CZC

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EMID
Chipless RFID Technologies
Technological Landscape

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1. Foreword

The main issue of chipped RFID tags is the cost of the IC and its assembly to the printed antenna. RFID technology has not replace optical barcodes due to the greater price of the RFID tag (10 cents) compared to the price of the optical barcode (less than 0.1 cent).

Given the inevitable high cost of silicon chip RFID transponders which cannot be lowered further, efforts of designing low cost RFID transponders without the use of traditional silicon ASICs have emerged around 2000. These transponders and their associated readers are known as chipless RFID systems.

It is important to note that chipless tags are not one single standalone technology. Chipless RFID systems are based on using the electromagnetic properties of materials and/or designing various conductor layouts/shapes to achieve particular electromagnetic properties/behaviors. The challenge that researchers face for all designs of chipless RFID transponders is how to perform physical data encoding without the presence of a chip. There are many different types of technologies that in essence do not contain any silicon-based materials and are therefore called chipless and that encompass 6 ITU bands of frequencies in the radio spectrum.

A Chipless RFID (or EMID – Electromagnetic Identification, or 'chipless ID' or 'polymer RFID') transponder is usually a passive device generally formed from low cost inductive, capacitive and resistive components, specialty magnetic materials (ultra-soft, magnetostrictive, semi-hard), electrostrictive substrate materials (piezoelectric) and highly reflective or absorptive materials at UHF. These devices are generally low data capacity data devices compared to RFIDs.

2. Introduction

The following is a high level technical description of printed and chipless RFID technologies. <u>The main intent of this report is trying to understand the technological landscape, i.e. the physical phenomena on which Chipless RFID (a.k.a EMID) technologies are based on.</u>

No supplier has been contacted. For this report, I used data collected in the open literature, as well as personal data and experience in magnetic technologies. I also had conversations (without mentioning the raison of my enquiry) with several colleagues expert in the field. The accuracy of claimed performance and list of presumed manufacturers have not been verified (unsubstantiated and unrealistic claims about Chipless RFID smart labels are found in the literature as well as misleading information about the status of some manufacturers.)

The performance of these devices is often difficult to understand because they use physical properties of materials not common unless you are specialized in physics (i.e. magnetostriction, electrostriction, materials properties at UHF) or circuits difficult to design (circuits having multiple resonant frequencies using distributed capacitance…). The same technology can differ greatly in performance depending of its particular implementation, design parameters and environment, making the development of new tagging system a promising field of research for applied physics.

Chipless technology devices generally have the following characteristics:

- Thin form factor. The devices are realized using thin foil or film materials.
- Low data capacity (maximum 100 bits)
- Ranges of less than 1 meter (3 feet)
- Wider temperature ranges (-40 C to +250 C) than chip-based RFID devices
- Lower cost relative to chip-based devices. For most technologies, prices should be less than 20 cents in volume.

These advantages have to be offset against the limited data capacity and higher cost for the readers compared to chipped technology.

3. The Technologies

3.1 Sweep RF LC Array/Circuit-Based Technologies (ITU bands 5,6,7)

Initially developed at the MIT (50 to 500 kHz sweep)

LC array technology exploits the resonance of inductor-capacitor circuits as a basis for data encoding. Devices using this approach, otherwise known as Multiple Tuned Circuit Identification (MTCID) tags, are characterized by arrays providing a range of resonant frequencies. The presence or absence of frequencies in a scan across the frequency range defines the code held by the tag. The greater the number of resonant points defined, the greater the number of code combinations (or data capacity) can be accommodated. These devices are low capacity, typically 12 bits, and range up to 1 meter.

Miyake, Lintec, CWOSRFID, Navitas, Checkpoint, Tagsense, RFCode are all EAS manufacturers developing MTCID tags. Interestingly, few of the biggest chip RFID suppliers are working on these technologies. Miyake’s chipless swept RF (LC array) tags are used for auto payment (toll).

3.2 Magnetic Materials Based Technologies (ITU bands 4,5)

These are non-contact magnetic encoded devices. Many companies are (or were) involved in the development of such as Flying Null, Link-Sure, Confirm Technologies, REMOSO, HoloTag, Zebra Technologies, Scipher TSSI, MXT, Fuji Electric, Unitika.

The four principal technologies are Wiegand/Barkhausen Effect (WBE), Programmable Magnetic Resonance (PMR), Flying-Null (FN) and Holotag low frequency magnetic (LFM) tag technologies.

