EC0238

Radio Frequency Identification

Radio Frequency Identification (RFID) refers to an Auto-Identification system comprised of RFID tags, readers and the requisite middleware that interprets tag information and communicates it to the application software. RFID tags contain specific object information in their memory, accessed via the radio signal of an RFID reader .On the surface, this appears to be similar to how a barcode infrastructure works: the barcode label contains the relevant product information that is read by a barcode reader, and then communicated to the application software. However, there are significant differences with RFID from an operational perspective that gives businesses the opportunity to redefine their logistical processes. Many have referred to this technology as a replacement for barcodes; this is simplistic as it has advanced capabilities that cannot be duplicated with barcodes.

Unlike the barcode where identification is limited by line-of-sight, RFID technology and its reliance on radio waves does not require a line-of-sight for identification or a straight-line alignment between the tags and readers. As is common with emerging technologies, several challenges must be overcome for the technology to mature to its full potential. In the case of RFID, these challenges include: maturation of technology, harmonization of standards for hardware/software and wireless spectrum operations, privacy and security concerns, and implementation cost barriers. As these technical and policy challenges are mitigated, RFID will likely become the system of choice for global commerce.

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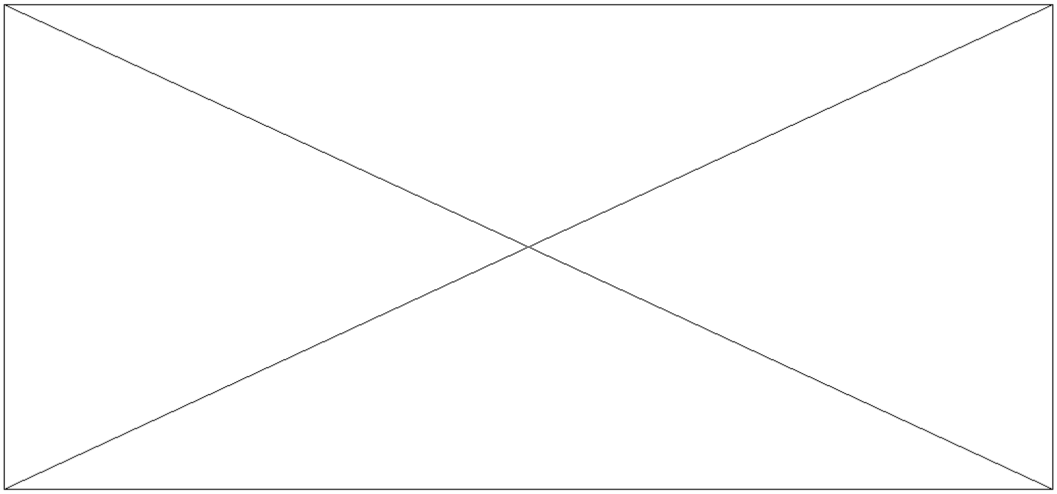
Introduction

Radio Frequency Identification (RFID) has been emerging as a powerful technology over the recent times. The efficiency and flexibility of RFID made it a superior technology replacing other available technologies such as bar-code readers. RFID is an automatic Identification means of identifying a person or object using a Radio Frequency transmission. This can be used to track, Identify and store Information of object such as product, case or pallet, that help the speed the handling of manufacturer goods and materials. RFID enables identification from a distance, and unlike earlier bar-code technology, it does so without requiring a line-of-sight. RFID can incorporate additional data such as manufacturer, product type and even measure environmental factors, such as temperature, live stock Identification and automated vehicle Identification because of its ability to track moving objects. RFID system can perceive many different tags located in the same area without human assistance. In contrast, in bar-coded, item must orient toward a reader before scanning it.

Comparison of RFID with Bar codes



Principles

Elements RFID System:

1. The RFID tag (transponder) that carries the identifying the data. 2. The RFID readers (transceivers) that read and write the tag's data
3. The back end database connected to their readers that record information related to the tag data.

