Electro- Magnetic RFID:

Everything You Need to Know About Inductively coupled RFID

EVERYTHING YOU NEED TO KNOW

A White Paper on Radio Frequency Identification (RFID) technology.

How it works and when to use it.

This paper was revised in 1997, as RFID continued to emerge as a major automatic identification technology. The updated information is accurate as of the publication date, but this evolving technology changes quickly.

RFID is often embedded in systems with other technologies such as bar code and RF data collection systems. Integrated manufacturing systems, for example, are using bar coded shop floor documents to log labor to a work order while RFID is used to automatically route the work in process inventory to the correct work centers.

WHAT IS RFID?

RFID is an automatic identification technology similar in application to bar code technology, but uses radio frequency instead of optical signals.

Bar code systems employ a reader and labels attached to objects. RFID uses a reader and special tags or cards attached to an integral part of the object. Instead of using laser light reflections off printed bar code labels, RFID uses low-wattage radio frequencies. These broadcasted radio waves do not require a direct line of sight; they will travel easily through nonmetallic materials and do not have to be in contact with the device which ìreadsî the radio signal.

RFID manufacturers use selected frequencies from a low of 50 kHz to a high of 2.5 GHz. Low frequency (50 kHz to 14 MHz) systems are generally low cost, work at close range, do not require licensing and are tolerant of metal and electrical noise. High frequency systems (14†MHz to 2.5 GHz) generally cost more, work over greater distances, are more directional, and may require licensing and site surveys. Performance of RFID technology may be adversely affected by the presence of electromagnetic noise or metal in the environment.

BENEFITS OF RFID

Like other automatic identification technologies such as bar codes, RFID speeds the collection of data and eliminates the need for human operations in the process. The amount of data needed by modern factory automation is so overwhelming and the time needed to process it so long, the only practical method of collecting process data is automatically with the help of computer-based identification and tracking systems. Automatic data acquisition improves the value of the information in a system by making it available sooner. In a manufacturing facility, finding out that the work in process inventory has been mis-routed, for example, is valuable only if discovered quickly, so corrective action can be taken immediately.

Other automatic technologies rely on optics (bar code and vision systems) and require a relatively clean and moisture-free environment. Touch memory does not use optics but does require a relatively clean environment because contact must be made to read the tag.

RFID is ideal for dirty, oily, wet, or harsh industrial and commercial environments. RFID tags and readers have no moving parts; the system rarely needs maintenance and can operate flawlessly for extended periods of time. Passive RFID tags have extremely long life. They will usually last longer than the object to which they are attached. Active tags will often last three to ten years. RFID is clearly the cheapest form of automatic identification when evaluated over time.

Unlike bar codes, RFID tags are virtually impossible to copy. The technology is ideal for confidential identification of people or assets. RFID is fast: The tag and reader communicate in milliseconds. Actual throughput depends on communication with the host computer, but the total speed of a valid read is 30 to 100 milliseconds using an Indala read-only tag.

Because RFID will read through nonmetallic materials, the internal components are often packaged in materials that will survive very harsh environments. Some Indala RFID tags (IT-52E, IT-253E, IT-254E) will survive temperatures ranging from minus 40 degrees centigrade to 200 degrees centigrade. The toughest tags are not affected by most acids and caustics. RFID tags will read through dirt, paint, and cement!

HOW RFID WORKS

Reader sends energy to tag for power

Tag sends ID data back to the reader

Reader decodes and transmits to the host

An RFID system consists of two major componentsóthe reader and the tag or card. They work together to provide the end user with a non-contact solution to uniquely identify people, animals or objects.

The reader performs several functions, one of which is to produce a low-level radio frequency magnetic field. The RF magnetic field emanates from the reader by means of a transmitting antenna, typically in the form of a coil. The magnetic field serves as a ìcarrierî of power from the reader to the RFID tag.

A passive RFID tag contains an antenna, also in the form of a coil, and an integrated circuit, or IC. The IC requires only a minuscule amount of electrical power to function. The antenna in the tag provides a means for gathering the energy present in the magnetic field produced by the reader, and converts it to an electrical form of energy for use by the IC.

When a tag is brought into the magnetic field produced by the reader, the recovered energy powers the IC, and the memory contents are transmitted by the tagís antenna. With Indala products, this data transmission occurs simultaneously with the gathering of energy from the antenna, minimizing the amount of time required to read a tag. In Indalaís line of passive tags, the output signal is in the form of an alteration of the existing magnetic field (from the reader) surrounding the tag. This approach affords higher power efficiency. Higher efficiency translates into greater read range, as well as lower tag cost.

The electromagnetic signal from the tag is recovered by an antenna within the reader, and converted back into an electrical form. The reader contains a sensitive receiving system that is designed to detect and process the weak tag signal, demodulating the original data stored in the tag memory. Once the tag data has been demodulated, a microcomputer within the reader performs error-checking functions to verify that it has received a valid signal. The reader uses additional information stored within tag memory to perform the validation process. Once the reader has checked for errors and validated the received data, the data is decoded and re-structured for transmission in the format required by the end userís host computer system. All of these operations take place in the blink of an eye.

Active tags contain a miniature battery that provides the operating power for the IC. When interrogated by the reader, the IC broadcasts a signal that identifies itself to sensitive reader detection and data transmission circuits. This allows the tag to begin sending its data at a considerably greater distance from the reader than its passive counterpart. Additionally, an active tag uses battery energy to produce a much stronger electromagnetic return signal. All of this results in a significantly greater read

