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Understanding

RFID (Radio Frequency Identification)

(Passive RFID)

Second Edition

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FOREWARD

RFID Canada is a leading technology provider with 25 plus yearsôexperience in providing solutions including barcode, passive and active RFID (radio frequency identification).

RFID Canada warrants its success in identifying and developing comprehensive solutions in partnership with some of the most innovative companies, such as software providers, engineering firms, automation companies and system integrators that provide solutions to specific vertical markets domestically and globally.

Solutions include applications such as animal identification, document tracking, traceability, asset tracking, work-in-process, stock replenishment, personal identification and sporting events in a wide range of industries including agriculture, manufacturing, transportation, supply chain and distribution, retail, healthcare, pharmaceutical, libraries, government and many others.

A thorough understanding of RFID is crucial in assessing it as a solution for implementation and its return on investment (ROI). If the accuracy of your current system is nearly perfect and you have complete visibility into all your business processes, you may be questioning the benefit of RFID. If you simply look at the cost of implementing and supporting a new technology, without looking at the benefits that it can bring your operation, you may be asking yourself why RFID? If you do not take the time to learn about RFID and how it can improve your operation, it may seem that the cost is too high and the potential return unclear or not worthwhile.

RFID can maintain or increase your level of accuracy and visibility at a reduced cost. Although implementing an RFID system requires initial investment, the investment in new technology can improve the efficiency of your operation, reduce errors and improve on operating costs. With RFID, any movable item or asset can better and more efficiently be identified and tracked.

To be successful and to get the most benefits from implementing RFID, you will need to take the time to understand the technology and how it can work in your environment. You will also need to review your operations and identify all the areas or points where product is being handled and where data is collected.

RFID may be able to eliminate these manual data collection points by reading tags automatically as they pass through specific points giving you the accuracy that you require at a reduced cost.

The intent of this document is to provide a better understanding of RFID technology; its features, capabilities and limitations. Throughout we will illustrate the benefits that the technology can deliver through examination of some typical applications.

The discussions in this paper have been organized around the classifications along with the technology architecture and frequency lines. We will also provide some insight into important areas such as standards, regulations, safety and privacy, which are of concern to the users and providers of the technology alike.

1.0 INTRODUCTION TO RFID

Simply put, RFID is a form of automatic identification. However, its capabilities surpasses the traditional forms of auto ID technologies such as barcoding and magstripe, allowing to enhance and improve current applications and processes or enabling new identification and tracking applications not feasible or possible through traditional auto ID technologies in the past.

In the past 10 years, RFID has emerged as an innovative mainstream technology expanding beyond its proprietary and obscure application base in the decades previous. Today, RFID is considered an enabling technology, numerous applications and implementations across a wide range of industries and markets are testaments that the technology is beyond the hype curve and is solving problems and delivering real value on the ground.

RFID in principle is a simple technology, yet it is powerful, feature-rich and functional. At the highest level, RFID systems can be classified into active, passive and semi passive types with further grouping based on the frequency band they operate in, most notably, low frequency (LF ï 125 KHz to 135 KHz), high frequency (HF ï 13.56 MHz) , ultra high frequency (UHF ï 433 MHz and 868 MHz-956 MHz) and microwave[1] (2.4 GHz). We will discuss the characteristics of different types and different frequencies in more detail in later sections of this whitepaper.

Figure one shows the main components of a typical RFID system. The focal point in an RFID system is the RFID tag or transponder [2].The IC based RFID (as opposed to polymer based chipless RFID) in its simplest form comprises of an integrated circuit chip and an antenna mounted onto a substrate or an enclosure. The chip consists of a microprocessor, memory and RF communication, command control as well as data storage and processing. Depending on the type of technology, active, semi active or passive and the operating frequency, they vary in data storage, communication method and power source.

Distinguishing factors:

- Type : active , passive, semi active
- Frequency, LF, HF, UHF , microwave
- Electrical field , magnetic field
- Reader talks first vs. tag talks first
- Memory: read only (RO), Read-Write (R/W)
- Power
- Antenna ï gain, polarity

The transponders communicate via radio frequency to a reader, which has its own antennas. The readers can interface through wired or wireless medium to a main computer. Transponders are also known as smart or radio tags. The memory will vary, depending on the manufacturer, from just a few characters to kilobytes.

The two most common types of RFID technologies are Active and Passive. Active RFID transponders are self-powered and tend to be more expensive than Passive. Having power on board allows the tag to have greater communication distance and usually larger memory capacity. The most common application for Active RFID is for highway tolls such as the Highway 407 in Toronto, ON, Canada.

As for passive RFID transponders, which are available with chips and without chips, they have no internal power source therefore require external power to operate. The transponder is powered by an electromagnetic signal that is transmitted from a reader. The signal received will charge an internal capacitor on the transponder, which in turn will then supply the power required to communicate with the reader.

