits.

2.6 Proposed Chipless RFID Tag

The review of available and reported chipless RFID transponders has shown the lack of an operational fully printable multibit chipless RFID transponder. This section presents the proposed novel chipless RFID transponder based on multiresonators. The main components of the transponder are the transmitting (Tx) and receiving (Rx) antennas and multiresonating circuit. Block diagram of the integrated chipless RFID transponder with basic components is shown in Fig. 2.8.

The proposed chipless RFID transponder consists of a vertically polarized UWB disc-loaded monopole receiving (Rx) tag antenna, a multiresonating circuit and a horizontally polarized UWB disc-loaded monopole transmitting (Tx) tag antenna.

When the interrogation signal reaches the transponder, it is received using the receiving monopole antenna and propagates further on towards the multiresonating circuit. The multiresonating circuit encodes data bits using cascaded spiral resonators, which introduce attenuations and phase jumps at particular frequencies of the spectrum. After passing through the multiresonating circuit, the signal contains the unique spectral signature of the tag and is transmitted back to the transmitter using the transmitting monopole tag antenna. The receiving and transmitting tag antennas are cross-polarized in order to minimize interference between the interrogation signal and the re-transmitted encoded signal containing the spectral signature.

The main differences between our spectral signature-based transponder and the ones reported in the previous section are that we encode data in both amplitude and phase, the transponder operates in the UWB region and that the tag responses are not based on radar cross-section (RCS) backscattering, but on retransmission of the cross-polarized interrogation signal with the encoded unique spectral ID.

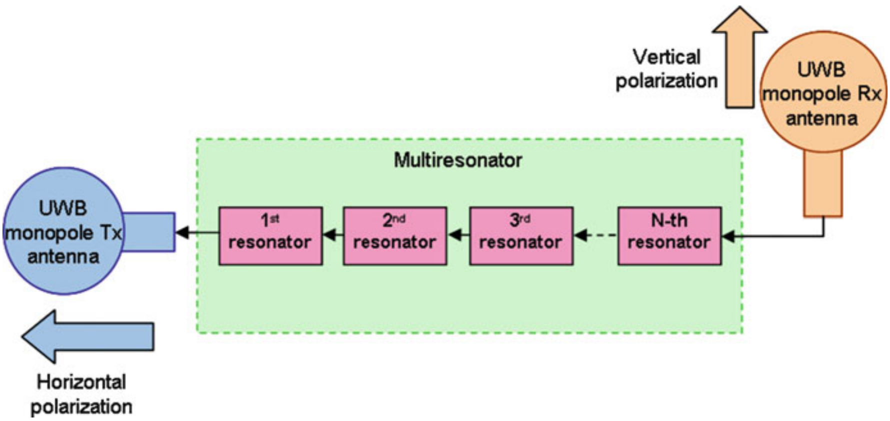

Fig. 2.8 Chipless RFID transponder circuit block diagram

2.7 Proposed Chipless RFID Reader

In this book, three types of RFID readers will be presented: first Generation (Gen1) chipless RFID reader, second Generation (Gen2) chipless RFID reader and the UWB RFID reader (Table 2.2).

The Gen1 and Gen2 RFID readers are designed as the first and second generation RFID chipless tag reader prototypes operating between 1.9 and 2.5 GHz. The two main parts of the RFID reader are: the Digital section and the RF section. A block diagram of the RFID reader is illustrated in Fig. 2.9.

Table 2.2 Specifications for chipless RFID tag reader

Electrical specifications	
Frequency of operation	3.1–10.7 GHz
Transmitting power	15 dBm
Number of reader antennas	At least two antennas—transmitting and receiving
Reader antenna polarization	Linearly polarized
Reader antenna gain	Above 5 dBi
Communication interface	Serial bus interface (RS-232)
Mechanical specifications	
Connector	SMA/DB-9
Operations	Mountable over a conveyor belt
Size	Portable—within 200 mm by 200 mm
Weight	Less than 5 kg
Environmental	Suitable for work in industrial environment
Operating temperature	–20° to 50°C
Commercial	
Cost	Less than AU $2000 (a guide only)