range than a passive tag. Indalaís active tags do not require special readers, and can therefore readily satisfy applications that require a mix of both passive and active tags.
It is important to note that a finite amount of time is required to read a tag, process the information and transmit the data to the host computer system. If the tag is moving past a reader quickly, and does not remain in the read zone long enough, a successful read will not occur. The tag may communicate with the reader, however, if it is moved closer to it, even with the same presentation speed. This may give the impression that the read range performance is deficient. The tag will read at the closer distance because the field is broader(covering a larger area closer to the reader. Therefore, the tag can be read because it is in the read zone long enough to transmit all of its data before leaving the field. In the design of an RFID system, the speed of travel and read area requirements must be considered in addition to read range.
Active tags can be useful in applications with limited read areas and high tag travel speeds. Because active tags begin transmitting farther away from the reader than passive tags, the use of an active tag effectively increases the size of the read zone.
Read range, or the maximum distance from the reader at which a tag may be read, is generally a function of the antenna size within the reader and/or the tag for a given operating frequency. Larger readers and/or larger tags usually have greater read range.
The read area is also a function of the antenna size and shape. Higher operating frequencies such as 900 MHz and 2.45 GHz provide longer read range with smaller antenna sizes. Indala manufactures a line of low frequency, 125 kHz, RFID products with many different readers, tags, and cards designed to meet the needs of a wide range of applications.
RFID tags (commonly known as transponders) are available in many sizes and shapes, but all contain these common elements:
A coil or coils, which act as the antenna.
A silicon chip, which contains a radio transceiver; an analog-to-digital converter; a computer and memory.
The core can be air or ferrite (rod). If the tag contains a battery or another means to supply power, then it is considered an ìactiveî tag. Active tags running on a battery usually have the same shelf life as the battery, i.e., three to ten years.
The final element is the packaging, which can look like virtually anything: a credit card, a button, a hockey puck, a grain of rice, or a tube of lipstick.
All RFID readers have the same basic architecture: an antenna (a coil of wire in a housing with a driver board), reader electronics (decoder, data converter, computer interface), and a power supply. Computer interfaces available from vendors are usually RS232, RS422, and RS485. Ethernet and LONworks communications are also possible. Typically, plug-compatible interfaces that emulate bar code wand, Wiegand ™ card, and magnetic stripe technology are common. Ease of connectivity allows RFID readers to talk to virtually all popular data collection terminals, computers, and networks.
Portable readers have the same basic architecture as other RFID readers but t____ the elements are typically enclosed in a single hand-held unit. The portable readers often draw power from their host. Indala portable units can be configured with RS232, bar code wand, or keyboard emulation.
COMMUNICATION METHODS
Various communication methods are employed by RFID vendors to provide a link between the tag and reader. The objective is to transmit the tag data to the reader in a fast, reliable manner. Normally, a reader will generate a carrier signal by modulating

a magnetic or electric field at a given frequency. The basic process is for the tag to modulate data using the carrier signal provided by the reader as a power source and reference clock. The tag modulates the carrier signal by varying the frequency, phase, or amplitude. The carrier signal may be pulsed on and off at a certain rate or transmitted continuously. In the presence of this signal, the tag will activate and transmit either pulsed or continuous data. For a carrier signal of a given frequency, a continuous type can transmit data faster than one that is pulsed. In turn, the reader demodulates the signal from the tag to extract the data. Indala systems use the continuous transmission method.

Communication systems are subject to interference from unwanted signals(electromagnetic noise. As an example, nearly everyone is familiar with the difference in sound quality between AM and FM radio which illustrates how amplitude modulation is more susceptible to noise than frequency modulation. Phase modulation is an advanced type of frequency modulation that provides for faster transmission of data. Indala uses a phase modulated continuous carrier; because it is an FM system, itís not as sensitive to noise.

To protect against a noise-induced ìmisreadî, tag data contains bits that are encoded to provide for error detection by the reader. This can range from a simple parity check to a more elaborate Cyclical Redundancy Check (CRC), the type used by Indala. This improves the reliability of the system because corrupted data from the tag is ignored.

TAG ORIENTATION

RFID tags operate most efficiently when ìin phaseî with the antenna. Optimal electromagnetic coupling occurs when the antenna coils of the tag and the reader are parallel to each other or ìin phase.î

When the tag is perpendicular to the antenna, it is ìout of phaseî and read range is reduced.

With low frequency tags (100 kHz to 400†kHz) which are generally short range, the read range of an ìout of phaseî tag could be as much as 50%. This means a tag that will read at 12 inches will read at 6 inches when out of phase. A low frequency tag must be at 90 degrees or perpendicular to be out of phase. A slight tipping of the tag toward the antenna will bring the tag into phase.

For high frequency tags (above 1 MHz), which are generally used for long-range applications, this out of phase phenomenon has a more dramatic effect on read range. With simple antennas, high frequency tags have to be ìbeamedî or aimed towards the antenna analogous to a flashlight beam. To overcome this beam effect, complex antennas incorporating backscatter are used.

Successful implementation of an RFID system will take into consideration tag orientation.

MULTIPLE TAGS IN A FIELD

Reading multiple tags in a field is a complicated problem and very difficult to accomplish with efficiency. Since the tags transmit weak signals, the challenge is to read all of the tags accurately within the constraints of the applicationís time window.

Collisions

When two transponders are in the field of a reader at the same time, they may both try to transmit to the reader simultaneously. The reader will likely read the strongest signal, but there is a chance that no tag will be read. The simplest solution is to use a reader with just adequate range so that the reader will usually have only one transponder that is within its short range. Phase or frequency modulation may be used for communication so the receiver is able to ignore weaker signals. A common method used to avoid collision is to design the transponders to select random delay

times before replying. This allows the reader to receive transponder signals one at a time.
Other methods involve using directional antennas to reduce the number of transponders that reply to each request. In addition, transponder (tag) frequencies may be spread over a band of frequencies, which the reader then scans.
When a larger number of transponders are in the field at the same time, it is essential that the reader can turn off each transponder after its transaction is complete; this eliminates collisions from unnecessary repeat transmissions. RFID vendors may use any combinations of these techniques to eliminate collisions.

Speed: Some Important Design Issues

When phase or frequency modulation is used, the transponder with the strongest signal will be read immediately but other transponders will not be read until they have the signal strength advantage over the other tags in the field. Maximum speed is obtained when short range allows reading a single transponder so that no anti-collision delays are needed.
All other methods add some delay to the average transaction time. Addressing specific transponders may require a long delay while a number of requests are transmitted, and this delay can often be unacceptable for the application. Random reply times add a statistical delay. Directional antennas require time to address each antenna pattern. Frequency dispersion requires time for the reader to scan through the band of frequencies.
Interference may slow the transaction by requiring repeated transmission, and longer transactions to provide better error detection or error correction.
All of these problems must be addressed successfully at the front end of the design process and some trade-off must be expected.

Accuracy

Multiple transponders in a field may interfere with each other in such a way that data transmission is corrupted. The interference may corrupt a transmission that is not detected by error detection. A write to one transponder may overwrite data in other transponders.
Some transponders achieve better accuracy by sending repeated data, so that several sets of received data may be compared. Error detection methods are used to determine when an error occurred, so that the data may be retransmitted. Error detection requires the transmission of additional bits with the data and requires additional processing time to test the data.
Read-only transponders need only send repetitive data to the reader when they are powered up by the reader exciter field. Read/write transponders usually wait for a query from the reader before responding. When the read/write transponder is written to, it needs to perform three operations: a read, a write and a verify which ensures that the write operation has been accurate.