[1] In the electromagnetic spectrum, Microwave refers to the frequency range between 300 MHz and 300 GHz, which includes the Ultra High Frequency (UHF ï 300 MHz to 3Ghz band). In the RFID world, however, the microwave systems are understood to be the systems operating at 2.4 GHz range.

[2] At times the term ñTransponderò (**Tran**smitter-Res**ponder**) is used to refer to RFID tags, specifically when referring to active tags which actively transmit signals or low frequency passive tags.

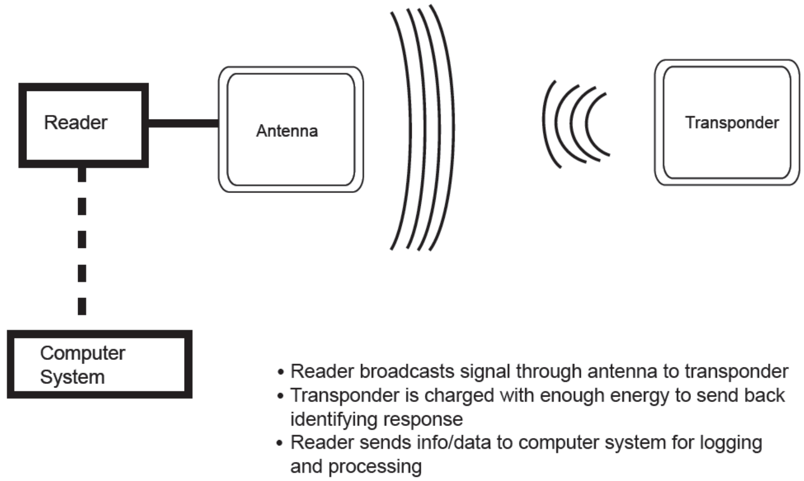

Figure 1

A BAP RFID (battery assisted passive) tag is fundamentally different than an active RFID tag because it utilizes the "reader-talks-first" principle. The batteries on BAP tags are activated only when scanned by a reader. Once activated, it uses the power of the battery. Once read, the tag goes back to "sleep", which helps extend the tag's battery life. The ISO/IEC 18000-6:2010[3] BAP RFID standard implements sophisticated tag selection capabilities, allowing readers to only request responses from tags meeting certain selection criteria. Using the "reader-talks-first" principle, combined with the sophisticated tag selection capabilities, readers can inventory all tags on a programmable periodic basis while also constantly inventorying tags based on certain selection criteria (e.g. only read tags that have alarm events).

Because of the high sensitivity of the BAP tag, the RFID reader's receiver sensitivity also should be high to be able to receive this signal. Keep in mind that high reader sensitivity does not help the performance of standard passive tags because performance in this case is limited by the reader-to-tag link. Lower sensitivity readers will still work, but they will provide shorter read distances.

Some of the most common uses of passive RFID today are for security and access control, payment, animal identification, waste management, work-in-process, asset tracking and electronic commerce.

Whether we are talking about active or passive RFID, the features and benefits are the same.

The following details some of the benefits:

- Transponders can be read from a distance and from any orientation, thus they do not require line of sight to be read.
- Transponders have read and write capabilities, which allow for data to be changed dynamically at any time.
- Multiple transponders can be read at once and in bulk very quickly.
- RF-Tags can easily be embedded into any non-metallic product. This benefit allows the tag to work in harsh environments providing permanent identification for the life of the product.

[3] The Revision 1 of the ISO/IEC 18000-6:2010 RFID received final committee draft approval in March of 2010 and was published in November 2010. This revision adds, among other new features, support for battery-assisted passive (BAP) RFID tags in two forms: a simple PIE mode battery assist extension for improving the range and reliability of ISO/IEC 18000-6:2010 (C1G2) tags, and a Manchester forward link mode (sometimes referred to simply as "Class 3") which adds many new mechanisms to enable significantly longer ranges (10X), maximize battery life, and to control the interference that results from such long ranges.

It is important to take the environment into consideration when implementing RFID. For example, metal, electrical noise, extreme temperatures, liquids and physical stress can create a challenge and may affect performance. For seamless integration, RFID Canada highly recommends that a site survey and testing be done. System implementation will be reviewed in Section VI.

Today, most implementations involve passive technology. For this reason, this document is based solely on passive RFID. There are different frequency bands which passive technology operates within.