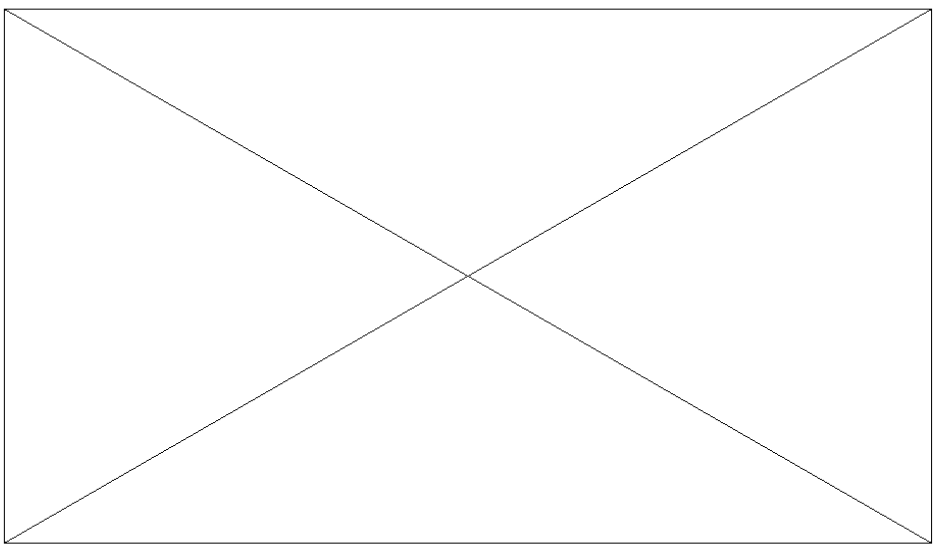


Figure: Basic Operations of RFID

Transponders / Tags: The word transponder, derived from Transmitter/responder, reveals the function of the device. An RFID tag is a tiny radio device that is also referred to as a transponder, smart tag, smart label, or radio barcode. The tag comprises a simple silicon microchip (typically less than half a millimeter in size) attached to a small flat aerial and mounted on a substrate. The whole device can then be encapsulated in different materials (such as plastic) dependent upon its intended usage.

The finished tag can be attached to an object, typically an item, box, or pallet, and read remotely to ascertain its identity, position, or state. The tag responds to a transmitted or communicated request for the data it carries, the mode of communication between the reader and tag being by wireless means across the space or air interface between the two. The term also suggests the essential components that form an RFID system - tags and a reader or interrogator. The basic components of a transponder may be represented as shown below. Generally speaking they are fabricated as low power integrated circuits suitable for interfacing to external coils, or utilizing "coil-on-chip" technology, for data transfer and power generation (passive mode).

Basic features of an RFID transponder: The transponder memory may comprise read-only (ROM), random access (RAM) and non-volatile programmable memory for data storage depending upon the type and sophistication of the device.

The ROM-based memory used to accommodate security data and the transponder operating system instructions which, in conjunction with the processor or processing logic deals with the internal "house-keeping" functions such as response delay timing, data flow control and power supply switching. The RAM-based memory is used to facilitate temporary data storage during transponder interrogation and response. The non-volatile programmable memory may take various forms, electrically erasable programmable read only memory (EEPROM) being typical. It is used to store the transponder data and needs to be non-volatile to ensure that the data is retained when the device is in its quiescent or power-saving "sleep" state.

- **The Reader / Interrogator** :

The reader sometimes called an interrogator or scanner sends and receives RF data to and from the tag via antennas. A reader may have multiple antennas that are responsible for sending and receiving radio waves. Functions performed by the reader may include quite sophisticated signal conditioning, parity error checking and correction.