System Implications

Systems must be designed or specified to handle the actions and interactions of multiple transponders.
Range should not be longer than required.
Modulation should be Binary Phase Shift Keyed (BPSK), and the data rate may need to be increased to allow for reading multiple transponders and for collision avoidance techniques.
Frequencies may need to be higher to support higher data rates.
More complex directional reader antennas may be required.
Larger reader antennas may be needed to increase the time a moving transponder is in

the field.
Error detection and data re-transmission are usually required even for a single transponder.
A system design approach is required for any transponder system. The requirements for multiple transponders, speed of operation, accuracy, cost, and security must all be considered to provide the result demanded by the application.
Indala does not currently offer RFID systems that read multiple tags in a field. Indala tags read continuously. Tags moving through a field will be read as they become the strongest tag in the field. This happens at high speeds and can give the illusion that multiple tags are read in the field. In reality, only one tag is read at a time as it becomes the strongest tag in the field.

Radio Frequency Selection

The radio frequency selected for use to power up the tag is based on maximizing proximity read range performance while staying within the limits of radiated power levels imposed by various national authorities. Allowed power radiation varies from country to country and is often subject to change. Data transmission and communication frequencies from reader to tag are not subject to government power regulation because the transmissions are extremely low power. Data from the tag to the reader are typically sent on a binary divisor band of the powering frequency. Division of the powering frequency to create a data frequency is done because it is easy to implement in IC logic in the tag and does not overlap with harmonics generated by the powering frequency operations.
The drivers for RF band selection for use in RFID products include:
1. Radio frequency availability. The RF spectrum is publicly owned and controlled by national governments. Most users want an RFID product that does not require a site survey and site license for use.
2. The ability to economically and successfully integrate functions into silicon.
3. The required speed at which the RF device needs to accomplish a communications transaction.
4. The required range of proximity operation that the application demands.
5. Cost. Typically, as you move up the RF spectrum it costs more to build the tag IC.
6. The power requirements to run the tagís logic.

Most commonly used RF powering frequencies include:
125 kHz
13.56 MHz
27 MHz
40 MHz
400-450 MHz
915 MHz
2.4 GHz

As you move up in frequency, tag and reader costs increase. Tags that use the 125 kHz frequency have ICs costing cents as compared to 2.4 GHz tag ICs costing several dollars. As you move up the RF frequency table you receive an increase in passive read range as well as an increase in the speed at which the device can operate. Longer range tags in the hundreds of MHz and GHz are measured in yards and miles whereas lower frequency tags, operating at 125 kHz or 13.56 MHz, have read ranges measured in inches and feet. Application requirements for minimum read range, product cost ceilings, speed of operation and communications complexity drive the decision as to the frequencies to deploy.

MEMORY TYPES

RFID tags typically fall into one of two categories: read-only (R-O) and read-write (R/W). In general, the memory content (data) of read-only tags is programmed during the manufacturing process, and cannot be altered later. A read-only tag transmits the data contained within its memory every time it is energized by an appropriate electromagnetic field. Read-only tags offer the lowest cost and highest level of data non-volatility.

A third type of RFID tag is ìWrite Once / Read Many,î or ìWORM.î WORM tags are essentially read-only tags, except that the memory content may be insertedóone time onlyóafter manufacture.

Read-write tags possess memory types and operational architectures that allow the memory contents to be ìwritten toî(changing their content(as well as being ìread fromî; both functions are accomplished at some critical distance from the reader.

Read-write systems differ from read-only systems by more than just the tags. Since tag memory contents may be changed at will by the user via commands sent to the reader, the reader must also be capable of writing new content into the tag. Although it is easier to refer to them as readers, read-write readers are sometimes called ìreader-writers.î

Reader-writers must transmit information to the tag. The information consists of operational commands, the userís process data, error checking data and other information to ensure that only valid and reliable transactions occur. Security and encryption functions may also be involved. The tag must receive and store this information.

Applications that benefit from the read-write capability typically require larger amounts of data stored in the tag than is usually available in read-only tags. Therefore, the memory capacity of read-write tags is typically larger than that of read-only tags. Antenna design for read-write tags can become more complex as well. The additional functions and larger memory result in larger and more complex tag ICs. The bottom-line, of course, it that read-write tags tend to be more expensive than read-only tags. For similar reasons, reader-writers are more expensive than their read-only counterparts.

EEPROM memories are used in many read-write products in the marketplace. This technology requires ìcharge pumpî circuitry within the IC that boosts the voltage available from the RF electromagnetic field to a substantially higher voltage that is required to change the contents of EEPROM cells. Charge pump circuitry adds to the current consumption of the IC, potentially impacting the write range. The energy required to write new information to an EEPROM cell may be several orders of magnitude higher than whatís required to read the data contained in it. This has resulted in many read-write products in the marketplace that have acceptable read ranges, but a substantially shorter write range. This may prevent its use in some applications.

Additionally, EEPROM memories require a substantial amount of time to program. This time can be an obstacle to achieving higher data rates (faster transaction times), unless additional logic is provided within the IC to process multiple memory cells simultaneously. Additional logic carries a penalty in power consumption.

Another class of memory is referred to as FeRAM, or ferroelectric memory. Ferroelectric memory technology offers advantages over EEPROM memories in that it programs with substantially less energy. Programming time is also substantially reduced when lower programming voltages are required. Ferroelectric memories do not need charge pumps as do EEPROM memories, nor do they require special logic to process multiple cells simultaneously. The elimination of these circuits allows the system to operate more efficiently, and simultaneously achieve greater range. Ferroelectric memories require additional refresh circuitry to maintain data integrity requiring more power for this function. Ferroelectric memories have essentially equal read and write distances.

As the functionality of a read-write system is increased, so is the amount of logic required within the tagís IC. In addition, with larger memory sizes, higher data rates are required to allow transaction times that are acceptable for the application. The higher data rates usually dictate higher operating frequencies. All of these combined cause a significant increase in the amount of power consumed, which translates to lower range. As overall power consumption increases, the low power consumption benefits of ferroelectric memories begin to have a smaller effect on total system efficiency. One advantage that remains, however, is the speed advantage of ferroelectric memories over EEPROM(an advantage that becomes more important as higher data rates are required.