Low and high frequency RFID operate on the inductive coupling principle. That is, the energy is transferred from the reader to the tag through shared magnetic field. The amount of transferred energy is proportional to the size of the transmitting and receiving antennas as well as the tag ability to operate at the resonance frequency. The resonant frequency is a state in which the impedance is at its minimum, allowing for maximum current flow in the circuit. The resonance frequency is a function of the inductance and capacitance of the tag circuit. The quality of a resonant circuit is measured by Q factor. The higher the Q factor, the higher the amount of energy transfer. Although higher energy transfer is desirable, the higher Q factor results in reduced bandwidth.

UHF RFID tags communicate with the reader using the backscatter principle. This is the same technique used in radar technology. The term backscatter refers to the portion of the transmitted signal that is reflected back 180 degrees opposite the direction of the incident signal, as opposed to random scattering that is lost in the space. The tag will send back data by means of varying the load of the received signal. The reader senses the varying field and demodulates the signal to retrieve tag data.

Currently, available UHF passive tags can contain a hybrid antenna which can operate with both the near-field and far-field components produced by the reader antenna. This appears as the combination of two topologies ï a closed loop to inductively couple the magnetic near-field and a dipole to couple the electric far-field. Such a tag can be used in a dual mode to take advantage of the different properties of each mode using a single tag design.

Of all the various frequency bands RFID operates within, there isnõt one that can address all applications. In essence, there is no super RFID frequency band; in other words, õone frequency does not fit allö. For this reason, the next three sections will review the most common passive RFID frequencies.

2.0 PASSIVE RFID

2.1 LOW FREQUENCY (LF) PASSIVE RFID

Transponders can either be read only (R/O) which are pre-programmed with a unique identification or they can be Read Write (R/W) for applications that require data to be stored in the transponder and can be updated dynamically. Another form of transponder is write once read many times (WORM). This will allow for an identification number to be written to the transponder once. The information is stored in the memory and it cannot be changed but the transponder can be read many times

Passive LF RFID has been utilized in several industries for many years. The most common frequencies used are 125 and 134.2 kHz.

One of the key features of LF RFID is that it is not as affected by surrounding metals. This makes it ideal for identifying metal items such as vehicles, equipment, tools and metal containers. The read range can vary from a few centimeters to a couple of meters depending on the size of the transponders and the reader being used.

Transponders come in various form factors, from glass, to wedge and disks of various sizes. Other form factors available are cards and cylindrical. These different form factors allow for the transponder to be embedded into most materials, except for metal. Other form factors such as key tags can also be customized.

LF RFID also penetrates most materials, such as water and body tissue. The limitations are that if used in industrial environments, electric motors may interfere with the LF system.

Due to the size of the antenna required, the LF transponders are typically more expensive than high frequency transponders. This limits the frequency to applications where the transponders can be re-used.

The following are some of the benefits and limitations of LF RFID:

- Penetrates most materials well including water and body tissue, which makes it ideal for animal identification
- Tags can easily be embedded into any non-metallic items such as pallets, key tags, cards etc.
- LF could be affected by electrical noise that may be generated by motors in an industrial environment
- Relatively low data transfer rate (70ms for read command), the lower the frequency, the slower the communication
- Transponders are more expensive
- Most LF systems can only read one transponder at a time and does not support simultaneous read of multiple transponders
- Read ranges are from a few centimeters to a couple of meters, depending on the size of the transponders
- Frequency is used worldwide. There are no restrictions

Numerous access control systems are based on LF, contact-less cards or key tags for security. A read only card can be used simply as identification or a read-write card can be used to maintain access or security information.

The largest user for LF RFID is the automotive industry. Currently, most car immobilizer systems use an LF transponder embedded into a car key with a reader mounted in the ignition. Other applications are vehicle identification for highway and parking lot access.

In Canada, the success story of Esso and their Speedpass system clearly exemplifies how this technology is being used to broaden and heighten brand awareness as well as customer loyalty program. In this case, a TI (Texas Instruments) glass transponder is embedded into a key tag. To maintain a high level of security, all transponders are programmed with an encrypted number, which is validated as soon as the transponder is presented to the gas pump. Following the validation at the pump, communication is established with Esso's accounting system. At that point, Esso's accounting system validates the customer's account, prior to activating the gas pump. The customer will then be charged for all purchases and Esso will automatically update their customer loyalty program.

Numerous automotive manufactures use LF RFID for work-in-process. Being able to insert a transponder into a pallet or product gives the manufacturer the reliability required and also allows for the product to be identified and used throughout the manufacturing process.

LF is also used for animal identification, from endangered species, to pets and livestock. Currently, cattle are identified with a bar coded ear tag. This form of identification is unreliable and is not robust enough for the environment. The Canadian Cattle Identification Agency (CCIA) is mandating that all cattle must be identified with an RFID ear tag. The standards being adopted are ISO 11784 & 11785, which have been in use in Europe for quite some time.