3.2.1 Wiegand/Barkhausen Effect Technologies (HID. Scipher TSSI).

The Wiegand technology transponder is comprised of data carrier elements formed from small, specially processed ferromagnetic magnetostrictive wire (Vicalloy). Sharp reversal of the wire's magnetization causes a short duration voltage pulse to be generated: the Barkhausen effect. Bit representation is achieved by the manner in which the data determining wire elements are arranged relative to a defined read line These devices are low capacity (tens of bits), short range (up to 2.5 cm) storage devices.

3.2.2 Programmable Magnetic Resonance Devices (a.k.a. Acousto-Magnetic)

PMR devices exploit resonance features of magnetically soft magnetostrictive materials in association with data carrying hard magnetic material, to provide tags that can be interrogated using an appropriate low frequency alternating magnetic field. The data are written to the tag using a contact method similar to that used conventionally for magnetic stripe. In response to the reader interrogation field, resonances from the PMR tag are detected and related to data stored in the hard magnetic material. The particular harmonics can be enabled or disabled to distinguish a bit-string along a magnetically hard coding strip forming an integral part of the tag. 20-bit and 64-bit tags (capable of supporting data encoding schemes with error correction) are available costing in the region of 25 cents and 50 cents respectively. An advantage is a larger detection range (up to 1 meter).

3.2.3 Flying-Null Data Carriers

Flying-Null technology exploits the properties of very high permeability magnetic materials. The data are defined by a series of simple, passive magnetic structures, analogous in many respects with the bars for conventional linear bar codes. The data are actually stored by reducing or removing the magnetic permeability of selected regions of the high permeability material by means similar to PMR devices. FN tags are capable of tolerating a reasonable amount of non-ferrous metal within the interrogation zone.

Read/write tags are simple to implement for FN technology. The writing process requires contact with the write head. However, the tag is read by means of a high-resolution magnetic inductive reader providing read ranges of typically 50 cm and up to 1 m with loop antennas (fixed reader) and of the order of a few cm for hand held devices. The interrogation process involves the use of an alternating magnetic field (typically 2 KHz) of intensity sufficient to saturate the high permeability material except in a null - or zero - region defined by two opposing fields. A scan field is applied to oscillate the null at a frequency that is typically 1/110th that of the interrogator field. Within the null of the scanning field, the data elements can be effectively revealed, the process being somewhat analogous to a scan of a linear bar code.

3.2.4 Holotag Low Frequency Magnetic Data Carriers

MXT Inc. of Montréal and Holotag Ltd. of Cambridge, UK have developed a new low-cost authentication and product-tracking technology based on MXT's high performance magnetic fiber and Holotag's universal EM (electromagnetic) reader system. The system may be thought of as EMID, as opposed to the traditional RFID based on radio frequency technology.

The Holotag reader can read a tag with rotationally distributed magnetic elements and turn the signal into a multi-digit code (up to 50 bits). The presence or absence of the directional magnetization in the individual direction determines the data stored. Reading is achieved by a rotating magnetic interrogation field and detection of the magnetic interactions.

The reading process is objective (i.e. requires no interpretation by the operator), non-contact, and non-line-of-sight. The reader exists in two versions: a "tunnel" device with an opening 18" square (later to be developed up to 30" square) and a Palm-size hand-held device.
The tunnel reader can read the tag at any orientation and in any position. In development is an "anti-collision" feature that will allow the reader to read and distinguish up to thirty tags at once. The tags may be concealed in the product and are not as sensitive to the presence of metal or conducting fluids as RFID tags. Reading time is about 0.1 seconds so that many tagged products inside a package may be read as the package passes along a conveyor belt.
The battery-powered hand-held reader is designed for use by an agent in the field. The reader simply has to be held near the tag (within 2") and will then give the same multi-digit code as the tunnel reader.

MXT fibers are an ideal match to the Holotag reader since their high performance means that they may be detected and read in very small quantities. For authentication and product tracking, MXT proposes tags containing fibers randomly distributed; the tags will then be read by the Holotag reader which will generate and assign a random multidigit (typically 10 to 12 digit) number to each tag. This number is stored in a database along with pertinent information about the product to which it is attached. Being random, the tag cannot be counterfeited, and furthermore the reader can be configured to check whether the material in the tag is MXT material. Also the tag cannot be destroyed by being "wiped" with a strong magnet. In the field the tag can be read and referred back to the database to check both for product diversion and authenticity.
MXT estimates that in large volume the tag could cost less than 1 cent.