RFID TAG COST

The cost of an RFID tag is primarily determined by its memory type. The following chart depicts the individual cost of a typical, unassembled RFID IC (chip only). The cost of building a completed RFID tag is not included in this chart. The cost to manufacture a full wafer of die varies based on many complicated variables. However, a generalization can be made that the cost of a wafer of die will range from $300 to $1,000.

A common 64-bit, read-only IC size is only 1†square millimeter. This will produce the lowest cost IC. In contrast, a 1-kilobit (128†byte) read/write EEPROM IC size is 10†square millimeters. Both ICs are currently available products.

EMBED Excel.Chart.5 \s

Effects of Metal

Performance of RFID readers and tags is reduced by the presence of metal. Metal near a tag or reader reduces the electromagnetic coupling required to transmit energy to the tag. Therefore, the tag must approach closer to the reader before it responds with data; in other words, the read range is reduced by metal in the environment.

RFID manufacturers should provide guidance (as Indala manuals do) on the effects of metal on system performance so that the overall system meets the customerís expectations.

Effects of Interference

The RFID reader acts as radio receiver similar to an AM/FM radio found in automobiles. Like AM radios, it is subject to interference from noise(what we hear as static on the radio. To prevent this, it is vital that RFID readers are installed in accordance with the manufacturer's instructions (found in Indalaís installation and operations manual).

A poorly grounded installation will result in excessive noise on the power supply or data lines, reducing the read range. This is analogous to ignition noise that crackles on a car radio when it is poorly grounded or filtered. In industrial environments, equipment nearby may radiate electromagnetic fields at the same frequencies used by the reader and tag. This co-channel interference may also reduce the read range. Itís like hearing two radio stations broadcasting at the same frequency.

They interfere with each other and neither can be heard clearly.

Site surveys, identifying possible sources for ambient stray EMR (electromagnetic radiation) are an important tool for system design. Indala continues to develop technology solutions to mitigate these noise effects, but there is no substitute for proper installation in accordance with the manufacturerís guidelines.

Use of Metal to Protect Tags and Readers

Although the best RF coupling from reader to tag will occur in the absence of metal in close proximity (directly mounted) to the tag and/or reader, it is possible to use metal near tags and reader antennas. Incorporating metal will attenuate the RF signals, resulting in reduced read range. By taking precautions with the metal being used to mount or shield the RF components, it is possible to reduce the attenuation effects of the metal. Fundamentally, one has to minimize the size and effect of ìshorted turnsî near any RF coils in tags and readers.

A shorted turn provides a closed path for current flow, which in effect is either in a single piece of wire closed on to itself, or a solid piece of metal without holes or slots. The effects of a shorted turn are easily demonstrated by observing the reduction of read range when a closed metal loop is held adjacent to a tag coil while the tag is being read.

The same principle applies to solid material such as a flat sheet or a solid block of material that provides a continuous path for closed loop current paths. By opening a short with cuts and slots or enlarged holes, it is possible to open the material, enabling RF coupling.

With an understanding of these principles, metal can be used as a protective cover for the tag and or antenna. For example, it is possible to shield a tag with metal to guard it against direct hits from metal tools tossed into a bin for cleaning.

It is best to experiment with the set of conditions to determine what works best for any particular application. In addition, factors about the tag and reader that affect system performance include the size of tag and reader antenna coils and type of core, e.g., air core vs. ferrite core. Indala application support specialists often help solve complex RFID problems involving metal.

Regulatory Standards

All RFID systems must comply with electromagnetic emissions standards that exist in various countries of intended use. A system is required to be tested as a computing device as well as source of radio frequencies. The reader should be labeled and a paragraph inserted in the user manual that contains the legal notices required by the testing agencies. Where a product is also CE marked for sale in the European Community, additional tests are required. The CE standards add both susceptibility and transient immunity requirements that are in addition to the FCC requirements.

The regulatory standard for the United States is FCC 47 CFR, part 15.

The regulatory standards that apply to products shipped to the EC are EN55022, EN50081-1, EN50081-2, EN50082-1, and EN50082-2, which cover radiated and conducted emissions.

Industry Standards

RFID has defied most attempts at standardization. Several industry associations have attempted with varying degrees of success. The following groups have standing standardization committees:

US Military X3T6 Committee

American Railroad Association

Automatic Identification Manufacturers Small Animal Task Force (AIM)

Automotive Industry Action Group (AIAG)

International Airline Transport Association (IATA) Baggage Identification

ISO Standards - RFID of Animals

ISO 11784:1996 Code Structure

ISO 11785:1996 Technical Concept

The goal of standardization is to create a generic tag and reader that ideally could be purchased from several vendors, resulting in lower costs and multiple ready sources of supply.

While standardization makes specifying easier, standards pose a problem in that the tag-to-reader communication is typically proprietary to each manufacturer. The problem is compounded by the fact that tags come in many differing forms and information capacities, and are used in different environments.

Even when the obstacles regarding standardizing the RFID technology are overcome, the system implications are difficult to solve. For example, the airline industry is addressing RFID implementation through IATA (based in Geneva) by setting worldwide standards of use. Implementation covers more than tags, however. Tags receive the most attention because they are the item with the most visible recurring cost. However, the rest of the system uses assorted readers with performance requirements yet to be defined. Implementation of any standard is extremely time-consuming because agreement is required not only among the carriers, but with worldwide airport authorities and regulatory agencies which are involved. These agreements enable domestic and international airline transportation systems to function. Indala has participated in this arduous process and can attest to the time-and-patience-consuming process.

Standardization work continues with promising work being accomplished by the Joint Technical Committee (JTC). The JTC is sponsored by the International Standards Organization (ISO) and the International Electrotechnical Commission (IEC). Two committees are addressing the critical issues of standardization. Sub-committee 31 (SC31) Automatic ID and Data Capture and Sub-Committee 17 (SC17) Contactless Card Working Group are working on critical standardization issues.

RFID VS CONTACTLESS SMARTCARDS

Contact smartcards have been in use in Europe, Australia, South Africa and Japan in telephone and banking applications. The concept of a ìcontactlessî smartcard that operates more or less like an RFID tag became a new concept recently.

Fundamentally, there is little difference between an RFID tag and a ìcontactlessî smartcard.

Smartcards standards are being developed by JTC subcommittee 17:

Type 1 cards are for basic identification and access control with up to 1m read range. Type 1 cards will have low memory and lower data rates.