2.2 HIGH FREQUENCY (HF) PASSIVE RFID

Passive high frequency (HF) operates at 13.56MHz and is a globally accepted frequency. This means that any system operating at HF can be used globally. However, there are some differences with regulations in the different regions of the world. These differences pertain primarily to power and bandwidth. In North America, Industry Canada (IC) and the FCC limit the reader antenna power to three watts while in Europe the regulations allow for four watts.

HF is also the basis of numerous standards such as ISO 14443, 15693, 18000-3. These standards and others will be discussed in more detail in section V on RFID STANDARDS.

With HF, the signal travels well through most materials including water and body tissue. It is however more affected by surrounding metals compared to Low frequency (LF).

In comparison to LF, the benefits of HF are lower tag costs, better communication speed and the ability to read multiple tags at once.

The length of the antenna is based on the length of the signal wave thus the higher the frequency, the shorter the wavelength. For this reason, there is the flexibility that an antenna for a HF tag is small enough that it can be produced by printing it onto a substrate, using conductive ink and then affixing the chip.

Tags produced with HF chips are typically less than 0.1mm in thickness and are available with different sizes of antennas. The larger the tag antenna, the greater the energy capture area the tag has and the greater the communication distance from the reader. Smaller tag sizes may be easier to package into a product but the downside is the reduction of communication distance available.

The capability of the small inlay size allows for it to be embedded into labels. Labels with inlays are called smart labels. Through the use of printers with embedded RFID or external readers, smart labels can not only be printed on; they can also be written to.

With the current power regulations, HF is designed for applications that require a 1m or less of communication range. Orientation of the tags with respect to the reader antenna will have an impact on the communication range. For optimum communication range, both antennas (tag and reader) should be parallel. Having the tag perpendicular to the reader antenna may significantly reduce the communication range.

The higher the frequency, the higher the data throughput and the faster the communication will be between the reader and the tags. This increase in speed allows for the reader to communicate with multiple tags at once. The process of communication with multiple tags is known as anti-collision and at HF, a reader can read more than 50 tags per second.

The following are some of the benefits and limitations of HF RFID:

- Penetrates most materials well including water and body tissue
- Not as effective as LF in the presence of metal and water
- Tags can easily be embedded into non-metallic items such as labels, pallets, key tags, cards etc.
- HF should not be affected by electrical noise that may be generated by motors in an industrial environment
- Higher data transfer rate (20ms for read command), the higher the frequency, the faster the communication
- Transponder are less expensive
- Reader can communicate with multiple tags simultaneously
- Read range is less than one meter
- Tags have larger memory capacity
- Frequency is recognized and used globally (no restrictions)
- Global standard: ISO 15693, 14443A, 14443B, 18000-3
- HF is also the frequency for NFC (Near Field Communication)

HF is also used for access control and security systems. The additional memory allows for improved security and the integration of biometrics as part of the security features. Enhanced access control systems have the ability to validate assets such as office equipment, i.e., computer equipment and other items as one passes through an access control system or portal. Assets embedded with a HF tag can be read and identified within the access control system. Documents and files can easily be identified and tracked as well.

Contact-less smart cards or RFID cards are going to be the next generation of credit cards. Credit card companies have been testing HF RFID based on ISO 14443 standards for some time. One of the main reasons for the switch to contact-less smart cards is primarily due to the ruggedness and consistent performance levels associated with RFID. When a tag is embedded into a card or other form factors, the tag is essentially protected from the surrounding environment. As for the readers, they can also be encased and protected from the surrounding environment. The second reason for the switch to RFID is the additional memory the tags can store. This allows for better security and protection of privacy issues. By using biometrics and personalized access numbers, improved security can be accomplished.

From a computing/communications infrastructure point of view, smart cards provide localized intelligence that enables distributed computing whereby transactions can be authorized and performed without continuous direct communication and intervention from a centralized backend server. Increased memory, security (encryption) and processing at user card interface reduces network traffic with this delegated local responsibility.

In Hong Kong, more than nine million people use the Octopus card to access their public transit system. The city of Toronto and surrounding municipalities have introduced a transit payment system, called Presto, based on ISO 14443, for payment and access to all transit systems in the area. This will allow travelers to move seamlessly between trains, light rail, metro and buses within the Toronto and greater area using one single, contact-less ticketing solution.

Numerous sports teams and events are using HF RFID for payment and access. Most ski hills in Europe use the technology for convenience and for prevention from fraud. Large events such as the Olympics and the world cup have used tickets embedded with HF inlays.

HF is also a solution for identifying products, such as cases and pallets. The communication range of HF limits the type of warehouse or logistics applications. For retail or for applications that do not require long communication distances, HF is a very good solution.

High Frequency RFID is an ideal solution for applications that require lower cost identification and the ability to read multiple tags at once at a distance of one meter or less.