Once the signal from a transponder has been correctly received and decoded, algorithms may be applied to decide whether the signal is a repeat transmission, and may then instruct the transponder to cease transmitting. This is known as the "Command Response Protocol" and is used to circumvent the problem of reading multiple tags in a short space of time. Using interrogators in this way is sometimes referred to as "Hands Down Polling". An alternative, more secure, but slower tag polling technique is called "Hands Up Polling" which involves the interrogator looking for tags with specific identities, and interrogating them in turn. A further approach may use multiple readers, multiplexed into one interrogator, but with attendant increases in costs.

End Data Base:

The end database is the point where the data collected from the local server and is stored here for further use in the future. The data collected here can be used for Enterprise resource planning and supply chain management. Enterprise resource planning deals with Demand forecasting for various products on the basis of data collected from RFID tags. Supply chain management is the use of the data collected from servers to know the exact quantity of materials present in the marketplace and the details regarding the amount ordered, amount received and all other logistics. Communication of data between tags and a reader is by wireless communication. Two methods distinguish and categories RFID systems, one based upon close proximity electromagnetic or inductive coupling and one based upon propagating electromagnetic waves. While the term antenna is generally considered more appropriate for propagating systems it is also loosely applied to inductive systems waves. Coupling is via 'antenna' structures forming an integral feature in both tags and readers.

The data acquired by the readers is then passed to a host computer, which may run specialist RFID software or middleware to filter the data and route it to the correct application, to be processed into useful information.

Automatic Identification:

RFID technologies are grouped under the more generic Automatic Identification (Auto-ID) technologies. Examples of other Auto-ID technologies include Smartcards and Barcodes. RFID is often positioned as next generation bar coding because of its obvious advantages over barcodes.

Transmitting data is subject to the influences of the channels through which the data has to pass, including the air interface. Noise, interference and distortion are the sources of data corruption arise in practical communication. Channels that must be guarded against in seeking to achieve error free data recovery. Data communication processes, being asynchronous in nature, requires attention to the form in which the data is communicated. Structuring the bit stream to accommodate these needs is often referred to as channel encoding and although transparent to the user of an RFID system the coding scheme applied appears in system specifications. Various encoding schemes and Modulation techniques are used for the efficient transmission of the data. It employs high frequency radio waves called carrier.

HOW RFID WORKS:

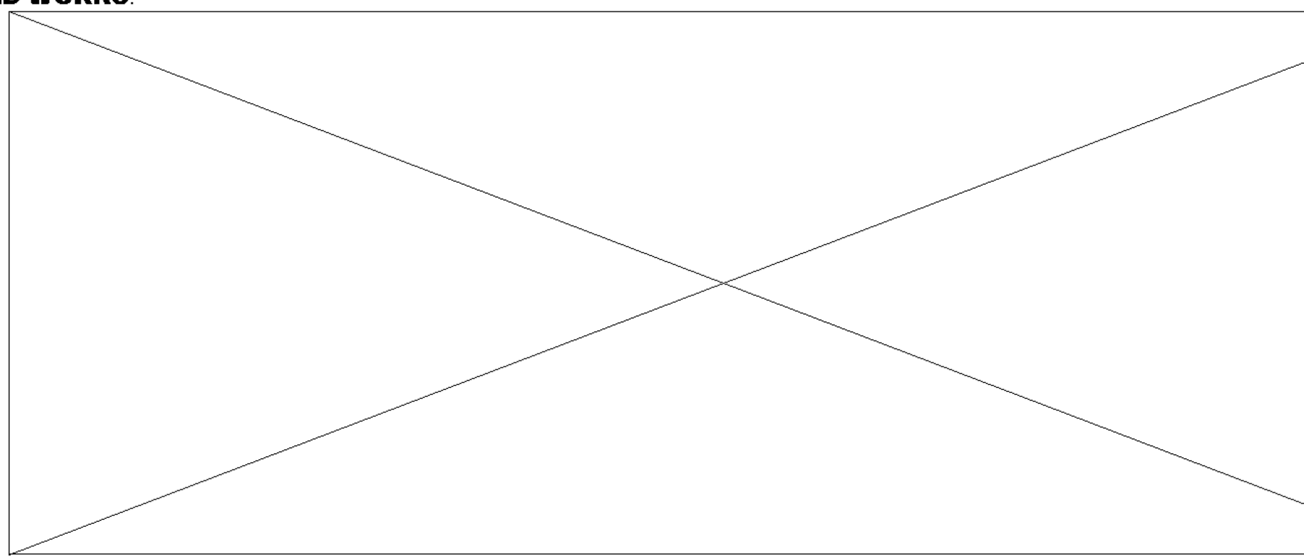


Figure showing the process of RFID Communication

The tag or transponder which contains an electronic circuit is attached to the object that requires a unique identification code. When the tag comes near the reader, the radio frequency field generated by the reader will power up the tag and causes it to continuously transmit its data by pulsing the radio frequency. The data is then captured by the reader and processed in the back-end by applications like the Enterprise Resource Planning (ERP) or Supply Chain Management systems.

Based on **power requirements** tags can be distinguished as:

Active tags: Have a battery to run the microchips and to retransmit the signal. **Passive tags**: Have no own power supply & they draw their power from the radio wave transmitted by the reader.

Active tags are suitable to track high cost items overlong ranges but they are too expensive, and tag's lifetime is limited by the stored energy, only passive tags are suitable.

PASSIVE TAG:

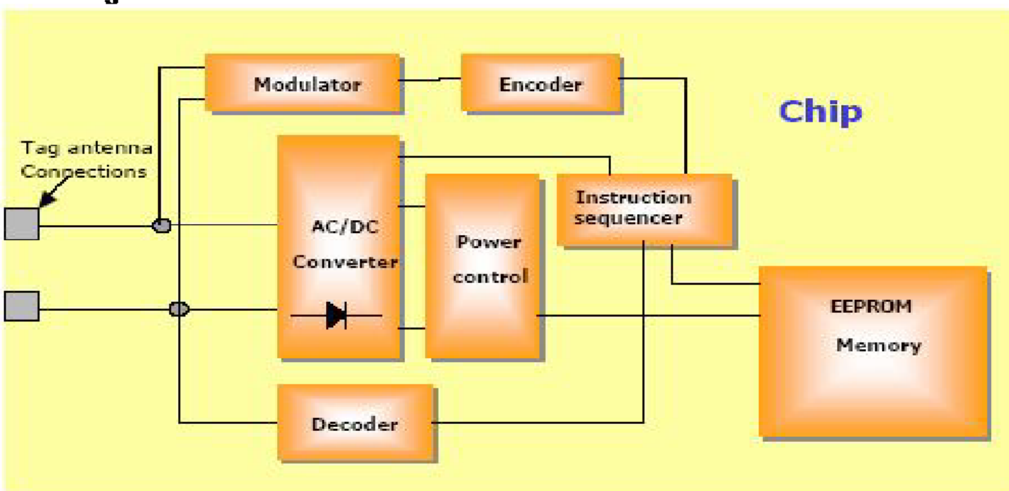
Consists of three parts: Antenna, Semiconductor chip attached to the antenna, and Encapsulation. The tag antenna captures energy and transfers the tag's ID. The encapsulation maintains the tag's integrity and protects the antenna and chip from environmental conditions. Encapsulation could be a small glass vial or a laminar plastic substrate with sticky on one side to enable easy attachment to goods.

Examples of different formats

- Credit card size flexible labels with adhesive backs

- Tokens and coins
- Embedded tags – injection molded into plastic products such as cases
- Wrist band tags
- Hard tags with epoxy case
- Key fobs
- Tags designed specially for Palettes and cases
- Paper tags