Type 2 cards will have high memory, high transaction rates. Type 2 cards are primarily focused on automatic fare collection (AFC). Type 2 cards will read at 10 cm and have high security encryption.

Type 3 cards are not well defined at present, but are expected to address the issue of long-range.

The promise of ìcontactlessî smartcards could have a large impact on RFID acceptance for general applications.

RFID PROJECT MANAGEMENT

Implementation of RFID technology requires a careful consideration of the applicationís system requirements. At the time of writing, most RFID technology is sold to the ultimate user in packaged systems or in custom systems supplied by experienced systems integrators and providers. An implementer of the technology should complete a preliminary walk-through of the environment to make sure tag and reader placement meet read range requirements and to spot obvious sources of interference. For systems requiring licenses this would require a site survey using frequency spectrum analyzers and a search of the area for frequencies already assigned to other users.

Custom systems should include a conceptual design that would allow the customer to study the design before implementation. The system provider should be willing to install a functioning prototype that demonstrates the basic concepts. This can quickly be expanded to a pilot system test to put the technology into everyday use on a small scale. Full-scale implementation can proceed quickly after that point.

Large-scale systems provide special challenges and require extraordinary care. Usually these issues involve communication and application issues far beyond the automatic identification technology.

APPLICATIONS

Access Control

Controlling access to a facility is one of the most practical uses of RFID. The employee uses an RFID card tag to gain access to authorized areas. RFID tags for vehicle identification are often bolted to the undercarriage of transport trucks and other vehicles to guard access to a facility.

The most basic element of security is the physical integrity of the tag itself. Compared to a metal key, a read-only RFID tag is much more difficult to reproduce. Unwanted interception and unauthorized playback of data between the tag and reader is another major concern. This threat is minimized when read range is short. Often, when higher security is required, the user must also enter a Personal Identification Number (PIN) via a keypad in addition to presenting an ID card.

Affinity Cards

Affinity RFID cards are issued to a special class of people to allow special privileges, such as access to airports clubs, ìfrequent flyerî programs or ìpreferred customerî programs. These cards act like access control cards to validate the customers right to special services. Use of affinity cards allows one to build points for later redemption of services or merchandise.

RFID affinity cards with printable surfaces are ideal for a ìpreferred customerî card. The customerís picture can be printed directly onto the card with a relatively low cost video camera connected to a PC and a dye sublimation printer. The RFID card tag allows users to let themselves into special areas by holding the card up to a small inexpensive reader. The tag can be easily monitored by security personnel by comparing the picture on the card to the person presenting it.

Animal Identification

The first implementation of RFID technology began by using a tag in the conventionally molded, flexible ear format commonly seen on farm animals. There have been variations of that tagging method with the RFID insert molded into a stem that holds a numbered tag. The flexible ear tag is made of a remarkable material that does not support growth of bacteria commonly found on animals. Cattle have tough ears which permit piercing and attachment of the number tags, but other animals are not as tolerant, such as sheep and pigs. Sheepís ears tend to tear and pigs will chew not only on attached ear tags but the ears to which they are attached as well.

Another hazard of using external animal tags is the possibility of tampering and switching of tags between animals. Reading requirements for these tags have never been uniformly defined. Generally, it would be desirable to read at long distance, 10 yards or so, but that sort of read range with the lower cost tags is not feasible or practical with current RFID technology.

To circumvent the problems with the external tags, glass encapsulated RFID inserts were developed that used small, wire-wound ferrite components developed for quartz wristwatches. These wire-wound ferrites were used as the antenna structure. The RFID electronics were hermetically sealed in a glass tube, making this glass-enclosed

RFID tag suitable for use inside the animalís body.

Insertable tags have limitations such as limited read range, migration (the tag could move around inside the body), breakage, and size. Initially, these tags were 4 mm in diameter (much too large for piglets). Later design improvements eventually shrunk them to 2 mm in diameter. It was hoped that slaughter animals could be controlled worldwide through the use of injectable RFID tagging, and the first countrywide tagging project was initiated by the Dutch to tag pigs for health monitoring and control. Despite major efforts by several manufacturers who set up glass RFID manufacturing capability, the Dutch government eventually abandoned the piglet RFID tagging project, leaving several manufacturing capabilities in place, but no application for the tags. The US had never been able to remove the possibility of having a consumer biting into a glass module in a piece of pork.

One viable application for the glass-encapsulated modules is in pet identification. This application was made feasible and successful because the manufacturer also developed a nationwide database registry in conjunction with veterinarians, enabling them, humane societies, and communities to implement RFID tagging. Today, external tagging is the most commonly used method for animal identification.

Asset Management

RFID is ideal for identifying assets that need to be checked in or out, routinely inspected or calibrated. RFID provides a permanent identification that can be attached in a manner that is virtually undetectable. Tags can be embedded under nonmetallic parts, painted over or molded into an asset. Portable RFID readers are easily interfaced to portable computers or data collection networks to permit easy access to database information. Data collection is accurate and quick.

Athletic Event Management

RFID tags have been tied onto the shoes of marathon runners in the Los Angeles marathon. Readers embedded in the ground report their progress and positively identify participants.

Automotive Anti-theft

Several major automotive manufacturers have chosen to use RFID to prevent theft of vehicles. In most implementations, the RFID tag is built into a special key. The RFID reader is integrated into the ignition system. Usually the communication between the tag and the reader is also enhanced with special formatting and/or special numbering schemes to enhance security.

Automotive aftermarket suppliers of RFID security systems usually employ the use of a key fob in place of the key. In the aftermarket type of solution, usually the reader is wired into the ignition system and placed by the installer in a location known only to the car owner. The car will not start until the reader has read the appropriate RFID tag for that vehicle.

Container tracking

Environmental concerns are causing a worldwide trend in industry to move from disposable containers. Reusable containers are expensive, however, so keeping a history of each is valuable to shippers. Each container has a service life after which it is recycled; tagging it ensures it gets maximum use before recycling.

If the containers have been used to deliver chemicals, RFID allows the user to meet government requirements to keep accurate records. In many situations, the tag will be read by an RFID reader attached to a portable computer or a vehicle-mounted RFID reader connected to a computer on the vehicle.