2.3 ULTRA HIGH FREQUENCY (UHF) PASSIVE RFID

Ultra high frequency is referred to the frequency range 300 MHz to 3 GHz in the radio spectrum. RFID technology has been developed in different regions using these bands, specifically, 433 MHz, 860 -956 MHz and 2.45 GHz. The focus of this article will be specifically on the 860-956 MHz range due to the fact that this range has attracted most R & D investments and is positioned to dominate the UHF passive RFID market space.

UHF coming to prominence in the RFID market place is a fairly recent phenomena compared to the more established High Frequency (13.56 MHz) and Low Frequency (125-134.2 kHz) technologies. HF is a robust technology, which works well for item management applications, but fails where read ranges of beyond 1m is required. UHF is ideal for applications such as supply chain market where longer read distances are required.

Technologically speaking, RFID in the UHF range differs from High Frequency systems in a number of ways. UHF operates, primarily, in 860-956 MHz range allowing for shorter antennas and longer read distances. Reader-tag communication is implemented using backs-scatter technology. In this method, tag communicates with the reader by modulating the received signal and radiating it back to the reader. This scheme is fundamentally different than the inductive-coupling method used in HF systems. Moreover, the anti-collision (simultaneous reads) feature implementation in UHF is achieved using a protocol based on bit broadcasting as opposed to HF protocol that operates based on the time slot concept. This allows for higher number of tags to be read simultaneously in the UHF range, typically greater than 200 tags as opposed to 50+ tags with HF systems.

Although the UHF RFID addresses some shortcomings of the HF RFID, primarily in terms of read range, it has to contend with its own limitations and challenges. UHF systems do not work well in the presence of liquids whereas HF and LF work fairly well in such environments. Metal poses a challenge for any RFID implementation, more so in the UHF range, however, the advent of UHF on-metal and in-metal tags have largely met this shortcoming. Still, longer read distance becomes a disadvantage in applications such as banking and access control.

Current UHF passive tags are designed for wideband operation. Readers must conform to the regulatory environment in which they operate, but today's tags may operate unimpeded globally. Inlays are designed to operate globally, delivering global operation from 840 to 960 MHz. This enables the same inlay to be used successfully at the diverse frequencies of the Americas, Europe, Asia, and Africa. World tags allow companies to manufacture products on one continent and ship worldwide utilizing a single RFID inlay.

The following are some of the benefits and limitations of UHF RFID:

- Provides good read distances, up to 10 m
- Tags can easily be embedded into solid non-metallic items such as labels, pallets, cards etc.
- High data throughput and faster anti-collision scheme facilitate higher read rates. 800 reads, per second, is achievable in theory but 200 is the read rate for practical purposes
- UHF transponders cost less compared to HF due to simpler manufacturing processes such as printable antennas
- TAGS – serialized unique TID (tag ID), extended commands (EAS), larger specialized memories (64kByte)
- READERS – reporting tag velocity and directionality
- Poor performance around liquids and metals extended by specialized on-metal, in-metal, balanced in-on metal tags
- Crowded frequency band, 860-960 MHz falls within the ISM (Industrial, Scientific, Medical) band, making it one of the more crowded regions of the spectrum

There are complicating factors that have somewhat hindered faster progress in the UHF RFID market. ISO and EPC Global are the main bodies that work to draw standards and specifications for UHF RFID. The ISO standards for the 900 MHz UHF band are 18000-6-x.

The RFID industry is on the verge of a breakthrough. The market has passed its infancy and there is no doubt that this technology is going to revolutionize the way we live. RFID will add intelligence to objects and that will change the way rfidcanada

people interact with them. There is no single RFID technology capable of working in all the applications. Different RFID technologies will be complementing each other, each serving functions that most suit its characteristics.

3.0 RFID STANDARDS & Regulations

The purpose of standardization is to define the most efficient platform on which an industry can operate and advance. There are several organizations involved in drafting standards for RFID technology. Most notably, International Standards Organization (ISO) and EPC Global (Electronic Product Code) have had many initiatives related to RFID standards.

ISO, which represents true global interest, has been involved with different RFID technologies for many years. Most of the work has been through various sub-groups of Joint Technical Committee One (JTC1[4]) which is responsible for drafting standards for information technology.

In 1999, several universities sponsored by the consumer product industry formed Auto Id Center with a mandate to advance RFID technology. In 2003, the Auto Id Center was reorganized to create EPC Global under the GS1 umbrella to manage the business side of the RFID market. The founding universities continue their research and development for the EPC Global under newly formed Auto Id Labs. EPC Global is responsible for defining specifications for all aspects of RFID technology including standardization.