Basic Tag IC architecture



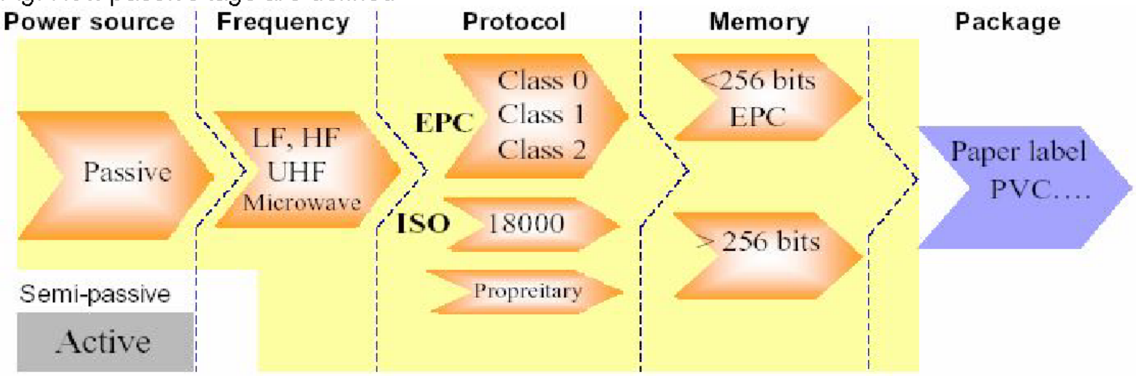
Tag Classes:

One of the main ways of categorizing RFID tags is by their capability to read and write data. This leads to the following 4 classes. EPC global has also defined five classes which are Similar to the ones below.

Class	Known as	Memory	Power Source	Application
0	EAS EPC [1]	None EPC	Passive	Ant-theft ID
1	EPC	Read -Only	Any	Identification
2	EPC	Read-Write	Any	Data logging
3	Sensor Tags	Read-Write	Semi-Passive/Active	Sensors
4	Smart Dust	Read-Write	Active	Ad Hoc networking

Data transfer rate and bandwidth: The rate of data transfer is influenced primarily by the frequency of the carrier wave or varying field used to carry the data between the tag and its reader. The higher the frequency, higher the data transfer that can be achieved. This is intimately linked to bandwidth or range available within the frequency spectrum for the communication process. The channel bandwidth needs to be at least twice the bit rate required for the application in mind.

Fig: How passive tags are defined



Range and Power Levels: The range that can be achieved in an RFID system is essentially determined by

- The power available at the reader/interrogator to communicate with the tags .
- The power available within the tag to respond.
- The environmental conditions and structures, the former being more significant at higher frequencies including signal to noise ratio.

The power within the tag is generally a lot less than from the reader, requiring sensitive detection capability within the reader to handle the return signals. Although it is possible to choose power levels to suit different application needs is not possible to exercise complete freedom of choice. There are legislative constraints for power levels. 100 - 500mW is values often quoted for RFID systems.

Two Approaches for Transferring Power from Reader to Tag:

1. Magnetic Induction
2. Electromagnetic (EM) Wave Capture.

These two methods take advantage of EM properties associated with RF antenna.

- Near Field
- Far Field

Near-Field RFID:

Faraday's principle of magnetic induction is the basis of near-field coupling between a reader and tag. A reader passes a large alternating current through a reading coil, resulting in an alternating magnetic field in its locality. If you place a tag that incorporates a smaller coil in this field, an alternating voltage will appear across it. If this voltage is rectified and coupled to a capacitor, a reservoir of charge accumulates, which you can then use to power the tag chip. Tags that use near-field coupling send data back to the reader using load modulation.

Load modulation: because any current drawn from the tag coil will give rise to its own small magnetic field- which will oppose the reader's field- the reader coil can detect this as a small increase in current flowing through it. This current is proportional to the load applied to the tag's coil (hence load modulation).

This is the same principle used in power transformers found in most homes today- although usually a transformer's primary and secondary coil are wound closely together to ensure efficient power transfer. However, as the magnetic field extends beyond the primary coil, a secondary coil can still acquire some of the energy at a distance, similar to a reader and a tag. Thus, if the tag's electronics applies a load to its own antenna coil and varies it over time, a signal can be encoded as tiny variations in the magnetic field strength representing the tag's ID. The reader can then recover this signal by monitoring the change in current through the reader coil. A variety of modulation encoding are possible depending on the number of ID bits required, the data transfer rate, and additional redundancy bits placed in the code to remove errors resulting from noise in the communication channel.