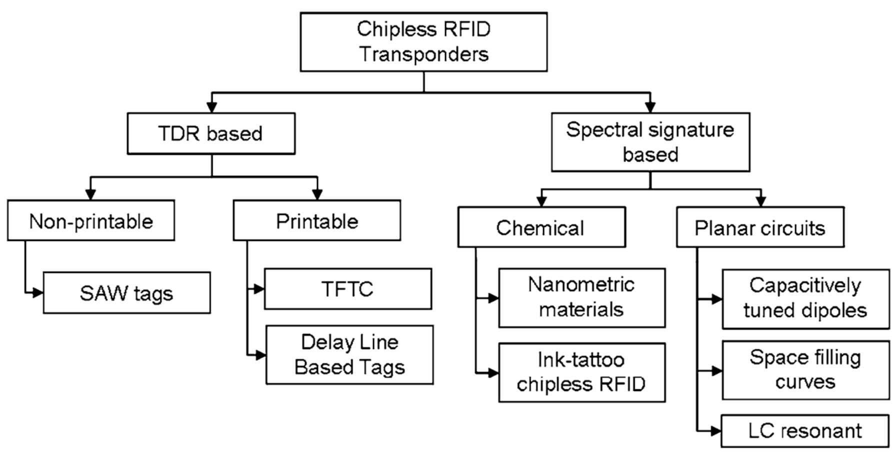
The MXT/Holotag technology offers a similar performance to passive RFID systems in that it is a multi-bit read-only technology where the reading can take place at a distance. Unlike RFID however it includes authentication, and does so with a tag that is a fraction the cost and considerably more robust. Comparing it with existing product tracking technology, such as bar-codes, Holotag EMID offers a tag that may be concealed in the product, cannot be duplicated and may be read several at a time.

3.3 Low Cost Chipless RFID – UHF - EM Systems (ITU band 9)

Two general types of chipless UHF RFID transponders can be identified: time domain reflectometry (TDR) based and spectral (frequency) signature (SS) based.

To my knowledge there have been a few reported chipless RFID tag developments in recent years; 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.

Although the use of conventional off-the-shelf RFID readers would be preferable, the new chipless RFID tags demand a fully new development of the reader from scratch. Three main differences between the developed chipless RFID tag reader and conventional off-the-shelf RFID reader are: (1) conventional RFID readers operate mostly at HF (13.56 MHz), UHF (915 MHz) and microwave (2.45 GHz) bands, while the chipless tag readers operates outside these bands.



The figure shows the classification of reported chipless RFID transponders.

3.3.1 TDR-based chipless RFID transponders

(RFSAW, X-CYTE, MicroDesign, iRay Technologies, Thoronics, CTR).

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. 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.

Printable TDR-based chipless tags have been reported as products under development. These tags encode data using a train of precisely delayed backscattered pulses of the interrogation signal (1 ns pulse) by using multiple capacitive loadings at particular points of the microstrip line. Each data bit needs a delay line that significantly increases the size of the tag. The drawbacks of this technology are the amount of bits that can be encoded, the size of the tags, and the amount of spectrum used.

3.3.2 SS-based chipless RFID transponders.

Fully printable SS-based chipless tags, (which use spectral signature encoding), have been reported using space-filling curves (filter miniaturization using Hilbert fractal curves) and capacitive tuned dipoles. The space-filling curves require considerable layout design for data encoding. The capacitive tuned dipoles could have undesired parasitic mutual coupling effects and large layout areas restricting efficient data encoding. Development of fully printable chipless RFID system based on multiresonators and cross-polarized ultra wideband (UWB) monopole antennas are on the way. The tag's unique ID is encoded as the spectral signatures of the resonators.

Hence, it is imperative to design a reader that can read the multiresonator-based chipless tag by decoding data from their spectral signatures.

3.3.3 Microwave Chipless Technologies (ITU band 9)

Although still under development, amorphous alloys in the form of small diameter (100 125 microns) glass coated wires are being used to structure tags that can be interrogated by microwave (2.45 GHz) sources to reveal a signature code or data sequence.

3.3.4 Millimeter wave identification (MMID) (ITU band 11)

A fully printable, passive and planar chipless millimeter wave identification (MMID) tag at 30 GHz is currently developed. The chipless tag encodes data into the spectral signature using a multi-resonator. Both amplitude and phase components of the spectral signature is used for data encoding. The chipless MMID tag is a prototype and comprises a microstrip multi-resonating circuit with 6 spiral resonators and two cross-polarized transmitting and receiving circular UWB monopole antennas. The chipless MMID tag has the potential of encoding a larger number of data bits (20 to 100) with the extension of the operating frequency band it uses. The chipless tag is designed for low cost item tagging and security applications.

4. Potential of chipless RFID systems

Currently the chipless tag technologies that show the most potential are swept-RF-LC array tags (printed with conductive ink), surface acoustic wave (SAW) tags and low cost UHF printed chipless RFID.