In addition to ISO and EPC Global, there are many other global and regional organizations and regulatory bodies involved in RFID standardization. Organizations such as the AIAG, NISO, FDA and UPU are some of these.

In this section, we embark on exploring the status of standardization in the RFID industry with the focus on ISO and EPC.

3.1 ISO (LF, HF and UHF)

Low frequency is the oldest adopted RFID technology, which has been implemented mostly in manufacturing and agricultural applications. Thus far, there has been little work done in terms of standardization in the low frequency arena. This is mainly due to the fact that most of these implementations have been in closed-loop and controlled environments. In the agriculture sector, however, the nature of animal tracking has required some standardization. ISO 18000-2, 11784 and 11785 are the notable standards in the low frequency technology that has been in use for some time in animal tracking.

ISO 11784 and 11785 are specifically designed for animal tracking and work in tandem. In brief, ISO 11784 defines the data structure of the animal tag. In this standard, animals can be identified by country code and unique national ID. There are also provisions to use a manufacturer code in place of the country code. ISO 11785 is concerned with the technical aspects of reader-tag communication. There are several shortcomings in these two standards that have limited its widespread usage but they have proven effective where implemented.

ISO has renewed its efforts to develop standards for the low frequency. The process is managed by the SC31 / WG 4 which has been mandated with the responsibility to create standards for "Radio Frequency Identification for Item Management". The 18000 series encompass all different frequencies. ISO 18000-2 was finalized and published in 2004. This is the standard defining parameters for air interface communications below 135KHz, that is, the LF range. We should take note that the EPC Global is also working towards creating standards and specifications for the LF RFID.

Amongst all the different RFID technologies, high frequency has the most established and commonly used standards. This could be attributed to the fact that 13.56 MHz is a globally available frequency for RFID, JTC1/SC17/WG8, which is the work group for "Contact-less Integrated Circuit Cards", and started the standardization process for HF RFID in 1995. That resulted in ISO 15693 and 14443, the most widely RFID standards used to date.

ISO 15693 was published in 2000 defining parameters for vicinity RFID cards, generally used in applications that require read ranges of more than 10 cm. The specifications have been organized in three separate parts covering physical characteristic, air interface and communication protocol.

[4] ISO and International Electrotechnical Commission formed the Joint Technical Committee 1 (JTC1) in 1988 to develop standards for Information Technology.

ISO 14443 is the standard for the proximity RFID cards with the read range being limited to less than 10 cm. This standard is organized much the same way as the 15693 standard defining similar parameters in different parts of the standard. The main difference between these two standards is their intended application. ISO14443, because of its short read distance and encryption capabilities, is more suitable for applications where security is a serious concern such as electronic payment, banking and financial transactions. In addition to the two standards discussed, SC17/WG8 has drafted several other standards pertaining to the use of RFID which is outside of the scope of our discussions here.

Although ISO 15693 and 14443 are the established standards and have worked well so far, some industry experts are of the opinion that they do not address all the issues. ISO started a more focused process under the SC31 umbrella for RFID standardization. ISO 18000-3 is the new standard for 13.56 MHz RFID. This standard was published in 2004 after 3 years of deliberation. ISO 18000-3 is a comprehensive standard that has built upon the existing ISO 15693. It has two versions, with version 1 being very similar to ISO 15693.

Moving on to the UHF (860 MHz-956MHz) band, we see the highest concentration of energy and efforts to draw standards. At present, there is no globally accepted frequency within the UHF band, due to restriction in different regions of the world. Realizing that RFID will not have access to a uniform worldwide frequency in the UHF band, the industry has come to terms with this fact and have started developing products that are either specific to the region or able to work with different frequencies. In North America, UHF RFID uses 902MHz-928MHz where 860MHz-868MHz and 950MHz-956MHz are used in Europe and Japan respectively.

ISO's work in the 860 - 956MHz UHF band has resulted in ISO 18000-6, which has been published. This standard defines parameters for air interface and communications. As in the case of other 18000 series standards, part 6 covers all technical aspects of RFID communications in great detail.

As mentioned above, 18000 series defines the air interface parameters for different frequencies in parts 2-7 and part 1 covers general parameters common to them. In addition, ISO/IEC 15961, 15962 and 15963 have been finalized and published in the fall 2004. ISO/IEC 15691 defines parameters and commands for communication with the application software while ISO/IEC 15962 deals with the processing of data and its presentation to the RF tag, and the initial processing of data captured from the RF tag. ISO/IEC 15963 deals with the unique identification code (UID) and describes the numbering scheme for tags.

Table 1 below is a summary of the most common ISO standards.