Electronic Article Surveillance (EAS)

EAS is very popular in the retail industry for preventing theft. The current technology used by these retail systems detects the presence or absence of an object in the field. Radio frequency is only one of the popular methods used to detect the tag. Others are microwave, magnetic, and acousto-magnetic. The currently deployed retail technology is not RFID because there is no identification of the object; no identification number is transmitted back to the receiver. There is no integrated circuit in these tags. They are effective for theft detection but not identification of the object. RFID Tags capable of transmitting an identifier and capable of multiple tags in a field are highly complex and expensive. Often these are active tags with additional power to boost the processing and transmission capability. These tags also require expensive reader systems to ensure that multiple tags in a field are efficiently read. These facts make EAS an elusive goal for current RFID technology.

Electrical Utilities

Electrical utilities need to identify, inspect and report on the condition of a variety of assets from electrical transformers to tools. Other forms of automatic identification technologies such as bar code and touch memory are ineffective because of the harsh outdoor environments. Currently, electrical utility customers are using RFID tags to identify transformers, rubber gloves, chaps, test tools and grounding cables.

Fare Collection

One of the major high volume applications for read/write RFID tags is in passenger ticketing for mass transit automatic fare collection for trains, subways, busses, and ferries. Over 40 mass transit authorities worldwide have conducted pilot tests confirming the viability of using read/write RFID tickets. The advantages of RFID tickets over traditional magnetic stripe tickets include:

Faster transaction speedsóthe passenger simply waves their card within 10 centimeters (about 4 inches) from the reader to deduct the fare charge without even having to break stride while boarding. The speed at which a read/write debit transaction can occur is typically under one-third of a second, which is faster than the person can move through a boarding gate.

User convenienceówith RFID, the passenger will no longer fumble to insert a fare ticket into a magnetic reader slot, watch it exit the other side and then have to grab it again on the way out of the gate.

Reduced equipment maintenanceóusing RFID means that are no slots in the reader to get jammed up with debris and there are no moving parts required to read the card, unlike magnetic stripe reader technology.

Higher transaction reliabilityófast transactions means there is less time for the passenger to pull the card out of the operating range before a transaction is finished.

ìCross-boundaryî multi-agency seamless travelóthe ticket acts as a traveling database to calculate actual fares automatically with no driver interference.

Increased user safetyóthere is no cash exchanged between the driver and passenger making them less likely targets for robbery.

In addition, many cities are planning to deploy the fare collection ticket as a stored value card so that the traveler can also purchase other goods and services with the fare tag. Several major metropolitan areas are planning to deploy the read/write RFID cards en masse in their systems over the next few years.

Fueling Management

Using RFID to allow access to a fuel pump is a variation to the access control theme. This has been used in commercial closed loop applications for years.

In 1996, a retail use of RFID technology was pioneered by a major oil company in the St.†Louis area. This system identified the vehicle using an RFID tag or the individual using a tag in a key fob or a badge.

RFID readers have also been mounted on the fueling nozzle with specialized RFID tags mounted on the tank to ensure that the proper fuels or fluids are being loaded.

Fugitive Emission Inspection Systems

Fugitive emission inspection systems are physically tough, demanding, fatiguing tasks. RFID ensures that the inspector was at the valve to do the inspection and makes the job easy to do correctly. It also makes the job easier because the RFID tag can be read regardless of the dirt, chemicals or paint that might cover it. An Indala passive tag can be read with a small hand-held reader placed within 2 inches of the tag. BRADY USA, a reseller of Indala RFID products, has integrated an Indala reader with a SYMBOL Technologies hand-held computer and a Foxboro OVA gas analyzer into an intrinsically safe portable system called ìLEAKTRAKKERî. This unique, patented system is one of the most advanced systems on the market for fugitive emissions monitoring.

Gas Cylinder Tracking

RFID tags are ideal for identifying and tracking gas cylinders. Gas cylinders have defied all other types of automatic identification technology because of the rough treatment that they endure(abusive handling, heavy soiling, outdoor storage, shot blasting and repainting. Robust RFID tags can be installed directly on the cylinder then painted over, shotblasted, and repainted without failure.

The wide choice of reading devices offered by the RFID vendor permits the tags to be read automatically at the fill plant or with a hand-held reader by delivery people.

Hazardous Materials

RFID is ideal for tracking hazardous materials (HAZMAT) because other technologies often cannot function efficiently in this environment. RFID also can be integrated with other technologies. For example, an RFID read/write tag can be embedded in a hazardous materials warning sign. When the hazardous chemicals are removed from the container, the amount can be electronically deducted from total on the tag. The collected information can easily update an information database by either batch or on-line using an RF data collection network. Management reports are then accurate and government inspectors can make on-site inspections and audits to make sure that chemicals stored in various locations are being accurately monitored.

Industrial Laundries

The original interest in RFID came from the developers of inventory control systems for commercial laundry processes, specifically for the higher valued rental garments. Developers wanted to improve processing throughput on garment identification systems originally implemented with barcode. The challenge as originally posed for RFID was to provide a means of automatically reading garments without a line-of-sight read requirement and provide a durable tag that could survive multiple washings.

The challenge was manifold. Indala had to clearly define the industryís needs and requirements, develop a design that would survive the extreme harsh environment, produce it economically, and find a market segment whose need was pressing enough to make the initial RFID investment.

Indalaís ìbutton tagî product family evolved from a series of developments where improvements were tested in actual operation. The original button tag actually had two small holes for sewing in place with machines common in the industry.

The Indala IT-253E button tag has evolved into a well tested, extremely durable tag designed to exceed all known moisture, temperature, and pressure requirements for a garment life cycle including 38 bar pressure water extraction (membrane and piston types). The tag is encapsulated with proven, high-quality durable semiconductor grade material for long tag operating life. The IT-253E tag has been designed to withstand the 205(C, 30-second exposure for heat press patches as well as recycling in 160(C steam drier tunnels.

Intermodal Containers

Railroad cars and intermodal containers have been identified using high frequency RFID tags since the late 1980s. The American Association of Railroads has one of the few RFID standards for a passive, long-range tag. The military used active, high frequency, and long-range tags for tracking containers in the deployment for Desert Storm.

Luggage Tag

RFID in both baggage tagging and boarding passes have been demonstrated to the airline industry. In 1991 Indala demonstrated a working system on a curbside baggage check in conveyor at Dallas-Fort Worth Airport in conjunction with a major U. S. based airline. A 99.7% reading accuracy was achieved in a weeklong trial. In 1995, another airline conducted a one-month test with an RFID vendor and demonstrated a reading accuracy in excess of 95%.