Limitations:

- The range for which we can use magnetic induction approximates to c/2Πf, where c is a constant (the speed of light) and f is the frequency. Thus, as the frequency of operation increases, the distance over which near-field coupling can operate decreases.
- Energy available for induction varies as a function of distance from the reader coil. The magnetic field drops off at a factor of 1/r3 where r is the separation of the tag and reader, along a center line perpendicular to the coil's plane. So, as applications require more ID bits as well as discrimination between multiple tags in the same locality for a fixed read time, each tag requires a higher operating frequency.

Far-Field RFID:

RFID tags based on far-field emissions capture EM waves propagating from a dipole antenna attached to the reader. A small dipole antenna in the tag receives this energy as an alternating potential difference that appears across the arms of the dipole. A diode can rectify this potential and link it to a capacitor, which will result in an accumulation of energy in order to power its electronics. However, unlike the inductive designs, the tags are beyond the range of the reader's near-field, and information can't be transmitted back to the reader using load modulation. The technique designers use for commercial far-field RFID tags is back scattering.

Back Scattering:

If they design an antenna with precise dimensions, it can be tuned to a particular frequency and absorb most of the energy that reaches it at that frequency. However, if an impedance mismatch occurs at this frequency, the antenna will reflect back some of the energy toward the reader, which can then detect the energy using a sensitive radio receiver. By changing the antenna's impedance over time, the tag can reflect back more or less of the incoming signal in a pattern that encodes the tag's ID. Tag's that use far-field principles operate at greater than 100 MHz typically in the ultra high frequency (UHF) band (such as 2.54 GHz); below this frequency is the domain of RFID based on near-field coupling.

Limitations:

- A far-field systems range is limited by the amount of energy that reaches the tag from the reader and by how sensitive the reader's radio receiver is to the reflected signal.
- The actual return signal is very small, because it's the result of two attenuations, each based on an inverse square law. Thus the returning energy is 1/r4(r is the separation of the tag and reader).

Reading Co-located Tag's:

One commercial objective of RFID systems is to read, and charge for, all tagged goods in a standard supermarket shopping cart as it is pushed through an instrumented checkout aisle. Such a system would speed up the check-out process and reduce operational costs. Consider two tags situated next to each other and equidistant from the reader. On hearing the reader's signal, both would acquire enough power to turn on and transmit a response back to the reader, resulting in a collision. The data from both tags would be superimposed and garbled. In CSMA (carrier sense multiple access)-based communication networks, Ethernet protocol can inserts a random delay between the beginning of the interrogation signal and the tag's response. So, the reader must initiate several rounds of interrogation until it hears all the tags in that area with high probability.

Distributed memory revolution:

RFID tags can contain far more information than a simple ID. They can incorporate additional read-only or read-write memory, which a reader can then further interact with.

ROM: Read-only memory might contain additional product details. The tag memory might contain a batch code. If some products are found to be faulty, the code can help find other items with the same defects. Tags memory can also be used to store self-describing information. If a package is misdirected during transportation, the receiving organization might not be able to determine its correct destination. Additional destination information written into the tag would obviate the need and cost of a fully networked tracking system.

RAM: These tags could lead to a distributed memory capability embedded in our surroundings. Tags could contain ownership history. A tag attached to the secondhand consumer goods might tell about the previous owners and when and where the product changed hands.

ADVANTAGES OF RFID

- **Rapid charging/discharging**

The use of RFID reduces the amount of time required to perform circulation operations. The most significant time savings are attributable to the facts that information can be read from RFID tags much faster than from barcodes and that several items in a stack can be read at the same time

- **High reliability**

The readers are highly reliable. Several vendors of RFID library systems claim an almost 100 percent detection rate using RFID tags. There are fewer false alarms than with older technologies once an RFID system is properly tuned. Some RFID systems have an interface between the exit sensors and the circulation system to identify the items moving out of the library.