Table 1 - Common ISO Passive RFID Standards

ISO Standard	***Title***
ISO 11784	Radio frequency identification of animals -- Code structure
ISO 11785	Radio frequency identification of animals -- Technical concept
ISO/IEC 14443A,B	Identification cards - Contactless integrated circuit(s) cards - Proximity cards
ISO/IEC 15693	Identification cards - Contactless integrated circuit(s) cards - Vicinity cards
ISO/IEC 18001	Information Technology - AIDC Techniques - RFID for Item Management - Application Requirement Profiles
ISO/IEC 18000-1	Generic Parameters for Air Interface Communication for Globally Accepted Frequencies
ISO/IEC 18000-2	Parameters for Air Interface Communications below 135KHz
ISO/IEC 18000-3	Parameters for Air Interface Communications at 13.56 MHz
ISO/IEC 18000-4	Parameters for Air Interface Communications at 2.45GHz
ISO/IEC 18000-6	Parameters for Air Interface Communications at 860-960 MHz
ISO/IEC 18000-7	Parameters for Air Interface Communications at 433 MHz
ISO/IEC 15961	RFID for Item Management – Data protocol: Application interface
ISO/IEC 15962	RFID for Item Management – Protocol: Data encoding rules and logical memory functions

ISO/IEC 15963	RFID for Item Management – Unique Identification of RF Tag

Thus far, we have mainly focused on the ISO standards. At this point, we are going to turn our attention to EPC Global initiatives.

3.2 EPC (HF and UHF)

EPC Global's mission started with the vision to identify every item with a unique electronic product code (EPC). A global network will be implemented to make every item visible throughout the supply chain. A great amount of research and development resources have been invested in creating specification and standardization of the EPC tags and the required infrastructure. Although EPC Global efforts are not limited to the UHF, it has been their main focus.

EPC Global through its research wing, Auto ID Labs, has defined specifications for different classes of EPC tags. Currently, class 0 and class 1 tags are commercially available. Class 0 EPC tags have a factory programmed 96 bit code whereas class 1 facilitates user programmable codes. EPC Global has proposed other classes of EPC tags that would provide user memory beyond the ID code. It has also created detailed specifications for the structure of the 96-bit code flexible enough to incorporate other coding standards currently in use in the supply chain. The 96-bit EPC provides unique identifiers for 268 million companies. Each manufacturer can have 16 million object classes and 68 billion serial numbers in each class. There are new numbering schemes have been introduced with 128-bit and 256-bit serial numbers to accommodate exiting identification standards. The latest EPC standard, Class 1 Gen 2 has been ratified.

EPC network or UCCNET as dubbed recently, will track EPC tagged objects as they move through the supply chain from source to consumption. We will briefly describe different components of the EPC network below:

EPC Network Description:

- ONS (Object Naming Services) is analogous to DNS (Domain Name System) in a typical network. Every EPC tag is tied to the detailed item information through a local network or the Web
- Savant is the software technology to serve as the nerve system for the network managing flow of data
- Physical Markup Language (PML) is a sub set of XML language that has been specified as the standard development platform for the EPC network

The RFID industry is moving fast to enhance current standards and create the new ones required for the worldwide implementation of the technology. We are witnessing considerable efforts channeled towards this goal and we hope that standardization process can soon catch up with advancements in other aspects of the industry. ISO is the global authority for standardization and EPC Global is a major force in the RFID market with the great support of the consumer industry. Although it is possible for these two organizations to work side by side, some believe that there could be more achieved through collaboration than competition when it comes to standardization.

Table 2 below is a summary of EPC Global specifications

Table 2 – EPC Global Specifications

EPC Global Specifications	
EPC Tag Data Standards	Specific encoding schemes for a serialized version of the EAN.UCC Global Trade Item Number (GTIN®), the EAN.UCC Serial Shipping Container Code (SSCC®), the EAN.UCC Global Location Number (GLN®), the EAN.UCC Global Returnable Asset Identifier (GRAI®), the EAN.UCC Global Individual Asset Identifier (GIAI®), and a General Identifier (GID).
UHF Class 1, Generation 2 Specifications	Communications interface and protocol for 860 - 960 MHz, built upon Class 1
HF Class 1 Specifications	Communications interface and protocol for 13.56 MHz Class 1
Reader Protocol	Communications messaging and protocol between tag readers and EPC compliant software applications

Savant Specification	Specifications for services Savant performs for application requests within the EPC global Network
Object Name Service Specification	Specifications for how the ONS is used to retrieve information associated with a Electronic Product Code (EPC)
Physical Markup Language Core Specification	Specifications for a common vocabulary set to be used within the EPC global Network to provide a standardized format for data captured by readers

- The UHF and HF specifications are logically similar. Consequently, the Low-Level Reader Protocol (LLRP) supports EPC Global UHF Gen2 V1.2.0 and EPC Global HF Gen2 V1.0.3.
- The data format, memory partitioning and essential functions (inventory, read, write, lock and kill) are identical for both standards. This implies that EPC based applications can treat UHF tags and HF tags identically.
- The signaling layer used by EPC Global UHF Gen2 V1.2.0 and EPC Global HF Gen2 V1.0.3 are diverse ways of communicating with HF tags and UHF tags.
- Both the UHF and HF Standards implement the item level requirements identically

4.0 RFID SYSTEM IMPLEMENTATION

For an RFID project to be successful, it is necessary to approach the business problem and potential RFID solution using a systems approach. In your design process, you will need to look at all the processes, be forward thinking and think creatively on how you can improve on each operation.