Implementations of RFID solutions for luggage management have been hampered by the lack of common systems operating between airlines and the fact that bar code, although less efficient, has been easier to adopt. Bar code line-of-sight read requirements limit their effectiveness and reliability in a flight line environment, since baggage tag orientation affects consistency and time to load an aircraft.

Meatpacking Plants

The pressure placed on meatpacking companies to control and inspect inventory has created a need for RFID. Tracking work in process or managing the product flow had never been an exact science in a meatpacking plant until RFID proved that it could withstand the harsh environment. Rugged tags embedded in gambrels or over-molded and attached on the side of the metal ìtreeî that transports the meat. The tags have been tested by meatpackers for survivability from shock and from washdown with diluted acids and caustics used to control bacteria. Rugged readers that are potted to withstand washdown and infiltration from bacteria are a requirement in this environment. RFID offers the meatpacking industry and other food processors an automatic identification technology that is reliable and effective.

Process Manufacturing

In manufacturing processes that require relatively small batches of chemicals to be mixed, RFID provides a means to automatically verify weight and contents of components to prevent errors. One example is an Indala customer who manufactures rubber components (mostly rubber seals) for automotive and industrial uses. RFID is used to prevent bad batches due to missed ingredients or improper quantities. The operator hand-scans each container before mixing to validate that the proper ingredients are being used.

Product Identification

RFID is also ideal for items that have defied other means of automatic identification. High value items such as furs, skis, and helicopter parts are examples. RFID tags can either be molded directly into the product or laminated into the productís logo or nameplate to thwart counterfeiters. Tags on steel beams or cement pipes ensure that the correct grade is sold and installed at the construction site.

Raw Material Inventory Control

Often suppliers deliver raw material inventory to manufacturers in packages that are stored on site but not paid for until used. In non-automated systems, the supplier must rely on customer-generated reports or visits by reps to take inventory before billing

for inventory usage.
RFID permits automation of this process by attaching RFID tags to containers or embedded in covers or locks that must be removed before the inventory can be used. The RFID tag is automatically read when it is removed.
For example, some chemicals are shipped in large pallet-size rubber tubes inside a carton. These rubber tubes can have the RFID tag built into the valve cover. When the valve cover is removed, it is dropped into a container that reads the tag and stores the data for transmission to the chemical supplier.

Restaurant Service

Card tags or small tags attached to a wristband permit easy employee identification and access to an automated point-of sale order entry system. Once the order is correctly entered, the tag can be used to verify that it is correct. When the order is ready for delivery, the next available employee can deliver the food and accept payment. Using RFID to permit access to the finished order ensures accountability for correct cash tendering to each employee. The result is quick and accurate customer service with excellent record keeping.

Scale Interface

RFID is becoming increasingly popular in systems that employ weighing scales to record data. RFID is popular for these applications because it does not require operator intervention. A strategically placed antenna automatically reads the tag as the carrier is positioned on the scale.
These applications range from agricultural grading, fuel delivery, baking plants, meatpacking facilities, rubber processing and waste pickup. Wherever scales are involved, RFID is a good choice because it can be integrated into a data collection system and permits automatic identification. Moreover, it is virtually maintenance-free.

Ski Industry

The ski industry holds great promise for RFID systems applications. The industry would like to have an automatic identification technology that would allow lift operators to bill the customer per lift ride and eliminate the long lift ticket lines. Replacing paper lift tickets with firmly affixed RFID tags also reduces one source of pollution on the slopes.
At a popular North American ski slope, card tags are sold to skiers who track the number of trips they make up the lift. The skier accumulates credits for each ride and the accumulated ìaltitudeî results in a frequent skier type of club. Points can be spent by the skier for resort services. One innovative system integrator has also built a communication kiosk that is activated with an RFID card tag to provide information to the preferred customer.
RFID tags have also been installed on ski lift gondolas to track the number of cycles they make in order to schedule lift maintenance.

Time and Attendance

RFID tags are ideal for employee identification. Current RFID card tags comes in two main varieties. One, a laminated card has the look and feel of a credit card. One side of the card is imageable and permits printing of pictures and other data via a dye sublimation process. The imageable RFID card provides visual and RFID security.
Another popular card is constructed by welding components inside of a plastic housing. Usually only 0.060 inches thick, these rugged tags boast a lifetime guarantee. These versatile passive RFID tags are ideal for recording time-in and out data and permit positive employee ID for tool check-out, job log-on and access to secured areas.

Tools
Many industries require special tools and garments that are inspected and regulated. Their use needs to be managed and reported. RFID tags embedded into these assets make them easy to track with fixed or portable readers.
An employee can use his or her RFID employee badge to check out a garment or tools, quickly and easily. Robust RFID tags can be embedded into the tools with epoxy and painted over so that the tool appears to be unmarked(yet it is easily read with a portable or hand-held reader. A fixed reader at the tool crib is used to interface directly to the computer to identify employees and the tools they have checked out.
Toll Roads
An Electronic Toll Collection (ETC) System employing RFID technology provides a means for vehicles traveling on toll roads to automatically pay their toll fees without having to stop. As a result, the fundamental requirements of an RFID ETC system must include reliable operation under all weather conditions, immunity to electromagnetic interference in the local environment, and the capability to interface with other equipment needed for vehicle classification, violation enforcement, lane control, and data base management.
The plaza computer is the final processing stage for all the data generated by the system. It takes the toll information from the readers from each lane, the picture from the violation enforcement system (VES), and acts as an information manager. The toll plaza functions required for this system are to identify the tag, processes the information stored on the tag, writes back to the tag, and controls all the other functions of the toll plaza. There will usually be one host computer for the entire system, one plaza computer for one or several toll plazas, and one lane controller and reader for each lane. How the different functions are divided between the three parts varies from vendor to vendor, but together they will perform the same general functions.
The VES consists of an interface to the lane controller, a camera for each lane, a triggering system to ensure that a picture is taken when the transponder is in the center of the lane, and a storage media for the pictures.
The evolution of RFID tags for toll roads has progressed from a read-only application to a transponder that can be ìreadî from as well as ìwrittenî to. Unique variable data contained within the transponder is updated such as entry/exit locations, account balance, vehicle maintenance and inspection reports. Even more advanced RFID tags are available, which have the capabilities to interact and communicate with the driver.
Two types of reader/tag protocols are typical:
Two-way communication intended only for the single tag in the readerís field: The direct access protocol is ideal for electronic toll collection and gate access applications that must localize communication to a particular area or traffic lane. This can be low frequency or high frequency depending on the vendor. It allows the computer system to properly associate tag data with other information, such as from a vehicle classification system, with a particular vehicle.
Multiple tag communication with all tags in the readerís field: This protocol allows communication over an extended area - a number of lanes, for example. For applications that do not require lane-specific communication, this capability lowers the cost of system implementation by allowing a reader to provide coverage over an area that may contain many tags. This is a high frequency application.
Totes/Conveyor
Tags mounted on totes, embedded in skids, or attached to carriers on overhead or rolled conveyors are natural applications for RFID. Rugged RFID tags will last

virtually as long as the tote or carrier while permitting control of the routing and accurate collection of transaction data.