So far, the only commercially successful chipless RFID system that meet 3 feet, 96 bits requirements is developed by RFSAW. The RFSAW tag is based on surface acoustic waves (SAWs) and utilizes TDR encoding scheme. Although SAW tags are fully functional and could well replace the chipped tags, they do not provide a fully printable solution due to their piezoelectric nature, hence a potential problem of embedding the tag. The problem of having a robust tagging system for paper/plastic products is still open at the R&D stage.

5. Conclusion

Chipless tag technology is relatively new (although the concept was the Holy Grail of the EAS technology), and it is slowly gaining importance due to its ability to provide track and trace on a wide host of applications at a fraction of the cost of RFID technology. However, there are still a range of limitations that need to be resolved in order to ensure its proper incorporation. For instance, the technology still lacks the standards already present in RFID, and has limited functionality. More progress has still to be done in this area.

Experts are not aware of anyone who has a chipless product that can meet the 3 feet, 96 bits, requirement except for RFSAW.

The future for chipless tag technology looks promising. Compared to RFID, chipless tag technology is still in its nascent stage and is expected to grow further in terms of functionality, performance and applications. However, if this technology is to continue its positive growth, end-users need to understand their needs and requirements before deciding to adopt this technology. Potential end-users of chipless tags can learn from the past mistakes of early RFID adopters and can still influence the outcome of their development.

An appropriate set of standards would eventually be one of the key drivers of this technology. With standards and guidelines set in place, interoperability issues are less likely to arise. This is likely to reduce the amount of time, resources, and money that end-users spend on fixing unnecessary technical and product related issues.

6. Potential development

If xxxxxxxxxr ® is interested, CZC could provide the following professional services to help xxxxxxxxx ® in its development of innovative strategies concerning EMID:

Two questions have to be answered:

Chipless RFID Technologies

- Where is the convergence of Chipless RFID technology and tires today?
- What improvements/optimization this technology needs to be applicable to and adopted by the Tire Industry?

In order to develop an in-depth technical understanding/description with mathematical modeling of the relevant and most likely to succeed technologies, this effort could include:

1. Analysis of reports such as Printed and Chipless RFID Forecasts, Technologies & Players in RFID 2011-2021 by IDTechEx Ltd (US $3495)
2. Access to IEEE *Xplore* Digital Library
3. Contacts with vendors and technical leaders in the field

7. Annexes

Electromagnetic Chipless Tags vs. RFID

Chipless Tags	RFID
• Do not contain any silicon material	• Made of silicon-based materials
• Only passive tags	• Passive, active and semi-active tags available
• Read option only	• Read and read-write options
• No open or fixed standards (only the SAW tag looks like it may be able to have ISO 18000 standards)	• Many EPC and ISO standards are already in place. The EPC Gen 2 standards further strengthen regulatory issues
• Currently have limited memory capacity, typically less than 100 bits (only a few exceptions, such as SAW tag)	• Able to store more because of the memory on the IC (EPC Gen 2 has option to extend memory to 512 bits or more for item ID)
• Frequency range varies between different tag types and developers	• Frequency ranges are specified according to type (HF, UHF, microwave, ISM)
• Usually single read rate capability (although there are exceptions, such as SAW tags)	• Multiple read rate capability
• Generally not damaged by irradiation	• Still prone to damage by irradiation
• Security features are limited or still not present	• Many tags come with some form of security (eg. EPC Gen 2 tags have a 32 bit bit lock and kill password feature)
• Price of tags are generally lower, especially at higher volumes	• Although prices are dropping, RFID tags remain generally more expensive than chipless tags

Radio spectrum

Band name	Abbr	ITU band	Frequency and wavelength in air	
Very low frequency	VLF	4	3–30 kHz 100 km – 10 km	Magnetic Materials-Based
Low frequency	LF	5	30–300 kHz 10 km – 1 km	Sweep RF LC Array Magnetic Materials-Based
Medium frequency	MF	6	300–3000 kHz 1 km – 100 m	Sweep RF LC Array
High frequency	HF	7	3–30 MHz 100 m – 10 m	Sweep RF LC Array
Very high frequency	VHF	8	30–300 MHz 10 m – 1 m	
Ultra high frequency	UHF	9	300–3000 MHz 1 m – 100 mm	Chipless RFID – UHF Microwave Chipless
Super high frequency	SHF	10	3–30 GHz 100 mm – 10 mm	
Extremely high frequency	EHF	11	30–300 GHz 10 mm – 1 mm	MMID
Terahertz or Tremendously high frequency	THz or THF	12	300–3,000 GHz 1 mm – 100 μm	