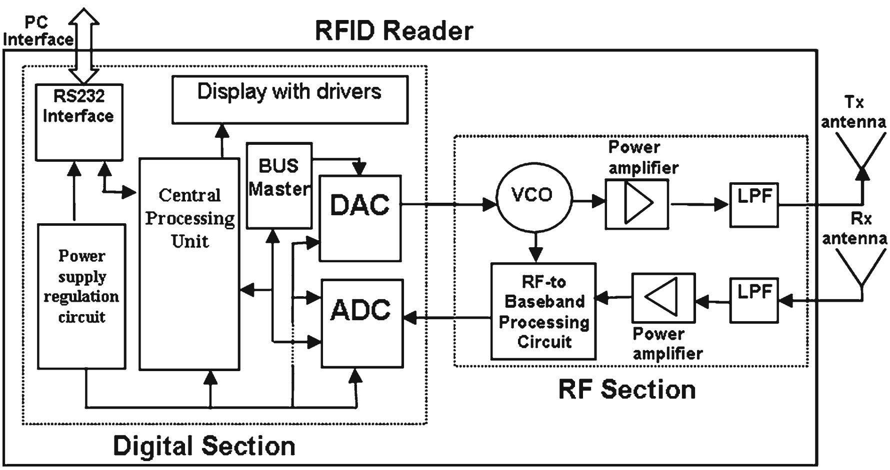

Fig. 2.9 Block diagram of Gen1 and Gen 2 chipless RFID reader

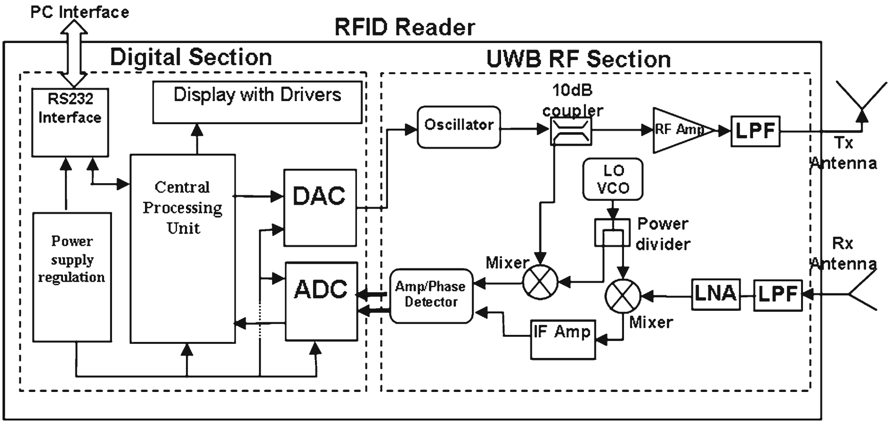

Fig. 2.10 Block diagram of proposed UWB chipless RFID reader (7–9 GHz)

The central processing unit (CPU) sends data to the RF section using a digital-to-analogue (DAC) converter. The analogue data is the tuning voltage for the voltage-controlled oscillator (VCO), which generates the RF signal for interrogating the chipless tag. The received signal from the tag is amplified and filtered before being sent to the RF-to-Baseband (RTB) circuit, where it is converted to a DC analogue value and sent to the digital section. The analogue signal is then converted to a digital signal using the ADC and sent to the CPU for tag ID decoding. The tag ID is displayed on a 7-segment LED display section and/or sent to the host computer.

The digital section is designed around an 8-bit Atmel AT89C52 microcontroller [110], which performs the major signal processing and data-decoding algorithms. The RF section consists of two RF paths: transmitter and receiver. The transmitting circuit is comprised of a VCO, which generates the RF interrogation signal and is used as a reference signal for the receiver. The interrogation signal is thus amplified and filtered and transmitted by a wideband directive reader antenna. The signal is received by a cross-polarized receiver antenna and processed (filtered and amplified) before being sent to the RTB circuit. The RTB circuit differs between the Gen1 and Gen2 RFID reader. The Gen1 reader uses magnitude detection, hence a diode rectifier is used as the RTB circuit. The Gen2 reader utilizes a Gain/Phase detector AD8302 [111] as the RTB. The AD8302 compares the received RF signal from the tag with the reference signal from the VCO and yields DC equivalent values of magnitude and phase difference between the two RF signals. The two DC values are multiplexed and sent to the digital section of the reader for further processing (digitizing) and decoding.

The UWB RFID reader is upgraded to work in the UWB region by introducing a wide-band oscillator and down-converting mixers as shown in Fig. 2.10. The mixers are used to down-convert the UWB signals (from 5 to 9 GHz to below 2.5 GHz), where the gain/phase detector AD8302 operates. The received tag signal and reference signal are compared in amplitude and phase by the AD8302. The amplitude and phase difference are given as separate DC values by the AD8302. The 2 DC values are multiplexed and then sent to the digital section, where they are digitized and processed further on for tag ID detection.

With the design proposals of the chipless RFID reader and transponder, we can conclude this chipless RFID system specification. The following chapters will focus on the tag and reader design and experimental results.

2.8 Conclusions and Motivation

In this chapter, we have presented novel classifications of RFID transponders and RFID readers. The classification was based on open literature and published research articles. As shown, there are various types of RFID systems. The majority of RFID transponders are chipped based, and hence require power supply in order to operate. This puts limitations in terms of cost and implementation.

A fully printable chipless RFID transponder which can be used on paper-/plastic-based items has not been yet developed. Most chipless transponders found in the review are either in early prototyping stages or have been there for quite a while (5 years or so). This leaves an open area for research where a novel and operating chipless RFID system can be developed. The proposed chipless RFID transponder based on multiresonators was presented. The transponder is comprised of two cross-polarized UWB monopole antennas, a multiresonating circuit.

The advantages of fully printable chipless transponders are the fact that they have the potential to be extremely low cost (less than 1 cent), robust (no chip—no mechanical damage), secure (using transparent conductive ink), zero-power consumption and zero maintenance.

The next step was the proposal of a circuit for interrogating the chipless transponders—a chipless RFID reader. The hardware and software development of a fully operational reader enables the proposal of the chipless RFID system to transform into a potential application, which could be commercialized or optimized for tagging particular items (mainly, conveyor belt applications where items are scanned one at a time).

The successful development of this chipless RFID system will be the most cost-effective tagging solution for low cost paper/plastic items and will provide an extra layer of security against counterfeiting, passport and sensitive documents control, enable cheap and effective tracking of currency and open the door towards the era of ultra-low cost printable chipless RFID.

As mentioned in Sect. 2.6, the transponder requires narrowband resonators in order and UWB antennas in order to encode as many bits possible and provide enough frequency spectrum for fitting all of the bits. The resonances are obtained by utilizing fully printable planar microwave resonant structure—resonators. UWB tag antennas are designed as linear-polarized UWB monopole antennas, which are fully planar. Hence, the following chapters will focus on the design of the tag multiresonator and UWB antenna.

http://www.springer.com/978-1-4614-2094-1

Multiresonator-Based Chipless RFID
Barcode of the Future
Preradovic, S.; Karmakar, N.C.
2012, XX, 172 p., Hardcover
ISBN: 978-1-4614-2094-1