Applications abound; a few worth noting are processing orders at a mail-in automated pharmacy, tracking assembly of high fidelity speakers and tracking the routing of motorcycles as they are manufactured.

Attaching RFID tags to totes or carriers permit automatic data collection. The results are automated, state-of-the-art operations at very low cost for the technology and very low system maintenance.

Vehicle Identification

RFID tags and readers are usually designed specifically for a vehicle ID application. A long read range is needed that allows trucks to be easily read as they enter and exit a facility. The RFID tag is typically an active tag, also designed to be mounted on the outside or undercarriage of the vehicle and read with a pole mounted or an in-ground reader.

Most trucking operations can estimate when a truck will arrive at its assigned destination if departure time can be confirmed. The RFID permits automatic recording of truck departure and arrival. It also may be used to accurately record maintenance and vehicle preparation prior to loading.

Warehouse Management

The use of RFID technology in warehouse management systems has potential for growth. Large warehouse facilities are becoming automated using RF data collection systems. These systems require automatic identification of warehouse locations to be effective. Large warehouses are difficult to lay out because of the large open spaces. RFID tags embedded in the ground offer an easy and efficient solution to this problem.

An RFID tag with a ferrite core can be installed by drilling a hole in each storage location or in strategic locations. The driver drives the forklift over the tag when picking or placing a pallet at that location. The rugged RFID reader mounted under the forklift automatically reads the location, without the driverís hands leaving the steering wheel.

Waste Management

Waste management is a big issue for business and municipalities. Landfill management is vital, with government regulators levying large fines for mismanagement. RFID is ideal for this rugged, aggressive, dirty business.

Tags on commercial bins permit tracking of usage by weight at the landfill or at the time of pickup. This permits accurate identification of trash type for customer accounting.

An emerging market is home residential pickup. The ability to positively identify the container automatically at the time of pickup is being used by several municipalities to gather data that helps manage the cityís waste stream better.

Work In Process

RFID tags mounted on carts, totes or carriers identify the work in process inventory as it enters a work center. A major automobile manufacturer uses a small passive RFID tag to identify each automobile chassis. This permanent tag never is removed, allowing the manufacturer to know where a particular chassis has been. Some chassis are pulled off the line for assorted reasons. The RFID tag provides traceability to prevent those chassis from being lost or forgotten.

Yard Management

Yard management, an expansion of truck identification systems, is a promising area for RFID technology. Most warehouses have a yard management problem. They need to identify when a truck is on premises, where it is parked, and what inventory is on the truck.

With the advent of modern Electronic Data Interchange (EDI) and Warehouse Management Systems, the automatic identification of trucks and their location in the yard is more time critical. The EDI system identifies the inventory on the truck. When the RFID tag on the truck is read as it enters the gate, the warehouse management system knows that the inventory is now available to fulfill orders. The driver is directed to park the truck in a designated pick-up spot.

The warehouse management system issues a pull/put instruction to the tug that moves the trailer from the drop-off location to a parking slot. The RFID reader on the tug verifies that it is picking the right trailer. A second reader reads the tag in the ground to verify the pull and parking location. This is very similar to the same transaction issued to a forklift as it tracks pallets.

Cost Justification

Cost justifying an RFID system is very similar to justifying the implementation of any automatic identification technology such as touch memory, vision systems, or bar codes.

The cost justification should always take into consideration the entire system cost for the life of the system. Often potential purchasers will compare the cost of an RFID tag to a bar code label. The difference could be quite dramatic, $3 versus $.25. However, an entirely different picture may emerge when viewed on a system level. RFID is the lowest cost technology available if the tags are used repeatedly in cycles.

A sample cost justification analysis is offered here that compares the cost-to-purchase and operate a bar code system versus an RFID system for a manufacturer of printed chipboard cartons used for soft drinks and other canned items. This is an example of tracking of full pallets of finished goods.

Costs for bar code system (estimated):

Costs for Indala RFID system:

Label costs
.03 per label
5.7 Pallets per hour
7 days per week
50 weeks per year
$10,054.80

IT39E Lipstick Tags
1600 Pallets
130 Locations
$10 per tag
$17,300.00

Laminated labels
130 locations
195.00

Printer costs
7 printers at $2,400
16,800.00

Bar code readers
7 Palletizing stations
2 Glue lines
10,755.00

IR100E Portable readers
9 X $1195
10,755.00

Long-range scanners
2 Forklifts
4,000.00

IR52E Vehicle Mount readers
2 X $2600
5,200.00

Labor
Changing ribbons
Label stock
Replacing labels
5 hours per month/$40 per hr
2,400.00

Labor

.00

First year costs

$44,204.80

First year costs

$33,255.00

Second year costs

+12,454.80

Second year costs

+ .00

Two year cost

$56,659.60

Two year cost

$33,255.00

The Future: What to expect...

A use-once-and-throw-away low cost, read-only RFID tag will eventually be possible, but clear features, functions, costs and markets for it have not been defined. Adapting todayís RFID magnetically coupled (IC and coil) to a disposable type envelope such as paper was developed in 1991 for a major US based airline baggage tag demonstration project. It showed that an environmentally-friendly label material available today could be adapted to receive todayís RFID electronics. When recycled, the remains would consist of paper fibers, silicon (sand), copper, and minute traces of aluminum.

To implement such a product requires fundamental changes to existing RFID technology. Tag architecture and tag-reader communication will require change on a very broad scale. Motorola Indala continues to research the potential for developing such technology. Higher functionality read/write solutions will continue to evolve as the problems associated with longer range, transmission collision, data integrity and tag durability are overcome. These higher function tags will in all likelihood cost more than their read-only counterparts, but they hold great promise to keep pace with the rapid evolution of computerized systems.

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