RFID systems should be conceived, designed, and implemented using a systematic development process in which end-users and specialists work together to design RFID systems based on the analysis of your business requirements of the organization

Implementing an RFID based system is like implementing any system. You will need to determine where RFID can be used and prioritize your strategy based on where you will achieve the fastest and highest level of benefit. You will need to think big but you should start small with pilot projects.

In addition, you will need, like any system implementation, to allow and plan for potential failures and problems. To successfully implement an RFID system, the following is a checklist that will help you in your design and the potential for problems or failures.

Business:

- What are the Business Requirements?
- Why are you implementing RFID?
- Are you being mandated or are you looking at improving your internal operation?
- Is there a requirement or preference for standards?

Tags:

- Do you require disposable tags or can you use reusable tags?
- Type of tag required (Read only, R/W, WORM)?
- Maximum amount of data to be stored in the tag (data capacity)?
- What is the data format?

Reader:

- What is the required read zone (width, height, and depth)?
- How may tags will the reader read or write to at one time?
- What are the possible location(s) for the tag?
- Orientation of the tag?
- Distance between tags?
- At what speed and direction will the tags be travelling?
- What error control and correction will be required?
- Do you require any data security?
- What will the required distance be between different reader antennas?
- What is the distance between antenna location and the reader?
- Is portability a requirement?
- Data interface and protocol ï reader/interrogator (batch, on line, wireless, Ethernet, etc.)?
- Reader Power Supply ï DC, AC, POE?

Environment:

- Environment: Metal, Tags and reader antenna proximity to metal?
- Temperature, humidity, and exposure to chemicals, UV and X-rays, mechanical stress?

Systems:

- How and where will the tags be applied?

- What do you do when a tag is read?
- What do you do if a tag is not read?

It should be noted that the larger the coverage area in the environment, the greater the implementation challenges. Therefore, the longer the reading distance between the tag and the reader, the greater noise and interference are to contend with.

There seems to be a lot of attention given to the cost of tags. The benefits that can be derived from implementing RFID can far outweigh the cost of the tags. There is an investment in time and money required however to be successful and get the best return on investment, you need to understand the technology and how it can benefit your organization.

By understanding the technology, you will be able to reduce your overall cost of implementation. In addition, you will not only be able to meet the demands that may be imposed upon your company but also achieve the increased revenue associated with implementing this technology.

We hope that you can benefit from this document and should you have any comments or questions, please contact RFID Canada at +1 (905) 513-8919 ext.25 or email at info@rfidcanada.com.

As part of our marketing and educational processes, RFID Canada regularly hosts educational seminars and works with the public education sector (post-secondary institutions) to create a level of knowledge for students that can be utilized as they enter the work force.

RFID Canada is a technology provider and works closely with systems integrators to provide a complete solution.

Glossary of Terms

AIAG	Automotive Industry Action Group
BAP	Battery Assisted Passive
C1G2	Class 1 Generation 2
CCIA	Canadian Cattle Identification Agency
DNS	Domain Name System
EAN	European Article Number (renamed International Article Number)
EAS	Electronic Article Surveillance
EPC	Electronic Product Code
FCC	Federal Communications Commission (USA)
FDA	Food and Drug Administration (USA)
GIAI	Global Individual Asset Identifier
GID	General Identifier
GLN	Global Location Number
GRAI	Global Returnable Asset Identifier
GTIN	Global Trade Item Number
HF	High Frequency
IC	Industry Canada
IC based RFID	Integrated Circuit RFID
IEC	International Electrotechnical Commission
ISM	Industrial, Scientific and Medical
ISO	International Standards Organization
LF	Low Frequency
NISO	National Information Standards Organization (USA)
NFC	Near Field Communication
PML	Physical Markup Language
ONS	Object Naming Services
RFID	Radio Frequency Identification
RO	Read Only
R/W	Read Write
SCC	Shipping Container Code
SSCC	Serial Shipping Container Code
UCC	Uniform Code Council
UCCNET	UCC Network
UHF	Ultra High Frequency
UPU	Universal Postal Union
WORM	Write Once read Many times
XML	Extensible Markup Language