- **Automated materials handling**

Another application of RFID technology is automated materials handling. This includes conveyor and sorting systems that can move library materials and sort them by category into separate bins or onto separate carts. This significantly reduces the amount of staff time required to ready materials for reshelving.

- **Long tag life**

Finally, RFID tags last longer than barcodes because nothing comes into contact with them. Most RFID vendors claim a minimum of 100,000 transactions before a tag may need to be replaced.

The real **benefits** of RFID can be summarized as follows:

- Line of sight not required
- Durability
- Range
- Data volume
- Multiple read–Speed
- Read/Write–Update

✓ **STRENGTHS** OF RFID :

- Tags can be hidden or embedded into any object.
- No wear and tear due to its contact less nature .
- Tags can be read even if covered with dirt or submerged in water.

- Unalterable permanent serial code prevents tampering of tags.
- The small size of RFID allows it to great movement of freedom eliminating need for direct contact between the two bodies.

Applications Of Rfid

- High-frequency RFID tags are used in library book or bookstore tracking, pallet tracking, building access control, airline baggage tracking, and apparel item tracking. High-frequency tags are widely used in identification badges, replacing earlier magnetic stripe cards.
- UHF RFID tags are commonly used commercially in pallet and container tracking, and truck and trailer tracking in shipping yards.
- Microwave RFID tags are used in long range access control for vehicles.
- RFID tags are used for electronic toll collection at toll booths The system helps to speed traffic through toll plazas.
- Sensors such as seismic sensors may be read using RFID transceivers, greatly simplifying remote data collection.
- Location sensing of RFID with milimeter accuracy is possible by adding a low cost photosensor. The real time location sensing (RTLS) supports many complex geometric queries.
- RFID systems are being used over a wide range in big sopping malls, retail outlets to keep track of their stocks, shop lifting etc.
- Microwave RFID tags are commonly being used for truck tracking trucks in shipping, cargo industry..
- Smart cards embedded with RFID chips are being used as electronic cash.
- A Smart Key option is available for ssome of the cars models. The driver can open the doors and start the car while the key remains in a purse or pocket.
- Sensing: sensing is in relation to perishable goods, items such as meat, fruit, and dairy products shouldn't exceed a critical temperature during trasportation. An RFID temperature sensor could both identify goods and ensure they remain within a safe range.

Frequency Bands and Applications

FREQUENCY BAND	CHARACTERISTICS	TYPICAL APPLICATIONS
Low 100-500 kHz	Short to medium read range Inexpensive Low reading speed	Access control Animal identification Inventory control Car immobiliser
Intermediate 10-15 MHz	Short to medium read range potentially inexpensive medium reading speed	Access control Smart cards
High 850-950MHz 2.4-5.8 GHz	Long read range High reading speed Line of sight required Expensive	Railroad car monitoring Toll collection systems

Conclusion

Though widespread RFID solutions are on the horizon, there are a number of reasons why it is just growing out of its infancy. In the supply chain, not only does it require high up-front costs -

software, hardware, data storage, security solutions, and core technology implementations – but also the tags are still relatively expensive when compared to barcodes. Also, while customers are evaluating which RFID solution would work best for them, many technical issues are unresolved – such as the lack of global standards for tags, the lack of standard radio frequencies, the wide range of radio frequency transmission distances, potential problems with the use of tags and readers in a small space and finally the affect of metal or liquids on tag performance.

However, the landscape is changing, and none of these challenges are insurmountable. RFID represents an exciting opportunity for customers with automatic data collection needs. As the technology continues to evolve, increasing numbers of customers across all markets will choose to implement RFID because of the unique capabilities it can deliver that drive efficiencies into their operations. Although transition to RFID will not occur immediately or quickly, market indications suggest that the shift is beginning.

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